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Terra Australis reports the results of archaeological and related research within the south and east of Asia, though mainly Australia, New Guinea and Island Melanesia — lands that remained terra australis incognita to generations of prehistorians. Its subject is the settlement of the diverse environments in this isolated quarter of the globe by peoples who have maintained their discrete and traditional ways of life into the recent recorded or remembered past and at times into the observable present.

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Ten Thousand Years of Cultivation at Kuk Swamp in the Highlands of Papua New Guinea

Edited by Jack Golson, Tim Denham, Philip Hughes,
Pamela Swadling and John Muke

Australian National University

PRESS

Published by ANU Press
The Australian National University
Acton ACT 2601 Australia
Email: anupress@anu.edu.au
This title is also available online at press.anu.edu.au

National Library of Australia Cataloguing-in-Publication entry

Title:	Ten thousand years of cultivation at Kuk Swamp in the highlands of Papua New Guinea / editors: Jack Golson, Tim Denham, Philip Hughes, Pamela Swadling, John Muke.
ISBN:	9781760461157 (paperback) 9781760461164 (ebook)
Series:	Terra Australis ; 46.
Subjects:	Agriculture, Prehistoric--Papua New Guinea--Kuk. Anthropology--Papua New Guinea--Kuk. Wetland archaeology.
Other Creators/Contributors:	
	Golson, Jack editor. Denham, Tim, editor. Hughes, Philip, editor. Swadling, Pamela, editor. Muke, John, editor.

Cover design and layout by ANU Press. Cover photograph by Philip Hughes.

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Prologue

Tim Denham

It is an honour for me to have been invited by Jack Golson to write a prologue to this volume on *Ten Thousand Years of Cultivation at Kuk Swamp in the Highlands of Papua New Guinea*. I became involved in the Kuk Project in 1997, when I began my PhD at The Australian National University under Jack's watchful eye. My PhD research was designed to investigate several substantive problems with the original claims for early agriculture based on the 1970s excavations at Kuk led by Jack with numerous colleagues. In the late 1990s, the antiquity, function and types of cultivation represented by the earliest archaeological phases of wetland manipulation at Kuk were debated. The New Guinea evidence was still peripheral to many discussions of global agricultural origins.

There were several reasons for the lack of acceptance of the Kuk evidence. By the late 1990s, only limited archaeological evidence for the earliest phases of wetland manipulation had been published. These phases represent the earliest episodes for plant exploitation at about 10,000 years ago (Phase 1), mound cultivation on the wetland margin at c. 7000–6400 years ago (Phase 2), and ditched drainage for cultivation from c. 4400–4000 years ago (Phase 3). In the limited publication record over the 20 years since the main fieldwork had been done, interpretations of the archaeological evidence associated with the earliest phases had changed through time, fostering a sense of uncertainty. More significantly, though, there were major gaps in the multidisciplinary record for Phases 1–3 at Kuk Swamp, principally: archaeobotanical evidence for the presence, use and cultivation of major staple crops; palaeoecological evidence for landscape change coincident with early phases of cultivation; stratigraphic evidence for cultivation practices; and high-resolution radiocarbon dating.

These lacunae were a product of the times in which the original work was undertaken. In the 1970s, these diverse fields of archaeological science had not been applied to the investigation of the past of tropical agriculture. Although the original Kuk Project in the 1970s was a state-of-the-art multidisciplinary endeavour, it was effectively constrained by a lack of development or availability of these fields. Consequently, there was a need for renewed investigation.

In the 1970s, the archaeobotanical investigation of tropical agriculture had only just begun. Researchers realised that traditional types of archaeobotanical evidence for agriculture—often focused on charred seeds of cereals and legumes, as well as charred nutshells and fruit stones—were poorly suited to the wet tropics. Most staple plants in the wet tropics are not cultivated for seed, or ordinarily produce seeds under cultivation; rather, plants are cultivated for soft tissues such as tubers, corms and rhizomes, starch-rich pith or sago, green leaves and shoots, and so on. These plant parts are rarely preserved as charred macrofossils, except when waterlogged, desiccated or frozen, and require the application of a relatively new suite of archaeobotanical techniques for detection and identification. These techniques include phytoliths and starch grain analysis, as well as archaeological parenchyma. Such techniques were not well established or widely available in the 1970s, yet phytolith and starch grain analysis have been pivotal for identifying staple crops—bananas (*Musa* spp.), taro (*Colocasia esculenta*) and a yam (*Dioscorea* sp.)—in the archaeological record of Phases 1, 2 and 3 at Kuk.

Palaeoecology, especially pollen analysis, was well established in the 1970s. However, problems had arisen in the extraction of pollen from clay-rich sediments dating from the Late Pleistocene to the mid Holocene at Kuk and other sites in the highlands. Thus there was no clear indication of how environments changed with the emergence, transformation and expansion of agricultural practices. With the advent of new pretreatments, it became possible to reconstruct vegetation history as it pertained to these key agricultural milestones.

The original stratigraphic investigations at Kuk focused on field recording, physical and chemical composition, and X-radiography. These analyses were used to develop sedimentological and pedogenic interpretations of the stratigraphy in terms of depositional and soil formation processes respectively. In my renewed investigations, these stratigraphic frameworks were extended through the application of further X-ray imaging, thin section micromorphology and X-ray diffraction. Together these multiscale and mixed-method investigations enabled major and minor stratigraphic units to be characterised, site formation processes to be reconstructed and some activities associated with early cultivation to be identified.

Archaeologists in the 1970s were limited to the conventional radiocarbon dating of charcoal samples that weighed in grams. The advent of Accelerator Mass Spectrometry (AMS) dating by the time of the renewed investigations made it possible to date charcoal samples weighing milligrams. This allowed the establishment of a more robust chronology of early cultivation using small samples collected from the fills of associated features.

Thus the renewed archaeological excavations and multidisciplinary investigations undertaken by myself and a team of collaborators from 1997 onwards benefited from a range of advances in archaeological science that were not available to the original investigators in the 1970s. When taken together, the results of the original and renewed investigations determined the antiquity and function of features associated with Phases 1, 2 and 3, identified the suites of plants being exploited and cultivated, and inferred associated landscape changes.

The new phase of investigations at Kuk was built on the enormous foundations laid by Jack Golson and colleagues from the 1970s onwards. The results of both sets of investigations are presented in this volume. Together, they provide a robust basis for understanding long-term agricultural history at Kuk that extends from 10,000 years ago to the present. This body of work represents 50 years of research that has established Kuk Swamp as the 'type site' for the investigation of early agriculture in New Guinea, and New Guinea as a globally significant centre of early agriculture and plant domestication. Furthermore, the global, national and local significance of Kuk has been recognised through its successful nomination to the United Nations Educational, Scientific and Cultural Organization (UNESCO) list of World Heritage Sites in 2008.

Despite all these advances, much remains to be done. Our understanding of early agriculture in the highlands of New Guinea is still in its infancy. A new generation is needed to initiate investigations and take this multidisciplinary research to the next level.

Acknowledgements

Jack Golson

This is a section where, on behalf of the editors and writers of this book, I acknowledge our appreciation of the contributions of other people who have made it possible. I do so in terms of the three major periods of activity dealt with in the book, and two subsequent periods during which it was written and approved for publication, Period 4, and then passed on to the *Terra Australis* team for copy-editing, Period 5. These acknowledgements follow the structure of Chapter 1.

The first three periods were:

1. The major fieldwork of the 1970s and the small-scale work undertaken in following years until the closure and effective abandonment of the Kuk Agricultural Research Station at the end of 1990, a year before my formal retirement.
2. The reoccupation of the Station land by its traditional owners, the Kawelka, a growing concern about the effects of renewed gardening on the integrity of the site and the negotiation of a second period of Kuk fieldwork in 1998 and 1999 for Tim Denham's doctoral research.
3. The building of a case for UNESCO World Heritage status for the site and the negotiation of local consent to its proposal.

Acknowledgements outside this framework are made by relevant people in relevant places throughout the book.

It is appropriate to start with Jim Allen, who, in 1969, a recent PhD graduate from The Australian National University (ANU) appointed to teach prehistory in the anthropology department at University of Papua New Guinea (UPNG), made a fieldwork visit to the upper Wahgi Valley. Here he was taken to Kuk and shown the finds made during drainage work at the infant Kuk Tea Research Station. He realised that this could be the site that I was looking for to investigate the history of highlands agriculture and passed the information over to me.

Period 1

This extended from mid-1972, three years before Papua New Guinea (PNG) Independence Day on 16 September 1975, until Kuk Station closed at the end of 1990.

A. Government, Research Station and upper Wahgi plantations

Acknowledgement is made of government authorities before and after Independence Day for permission to carry out the research and to the Department of Primary Industry/Agriculture, Livestock and Fisheries for allowing it to take place at one of its research stations. Ron Hiatt, Senior and Regional Highlands Local Government Officer 1965–72, Deputy District Commissioner–Western Highlands Province[1] 1972–78 and Deputy District Commissioner–Regional Inspector for all Highlands Provinces 1978–80, was unfailingly helpful as our immediate point of contact with the local administration.

1 'Province' replaced 'District' following Independence Day.

I thank the management of Kuk Tea, later Agricultural, Research Station for housing us there, treating us as members of the Station community and being at all times ready to discuss our plans and help with their implementation. All this began with John Morgan, the first Officer-in-Charge, who in 1971 secured the agreement of head office in Port Moresby for these arrangements. In general, they continued after his sudden death in 1974 under his successors, Doug Grace, Batley Rowson and Martin Gunther. Gunther was in charge during the final decade of the Station's existence, from three years after the end of our major fieldwork in late 1977 until the Station was closed at the end of 1990. The Station staff with whom we were the most engaged over Period 1 were Terry Aldous and Barry Blogg (office), Graeme Baker, John Bohn and Brian Thistleton (field and laboratory) and Alan McGrigor, who had designed the Station drainage plan.

The Research Station was an important part of the upper Wahgi scene as a source of information and advice on agronomic matters about and beyond tea. Visiting plantation owners and staff were interested to hear about the Kuk Project's work, which was making the same sort of discoveries of artefacts and structures that some of them had themselves made. This led to invitations to Project members to make visits to inspect sites and finds. Close to Kuk there was Mark and Nerida Fallon's property near Baisu and, at the head of the North Wahgi Swamp, Dick and Caroline Hagen's Gumanch Plantation. South of the Wahgi was John and Edith Watts' Ulya Plantation, not far from Ivor Manton's Warrawau tea estate where in 1966 the initial investigations had been done out of which the Kuk Project developed.

B. Launching the Project

The multidisciplinary fieldwork programme of the Project that was launched in mid-1972, and the people involved, comprised:

- archaeological investigation of drainage and cultivation systems in Kuk Swamp—Wal Ambrose, Jack Golson, Winifred Mumford, all ANU Department of Prehistory, and Mary-Jane Mountain from UPNG—with the emphasis in 1972 on the youngest systems, those of Phase 6, visible at the surface of the swamp after removal of the grass cover;
- interrogation of the oldest members of local communities as to their knowledge about drainage of wetland for cultivation, given the virtual lack of evidence for such in the 40 years of European contact—Ian Hughes, ANU New Guinea Research Unit;
- house site excavation, not an initial inclusion, but quickly added as removal of swamp vegetation revealed the frequency of house sites with the latest phase of cultivation—Ron Lampert, Department of Prehistory, ANU;
- geomorphological study of the stratigraphy of the swamp and its relationship with the natural and artificial processes taking place there over time—Russell Blong, Macquarie University, Sydney, some of it carried out with Colin Pain, who, after earning his PhD in the Department of Geomorphology and Biogeography in the Research School of Pacific Studies, ANU, joined the School of Geography at the University of New South Wales; and
- systematic sampling of the swamp deposits for the analysis of the included pollen to reconstruct the history of the regional vegetation and track the effects of human activities—Jocelyn Powell, who had worked at the Manton site with Ambrose, Golson and Lampert, and whose husband had begun teaching at UPNG.

There were many volunteers and visitors during the opening months of the first season, mainly people with ANU and/or PNG links and reason to be in the country, who helped with different aspects of the archaeological investigations:

- Jim Allen, Brian and Julie Egloff, Geoff Irwin, Johan Kamminga and Ron Vanderwal recorded a variety of surface features and ditch exposures;
- Sandra Bowdler, Murray Woods and Pamela Swadling helped Ron Lampert with his house excavations;
- Trish Barnes operated the flotation machine that Jocelyn Powell used for retrieving seeds from samples taken at different parts of the site;
- in mid-December 1972, Jim Bowler, then geomorphologist in the Department of Geomorphology and Biogeography, ANU, spent a week at Kuk taking aerial photographs (black-and-white and infrared) to improve our understanding of the images of drainage ditches and cultivation areas that were visible from the air; while
- during the period discussed above, Ray and Vicki Lehrer, Canberra friends of mine, saw to the welfare of members of our various working groups, including those hired locally.

Because our Project began in 1972 at an already operating and still developing Research Station, there were complications with the hiring of a workforce for the Project itself. As a result, the early wage books of the Project are full of the names of workmen who did not continue as employees and the same is true of later periods when there was need to hire extra men for specific tasks.

On the whole, the names that are listed below are those of men who were likely to be employed from season to season. Most were Kawelka, but from the beginning there were a few from other Melpa tribes, mainly Elti and Penambe. I apologise for any errors in the listing that follows:

> Aris, Berim, Bosboi Kopen, Doa, Elua, Edward Kewa, Gor, Ivan Kuri, Joe, Josep, Kalg, Ketiba, Konga, Korowa, Kui, Kum, Kundil Umba, Kupalg, Mek Mel, Moni Mel, Nema, Neringa, Pep, Pik Ok, Simon, Thomas Pok, Timbi Kopen, Tipuka, Wai, Wama Kenken, Wap, William Thomas, Wingti.

These were the men who cut the grass and dug the drains as the focus of the investigations extended block by block north and east over the years. In 1974, Philip Hughes took over the stratigraphic record of these drain walls from Russell Blong, in the process moving from the School of Geography at the University of New South Wales to the Department of Prehistory at ANU.

Mal Gray of the Department of Lands and Survey in Mount Hagen set up the datum lines from which the N–S drains chosen to be dug in a particular block at a particular time were marked out by Siaoa, the Station's drain surveyor. By the end of intensive fieldwork at Kuk in late 1977, drain digging and recording had reached the northern and eastern boundaries of the Station. There followed short annual visits for specific purposes. In 1983, I made arrangements with Lands and Survey for renewed help at Kuk. By courtesy of Doug Millar, a small team under David Ward spent a week establishing the framework for a new map of the drains that had been dug following the initial survey by Mal Gray. The aim was to rerecord the location of the dug drains in relation to the road drain network and to each other, and to check the distances from individual drain datums of a few of the pegs used by Philip Hughes for his stratigraphic recording and by me for my archaeological feature record, as well as to take new level measurements on a few pegs per drain. The reason for the new survey was the arrival of John Burton, a doctoral candidate in prehistory in the Research School of Pacific Studies at ANU, who offered to computerise all of Hughes' stratigraphic records. The result is an integrated record across the site, both tabulated and displayed.

C. Fieldwork seasons during 1973–77

From late 1973 things were much more orderly after work unfinished in 1972 was tidied up on a return visit in early 1973. In the late 1973 season, two University of Minnesota graduate students, Laurie Lucking and Jim Rhoads, were introduced to the Kuk Project by a staff Minnesota anthropologist, Eugene Ogan, with PNG research interests and ANU colleagues.

- In late 1973, Laurie Lucking worked with Ron Lampert on his second and last season investigating house sites in Kuk Swamp. In 1974, she joined Jocelyn Powell collecting samples from the swamp for seed extraction and analysis, as well as preserved wood for identification. She worked on the collected samples in PNG in 1974 and 1975 and in Australia in 1976, after Powell moved there in 1975.
- The second Minnesota student, Jim Rhoads, worked with me in 1973 and with Philip Hughes and me in 1974, when Hughes joined the Kuk team. He was involved with them in the necessary task of untangling the evidence of the major and minor disposal channels and field systems of Phases 4 and 5. In 1975, he went to ANU as a PhD scholar.
- Hughes' partner, Marjorie Sullivan, came into the field with him in 1974 and 1975 to help in the work, as did Barbara Greaves, a student of theirs when they were at the University of New South Wales. In 1975, they were joined by Simon Harrison who has been mentioned in Chapter 1 in connection with Jocelyn Powell's work on subsistence and swamp cultivation in Southern Highlands Province.

In the excavation of the earlier cultivation systems of Phases 1–3, which began in late 1975 and continued in 1976 and 1977, I was well served by the volunteers who were available:

- in 1975, the Australian Klim Gollan, back from MA studies at the University of London Institute of Archaeology, was well equipped to map and record the ditch networks of Phase 3 that were being widely exposed in area excavations;
- in 1976, Alistair Marshall, an Englishman with excavation experience in UK, then working at the School of Biological Studies at Flinders University, undertook excavation, mapping and photography of the evidence of Phase 2 mounded cultivation; and
- in 1977, the very experienced American archaeologist Art Rohn, at the University of Sydney on sabbatical leave from Wayne State University, Kansas, and his cartographically skilled wife Cherie took on Phase 1 and Phase 2 investigations; and
- also in 1977, as discussed in Chapter 17, there were substantial contributions to the understanding of Kuk settlement from two PhD students: Ed Harris of University College London, who was looking at the operation of the principles of archaeological stratigraphy in different cultural and field situations; and Paul Gorecki from the University of Sydney, who came to study agricultural and settlement site formation processes through observation of the activities of the modern community at Kuk.

The New Guinea School Services branch of the New Guinea Research Unit, ANU, in Port Moresby helped such recruits on their way to Kuk by providing accommodation and transport as they passed through Port Moresby and making a vehicle for long-term transport available to us all in Mount Hagen. The field managers at the time of the Kuk fieldwork were successively Jim Toner, Pat O'Connor and Tau Manega.

D. Fieldwork Funding

Up to the end of Period 1 of the Kuk Project at the close of 1990, its funding was almost entirely provided by ANU through the Research School of Pacific Studies. There were three other much appreciated contributions:

1. The Wenner-Gren Foundation for Anthropological Research (grant 3016) contributed to the labour costs in the 1974 and 1975 seasons;
2. Tony Sorrell, Area Manager of Shell, made a grant in 1976 for the carriage of archaeological material accumulated at Kuk by road from Kuk to Lae and onward by sea; and
3. Royal Australian Air Force aircraft returning empty from training flights to PNG brought archaeological material from Mount Hagen to Australia, especially wood requiring conservation treatment, on several occasions in 1975 and 1976.

E. Backup at ANU

The Department of Prehistory provided support for dealing with the data that were being brought back to Australia. This included secretarial work successively from Lois White, Jill Johnston and Gabrielle Braun; editorial work from Maureen Johnson; photographic work from Dragi Markovic; cartographic and illustrative work from Winifred Mumford.

Increasingly, however, the considerable cartographic and illustrative load was taken over by the then Cartographic Unit in the Research School, headed by Keith Mitchell, who steered most Kuk work to Anthony Bright. Later Kay Dancey became head, with Jenny Sheehan inheriting Kuk, in a unit now known as CartoGIS. The photographic burden of Kuk was similarly heavy and Wal Ambrose took it up. He kept a catalogue of site photographs to be considered for publication in the core chapters of the book (numbers 6 and 11–17 here) and made scans of them for selection.

Another labour-intensive task was the registration and storage of archaeological finds. Two undergraduate students, Kieran Hotchin and Peter May, helped me with the stone finds, while the wooden items were largely Wal Ambrose's responsibility, since they had to go through prior conservation in his laboratory. At first Stella Wilkie looked after the stone and wood records, but was needed increasingly to do office work for Henry Polach in the radiocarbon laboratory.

In 1983, Axel Steensberg, a leading Danish scholar of peasant life whose connection with Kuk is discussed in Chapter 1, came to ANU as a departmental visitor to make a catalogue of the wooden artefacts from Kuk, and some from elsewhere, which are the subject of Chapter 19.

In the later 1980s, Tom Loy, a pioneer in the study of organic residues on the working edges of stone tools, was appointed to set up a residue laboratory in the Department of Prehistory with Barry Fankhauser, who had worked on chemical residues from Maori earth ovens at Otago University. Before he left ANU for the University of Queensland in early 1995, Loy made a selection of some 58 stone tools from the Kuk collection with promising signs of use wear or residues. These were inherited by Tim Denham when he joined ANU as a PhD scholar in 1997 (see Chapter 20).

Identifiable bones found where Station drains cut across two old drainage ditches were identified by Colin Groves, of the ANU School of Archaeology and Anthropology, as pig. There was hope that they might give some hint of the age of the animal's arrival in the highlands, but two radiocarbon dates run on bone from the two occurrences, one at the Kiel laboratory (KIA) in north Germany, the other at the New Zealand Waikato laboratory (Wk), were disappointingly recent (see footnotes 7 and 8 of Chapter 15). Each date, as we see there, was kindly sponsored by a colleague with whom we were linked by an interest in the spread of people, plants and animals across the Wallace Line into the Australia/Pacific region, Keith Dobney and Elizabeth Matisoo-Smith, at the time located respectively at Durham University and Auckland University.

Carbonised plant and animal remains were excavated from hearths and ovens at houses excavated by Ron Lampert and his helpers in 1972 and 1973. Johanna Pask, who had been a laboratory technician in the ANU Research School of Biological Sciences, worked on the plant remains after

moving to do joint honours in prehistory and geography in the early 1990s. The name of the person to be thanked for the sheet of faunal identifications—mainly, if not totally, of pig—seems unfortunately to have been lost.

There was continuous need for radiocarbon dates during Period 1 of the Kuk Project, which supplied 78 samples for dating, including 13 from the exploratory years 1970 and 1971 before the Project had been formally launched. They were processed in a laboratory that was part of the Research School of Earth Sciences, while its staff were listed as members of the Department of Prehistory in the Research School of Pacific Studies. Henry Polach was head until 1992, with John Gower and John Head as Technical Officers (61 out of the 78 samples dealt with); and Rainer Grün head until the end of 1997, with John Head and Steve Robertson (a further 10 of the original 78 samples processed). The last seven samples were dealt with after John Chappell took over as head of the laboratory in 1998 and its affiliation moved with him and his staff, Abaz Alimanovic and Steve Robertson, to the Research School of Earth Sciences.

The final important development in Period 1 was the recruitment of the University of Cambridge geographer Tim Bayliss-Smith, who went to Kuk in 1980 and made it his base for the study of existing cultivation systems in the region and an understanding of their equivalents and predecessors at Kuk.

Bayliss-Smith thanks Martin Gunther, manager Barry Blogg and entomologist Brian Thistleton, at Kuk, John Dubai at Baisu Corrective Institution and Aregina Mengge-Nang at Tambul High Altitude Experiment Station. He also set up taro cultivation plots at Kuk and Tambul and thanks Jean Kennedy, then of UPNG, for help in harvesting them in 1981.

This led to Bayliss-Smith's joint authorship of Chapters 14–16 and the appearance there of work by members of the cartographic section of the University of Cambridge Department of Geography to which he belonged, specifically Philip Stickler, Ian Agnew and David Williams.

Period 2

This extended from the close of 1990 until the completion of Tim Denham's thesis in 2003, and early in this period the Research School of Pacific Studies (RSPacS) became the Research School of Pacific and Asian Studies (RSPAS).

The first half of Period 2 saw the essential abandonment of the Station by the PNG central government that had bought the land for it, followed after a few years by its repossession by its traditional owners, who allocated it to tribal members for settlement and cultivation.

Then, at a UNESCO meeting at the Fiji Museum in Suva in mid-1997, the Director of the PNG National Museum nominated the Kuk site for World Heritage listing. The nomination was made on the grounds that '[t]he archaeological finds at Kuk indicate that Pacific Islanders were amongst the world's first gardeners' and took place on the eve of the investigations that provided the most convincing evidence to date for the claims. These were the work of Tim Denham over the years 1998–2003 in the field and the laboratory and by way of the specialist analyses that he sought for his material.

What follows until the end of Period 2 is taken, essentially verbatim, from the Acknowledgements section of Tim Denham's 2003 thesis (volume 1: vi–ix), where a wider range of obligation is acknowledged than here, as is proper for the thesis as a whole.

The fieldwork at Kuk in 1998 and 1999 was made possible by the National Research Institute (NRI) in Port Moresby, PNG National Museum and Art Gallery, Western Highlands provincial government and the Kawelka communities at Kuk. Fieldwork was greatly assisted by several individuals at institutions in Papua New Guinea, including Michael Laki (NRI), Nick Araho, Herman Mandui, John Dopp and Andrew Moutu (all PNG National Museum) and Dr Thomas Webster and Father Lak (formerly Western Highlands provincial government). Additionally, John Muke greatly assisted in getting the fieldwork started. Many thanks to all the Kawelka at Kuk who aided the running of the project, and in particular Ru Kundil, William Pik, Joe Ketan, Nicholas Namba. Anis, Berim, Dennis, Elua, James, Jackson, John Kanga, Ketepa, Korowa, Sandy Lo, Matthew, Mek, Nixon, Timba, John Ulg, John Wai, Waia, and Wingti patiently worked with me during the excavations. Assistance in the field was provided by Dr Thomas Wagner in 1998 and 1999 (formerly UPNG) and by Dr Robin Torrence (Australian Museum), Dr Peter White (University of Sydney) and Dr Tim Bayliss-Smith (University of Cambridge) in 1999. Many thanks to George Leahy for his advice during both field seasons.

The multiscale and multitechnique investigation of the stratigraphy would not have been possible without the assistance of Dr Alain Pierret, CSIRO Land and Water (conducted X-ray absorption imaging and provided advice on the translation of Dr Marc Latham's text from the French); Russell Blong (provided X-radiographs in original and digital form associated with his 1970s investigations); Dr Mac Kirby, CSIRO Land and Water (advice on X-ray absorption imaging); Dr John Vickers, Department of Geology, ANU (thin section preparation); Dr Anthony Ringrose-Voase, CSIRO Land and Water (advice on thin section preparation and description); Dr Kate Welham, School of Conservation Sciences, Bournemouth University (technical support for optical microscopy and digital camera operation); Dr Leah Moore, University of Canberra (processed many of the X-ray diffraction samples and provided preliminary interpretations of the results); and Dr Ulrike Troitzsch, Department of Geology, ANU (provided assistance with the compilation of composite diffraction images).

Accelerator mass spectrometry (AMS) dating was undertaken by the Australian Nuclear Science and Technology Organisation (ANSTO) as part of two grants awarded to Jack Golson in 1998 and 2000. Conventional radiocarbon (under the auspices of the Centre for Archaeological Research, ANU) and AMS dating of organic samples were conducted by Abaz Alimanovic and Prof. John Chappell, Research School of Earth Sciences (RSES). I am indebted to both for their time, efforts and advice on the submission, processing and interpretation of dating results. I would like to also thank Dr Mike MacPhail (RSPAS, ANU), Dr Janelle Stevenson (RSPAS, ANU) and Dr Sophie Bickford (CSIRO) for processing, or assistance with processing, of organic samples prior to submission.

All multidisciplinary palaeoecological analyses were undertaken by experts in their respective fields: diatoms (Dr Barbara Winsborough, Winsborough Consulting), phytoliths (Carol Lentfer, Southern Cross University), pollen (Simon Haberle, RSPAS, ANU), residue analyses (Dr Richard Fullagar, Michael Therin, Dr Judith Field, University of Sydney and Carol Lentfer). I am greatly indebted to all of these individuals who found space in their hectic schedules to invest enormous amounts of time in processing, analysis and reporting for little financial reward. Many thanks also to Gill Atkins and Dr Lynley Wallis (RSPAS, ANU) for assistance with the preparation of phytolith and pollen samples at RSPAS, ANU, and to Dr Doreen Bowdery (ANU) and Robin Torrence for initial advice on the use of phytolith and starch grain analyses, respectively. Many thanks also to Dr Huw Barton (Department of Archaeology, Leicester University), Dr Mike Bourke (Department of Human Geography, RSPAS, ANU), Dr Anita Diaz (Department of Geography, Bournemouth University) and Dr Peter Matthews (National Museum of Ethnology, Osaka) for illuminating discussions on asexual reproduction, vegeculture and plant use in New Guinea and the tropics.

Dr Soren Blau (Flinders University), Prof. Colin Groves (School of Archaeology and Anthropology, ANU) and Tom Heinsohn (National Museum of Australia) kindly examined a mandible fragment. Dr Melinda Allen and Dr Judith Robins (University of Auckland) kindly undertook molecular analysis of the specimen.

Kay Dancey (Cartography Unit, RSPAS, ANU), Rob Patat (formerly MGT Architects, now Patat Consulting) and Dahlia Enoch assisted with graphics. Pam Berg (formerly MGT, now Pamille Berg Consulting) kindly coordinated Patat's participation. Dr Malcolm Ross (RSPAS, ANU), Pam Swadling, Russell Blong and Paul Brugman, Alex Lee and Tess McCarthy (all Resource Management in the Asia-Pacific (RMAP) Program in the Department of Human Geography in RSPAS, ANU) provided graphics that have been used for this thesis.

The Australian National University funded this research by providing two scholarships for 3.5 years (ANU and Overseas Postgraduate Research) and a fieldwork grant in 1998. Additional assistance, grants and awards for fieldwork and analyses were obtained from the Pacific Islands Development Program (1999), Pacific Science Foundation (two awards to Jack Golson in 1998 and 1999), ANSTO (two awards to Jack Golson in 1998 and 2000), Department of Archaeology and Natural History (ANH) in the Research School of Pacific and Asian Studies (RSPAS, ANU), Resource Management in Asia-Pacific (RMAP) in the Department of Human Geography in RSPAS and the ANU Centre for Archaeological Research (CAR).

Within the School of Archaeology and Anthropology, ANU, Kathy Callen was exceptionally supportive throughout the period of research. Within the same school, Dave McGregor provided much-needed logistical support on an as-needed basis. The Research Students and Scholarships Office, ANU, facilitated the completion and submission process.

Period 3

This period starts with the submission of Tim Denham's doctoral thesis in June 2003, not long after the Canberra bushfires of January 2003 that destroyed the off-campus storage of the Prehistory Department's collections at Weston.

A. After the bushfires

The most conspicuous archaeological damage done by the fire was to the surface of hundreds of stone items from Kuk on which catalogue numbers written in ink had been rendered virtually unreadable. The department recruited Adam Black, a former student who had had some success in photographically enhancing the clarity of images of Australian rock art, to see whether he could improve the legibility of the affected catalogue numbers, but he had very little success (see Chapter 18, 'The aftermath of the Weston fire', and the paragraph immediately preceding it, and the introductory section of Chapter 20).

Adam Black also helped Golson with a new inventory of wooden artefacts after those at Weston that had survived the fires were reunited with those that had remained on the ANU campus and were now transferred to the university property to which all the collections salvaged from Weston had been moved (see Table 18.1).

Beginning in 2011, the storage of collections as a whole was rationalised, on campus and off, under the direction of Jack Fenner, who took on research laboratory management in addition to the normal requirements of his academic position.

B. After the submission of Tim Denham's thesis

This period was concerned with the problem of completing an agreed nomination plan for Kuk for World Heritage status, given the failure to achieve this in the years following the Suva meeting. After PNG signed the World Heritage Convention in 1997, a National Commission for UNESCO was set up under the chairmanship of Regina Kati and assumed a leading role in the promotion of Kuk as a World Heritage site.

There was activity at the national, provincial and local levels, as discussed in Chapter 25, in the section headed 'The nomination process: The first phase'. Responsibility for the nomination document was delegated to a study team with John Muke and Joe Ketan, both from UPNG, as head and deputy, two archaeologists from the National Museum, Nick Araho and Herman Mandui, and three consultants from ANU, Denham, Golson and Swadling. By mid-2004, however, despite the fact that a number of draft plans had been produced, the National Commission for UNESCO was ready to close the nomination process down on grounds of lack of progress.

As Chapter 25 explains, in the section 'The nomination process: The second phase', a solution was found through the efforts of Vagi Genuropa of the Protected Areas Branch of the Department of Environment and Conservation (DEC), who marshalled support for the acceptance of DEC as the proper agency for matters to do with World Heritage.

With UNESCO support, DEC organised a National World Heritage Planning Workshop in Port Moresby in March 2006 not only to look at the Kuk case but also the general problem of institutional arrangements for the nomination and management of World Heritage sites.

As for Kuk, Denham and Muke were asked to take on the remaining tasks. Muke invited Jo Mangi, a former student with him at UPNG and now a member of the same Port Moresby consultancy, to join him in the necessary fieldwork and community consultation. Denham, then based at Monash University in Melbourne, took on responsibility for the coordination, writing and production of the final document, which was submitted to UNESCO in January 2007 and approved in July 2008.

Period 4

Here I look at the help that was needed as the present book was being planned, written and assembled. The aim of Chapter 1 is to put the Kuk work in its historical and interdisciplinary context, based on the testimony of the main actors, most of whom are still alive, and the archives where relevant documents have been stored.

I am grateful for the input of Frank Oldfield about his years of PNG research when head of the Department of Geography at the University of Liverpool, and that of his one-time colleague, Donald Walker, who, as Professor of Biogeography in the Department of Biogeography and Geomorphology in the Research School of Pacific Studies, was a colleague of mine at ANU. Oldfield and graduate student Ann Worsley (née O'Garra) visited the upper Wahgi in the course of Oldfield's 1979 fieldwork season, as described below.

Oldfield had accepted my invitation for him to study, sample and comment on the Kuk stratigraphy on his 1979 visit, as had the soil scientist Marc Latham of the Office de la Recherche Scientifique et Technique Outre-Mer in Noumea. Though, to his regret, the two reports did not play the role that I had had in mind for them, both were used by Tim Denham in his dissertation (see Denham 2003a, vol. 2: Appendix E6 for Latham, Appendix E7 for Oldfield).

The complex story of Tibito Tephra and Long Island that linked Oldfield's work with that of Ian Hughes, Colin Pain and Russell Blong has been told with the help of Rachel Wood and Stewart Fallon of the Radiocarbon Facility of the ANU Research School of Earth Sciences. The Facility houses, among other things, the application forms and report sheets that provide information about the numbered samples dated by the ANU laboratory and copies of those that were relevant to the Tibito Tephra problem were provided on request.

In the discussion of matters related to Kuk, World Heritage and PNG's signing of the World Heritage Convention, three members of the Commonwealth Government's agency for Environment and Heritage, Richard Morrison, Sarah Titchen and Elizabeth Williams, were very helpful with information and advice over the years. Titchen worked at the UNESCO World Heritage Centre in Paris, the administrative agency for the World Heritage Convention, at the time of the Suva meeting of 1997, which she organised and Williams attended as Australian representative. They have been able to supply a context for PNG and other Pacific Island states in World Heritage matters, alerting us to documents publicly available through the website of the World Heritage Centre.

I wish to thank Bruno David of the Monash Indigenous Centre, Monash University, Melbourne, who read Chapters 14 and 15 to see whether statements made about the chronology of lowland influences on the PNG highlands, including the appearance of the pig, were compatible with the latest findings of the large-scale Caution Bay project that he and colleagues, in particular Ian McNiven, Matthew Leavesley, Thomas Richards, Ken Aplin, Robert Skelly and Bryce Barker, have been conducting on the Papuan south coast, 20 km to the northwest of Port Moresby, since 2009. Similarly Jim Specht (Anthropology, Australian Museum, Sydney) and Stuart Bedford (Archaeology and Natural History, School of Culture, History and Language, College of Asia and the Pacific, ANU) kindly commented on the same two chapters from the standpoint of the appearance of Lapita in the Bismarck Archipelago and Remote Oceania.

I wish to thank Damian Cole, Reference Librarian, Pictures and Manuscripts Branch, National Library of Australia (NLA), for advice about the acknowledgement of the library for our use of four photographs, two in Chapter 19 and two in Chapter 21, from the Michael Leahy Photographic Collection, of which the NLA is custodian.

I now turn to the backup provided by ANU Archives, my initial guide to which was Sarah Lethbridge, now Acting Associate Director, Records and Archives. A small part of the Kuk archive has been taken into ANU Archives because of lack of departmental space and is being worked on by Christine Bryan, Pacific Research Archivist. Independently, Russell Blong has deposited with ANU Archives a geomorphological report that he did on the North Wahgi Swamp for a group of consultants carrying out a feasibility study for its drainage in 1971 (see Chapter 1, footnote 2, the catalogue information for which was supplied by Christine Bryan).

The ANU Pacific Manuscripts Bureau (PMB) has material deposited by two Kuk Project members when Ewan Maidment was in charge:

- there are copies of five maps annotated by Ian Hughes when he was questioning older people of the upper Wahgi in 1972–73 about whether swamp was being drained for agriculture there at and before European arrival in the early 1930s (see Chapter 16, footnote 1, where the cited catalogue numbers have been checked with the PMB's current Executive Officer, Kylie Moloney);
- Russell Blong has deposited manuscript material from his enquiries into legends of a Time of Darkness caused by the volcanic ash from an eruption in the AD 1660s that covered large areas of the PNG highlands (see footnote 3 of Chapter 1, where the PMB reference was provided by Kylie Moloney).

Acknowledgement is made of the services of the staff across ANU library system, at its Chifley, Hancock and Menzies branches, with particular note of help with the New Guinea collection from Deveni Temu, Information Access Coordinator at Menzies.

Tracy Harwood is thanked for making a consolidated bibliography out of 25 separate and at times markedly overlapping ones.

Thank you also to the two unnamed readers who recommended the work for publication and in addition made a series of suggestions whose adoption has improved it.

I wish to thank the Department of Archaeology and Natural History, the School of Culture, History and Language and the College of Asia and the Pacific for their support by way of an office and access to facilities over the long period after my retirement that the Kuk research has continued and been written up.

Period 5

This is the period in which the text was handed over to the Terra Australis team for copy-editing and styling by Ursula Fredrick, assisted by Sally Brockwell and Katie Hayne. Philip Hughes assumed responsibility for final checking and updating of the chapters as they were returned from the copy-editors and Tim Denham prepared the final illustrations for publication. I thank all five of them for their efforts during this crucial final stage of preparing the manuscript for publication.

My personal thanks

There follows a number of acknowledgements to people on whom I personally was able to call for help at short notice:

- my departmental colleague Wal Ambrose, who was in the Kuk Project from the beginning to the end in some capacity—the field, the laboratory, the studio or the office;
- Edgar Waters, a friend from early days at ANU, who from a teaching post in the history department at UPNG in the 1970s spent a few weeks of vacation time as my amanuensis during fieldwork seasons;
- Robin Hide, a mine of information about New Guinea, with the ability to search multiple avenues to get more;
- Ray Lehrer, who was available to solve my problems with computer hardware;
- Harrison Pitts, who over a critical period did the same for me with computer software; and
- Alexandra Chiragakis and Bernadette Hince, from the world of IT, who over the years did difficult typing and formatting at my request.

I thank my fellow editors and contributors for their patience and cooperation throughout.

Finally, I acknowledge the debt that I owe to my wife Clare, who, while looking forward hopefully to my eventual retirement, never faltered in the support she gave me while waiting, at times impatiently, for it. Similar thanks are due to Toby Golson and Jacinta Lai, and to Kate Golson, for their help with checking and proofreading at the end of production.

1

An Introduction to the Investigations at Kuk Swamp

Jack Golson

The choice of Kuk

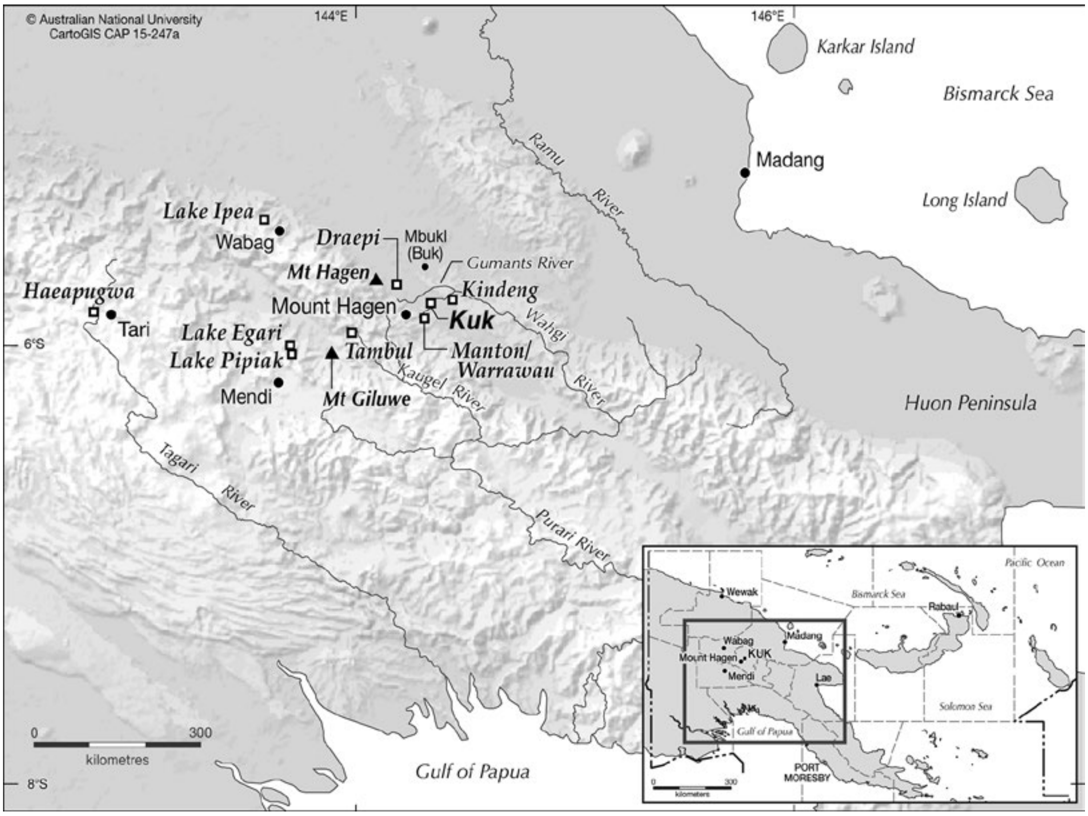


Figure 1.1 This shows the wider region where investigations directly or indirectly related to those at Kuk are discussed in this chapter.

For the relationship of the Wahgi and Gumants Rivers see Figure 1.2. The inset shows the region of the main figure in relation to PNG as a whole and has lines in the background indicating provincial boundaries at the time of the investigations.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Kuk Swamp is situated at an altitude of about 1550 m some 12–13 km northeast of Mount Hagen town in the upper Wahgi Valley of the central highlands of Papua New Guinea (PNG) (Figs 1.1 and 1.2). Until the 1930s, these were thought by outsiders to be a single continuous and uninhabited mountain chain. Exploration in the 1930s, however, coming from the east, revealed them to consist of a series of massive mountain ranges enclosing basins and valleys between 1400 and 2000 m altitude that were well populated and intensively cultivated, the dominant crop being the tropical American sweet potato (*Ipomoea batatas*) (Brookfield 1964: 20–22). The first European party to reach the Wahgi Basin, in 1933, described the swampy floor of the main valleys as uninhabited and uncultivated, with people and their gardens concentrated on the higher ground of the valley slopes (cf. Leahy 1936: 248, describing an area that is recognisable as including Kuk). Kuk itself, the home territory of the Kawelka people, was at the time uninhabited (see Fig. 22.1, which is a map of the tribal distribution in this area), following the defeat of its owners in conflict with more powerful neighbours possibly around AD 1920. They sought refuge with tribal relatives in the hills of the Sepik-Wahgi Divide to the north, as described in the oral histories discussed in Chapter 22.

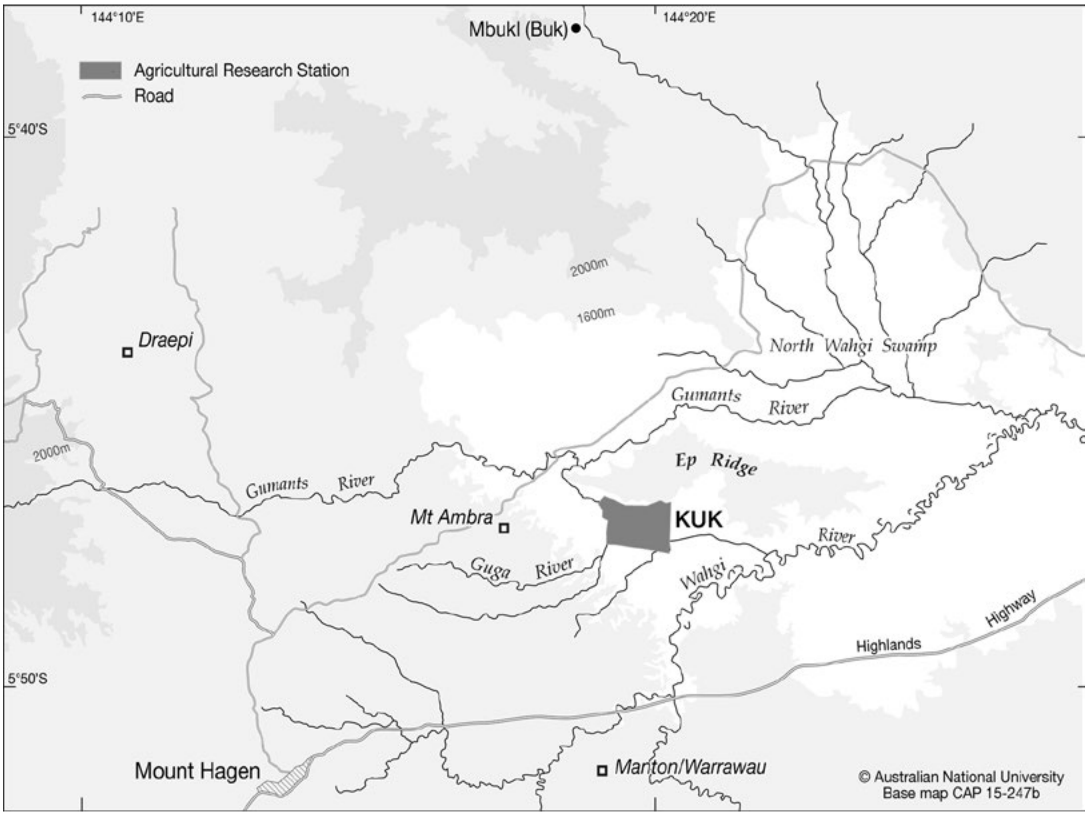


Figure 1.2 This map shows the upper Wahgi area, which was the focus of the investigations centred on Kuk. Figure 22.1 is a map of tribal distribution in this area.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

The recently contacted communities of the highlands became an important part of the Australian administration's expanded responsibilities with the end of World War II and the formal unification of the two hitherto separate entities of Papua and New Guinea. As regards Kuk, the suppression of tribal warfare allowed the gradual return of former inhabitants, beginning around 1960.

Hand-in-hand with these developments went the growth of academic interest and involvement in the highlands, reflected, for example, in the special issue of *American Anthropologist*, edited by James Watson (1964a), with two contributions relevant to our present theme of agricultural history: Harold Brookfield's 'The ecology of highland settlement: some suggestions'; and 'The prehistory of the Australian New Guinea highlands' by Susan and Ralph Bulmer, a pioneering discussion of the evidence for highlands prehistory. Both articles were in part concerned with the implications of the superior capability of sweet potato for growth at altitude compared with that of traditional Pacific cultigens like taro, yam and banana.

For Watson himself (1965a and 1965b), this was the crucial factor in New Guinea history in the context of general agreement that the plant did not make an appearance in the region until after Magellan's circumnavigation of the globe in AD 1519–1522 (Yen 1974: 259–260; cf. Roullier et al. 2013: 2205). This would have only allowed a few hundred years for the increase of population in the newly discovered highlands and the development of the complex economies and societies there that had been the object of study following European contact.

Watson's promulgation of the thesis of an Ipomoean Revolution evoked a swift academic response—the organisation of a three-day seminar at The Australian National University (ANU) in April 1967 by Brookfield and archaeology student Peter White to submit Watson's hypothesis to specialist consideration across the range of essentially synchronic evidence involved, from demography, social organisation and linguistics (Brookfield and White 1968). Before the meeting was held, however, new diachronic evidence became available, which had been unavailable to Watson but which '[demands] a revision of his hypothesis' (Brookfield and White 1968: 44).

From the 1950s on, developments sponsored by the Australian administration in the Wahgi Valley included swamp drainage for the establishment of tea and coffee plantations. In 1965, at one of these sites, Warrawau, an Australian visitor saw a stone mortar that had been unearthed during the digging of drainage ditches, together with stone axes and wooden digging sticks, paddle-shaped spades and fence posts. He wrote a letter about this to, among others, Fred McCarthy, long-time ethnologist at the Australian Museum in Sydney. McCarthy had recently become principal of the newly established Australian Institute of Aboriginal Studies in Canberra, where the letter was forwarded. McCarthy in turn passed it on to Jack Golson, who had been hired in 1961 to establish an archaeological unit in the Department of Anthropology and Sociology in the Research School of Pacific Studies (RSPacS) at ANU.

Golson's first two appointments were Wallace Ambrose, from the University of Auckland, to set up photographic and analytical facilities, and Ronald Lampert, from English Heritage, to undertake field reconnaissance. In 1966, when Fred McCarthy wrote to Golson, Lampert was in PNG and Golson sent word for him to visit the Warrawau plantation. Lampert reported enthusiastically on the prospects for exploratory excavations there and Ambrose and Golson joined him in the field. They invited a fourth person to be a member of the team. This was Jocelyn Wheeler of the Department of Geography, RSPacS. She was already in the highlands doing postgraduate fieldwork using pollen analysis to study human impact on the vegetation of the Mount Hagen region in the past.

The team carried out limited excavations of some 300 m^2 at what they called the Manton site, after the plantation owner. There was a series of ancient ditches cut at different levels in a black, well humified peat, interpreted as an old garden soil (Golson et al. 1967; Lampert 1967). Aerial photographs of the property taken in connection with its development showed the marks of gridded ditching and cultivation plots. The evidence pointed to the implements turned up by drain digging across the 350 ha plantation as a whole having come from the context of wetland cultivation.

A digging stick at the bottom of the oldest of the excavated ditches was dated by the recently established ANU carbon dating laboratory as ANU-43 = 2300±120 radiocarbon years Before Present (BP). Even though there was no way at the time to convert this date into calendar years, it was evidently well before the accepted arrival of the sweet potato in New Guinea a few hundred years ago. Progress over subsequent years in the conversion of radiocarbon dates to calendar years put the calendar equivalent of ANU-43 at two standard deviations between 2710 and 2040 cal. BP (calibrated Before Present = AD 1950 by radiocarbon convention) (see Denham 2005a: Table 5). This is an appropriate place to acknowledge the critical role of the laboratory in the Kuk story and our indebtedness to both Henry Polach, who set it up, and John Head, his right-hand man, over subsequent years.

Visits to other plantations in the region produced a similar story of stone and wooden implements being discovered during drainage, with aerial photographs showing evidence of former drainage of the swampland that they now occupied. The findings overall cast great doubt on Watson's theory of an Ipomoean Revolution, as noted in the discussion of the Brookfield and White seminar of 1967 above, but at the same time indicated the great potential of the Wahgi wetlands for investigating the history of agriculture in the PNG highland zone.

Planning for such a project began as soon as the implications of the Manton work became clear, and ANU was an excellent place to do so. The Department of Anthropology, of which the small archaeological unit was part, was an active centre of research into highlands ethnography. The Department of Geography in RSPacS was also engaged in a wide range of work in the highlands region. Of particular relevance was the palynological research of Donald Walker and his students, looking into highlands vegetation history as revealed in pollen diagrams, including the role of people in vegetation change, something that Wheeler, one of those students, had done for the Manton investigations. Of similar relevance was the work of Harold Brookfield and his students on variations in settlement, landuse and agricultural practice across the highlands and the nature of interrelationships between them. In addition, there were the records of PNG landscapes, soils, climate and vegetation being made by scientific teams from the Division of Land Use Research of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) over the road from ANU, and the programme of geological mapping by the Australian Bureau of Mineral Resources, also Canberra-based.

In this context, a multidisciplinary strategy was developed (Golson 1976: 209; cf. Denham, Golson and Hughes 2004: 263) comprising:

a. archaeological investigation of drainage and cultivation systems in swampland through time;
b. geomorphological study of the origin and history of swamps, with particular attention to interrelationships with human activities in the swamp and on its margins;
c. palynological reconstruction of the regional vegetation within which cultivation systems, both dryland and wetland, operated and with which they interacted; and
d. ethnographic study of traditional agricultural practice in the region.

A suitable site at which to implement this programme was not identified until 1969. A major problem was finding drained land where the investigations would not clash with the activities for which the land had been drained in the first place. A site of possible general interest on the south bank of the Wahgi at Kindeng, 25 km down the valley from Mount Hagen town, was reported by a contact in the Department of Forestry, which had land there. Excavations were carried out in 1968 by ANU archaeologists who had dug the Manton site, together with Peter White, an ANU archaeology PhD student who has previously been mentioned. Though Kindeng was not a useful site for wetland excavation, Wheeler, who had done palynological work at Manton for her PhD fieldwork and was again in the highlands, took a useful pollen core. She analysed this after completing her doctorate and delivered the results to the ANU Department of Prehistory in 1972 (Powell 1982a: 218, 223–224 and Fig. 4).

By this time, Jim Allen, who had recently completed his PhD in archaeology at ANU and was now teaching in the Department of Anthropology and Sociology at the young University of Papua New Guinea (UPNG), identified a potential site during a familiarisation trip to the highlands in 1969. The previous year, the Department of Agriculture, Stock and Fisheries had bought some 770 acres (311.6 ha) of swampland for the establishment of a Tea Research Station at Kuk Swamp,[1] and drainage for the development of its western part had begun in 1969.

Allen (1970: 177) visited the site during its initial drainage and noted similarities to the description (Golson et al. 1967) of the Manton site at Warrawau, located less than 7 km south across the Wahgi River, with the discovery of similar artefacts during drainage and the presence of former ditching in the walls of the modern drains. He returned to Kuk to do some investigation of these towards the end of 1969 and wrote to Golson, identifying the site as worthy of large-scale investigation. A most promising feature was that since the site involved a government agency and not a commercial entity, it should be possible to avoid a clash of interests, which indeed proved to be the case.

Golson was due to attend the 42nd Congress of the Australian and New Zealand Association for the Advancement of Science in Port Moresby in August 1970, so he planned to visit the Kuk Research Station with Lampert after the meeting to confirm the potential of the site and, if this were the case, raise the question of working there. The walls of newly dug drains exposed the swamp stratigraphy and the profiles of numerous ancient ditches for their inspection. While there, they were visited by two young geomorphologists: Colin Pain, a graduate student from ANU, who was on his way to his research area at Tambul in the upper Kaugel Valley further west, and his friend Russell Blong, a senior tutor at Macquarie University, Sydney. Both were New Zealanders and readily identified as volcanic ash a number of lighter-coloured occurrences in the swamp stratigraphy that Golson and Lampert had been unable to understand. As a result, they were asked if they would be interested in giving their geomorphological services to any future project. Both were interested, but only Blong was available.

Kuk management was agreeable to the idea of hosting a project at the site, but would need a detailed plan to consider the implications for the work of the Station before seeking the approval of head office in Port Moresby. Golson promised to return to Kuk in mid-1971, after field commitments elsewhere, to discuss with John Morgan, the Agronomist-in-Charge, the details of the proposed work and a start date in the dry season of 1972. Because of the interest in the proposed work on the part of the Station staff, Golson suggested that Blong return to Kuk with ANU support in the summer university vacation of 1971, to look for volcanic ashes in the part of the Station under development. This led to the identification of a young volcanic ash below surface peat in the southwest corner of Station block A4 on the bank of Tibito Creek (see Fig. 6.14), for which the ash was later named. Blong also found three other ashes in the northeast corner of block C6, all lower in the stratigraphy. He collected samples of ash for analysis and associated organic matter for dating at each location.

While he was engaged in this work, Blong was approached by a group of consultants doing a feasibility study for the Papua New Guinea Department of Agriculture, Stock and Fisheries for the drainage of a large block in the North Wahgi Swamp, over Ep Ridge from Kuk. This led to the drilling of a series of deep boreholes (>30 m) around the margins of that swamp, referred

1 Area varies in Station documents; see Chapter 6, section 'Kuk Swamp and its drainage for the Research Station'.

to by Blong as the Gumants Basin for the river that drains it and into which most of the runoff from Kuk itself flows. The boreholes provided evidence of a long history of volcanic, fluviatile, lacustrine and swamp sedimentation, most of it well beyond the range of radiocarbon dating.[2]

Another early start was made by Jocelyn Powell (née Wheeler), who had worked with ANU archaeologists at the Manton site and was available again because she had moved to Port Moresby with her husband. In mid-1971 she was at Kuk Swamp doing stratigraphic recording of drain walls and choosing a place where she could collect from a long swamp sequence. She recorded a 9 m long column through the deposits, collecting samples for pollen analysis and four samples for radiocarbon dating, two of these (ANU-955 and 956) giving dates in radiocarbon years beyond 20,000 BP (Powell 1984).

At his meeting with Golson in mid-1971, Morgan decided that the proposed work should take place in the eastern part of the Station to avoid interference with Station activities in the western half, and he undertook to provide the labour for the major drainage lines that would make this possible. The research team would be responsible for the minor drainage lines that would be needed to lower the watertable for its work and would have to hire its own workmen to dig them. These minor drains would be located and dug in conformity with the Station drainage plan, except that they could be 1 m wide at the top, instead of 0.61 m (or 2 ft), to make room for our recording of the walls. Approval for our project from Port Moresby was not long in coming.

At this stage, the question of large-scale area excavations, as distinct from localised testing, was put to one side due to the reluctance of the Station management, which planned to monitor soil fertility in various parts of the Kuk block, to consider major disturbance of the ground. However, as was clear from experience at the Manton site and the previous year at Kuk, the walls of the drains that were necessary to lower the watertable and give access to the site were ideal for stratigraphic and archaeological recording and the collection of samples for radiocarbon and other analyses. Drain digging indeed remained a major focus of our operations until mid-1975. By this time, Station management was well aware of the amount of disturbance that the Kuk deposits had undergone through ditch digging and earth moving in previous millennia and withdrew their objection to the area excavations that by then were essential to advance our knowledge of the site. From mid-1975 to 1977, the major focus was the area excavation of early cultivation systems and only a few drains were dug.

The Kuk Project: The main fieldwork, 1972–1977

The team that took to the field at Kuk in 1972 reflected the multidisciplinary character of the programme that had emerged in the later 1960s from the Manton work (Table 1.1). The archaeological component was Golson's responsibility but involved other members of what by this time was an independent Department of Prehistory at ANU, specifically Wal Ambrose and Winifred Mumford for the mapping of the surface evidence of the latest drainage channels and field systems and Ron Lampert for the excavation of surface-visible house sites. For the record of swamp stratigraphy there was Russell Blong, who had offered his services the year before, and for pollen work Jocelyn Powell. The role of swampland in traditional landuse practices in the upper Wahgi Valley was to be investigated by Ian Hughes of the New Guinea Research Unit of ANU based in Port Moresby.

2 Blong's (1972) contribution to the feasibility study forms a section of the first of five technical volumes accompanying the consultancy report: ANU Archives, Russell Blong papers, ANUA593/Box 2, Geomorphological Report, Part 3 of Technical Volume 1, Geomorphology, Site Investigation and Peat Shrinkage, pp. 4–48, September 1972.

Table 1.1 The archaeological, chronological, palaeoecological and stratigraphic work undertaken by Jack Golson with Philip Hughes and by Tim Denham under Golson's supervision.

Research Field	Period	Methods
Archaeology	Original	Excavation trenches (n=187) Archaeological and stratigraphic recording in plantation drain walls (n=>15 km)
	Renewed	Excavation trenches (n=19)
Dating[1]	Original	Conventional radiocarbon dating (n=78; ANU)
	Renewed	Conventional and AMS radiocarbon dating (n=36; ANU and ANSTO)
Palaeoecology	Original	Macrobotany: seeds and wood (n>500; J. Powell/L. Lucking) Phytoliths (n=30; S. Wilson) Pollen and microcharcoal (n=31; J. Powell)
	Renewed	Diatoms[2] (n=50; B. Winsborough) Insects (n=10; N. Porch) Phytoliths[2] (n=40; C. Lentfer) Pollen and microcharcoal[2] (n=60; S. Haberle) Tool residues (n=12; R. Fullagar, J. Field, C. Lentfer, M. Therin)
	Subsequent	Diatoms[3] (n=55; B. Winsborough, K. Saunders) Pollen and microcharcoal[3] (n=76; K. Sniderman)
Stratigraphy	Original	Deposition rates (P. Hughes) Organic matter and bulk density (P. Hughes) Chemical and physical composition (M. Latham) Ferrimagnetism (R. Thompson and F. Oldfield) Physical composition (J. Powell) X-radiography (R. Blong)
	Renewed	Thin section description (T. Denham) X-radiography (A. Pierret with T. Denham) X-ray diffraction (L. Moore with T. Denham)
	Subsequent	Geochemical characterisation of tephra (S. Coulter)

Note that the Renewed Period of investigation for Denham's PhD (2003a) and that of the Subsequent Period (Denham, Sniderman et al. 2009) focused on early and mid Holocene remains (Phases 1, 2 and 3; but see Haberle et al. 2012), as well as upon the geochemical characterisation of tephras at Kuk and Ambra Crater (Coulter et al. 2009).

Source: Updated version of Denham, Haberle and Pierret (2009: Table 2).

Notes:

[1] Conventional and AMS radiocarbon dating undertaken by ANU and AMS dating by the Australian Nuclear Science and Technology Organisation (ANSTO).

[2] During the renewed period of investigations, diatom, phytolith, pollen and microcharcoal analyses were undertaken by specialists on 40 'paired', or comparable, samples, with additional samples for some techniques. Several of these paired samples were also subject to AMS dating.

[3] During the subsequent period of investigations, diatom, pollen and microcharcoal analyses were undertaken on paired and contiguous samples through Phase 1, 2 and 3 contexts.

Over the six years of intensive fieldwork between 1972 and 1977, personnel changed as people moved on and new requirements emerged. Ian Hughes carried out his enquiries of older inhabitants about the agricultural use of swampland in the upper Wahgi during the first two years of the project, but stayed on with the New Guinea Research Unit in other roles.

It was in this planning stage that RSPacS awarded a PhD scholarship in its newly established Department of Prehistory to a Canadian applicant, Ole Christensen, who was well qualified to play a role in its Kuk project: MA research at the University of Calgary on prehistoric subsistence in Banff National Park and experience in tropical agricultural systems in Sudan and South America. He chose to undertake a study of resource utilisation in one of the side valleys of the Wahgi in the vicinity of Kuk to provide information about what was going on in dryland contexts while swamp agriculture was being practised. He did so in the Wurup area to which he was introduced by members of the Manton family whom ANU archaeologists had got to know during their 1966 excavations at the Warrawau Tea Plantation nearby. He was well advanced with his PhD research and had just submitted a summary of his work for publication (Christensen 1975) when he was killed in a road accident in December 1974. Besides the records on which the 1975 article was based, he left two important collections that have received subsequent attention. One is a large archaeobotanical collection from the wet sieving of four excavated rockshelter deposits in the Manim Valley (Donoghue 1988; and Chapters 10 and 14 here). The other is a stone axe collection from the Wurup area (White et al. 1977), which Chapter 21 notes as one of those that made it possible to study the nature and extent of the highlands stone axe trade and, because of axe fragments found in Christensen's rockshelter excavations, suggest a date for its beginning.

In order to provide a wider context for the understanding of the deposits that he was studying at Kuk, Russell Blong undertook cooperative work with Colin Pain, whose doctoral research on the Quaternary history of the Kaugel Basin, 40 km west of Kuk, was coming to an end (Pain 1973). They began with the unravelling of the stratigraphy of the thick older tephras deposited across much of the Western and Southern Highlands Provinces by eruptions mainly of Mt Hagen and Mt Giluwe more than 50,000 years ago (Pain and Blong 1976), as well as the nature of highland valley footslopes and fills (Blong and Pain 1976; Pain et al. 1987). Blong later persuaded a group of consulting engineers to drill a series of boreholes into the massive and widespread (>105 km^2) debris avalanche from Mt Hagen responsible for the presence of ash-mantled low hills beneath the swamp sequence at Kuk. The age of this avalanche is unknown, but it is at least 80,000 years old (Blong 1986a: 292).

Pain and Blong (1979: 229 and Fig. 2) note that while highlands volcanoes virtually ceased activity more than 50,000 years ago, numerous younger thin (<100 mm) tephra falls had been recorded, particularly at Kuk, where the most intensive work had been done. The youngest of these tephras was Tibito, first identified by Blong in 1971. A few years later, Blong (1975: 215) could report its age as about 250 years BP on the evidence of half a dozen radiocarbon dates and its distribution as covering an area of at least 5500 km^2, on the basis of trace element analysis of samples. Blong's 1975 article effectively discredited the 1883 eruption of Karakatau (the former Krakatoa) as the source of not only the ash but also the stories of a Time of Darkness when 'sand' fell from the sky and crops failed. These were widespread on mainland PNG, but Blong had to admit that the source of the responsible tephra remained unknown (1975: 215). The possibility that it was Krakatau had occurred to the American anthropologist James Watson (1963: 154) when he was told a Time of Darkness story in the Kainantu region of Eastern Highlands District in 1954 (Watson 1963: 152).

Beginning in the late 1960s, interest was independently shown by workers over a range of disciplines in the geological, biological and human history of Long Island, off the north coast of PNG about 140 km east of Madang and a member of the Bismarck Volcanic Arc. By mid-1976 the various projects had become 'so intertwined that a joint publication was decided upon' (Specht et al. 1982: 414–416).

Ian Hughes went to Long Island in 1972 as part of a Department of Agriculture, Stock and Fisheries team evaluating proposals for conserving the natural environment. He was impressed by the high cliffs of tephra on the north coast, saw buried soils at various places under the tephra and collected three samples of carbonised wood for radiocarbon dating. Among the first material to appear below the surface, they came from underneath several metres of sterile volcanic deposit later called the Matapun beds (Pain, Blong and McKee 1981: 104–105 and Fig. 3, where ANU-1127-1129 are the three samples collected by Hughes). Back at Kuk, Hughes described what he had seen and sampled and, knowing of the tephra in the Kuk stratigraphy, suggested investigations of the Long Island sites.

In 1973, Hughes went to Long Island with Jim Specht from the Australian Museum, Sydney, and Brian Egloff of the Papua New Guinea Public Museum and Art Gallery, as it was then. Specht and Egloff were archaeologists who had been PhD scholars in prehistory at RSPacS, ANU, around the time that Hughes was a PhD scholar in geography there, all three working on PNG topics. In their new positions, Egloff and Specht had separately taken up field research in adjacent areas of the PNG north coast, Madang (Egloff) and Huon Peninsula (Specht), with Long Island overlapping the boundary between the two and likely to have links with both (Egloff and Specht 1982: 427). On their combined visit to the island they collected potsherds, obsidian and molluscan remains from a number of archaeological sites and two radiocarbon samples to back up those collected by Hughes the year before (Pain, Blong and McKee 1981: Fig. 3, ANU-1307 and 1308; Egloff and Specht 1982: 427–431). Though, as Specht et al. say (1982: 415), the dates of the samples collected by Hughes in 1972 'bridged' those associated with Tibito Tephra at highlands sites, it is unclear how widely this was known in the mid-1970s because Blong did not allude to the Hughes dates in his 1975 article.

Blong and Pain made a first visit to Long Island in 1976, accompanying an officer of the Rabaul Volcanological Observatory, C. O. McKee, in the course of his geological and geophysical work (Specht et al. 1982: 415). They collected samples for further radiocarbon dating (Pain, Blong and McKee 1981: Fig. 3, SUA-623 and 624) and volcanic ash samples from the Matapun beds, which showed that the Tibito Tephra of the PNG highlands, the source of which Blong (1975) had had to admit was unknown, had in fact been erupted from Long Island (Pain, Blong and McKee 1981: 105). The earliest published notice of this is a *Nature* article of January 1978 in which Frank Oldfield reported an (undated) personal communication from Blong to say that his geochemical analyses showed that the latest tephra in the highlands sequence, i.e. Tibito, came from Long Island (Oldfield, Appleby and Battarbee 1978: 341).

It was now clear that the widespread stories of a Time of Darkness in most cases referred to Tibito Tephra, which originated from Long Island. Such stories had been collected over the years by anthropologists, missionaries, government officials and the like. With their renewed assistance and the use of a questionnaire that he circulated in 1976–78, Blong now began to collect further examples (Blong 1979a),[3] testing the accuracy of the detail that the answers provided against accounts from across the world of the observed consequences of thin falls of volcanic ash (Blong 1982; see Chapter 8 here). This is the background to his career move into the field of natural hazards and his well-regarded work on volcanic hazards (e.g. Blong 1984).

In 1974, Philip Hughes moved from the University of New South Wales (UNSW) to the Department of Prehistory, RSPacS at ANU, and assumed responsibility for the geomorphological work at Kuk in 1974 (Fig. 1.3). From 1974 to 1977, he extended the record of swamp stratigraphy begun by Blong and undertook a detailed study of the large water-disposal channels by which the swamp had been drained in the past (see Figs 14.2, 14.4, 15.2 and 15.4). In this he was helped from time to time by Marjorie Sullivan, a fluvial geomorphologist, also formerly of UNSW.

3 Blong has deposited his 1979 *Oral History* summary of all the legendary accounts with the Pacific Manuscripts Bureau, together with the correspondence that he received in response to his questionnaire: PMB MS 1329, Blong, Russell, Time of darkness legends from Papua New Guinea: questionnaire returns, correspondence and reports 1977–1982.

Figure 1.3 Jack Golson (second from left) and Philip Hughes (second from right) with workmen from Kuk village.

Source: Photograph by Barbara Greaves, 1974.

At the time of the first Kuk investigations, techniques were not capable of extracting pollen grains without damage from clayey formations like those making up the bulk of the Kuk stratigraphy. As a result, some of Powell's palynological work for the project took place outside Kuk itself. The picture of advanced forest clearance by the mid Holocene, provided by the Manton and Draepi sites in her ANU PhD thesis (Powell 1970a), was confirmed by investigations at a pond at 1620 m altitude 3 km west of Kuk just below the small volcanic cone of Mt Ambra. The name of this was borrowed to identify the palynological site as Lake Ambra (Powell 1982a: 218–224).

While Powell was conducting this palynological work in the upper Wahgi, complementary work was taking place to the west in Enga and Southern Highlands districts (soon to become provinces). This built on the pioneering reconnaissances of Donald Walker in the 1960s, of which the first results were Walker on the Lake Ipea region (1966, 1972) and John Flenley's doctoral thesis (1967), followed by Walker and Flenley (1979) and Walker and Hope (1982). Other work is associated with Frank Oldfield, who had been a graduate student for a year in the famous Subdepartment of Quaternary Research in the Botany School at Cambridge University, learning the techniques of pollen analysis and vegetation history. Here Walker was one of his teachers, who shortly afterwards moved to ANU, and after his pioneer trips in the PNG highlands persuaded Oldfield of the attractions of work there. Oldfield spent the northern hemisphere sabbatical year 1972–73 in the country, returning several times over the following decade for conferences, workshops and more fieldwork.

Oldfield inherited three sites from Walker's fieldwork, Lakes Egari and Pipiak in Southern Highlands and Lake Ipea in Enga, and these were the subject of renewed sampling in the 1970s (Oldfield 1977: 59–60, 1988: 529): in 1973 by Oldfield and his team and in 1978 by Walker. The aim was to supplement the evidence of pollen analysis on landuse history by looking at the chemical and magnetic properties of recent lake sediments and using lead isotope 210 (^{210}Pb) to date them, all this benefiting from the work of Oldfield and colleagues in the British Isles and elsewhere. The conceptual framework and results from the PNG field were described in a paper (Oldfield, Worsley and Baron 1985) given at a conference in Canberra in August 1981 that had been organised to complement the proceedings of the XIII International Botanical Congress in Sydney the following week.

Establishing the age of Tibito Tephra played an important role in the development of ^{210}Pb dating, as Oldfield has recently explained (pers. comm., March 2015). First indications, from measurements carried out at the Atomic Energy Research Establishment, near Harwell in Oxfordshire, suggested an age of around AD 1880, close to that of the Krakatau eruption and also compatible with indications from oral history. Subsequently, Blong's ascription of Tibito ash, on geochemical grounds and radiocarbon dating, to a caldera eruption on Long Island that must have predated AD 1827, when the French navigator Dumont D'Urville noted the outline of the island, prompted the development of an alternative basis for interpreting the results (Oldfield, Appleby and Battarbee 1978: 341). Using this new model, the estimated age was revised to around AD 1800. That age also was shown to be too young, as a profile of the island sketched in 1700 by the English sea captain William Dampier almost certainly of the coast of Long Island in the early 1700s clearly postdated the caldera created during ejection of the ash (see, for example, Blong, Kemp and Chen 2016). Detailed measurements on each sample in the newly established Radiometric Dating Laboratory at the University of Liverpool confirmed that the age of the ash lay beyond the reach of ^{210}Pb dating. These new results, together with measurements of palaeomagnetic secular variations recorded in lake sediments (Thompson and Oldfield 1978), placed the age of the ash in the mid-17th century (Oldfield, Appleby and Thompson 1980). The development of the new ^{210}Pb dating model and the establishment of the Liverpool laboratory were thus triggered by the challenge of dating the New Guinea tephra.

In 1979 only Lake Ipea was resampled (Oldfield, Worsley and Baron 1985: 390), by Ann Worsley (née O'Garra), a graduate student whom Oldfield brought with him into the field that year for her PhD fieldwork. However, cores were taken for magnetic measurements at two of Jocelyn Powell's Wahgi pollen sites, Lake Ambra near Kuk and Draepi in the hills of the Sepik-Wahgi Divide 13 km north-northwest of Mount Hagen town (Oldfield 1988: 542–548), while Worsley made collections for her own doctoral research (Worsley 1983).

This upper Wahgi activity was linked with a week of Oldfield's time that Golson had booked at Kuk at the beginning of July 1979 for him to make an assessment of site stratigraphy in the light of his wide experience of sites and methods and in which he was joined by Worsley. The same week Golson had independently booked a visit for a similar purpose for the French soil scientist Marc Latham of the Office de la Recherche Scientifique et Technique Outre-Mer in Noumea, with whom he had visited Matthew Spriggs on his doctoral work on the southern Vanuatu island of Aneityum. Both Latham and Oldfield produced reports that could not be immediately followed up since the main Kuk fieldwork was finished and Powell and Blong were engaged elsewhere. They were made available to Tim Denham, then in the Department of Archaeology and Anthropology in the faculties at ANU, when he started doctoral research at Kuk in the late 1990s and they feature in the appendices that form part of his dissertation (Denham 2003a, vol. 2, Appendices E6 and E7).

Attention now turns to the other work that Powell had done before she left PNG in mid-1975 to take up a position with the National Herbarium of New South Wales. She was interested not only in the plants, tools and techniques of traditional cultivation, but also plants and their uses in the non-agricultural and agricultural domain. She worked with UPNG students from the Mount Hagen area during their 1971–73 summer vacations to gather material for *Agricultural Traditions of the Mount Hagen Area* (Powell et al. 1975); and with Simon Harrison, a future ANU PhD, to do similar work in Southern Highlands Province, *Haiyapugwa: Aspects of Huli subsistence and swamp cultivation* (Powell with Harrison 1982). While with the ANU New Guinea Research Unit, Powell (1976a) contributed Part III, on ethnobotany, to a book on *New Guinea Vegetation*, edited by Kees Paijmans (1976).

Pollen was considered unlikely to provide direct evidence of the staples under cultivation in the prehistoric past of New Guinea agriculture, which were expected to be the yams, taros and bananas of contemporary Pacific agriculture, none of them regular pollen or seed producers under cultivation. However, as she had done earlier at the Manton site and the archaeological site of Kindeng, Powell began a programme of sampling for fossil seeds from stratigraphic columns and ditch infills across Kuk Swamp for the light they might throw on the swamp environment at different stages of its history and for the presence of native highlands species that had food or other uses for the current inhabitants (Powell 1982b). She instructed Laurie Lucking, a graduate student of the University of Minnesota introduced to the Kuk project in 1973, in seed extraction and identification, on which Lucking worked over the years 1974–76, as well as on wood identification (see Chapter 18). In the earlier 1980s, other samples from Kuk were used by Sam Wilson for his BA (Hons) research project at ANU exploring the potential of phytoliths in the investigation of agricultural history at the site (Wilson 1985). This was shortly before the ANU Department of Prehistory appointed Tom Loy, from the Royal British Columbia Museum, and Barry Fankhauser (formerly University of Otago) from the Chaminade University of Honolulu, to set up a laboratory for the analysis of organic residues in archaeological contexts. Loy subsequently made a selection of some 58 items from the Kuk stone artefact collection that showed promising evidence of usewear and residues (see Chapter 20).

There were two problems with doing most of our data gathering from the walls of the minor Station drains. At Kuk these ran parallel to each other, north–south, within the large grid of major road and boundary drains planned for the Station as a whole. One problem was that linear features like drainage channels serving gardening systems in the past were much more easily studied when they ran eastwards and could be crossed by the minor drains dug 22.5 m apart rather than when they ran northwards and would only be cut by the bordering drains of east–west roads some 250 m apart (cf. Fig. 15.4 and Fig. 16.12). There were, of course, channels running just west or east of north that were cut obliquely by north–south minor drains. In these cases, excavation was needed to supplement the drain record. Such targeted excavations were carried out in 1974 in connection with the complex courses of the Phase 4 disposal channels in the northern part of block A11 and the southern part of block B10. This work was done by Jim Rhoads, the second graduate student from University of Minnesota to join the project in 1972 and whose 1974 report is part of the Kuk Archive. At other times during 1973 and 1974, Rhoads worked on test excavations and drain recording with Golson and Hughes. He took every opportunity to explore the region around Kuk, recording oral histories, and between his two Kuk seasons worked under Egloff at the PNG Museum and with Specht in New Britain. He went on to become an ANU PhD scholar researching the past and present of Papuan Gulf sago exploitation (Rhoads 1980).

The second problem was that the Station management's requirement that drains once started be finished led to great differences in the completeness and comprehensiveness of archaeological and stratigraphic recording between drains. Some drains were dug for archaeological rather than stratigraphic purposes and others the reverse. In others the interest, whether archaeological or stratigraphic, was in a specific section of the profile. As a consequence, archaeological recording ranged from cursory notes to the comprehensive record of every archaeological feature and stratigraphic recording, from no record to systematic documentation at 10–15 m intervals.

Nevertheless, the study of the archaeological and stratigraphic evidence in drain walls had led to the conclusion that six phases of drainage and cultivation were represented in the swamp, all of them followed by a period of abandonment. Each phase was characterised by a morphologically distinctive set of features; associated with one or more specific water-disposal channels; and in a consistent relationship with the different units of the stratigraphy of the swamp and the volcanic ashes. The aim of area excavation, when this became possible, was to isolate the individual systems and to establish how they were organised and how they operated. The knowledge accumulated over preceding years about the distribution of archaeological structures through the swamp and the different contexts of their occurrence served as a guide for the location of excavations. It was possible to nominate areas of the site where individual phases would be best investigated because they were most abundant, showed the clearest expression or had the least interference from disturbance by activities in later phases.

The plan was to begin with the excavation of the earlier phases of the sequence, Phases 1–3, and finish with that of the later ones, Phase 4–6 (Tables 1.1 and 1.2). In the event, only the earlier phases were investigated, though none of them fully and Phase 3 very incompletely. In the case of the excavation of Phases 2 and 3, the procedure was to dig down to the surface of grey clay, a widespread component of the Kuk stratigraphy, where the darker fill of archaeological features identified them more clearly against the lighter background of the clay so that they were more easily recorded and, if necessary, cleaned out. Phase 1 features were beneath grey clay and typically revealed as disturbances filled with grey clay on a darker surface. Their investigation obviously involved the record of features on the surface of grey clay before this was removed to expose the earlier surface.

The grey clay was from the outset interpreted as the influx of eroded material from the catchments of the swamp due to forest clearance on the slopes in the course of shifting cultivation. Some years after the suggestion was made in public and in print (Golson 1977a: 612–613; cf. Golson and Hughes 1980: 296–298), Sam Wilson (1985: 96, Fig. 3) produced phytolith evidence from samples of the grey clay to support it. His analysis showed two differences in phytolith frequency over the early Holocene period of grey clay deposition: a drop in total phytolith density due to a faster rate of sediment deposition and a dramatic drop in the percentage of grass phytoliths seen as due to the inwash of material coming off swidden clearings in the forest.

Serious area excavations began in October 1975, and from then until the close of the 1977 season involved the investigation of Phases 1–3 concurrently. They were all located in the southeast corner of the Station, in blocks A11 and A12. Klim Gollan, who went on to do a PhD thesis on prehistoric dingo in the Department of Prehistory, RSPacS, ANU (Gollan 1982), took part in the 1975 excavations, assuming responsibility for mapping and photography. He had previously taught mathematics at the Teachers College in Port Moresby, to which he added the study of prehistory at UPNG, where his lecturer, Mary-Jane Mountain, encouraged him to do MA studies at the University of London Institute of Archaeology. Alistair Marshall of the School of Biological Sciences at the Flinders University of South Australia, brought archaeological experience on prehistoric sites in UK to help with the mainly Phase 2 excavations of 1976 and their mapping and photography. Arthur Rohn, an archaeologist in the Department of Anthropology at Wayne State University, Kansas, who was on sabbatical leave at the University of Sydney, directed Phase 2 excavations in 1977 and with his wife Cherie mapped these and some of Golson's Phase 1 excavations. Help with Phase 1 photography was given by Art Rohn and Ed Harris, a doctoral student from University College London working on stratigraphy in archaeology, who was excavating Phases 5 and 6 houses at the site as part of his study. In the same year, Paul Gorecki of the then Department of Anthropology at the University of Sydney arrived to begin fieldwork for his PhD thesis on archaeological site formation processes in the context of the activities of the contemporary Kuk community.

Though there were no substantial excavations targeted at the field systems of Phases 4–6, they were still investigated and recorded in detail. Aerial photographs of Kuk Station in 1970 at an early stage of its development showed a grid pattern identical to that of contemporary sweet potato gardens to be typical of the last stage of Phase 6 cultivation before gardening ceased. The evidence as to date was provided by the stratigraphy of the walls of the minor drains that our workmen had dug through them. Grid patterns were also typical of Phases 4 and 5, although they could not be readily seen, if at all, on aerial photographs because they were buried. However, since a grid pattern is formed by straight lines crossing or joining at right angles, the old drainage networks could be reconstructed by mapping and interpolating the direction of ditches of the same phase from the two exposures of every relevant ditch in the opposite walls of the same Station drain. The procedure was an intricate one, complicated by some ditches having been dug along the line of older ones. However, the reconstructions provided by Tim Bayliss-Smith for Phases 4, 5 and 6 allowed comparisons to be made of garden size and ditch shape through time that had interesting implications (cf. Bayliss-Smith 2007).

Golson had met Bayliss-Smith, a geographer from Cambridge University, when he briefly visited the Kuk excavations in 1976 on his way back from fieldwork in Fiji. They renewed their acquaintance when Golson was in Cambridge in 1978–79. They talked about taro as a possible highlands staple before the arrival of the sweet potato, particularly in the context of the garden grids that had made an appearance with Phase 4 of wetland drainage at Kuk. As a result, Bayliss-Smith spent the period from June to October 1980 in the highlands, establishing experimental taro plots at Kuk, making field observations at the drained taro plantings at Baisu Corrective Institution 4 km down the valley and, for comparison, setting up high-altitude taro plots in the upper Kaugel Valley near Tambul, some 40 km to the southwest. In August 1981, he went back to Kuk and Tambul to harvest the experimental taro plots, with the assistance of Jean Kennedy from the UPNG Anthropology Department. During this period, as far as he was able, he got information on drainage densities and planting densities, yields and labour inputs. With this background, he then worked with Golson on the records of Phase 4 ditch cross-sections and networks in the Kuk fieldbooks, initially for block A9, then for blocks A10 and A11 (Bayliss-Smith and Golson 1992a, 1999). This cooperative work then extended to other Phase 4 blocks as well as to Phases 5 and 6, resulting in a Phase 6 publication (Bayliss-Smith et al. 2005) and Chapters 14–16 here, dealing with Phases 4–6 respectively.

Other ethnographic data relevant to the recent agricultural systems had been investigated in 1975 by Axel Steensberg, specifically the traditional tools and techniques that had been used for land clearance and gardening. He did this with older men of the community, who made the tools and demonstrated their use. He discussed this work in a book (1980) and in 1983 brought his experience to the cataloguing of the wooden artefacts found at Kuk and elsewhere, which is the basis of Chapter 19 here.

Steenberg had been Professor of Material Folk Culture in the Institute of European Folk Culture at the University of Copenhagen from 1959 to 1970. This followed many years of service in the Danish National Museum's Third Department, which dealt with upper-class, urban and especially peasant life from 1660 to the 19th century and of which he was head from 1946 to 1959. Golson had worked under him in the early 1950s on excavations of Danish village sites and they had kept in touch. In 1968, he took advantage of a visit that Steensberg and a colleague, Grith Lerche, were making to a conference in Tokyo to invite them to visit the archaeological work beginning in the upper Wahgi Valley in the aftermath of the Manton excavations of 1966. Steensberg paid another two visits to New Guinea, the second in 1975, when he spent three weeks at Kuk working on agricultural tools and techniques associated with land clearance and gardening, as mentioned above. This had been preceded by a couple of weeks among the Duna people further west, where he had looked into traditional tools and techniques in tree felling, house building, fencing and cooking.

Closer to hand, staff members of the National Museum and UPNG provided on-site services as they were able. Mary-Jane Mountain of the Department of Anthropology at the university brought groups of students on different occasions for a period of excavation experience under her supervision. There were also regular visits by student parties from Mount Hagen High School, Mount Hagen Technical College and the Highlands Agricultural Training Institute.

Reading the history of highlands agriculture: The first period at Kuk

Before the end of the 1970s fieldwork, the first published reports about it were describing a sequence of six episodes of swamp drainage and cultivation running parallel with a continuous sequence of dryland cultivation, both beginning around a date of some 9000 radiocarbon years ago. Because this was before the days of calibration of radiocarbon dates to calendar years, 9000 radiocarbon years was referred to as 9000 BP (Golson 1977a: 612) or, more loosely, 9000 years ago (Golson 1977b: 46) (for the individual dates leading to this conclusion see Golson 2000: 236). After the appearance of the first accepted calibration curve (Stuiver and Kra 1986) and subsequent modifications, dates of around 9000 radiocarbon years for Kuk Phase 1 reported by Denham (et al. 2003: 189, 190, Table 1 and Table S1, note 4) from his 1998–99 fieldwork at Kuk gave calendrical dates of around 10,000 cal. BP (see Table 1.2 here).

Table 1.2 Archaeological phases at Kuk Swamp, Wahgi Valley.

Phase	Age	Description	Stone artefacts	Wooden artefacts[2]	House sites[3]	Ditches	Cultivation features[4]	Artificial channels[5]
6	AD 1700–1900	grid-like field systems	X	X	X	X		X
5	AD 1250–AD 1660s	grid-like field systems	X	X	X	X		X
4	2000–1230/970 cal BP	grid-like field systems	X	X	?	X		X
3	2700–2400 cal. BP	late subphase: rectilinear/dendritic ditch networks	X			X	?	X
	4350–3980 cal. BP	early sub-phase: rectilinear ditch networks	X			X		X
2[1]	6950–6440 cal. BP	mounded palaeosurface	X				X	?
1	c. 10,000 cal. BP	amorphous palaeosurface	X				X	?

Source: Update by Denham of Denham (2007a: Table 2).

Notes:

[1] Another possible Phase 2 subphase predates Kim (R) ash, which fell in the period between 3980 and 3630 cal. BP, although it is not well characterised and is not included in the table.

[2] No wooden artefacts were collected from Phase 1–3 contexts (cf. Powell 1982a: Table 2).

[3] Ed Harris in 1977 noted unexcavated house remains at a multi-occupation site that could predate Phase 5.

[4] Occasional features interpreted to represent 'within plot' cultivation features have been recorded for late Phase 3.

[5] Palaeochannels have been differentiated from ditches at Kuk on the basis of scale, although the mode of formation of some palaeochannels is debated (see discussion in Denham, Golson and Hughes 2004). Golson and Hughes have argued for the artificiality of all palaeochannels, whereas Denham has argued that the Phase 1 and 2 palaeochannels may not be artificial.

These dates suggested an antiquity for cultivation comparable to that of the extensively and intensively studied Fertile Crescent of the Middle East, at a time when the conventional wisdom was that New Guinea had received its agriculture from colonists moving out of Southeast Asia into the Pacific within the last few millennia (Yen 1971: 6; Golson 1985: 307, 308; Yen 1995: 831; Denham et al. 2003: 192; Bellwood 2005a: 141).

The period now claimed for New Guinea agricultural origins is when modern temperature levels arrived in the highlands at the beginning of the Holocene after a period of late glacial warming that followed the Late Glacial Maximum. The pollen evidence from the Wahgi Valley shows that the temperature regime after some 10,000 years ago was suitable for the major staples of Pacific agriculture (taro, yam and banana), generally considered as of tropical Indo-Malesian ancestry, to be grown in the New Guinea highlands. Indeed, there was a serious argument 40 years ago for their presence there around 10,000 years ago. This involved the introduction of hand-fed Southeast Asian pigs into New Guinea accompanied by the cultivated plants that kept them tied to people (Golson 2007: 113). It was an argument based on Susan Bulmer's report (1975: 18–19, 36) of a pig incisor in the basal layer of a Simbu rockshelter dating to the terminal Pleistocene, supported by comparisons of basins in Phase 1 and Phase 2 contexts at Kuk Swamp to modern pig wallows (Golson and Hughes 1980: 299).

The pig hypothesis remained weak because only one other claim for Late Pleistocene/early Holocene finds was made (for Yuku rockshelter, S. Bulmer 1982: 188) before direct dating of pig bone appeared on the scene to challenge it (O'Connor et al. 2011: 5). There were also explanations other than pig for the Kuk basins, including plant husbandry, as suggested by Doug Yen (1980: 143–144; cf. Golson 2007: 113). For Pacific ethnobotanists, however, the appearance of New Guinea plants like sago palm, *fehi* bananas and sugarcane in the register of Pacific cultigens was reason for the consideration of the region as an important division or extension of Vavilov's Indo-Malesian centre, following Barrau (1963: 6), or a site of agricultural origins parental to Oceanic subsistence systems, following (Yen 1995: 831; cf. Yen 1971: 4).

Golson came to know Yen in Auckland in the 1950s, when he was an archaeologist on the staff of the Department of Anthropology at the then Auckland University College and Yen was in charge of the Vegetable Breeding Station of the Crop Research Division of the New Zealand Department of Scientific and Industrial Research. In his work, Yen had a strong ethnobotanical interest in traditional Maori food plants, as a result of which he became associated with scholars worldwide through the Pacific Science Association. Yen came to concentrate on the history of the sweet potato, which he travelled widely to collect. This led in 1966 to his appointment as ethnobotanist at the Bernice P. Bishop Museum, Honolulu, where his monograph on the sweet potato was published in 1974.

Before Yen left New Zealand he had become mentor to Jocelyn Wheeler, a young cytologist at Crop Research, and steered her to undertake research at ANU into PNG palynology. He took a great interest in the Kuk project of the 1970s that grew out of the Manton investigations of the mid-1960s in which Wheeler had taken such an important part. In 1980, Yen moved from the Bishop Museum to a post in the Department of Prehistory at ANU, where he spent 10 productive years. He was intrigued by the implications of the sharing of genera of food plants by Australian Aborigines using them wild and gardeners in New Guinea (and more widely in Oceania) using them cultivated—in particular *Dioscorea* yams and *Colocasia*, *Alocasia* and *Amorphophallus* taros (Golson 2007: 116). He saw this geographical sharing of genera, and a few species, as a result of the collision some millions of years ago between the Australian/New Guinea fragment of the ancient continent of Gondwanaland with the Laurasian Plate at its margin in eastern Sulawesi (Yen 1990: 259, on the basis of Whitmore 1981). This raised the possibility that the Oceanic taro-yam complex was of Laurasian origin, with New Guinea domestication as an alternative to its human transport from Southeast Asia (Yen 1990: 260). It was shortly after this that Loy, Spriggs and Wickler (1992: 910) reported *Colocasia* starch grains some 28,000 years old on stone tools from a site in the northern Solomons and Simon Haberle (1995: 207) *Colocasia* pollen from Lake Wanum in the Markham Valley behind Lae in PNG dated about 9000 years ago.

Very few of the basic data relating to the claims about Kuk were published (cf. Denham, Golson and Hughes 2004: 261). The sequence of drainage episodes in the swamp and the characteristics of the cultivation systems established on the drained surfaces were summarised in an early article (Golson 1977a) that had been modified subsequently but not superceded. The evidence for the early beginnings of wetland and dryland agriculture was discussed by Golson and Hughes (1980) and the dryland evidence amplified in a later article (Hughes, Sullivan and Yok 1991). Overall, however, publication had less to do with the data from the site than the implications of the interpretations made of them for broad issues in New Guinea prehistory (see Golson 1990: 140, for a list of publications about Kuk to that date). As a result, when attempts were made to evaluate the Kuk claims in the light of the greater understanding of regional prehistory that had been achieved by the early 1990s, there was a limited data base to refer to (Bayliss-Smith 1996: 500, 507–510; see also Spriggs 1996: 528–529).

Renewed investigations, 1998–1999

The lack of publication of the primary evidence was only one of the difficulties facing Denham, when, as an ANU doctoral student in the later 1990s, he planned to address the claims for early and independent agricultural origins at Kuk, concentrating on Phases 1–3 of the sequence. As he worked through the files and collections from the previous work, he found weaknesses with the characterisation of the three phases related to the limited archaeobotanical evidence of cultivated plants, limited palaeoecological evidence for associated environments and environmental change, and the uncertain significance of archaeological structures and finds on the wetland margin (Denham 2003a: iii). As a result, with Golson's supervision, he planned new excavations of Phases 1–3 at Kuk.

The renewed excavations at Kuk were undertaken with permission and support from the Papua New Guinea National Museum. Members of the museum staff came to Kuk both years in order to engage with the local community, participate in the excavations and undertake field training. Staff members included Herman Mandui and Nick Araho. Additionally, John Dop and Daniel Gono, students at UPNG, came into the field for training. Fieldwork in both years was greatly assisted by John Muke, a lecturer in prehistory in the UPNG Department of Anthropology and Sociology, whose close engagement with the Kuk community is discussed below. Thomas Wagner, a lecturer in geology at UPNG, who over the years had worked with Russell Blong on Kuk tephras, joined both field seasons and undertook characterisation and sampling of volcanic tephras (see Chapter 7). In 1999, Tim Bayliss-Smith and Inga-Maria Mulk from Europe and Robin Torrence and Peter White from Sydney assisted with the fieldwork.

The 1998 and 1999 excavations undertaken by Denham were primarily designed to characterise the function of features associated with Phases 1–3 and to undertake sampling (Denham, Golson and Hughes 2004: 261). The sampling was to facilitate multidisciplinary analyses—chronological, archaeobotanical, palaeoecological and stratigraphic—to address the shortcomings of the existing evidence. These expanded on those that had been employed in the original fieldwork in decisive ways (see Table 1.1).

Denham's own efforts went into: assessments of the archaeology and stratigraphy recorded in previous investigations, with emphasis on the function of features, whether associated with cultivation or other activities; multiscale and mixed-method analyses of sediments, soils and fills of archaeological features; site formation processes over the long term; and the integrity of samples for radiocarbon dating and palaeoecological analyses (Denham 2003a: iii). The availability of AMS as well as conventional radiocarbon dates allowed better chronological resolution than the conventional dates of the previous investigations.

Denham directed a range of other analyses on archaeological features and stratigraphy associated with Phases 1–3. These were undertaken by people who were new to the project (Denham 2003a: iv; Table 1.1 here). Simon Haberle undertook pollen and microcharcoal analyses on samples from archaeological and stratigraphic contexts dating from the terminal Pleistocene to the mid Holocene (Haberle et al. 2012). Previous studies had been limited by processing techniques available to extract pollen from dense clays at the site. These methodological problems had been overcome by the late 1990s, thereby enabling a history of vegetation change and burning to be established for the key periods of early agriculture and subsequent changes at Kuk.

Since the investigations of the 1970s, there had been advances in the application of microfossil techniques to archaeological questions, especially in the fields of phytolith, starch grain, diatom and insect research. All these techniques enabled the environments associated with the earliest phases to be better characterised. Additionally, phytolith and starch grain analyses were employed to identify the presence, use and cultivation of key food plants in the highlands, most of which do not ordinarily preserve as microbotanical remains and do not produce abundant pollen in cultivated contexts.

Denham was fortunate to work with a number of key researchers within each field. Carol Lentfer (then at Southern Cross University, Lismore, NSW) had already established a reference collection for phytoliths in Island Melanesia, including for many cultivars of Pacific agriculture (Lentfer 2003a). Barbara Winsborough, an independent consultant from Texas, was a diatom specialist who had worked on wetland archaeological sites in the Pacific (e.g. Denham et al. 1999). Most of the pollen, microcharcoal and diatom analyses were conducted on 'paired' samples, i.e. the samples were from the same location in the fill of an archaeological feature or in the stratigraphy (Denham, Haberle and Pierret 2009; Denham, Sniderman et al. 2009). These analyses provide complementary records of environmental change through time: pollen and phytoliths on vegetation history; microcharcoal on burning; and diatoms on soil and open-water conditions. The analysis of insect remains by Nick Porch (then at Monash University, Melbourne) served to enhance the palaeoenvironmental record.

Richard Fullagar (then at the University of Sydney) undertook usewear analysis of stone tools from Kuk. Most of these were subsampled from those previously selected by Tom Loy, while some came from the new excavations of 1998 and 1999. Organic residues, especially those in the form of phytoliths and starch, were subsequently extracted for identification by Lentfer (phytoliths) and Judith Field (at Sydney University, starch) (see Fullagar et al. 2006).

Taken together with the results of previous research, the composite findings represented major advances in our understanding of the archaeobotany and palaeoecology of the early phases at Kuk (Denham et al. 2003; Denham, Haberle and Lentfer 2004; see Denham, Sniderman et al. 2009 for the subsequent extension of this work):

a. There emerged a sounder basis for the case for human disturbance of the primary forest in the early Holocene than that given by earlier work and a picture of its subsequent degradation to grassland by the start of Phase 2, roughly between 7000 and 6500 years ago. Golson (1977a: 621–622; cf. Golson 2007: 119–121) had argued that a prominent break in the Kuk stratigraphy at around 2500 years ago between the end of Phase 3 and the beginning of Phase 4 marked the beginning of soil tillage after the establishment of grassland. This is a disputed claim that is taken up again in Chapter 6, section 'Garden soils', and Chapter 14, section 'Soil tillage as an innovation';

b. There also emerged a list of edible plants present in Phase 1, the most significant being taro and a yam, with the presence and possible planting of Eumusa bananas from the end of Phase 1 and in Phase 2.

The conclusion that Denham (2003a: iv) drew from his work was that 'the multi-disciplinary lines of evidence presented in [his] thesis are consistent with previous claims for the early and independent origins of agriculture in New Guinea'. At the same time there were differences of interpretation between Denham on the one hand and Golson and Hughes on the other. These could involve both the interpretation of specific features of the field record, like the artificiality or not of some of the disposal channels in the early phases, and the assessment of the overall evidence on a question, for example as to whether Phase 1 sees the beginning of agriculture at Kuk (Denham, Golson and Hughes 2004: 294; Golson 2007: 117–119), or whether it is Phase 2 (Denham et al. 2003: 192). Such differences are presented here in the form of a dialogue where each side states its case (cf. Denham, Golson and Hughes 2004: 261–262).

Kuk Phase 8: Between the original and renewed excavations

With the end of the 1977 field season, the focus of attention had shifted to the records of six years of fieldwork and the collections of artefacts and samples that they had produced. Field visits did not completely stop, but were reduced to short periods by a few people doing necessary updates, like a resurvey of the site. It was also felt necessary to keep in touch with the Station personnel and the Kuk community to show continuing interest in the site in the light of the possibility that further fieldwork might be desirable there, as became the case with Denham's PhD research.

Golson was on such a visit to Kuk in August 1990 when Martin Gunther, the Officer-in-Charge for the previous 10 years, told him of the imminent closure of one of the two highlands research stations of the Department of Agriculture and Livestock. Shortly afterwards the axe fell on Kuk, which closed down at the end of the year. In Chapter 24, Golson and Muke discuss the uncertain years that followed, with government effectively abandoning the Station it had set up along with the land it had bought and still owned.

Golson did not visit Kuk again until 1993 and when he did so it was with John Muke, who had recently returned to the staff of the UPNG Department of Anthropology and Sociology from Cambridge University with a PhD in archaeology. He began an archaeological research and training programme in his home district near Minj in the middle Wahgi Valley, in which he invited Golson to take part. There was a plan to negotiate a visit to Kuk to assess the situation on the ground and this took place towards the end of 1993 and was highly encouraging. Muke and Golson paid a follow-up visit in 1994 (see Chapter 24, section 'Prelude 1991–1995').

Beginning in late 1995, the traditional owners started moving across the Station boundaries in a well-planned and efficiently executed operation that was followed by house building and garden preparation to confirm the act of repossession. This was the beginning of what Golson and Muke have called Kuk Phase 8 and raised concerns about the site's future. Muke and Golson paid a visit in early May 1997 to assess the prospects for renewed fieldwork in the changed circumstances of landuse and landholding. When he got back to Australia, Golson wrote a short report on the situation at Kuk, of which he sent one copy to Muke and one to Pamela Swadling, Chief Curator of Prehistory at the National Museum (cf. Muke 1998: 75). She received it at a time when the Director, Soroi Eoe, was preparing for a UNESCO meeting at the Fiji Museum in Suva, where he was to propose two PNG sites for World Heritage listing, one of them Kuk, on the grounds of its cultural values. It was in this context that the museum sent a small team to Kuk for a week (23–30 May) to report on two matters: the likely implications of the resettlement of the site for its archaeological features; and the views about its heritage aspects held by the people who had just repossessed it. Director Eoe submitted the museum report and Golson's earlier one at the Suva meeting, together with a World Heritage nomination proposal for Kuk by Golson and Swadling.

In addition to these documents, there were relevant early discussion papers that Swadling also thought deserved attention and she made a request for help in this respect from Andrew Strathern and Pamela J. Stewart, who were in PNG on anthropological work. Strathern had an association going back to 1964 with the Kawelka, the traditional owners of Kuk, which they had been forced to abandon around AD 1920 due to defeat in war. They moved to kinsfolk at Mbukl on the Sepik-Wahgi Divide, where it was that Strathern had first got to know them. He also knew the Kawelka who from about 1960 had moved back to live at Kuk and he had given Golson advice and support from the very beginning of the Kuk project. At the University of Pittsburgh he was starting a new programme of work in PNG with Pamela J. Stewart, his wife and University of Pittsburgh colleague.

At a meeting in Port Moresby, Stewart offered, on behalf of Strathern and herself, to take over the documents that Swadling had discussed with them and museum authorities gave their consent. In 1998, they presented them in an edited book, *Kuk Heritage: Issues and debates in Papua New Guinea*, the purpose of which was to show 'the complexities that surround matters to do with cultural heritage generally in cases where a delicate balance has to be sought between international, national, provincial and local interests' (Strathern and Stewart 1998a: Preface and Acknowledgments). A good number of copies went to PNG and copies were sent to libraries and scholars elsewhere.

The Suva meeting, for which the foregoing discussion provides a PNG context, was an important one for the Pacific region. It was a Global Strategy meeting organised by UNESCO's World Heritage Centre to identify World Heritage sites in the Pacific, of which at the time there was only one nominated for a Pacific island nation—the East Rennell natural area in the Solomon Islands. This situation was partly due to the requirement for a country to have signed the World Heritage Convention to be eligible to make a nomination for the World Heritage List. PNG became only the third Pacific island nation, after Fiji and the Solomon Islands, to do so when it signed in July 1997.

When Strathern and Stewart took over responsibility for a publication on Kuk linked to the Suva meeting with its emphasis on the heritage aspects of the story, Golson and Swadling began to develop sections of the chapter they had contributed to it (Golson and Swadling 1998: 7–9) for a volume reporting on the Kuk Project as a whole. The present book is the ultimate result.

Planning for it began in earnest when Swadling retired from the National Museum in 1999 and moved south to Canberra. John Muke, who was already involved, became PNG-resident editor. After the completion of Denham's doctoral work and the presentation of his results there was an obvious need to rethink the whole operation and he came onto the editorial committee. With his participation, the scope of the volume expanded and, as the work progressed, Philip Hughes was added to the editorial team. There was a conscious effort not to lose touch with a PNG readership that had been one of the targets of the planned publication. That is why we retain the original structure in the present volume.

The structure of the volume

Part 1 has four chapters that set the Kuk work in a number of different contexts:

Chapter 2 the world of agricultural origins, which New Guinea has now entered;

Chapter 3 the world of agriculture based predominantly on the vegetative exploitation of plants. This is true not only of root crops like yams and taros but also of a range of other plant types like bananas and several cane grasses, while many trees and palms are exploited by the transplanting of seedlings rather than the planting of seed;

Chapter 4 the world of New Guinea and the environmental factors that have been important in determining its agricultural present and past; and

Chapter 5 the world of living New Guinea wetland agricultural systems for the light these can throw on the abandoned wetland systems of the upper Wahgi Valley in terms of technologies and social contexts.

Part 2 has five chapters dealing with specific kinds of evidence provided by the project's field operations and crucial for their interpretation.

Chapter 6 discusses Kuk Swamp, its place in its local setting and its drainage for the establishment of the Kuk Tea Research Station. The drain walls revealed a stratigraphic record combining the biophysical processes of swamp formation with the evidence of its drainage for gardening and the inwash of eroded material from vegetation clearance for dryland gardening in its catchments. This stratigraphic record is the framework within which the discoveries are presented, dated and interpreted.

Chapter 7 is concerned with thin (<100 mm) occurrences of airfall volcanic ash that are preserved from place to place across the site and at different levels in its stratigraphy. There are at least 10 such occurrences between 18,500–15,000 years ago and the AD 1660s, seven of them in the last 4000 years. Each represents an instant of time and could be used, with other stratigraphic evidence, to define time horizons across the site. There is potential for this also to be done from site to site and over large areas. This requires geochemical characterisation of the different tephras in combination with careful dating, as demonstrated in the chapter.

Chapter 8 discusses the relationship between the fall of Tibito Tephra in the AD 1660s, the latest tephra in the sequence at Kuk, and the many versions of a Time of Darkness story collected within the 85,000 km^2 area that it covered, the first collection being made nearly 300 years after the eruption. The reports of the negative effects of the ashfall in the collected versions seem to be accurate in the main when judged against contemporary accounts of similar ashfalls elsewhere in recent times, with the effects repeated during every ashfall in the past. There are some localised versions of the legend that report the Tibito ashfall as agriculturally beneficial and a positive effect of soil replenishment by ashfall is cited by some modern authorities. The chapter views this hypothesis with caution.

Chapter 9 looks at the history of human and environment interactions at the Kuk wetland and its immediate catchments using a range of complementary techniques to reconstruct past environments, particularly pollen and charcoal. This is done in the context of pollen evidence from Kuk wetland and other sites in the upper Wahgi Valley and the result is an account of the vegetation history of the region told in three broad periods:

1. the Late Pleistocene (here referring to the period before 25,000 years ago), when the first human occupation of the region took place;
2. the Last Glacial Maximum to the early Holocene (25,000–7000 years ago), comprising:

a. the coldest period in the pollen records, the Last Glacial Maximum (25,000–18,000 years ago);
b. a period of late glacial warming (18,000–10,000 years ago) ushering in the early Holocene (10,000–7000 years ago) after the modern temperature regime was reached; and
c. the mid to late Holocene (7000 years ago to present).

The subject of **Chapter 10** is archaeobotany, the study of plants in archaeology, here with particular reference to food plants since Kuk is a site with a long history of cultivation. The methods used in the 1970s were traditional ones largely restricted to the identification and analysis of macroscopic remains like seeds, wood and nutshell and the microscopic evidence of pollen and spores. Because Kuk is a wetland site, where organic preservation is better than at most dryland ones, even in circumstances of periodic drainage, a wealth of information was produced about the past occurrence of plants important to contemporary communities for a variety of purposes, including food. Beyond the reach of the methods of the time were plants that did not seed or produce pollen under domestication, like the tubers and fruits of the likely cultivated plants of past Kuk communities, taro, yam and banana. These awaited the development of a battery of microscopic techniques to deal with plant tissues, as well as phytolith, starch and raphide analyses. The first stage of the Kuk investigations caught only the beginning of this process.

Part 3 has six chapters that describe the evidence for each of the six phases of swamp gardening recognised at Kuk in the light of the considerations discussed in the five chapters of Part 2. A seventh chapter deals with houses, which are significant in the Kuk story in Phase 6. The first three chapters deal with Phases 1, 2 and 3, which were the subject of extensive excavations during the mid-1970s and reinvestigation by Tim Denham at the end of the 1990s.

Chapter 11 discusses Phase 1, a short-lived period of activity around 10,000 years ago. The authors differ as to whether the disposal channel carrying water away from the area, Kundil's Baret, channel 101, is natural or artificial. They agree that the pits, runnels, stakeholes and postholes excavated on its banks indicate the cultivation of edible plants and that the grey clay that fills them and constitutes the upper fill of the disposal channel is the product of erosion from the catchments, due to forest clearance for dryland cultivation. They disagree, however, as to whether the activities of the phase constitute agriculture. Whatever is the case, the evidence recovered for edible plants in the vicinity at the time includes genera that were the basis of agriculture later: *Colocasia esculenta* taro, *Dioscorea* sp. yam and Musa section banana.

Chapter 12 discusses Phase 2, which is characterised by mounded cultivation in two subphases, the earlier falling within a period starting 6950 and ending 6440 years ago, the later within one starting 3980 and ending 3630 years ago. The former is considered by Denham to represent the earliest unequivocal evidence of agriculture in the New Guinea highlands.

1. The early subphase, which was investigated in the southeast corner of the Station, has three disposal channels, the nearest one over 300 m west of the excavated palaeosurface, which would have allowed use of the southern part of the swamp margin by limiting its flooding by incident water. Golson and Hughes think that all three channels are artificial, but Denham is unconvinced.
2. In the later subphase there are two palaeochannels, both accepted as artificial by all authors, one of which continued in operation into early Phase 3. As in the earlier subphase, their connection with the garden features of the later palaeosurface was indirect.

At the end, the authors make the point that these two straight disposal channels of late Phase 2 date, as well as two straight and one curvilinear alignment of human construction of the same age, are of potential significance in understanding the appearance of rectilinear ditch networks in Phase 3.

Chapter 13 discusses Phase 3, which has at least three palaeochannels that follow straight courses that are visible on aerial photographs and can be independently reconstructed from the points where they are crossed by modern drains. They are associated with the first networks of linear ditching to appear at the site and are restricted to the southern margin of the swamp. They are described as a technical innovation compared with previous practice, representing a deliberate attempt to drain the wetland margin for cultivation by way of large palaeochannels diverting incident water from the southern catchment and receiving discharge from artificial ditch networks dug to lower the watertable. The ditches have been grouped into three subphases by the stratigraphy of their fills, early (around 4400–4000 years ago), mid to late (undated) and late (closely predating 2700–2400 years ago).

The big question posed towards the end of the chapter relates to the appearance of rectilinear ditching in highland New Guinea. As discussed in relation to Phase 2, there is possible continuity with the linear and curvilinear features of that phase, in addition to which there is the late Phase 2 palaeochannel (Joseph's Baret, channel 107) that continued in use in early Phase 3. These considerations point to swift on-the-spot change. The authors argue that it happened before Austronesians arrived in the Bismarck Archipelago and there is no evidence of anything earlier in Southeast Asia.

Chapter 14 accepts the argument of Chapter 6 that a distinct break in the Kuk Swamp stratigraphy between wetland Phases 3 and 4, with a change in the composition of the deposits from black clay to soil, marks the introduction of soil tillage into dryland agriculture. This is seen as a response to problems following the progressive replacement of forest by grassland. The stratigraphic break is roundly dated at 2500 years ago. The beginning of Phase 4 at Kuk is not very precisely dated, but estimated as around 2000 years ago. The phase ends with the fall of Olgaboli Tephra, an event dated between AD 720 and 980 or around 1100 years ago.

Phase 4 is described as a new and distinctive system of swamp management. It consists of a hierarchy of major disposal channels taking water mainly northwest then west from the southern catchment to the Guga River, a distance of more than 2.5 km, and joined by at least two minor disposal channels that collected water from eastern areas of the swamp. The field ditches articulate with the disposal channels. They are linear gutter-like features, deeper than they are wide and crossing each other at right angles to form grid-like networks defining planting beds that are remarkably uniform in shape and size. It is suggested that the swamp was for taro cultivation, with yams and bananas in dryland gardens. The large disposal channels show evidence of at least two subphases of use.

Chapter 15 argues that Phase 5 began around AD 1250, which may have seen a transition to a cooler and more unstable climate, and ends in the AD 1660s with the fall of Tibito Tephra, the last of the ashes in the Kuk sequence. The Phase 5 drainage system is structured like that of Phase 4, with a hierarchy of major and minor disposal channels and a grid of field ditches defining the planting areas. The major difference is in the field ditches, with a change from the narrow slots of Phase 4 to a wide trapezoid shape with flat bottoms and steep sides, quite like the larger ditches of Phase 3.

The substantial field ditches provided a plentiful supply of soil for making raised gardens in the swamp. Similar ditches have also been found outside wetlands, in grid patterns antedating Tibito Tephra at Mugumamp Ridge in the North Wahgi Swamp and at Kuk. The practice suggests that taro was no longer the dominant crop that it is thought to have been in Phase 4, with its place taken by yams. By late Phase 5, pigs had moved into the highlands from the lowlands, where Austronesian-speaking colonists had been settled for some time. Houses were making an appearance in dryland and swampland situations, their size and shape suggesting that they were housing pigs as well as people. Given the limited opportunities for forage in the grasslands, they would have been partly fed on garden food, so that their ownership would have been a sign of wealth and prestige. The evidence from Phase 5 is that although cultivation may have become less intensive, it was not in crisis when Tibito Tephra fell in the decade of the AD 1660s.

Chapter 16 confirms this by showing that a new phase of swamp cultivation, Phase 6, was beginning by around AD 1700, ending a couple of hundred years later. The major and minor disposal channels of Phase 5 were redug, so must have been visible at the swamp surface. However, the system that the redug Phase 5 channels were employed to operate was one of quite a different kind. The line of the two main drainage channels, which was northwest from the southern catchments, then west to the outfall, separated gridded areas of raised gardens overlying those of Phase 5 on the shallower swamp to the west from the deeper swamp to the east, which had been under cultivation in Phase 5. In Phase 6, however, to judge from the fence lines that took the place of ditches, this area became pasturage for pigs. In between were clusters of house sites following the line of the major disposal channel, women's houses in the main, with room for pig stalls judging by house shape and size and conveniently situated for the two sources of their food, the gardens and the pastures.

The suggestion is that the centre of attention and production has become the raised gardens of the dryland sphere, where a new crop, sweet potato, had taken over as staple. The field evidence from Kuk and the lack of an oral tradition of large-scale drainage among the older inhabitants of the upper Wahgi questioned by Ian Hughes in 1972–73 would suggest that the widespread patterns of former swamp gardening on aerial photographs belong to Phase 5. The pattern of population distribution in the sweet potato epoch is the hill slopes of the upper Wahgi Valley and the volcanic apron of Mt Hagen at its head, the swampy valley flats largely unused perhaps with the arrival of malaria in the course of trade with people at lower elevation.

Chapter 17 deals with houses, or rather house sites, in and out of the swamp. The earliest of them appear in Phase 5, but in such small numbers that it is difficult to say very much about them, either in the swamp or on dryland. Most houses belong to Phase 6 and occur in the swamp and the majority of them can be interpreted in the light of ethnographic evidence as women's houses with room for the stalling of pigs. They have therefore been important in the interpretation of Phase 6. The chapter is based on the fieldwork reports of Ron Lampert for 1972 and 1973 and Paul Gorecki and Ed Harris for 1977.

Part 4 deals with the portable artefacts found either in the course of the archaeological excavations of 1972–77 or turned up by the drain digging and garden preparation that preceded and overlapped with them in the course of the establishment of the Kuk Research Station. The aim is to show what they contribute to an understanding of the activities that have been the subject of previous chapters.

Chapter 18, the first of four chapters, is introductory in the strict sense: it describes how inadequate storage facilities plus changes of storage initially resulted in poor curation of the collections. It goes on to describe how, after adequate storage had been secured off campus, a good proportion of those collections was destroyed, damaged or rendered unusable by the Canberra bushfires of early 2003.

Chapter 19 deals with the wooden artefacts, which were not as badly affected in these circumstances as the stone collections. This was because after they had all undergone freeze-drying in Wal Ambrose's conservation laboratory, some items were separately stored on campus. Before this separation they had all been drawn and catalogued by Axel Steensberg during an academic visit to ANU in 1983.

Chapter 20 is the first of two dealing with the stone items, which had been catalogued by the early 1980s. Material that had been withdrawn for study, including the selection made by Tom Loy of items that looked likely candidates for evidence of usewear and organic residues, avoided the 2003 bushfires. Such material formed the bulk of a small collection that was available to Richard Fullagar for the study of stone artefact technology and function, but it provided data of great importance.

Chapter 21 reports on the raw materials from which the stone artefacts reviewed in the previous chapter had been made. It reveals a striking difference between two groups. The flaked tools and grinding/pounding implements found throughout the six phases of the Kuk sequence were all made from rocks at home in or near the catchments of Kuk Swamp. The other group, consisting of fragments and flakes broken off ground and polished axes during use (and often recycled as other tools), appeared in small numbers in Phase 5 and more frequently in Phase 6. These came, for the most part, by way of trade and exchange from specialised quarries in the middle Wahgi and the Jimi Valleys.

The same is true of the axes of the upper Wahgi as a whole by the evidence of two large undated axe collections, one made at Kuk during the opening up of the Research Station and added to by Paul Gorecki and John Burton in later years, the other made by Ole Christensen in the Wurup area across the Wahgi from Kuk in the early 1970s. The axe trade has been mentioned in connection with the possible implications of the intensified agricultural systems at Kuk during Phases 4, 5 and 6. The chapter ends with Burton's reworking of archaeological evidence gathered by Christensen, which supports an antiquity for the axe trade in the Wahgi back to Phase 4 of the Kuk sequence.

Part 5 looks at the history of the Kawelka, the traditional owners of Kuk before and after their defeat in war and their resettlement with kinsfolk in the Mbukl (Buk) region of the Sepik-Wahgi Divide perhaps around 1920. The 1960s and 1970s saw their return in increasing numbers to Kuk following the establishment of Australian administrative control over the highlands in the aftermath of World War II. This included their successful adjustment to the sale of some of their Kuk swampland in 1968 for the establishment of the Kuk Tea Research Station. The closure of the Station in 1990 led to a period of uncertainty since there was no official presence at Kuk, though the government still owned the land. The traditional owners moved over its boundaries to repossess it late in 1995 and over the following period their reoccupation was consolidated by house building and gardening. It was in this context that the National Museum proposed the Kuk site for World Heritage listing by UNESCO at a meeting in Suva in 1997 and the landholders agreed to further archaeological fieldwork, which took place in 1998 and 1999. After this, a start was made on the complex task of preparing a formal nomination document for UNESCO to which the various interested parties could agree. Four chapters cover this ground.

Chapter 22 starts with an analysis of population figures for tribal groups in the Hagen area in the early 1960s that reveals large differences in size, with the Kawelka being just below the average. Their historical place was set by them being a small group that moved into Kuk from elsewhere and lived cheek by jowl with two very powerful groups. Their displacement from Kuk to Mbukl (Buk) was one result of this. Reasons for their return to Kuk can be illuminated by the oral histories. Different subgroups tend to maintain overlapping versions of the history of resettlement, each claiming some precedence respecting specific tracts of land at the former

Research Station. The chapter ends with a selection of such divergent narratives, commenting that the juxtaposition of cooperation and conflict that they reflect has relevance for the reoccupation of land at the former Kuk Station, including the section designated for World Heritage status.

Chapter 23, Phase 7, deals with the move back to Kuk by Kawelka from Buk and elsewhere, starting around 1960, in a different context: the suppression of tribal warfare by the Australian administration, which allowed freer movement of people, and the opening up of the upper Wahgi Valley to development, including the purchase of unused swampland for coffee and tea plantations. In 1978 came the sale by the Kawelka of perhaps a quarter of their land at Kuk for the establishment of a Tea (later Agricultural) Research Station. The unsold three-quarters occupied two blocks of unequal sizes, one north of the Station on and below Ep Ridge, the other, half the size, on the volcanic debris avalanche forming the southern catchment of Kuk Swamp and here called South Kuk. The inhabitants of South Kuk were able to connect with the drainage infrastructure of the Station and so make effective use of the swampland on their block, freeing up its dryland for cash cropping, particularly coffee. By the end of 1978, the population of Kuk overall—South Kuk and Ep Ridge—had overtaken that at Buk.

Some of **Chapter 24** is discussed above under 'Kuk Phase 8', since the official closure of the Kuk Research Station at the end of 1990, its effective abandonment by the authorities over the next five years and its occupation by its traditional owners from late 1995 into 1996 were important for both them and the site. In the absence of government authority, the Kawelka had regained both their land and the ability to say what happened on the land that the site occupied. This became important when the Director of the PNG National Museum proposed the nomination of Kuk for World Heritage listing on cultural grounds at a UNESCO meeting in Suva in 1997.

Chapter 24 pursues the matter of the local context within which grassroots agreement was sought for decisions made at the higher levels discussed above. It does so by reference to chapters in the Strathern and Stewart 1998 volume on Kuk heritage, and by considering the close on 30 years continuous association that Kuk Project members had had with the Kuk community.

Chapter 25 describes the new developments that occurred at the national, provincial and local levels regarding the formal nomination of Kuk for World Heritage listing. From 1997 onwards, various institutions and organisations in PNG contributed to the nomination process, which, however, by mid-2004 had stalled for various reasons. It was rescued by the Department of Environment and Conservation (DEC) and reinvigorated at a National World Heritage Action Planning Workshop in Port Moresby hosted by DEC in 2006. Here Denham and Muke volunteered to lead efforts to complete the nomination document.

A complete nomination document for the Kuk Early Agricultural Site was submitted by DEC to UNESCO in January 2007 (Muke, Denham and Genorupa 2007). It is described as an organically evolved cultural landscape comprising components past and present. The proposed management plan for Kuk as a World Heritage site is community-based. It formalises existing arrangements in that the Kawelka recognise the government's legal title to the land, while the government recognises the Kawelka as the traditional owners and grants them use rights over it.

Postscript

The Kuk Early Agricultural Site was formally accepted onto the World Heritage List at the 32nd Session of the World Heritage Committee in Quebec in July 2008. The management plan for the site is still to be completed, even though effective management occurs based on the preliminary plan detailed in the nomination document, as well as through the mutual support of local Kawelka, the Western Highlands Provincial Government and DEC.

Part One: Agriculture in a World, Regional and Local Setting

2

Early Agriculture in World Perspective

Peter Bellwood

Introduction

The worldwide archaeological record offers many instances, dated with varying degrees of reliability, of the appearance of domesticated crops and animals and the beginnings of settled agricultural life. At present, this database indicates to the satisfaction of most archaeologists that agriculture emerged directly from a hunter-gatherer background, without external diffusion, in at least six regions of the world. These are, with approximate starting dates for pre-domestication cultivation in brackets in years BP (Before Present, AD 1950 by radiocarbon convention): the Fertile Crescent of the Middle East (11,000 BP); the middle and lower courses of the Yangzi and Yellow River basins of China (9000 BP); the New Guinea highlands (between 10,000 and 6500 BP—see Chapters 11 and 12); Mesoamerica (8000 BP); northern South America and the central Andes (8000 BP), with perhaps more than one origin region; and the Eastern Woodlands of the USA (4000 BP). These regions are shown, with their major crops and animals, in Figure 2.1 and 2.2.[1]

Other possible regions of early agriculture, of less certain date and significance, occur in the Amazon basin (3000 BP?), sub-Saharan tropical Africa including Ethiopia, the southern Saharan Sahel zone and the northern rainforest fringes of West Africa (5000 BP), and India (5000 BP) (Bellwood 2005a). Although it is quite possible that native crops and animals were domesticated by people with an existing knowledge of cultivation and animal husbandry who entered these regions, and indeed any regions across the agricultural latitudes of the earth, current data are not always strong enough for firm statements to be made. For New Guinea, available archaeological, linguistic and genetic[2] sources of evidence are sufficient to indicate that both cultivation systems and domesticated crops were developed without external stimulus, as discussed further below.

It is necessary to stress here that two separate issues are involved in all debates about where, when and why agriculture developed. One issue concerns human agricultural behaviour, expressed through systems of plant cultivation and animal husbandry: conscious, repetitive, seasonal and with landscape consequences (fields, ditches, forest clearance and so forth). The other issue is domestication itself—the genetic changes selected for by human interference in the breeding cycles of animals and plants.

1 For further reading on these broad themes see Harris and Hillman 1989; Smith 1995; Harris 1996a; Bellwood and Renfrew 2002; Bellwood 2005a; Kennett and Winterhalder 2006; Zeder et al. 2006; Denham, Iriarte and Vrydaghs 2007; Demoule 2010; Gepts et al. 2012; and Bellwood 2013.

2 Genetic data are not discussed in this chapter, but those interested in such matters can consult the human biology chapters in Pawley et al. 2005. For a review of that volume see Bellwood 2005b.

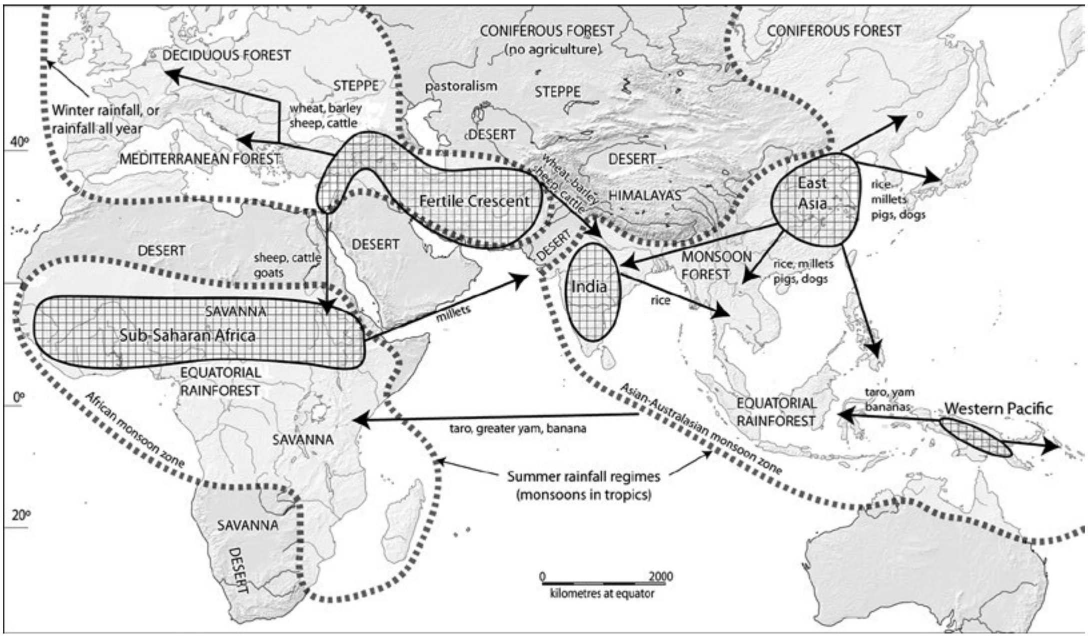


Figure 2.1 The major regions of the Old World involved in the independent development of food production, with their main species of crops and animals.

Source: Drawing by Peter Bellwood (Bellwood 2013: Fig. 6.1), reproduced with permission.

Cultivation and domestication are not one and the same thing. In the Middle East, for instance, people were cultivating and transporting wild annual cereals for a millennium or more before the carbonised remains of those cereals in archaeological sites begin to reveal the basic changes in stem, seed coat and grain structure that botanists recognise as characteristic of 'domesticated' plants (Willcox 2012). This has led to recognition of a transitional situation of 'pre-domestication cultivation', often lasting for several thousand years and now documented in regions such as central China, Mesoamerica and sub-Saharan Africa (Fuller et al. 2014). Changes with domestication in the annual cereals include loss of the ability to disperse seeds through shattering when ripe, loss of seasonal seed dormancy, reduction in the thickness of protective coats around seeds, as well as increase in seed size and the development of synchronous ripening of seed heads. For animals they include reductions in body size and increases in yields of secondary products such as wool and milk.

However, the vegetatively reproduced tubers and fruits that supported New Guinea agriculture did not undergo such visible morphological changes. Instead, evidence for the presence and potential domestication of plants like bananas and taro is based more on frequency changes through time in the occurrences of pollens, microscopic silica-skeleton phytoliths and starch grains in archaeological sites and environmental cores. Kuk is an excellent example of the application of such research. Even so, the basic historical issues worthy of debate—where, when and why did people begin to cultivate?—remain the same.

Figure 2.2 The major regions of the New World involved in the independent development of food production, with their main species of crops and animals.

Source: Drawing by Peter Bellwood (Bellwood 2013: Fig. 9.4, South American data from Piperno 2011), reproduced with permission.

Leaving New Guinea aside for the moment, of the major regions of early agriculture, we look to the Middle East for the origins of wheat, barley, sheep, goats, pigs, cattle and certain legumes (podded plants like peas and lentils); to China for the origins of rice, foxtail millet, soybean, pigs and perhaps dogs and chickens; to Africa and India for cattle, legumes, rice and several species of millets; and to various regions of the tropical Americas for maize, manioc, beans, squashes, tomatoes, potatoes and animals such as turkeys, guinea pigs, llamas and alpacas. These are only some of the major species—the minor ones would make a very lengthy list indeed. The list also indicates that some animals in Eurasia, such as pigs and cattle, and some plants, especially beans and squashes in the Americas, were domesticated more than once. However, as noted above, this need not mean that every domestication of a plant or animal species must be associated with a totally independent transition to agriculture from a foraging background. Many of these multiple domestications may have occurred as farmers moved into new regions and naturally paid attention to local wild species and their usage by local hunter-gatherers.

How did agriculture begin?

In order to understand the specifics of agricultural origins in each of the homeland regions, including New Guinea, we must consider a number of botanical/zoological, environmental and archaeological questions:

1. What habitats contained the wild progenitors of the major domesticated plants and animals when domestication first occurred (bearing in mind that modern environments and species distributions might be very different from those of 10,000 years ago)?
2. How did climatic conditions and environments change during the time span within which agriculture emerged in the various regions? What were the results of these changes on faunas, floras and human economies?
3. What kinds of hunting and gathering cultures made the transition to agriculture in the various regions? How important were preexisting patterns of sedentism, food storage and population density?
4. How rapidly did each transition occur and over how large a region initially?

For New Guinea, answers to these four questions will not come easily, particularly for the archaeological record before the agricultural utilisation of Kuk Swamp. However, there are reasonably detailed answers for the Middle East, the best-known area of the world from this perspective and also the one that witnessed the oldest and most significant transition to agriculture, followed very closely by China. The transition to agriculture in Western Asia was based on local resources of wild annual cereals, legumes (peas and lentils) and wild ruminants such as sheep and goats. The original distributions of these species can be reconstructed in reasonable detail (Willcox 2005). The transition occurred from a baseline of relatively sedentary Natufian hunter and gatherer communities around 11,500 BP, when climates attained levels of warmth, reliable winter growing-season rainfall and long-term stability much greater than conditions typical of the immediately preceding Pleistocene glaciation; a correlation that, in my view, was not coincidental. For instance, Richerson, Boyd and Bettinger (2001) provide a compelling argument for regarding the post-glacial global warming (from c. 15,000 years ago) as a crucial factor in the origins of agriculture.

Climate alone does not explain the development of agriculture—if it did, then the whole world within agricultural latitudes would have undergone the transition in unison, and this did not happen. In the Middle East, the sheer concentration of domesticable annual plants and herd animals capable of massive yields of food and other products undoubtedly helped. Many archaeologists believe that the transition in the Middle East reflected risk management just before the phase of maximal Holocene climatic stability and/or the existence of social competition as an inducement to increased food production in growing sedentary communities. In fact, we do not really know why farming began anywhere in the world and it is unlikely that there was ever a single worldwide cause.

As far as the Middle East is concerned, agriculture developed initially, and rapidly, in an overall region of quite limited extent, but possibly with multiple minor foci of innovation, covering the lands at the eastern edge of the Mediterranean and their extension into southeastern Turkey. The transition to agriculture probably involved a shift from the harvesting and replanting of wild cereals, while still slightly unripe or 'green' (a stage at which they will not shatter and lose their seeds on harvest), to a harvesting of fully ripe grain. The resulting selection pressures on the plant genotypes would, with continual replanting of stored seed from the previous harvest, eventually have produced the altered features that we term 'domesticated'. As for the humans, they grew rapidly in numbers,[3] as did their domesticated plants and animals, and developed a remarkably fast-spreading propensity for sedentary village life and associated cultural habits.

In understanding the origins of agriculture in all of the six or more homeland regions, we need to observe that the key to success was the practice of cultivation with replanting, usually in a specially prepared plot that then had to be guarded against pests while the crop was ripening. As noted, morphological (genetic) domestication of plants and animals was a logical result of cultivation and husbandry. In most regions for which good evidence exists, this occurred later than the initial evidence for human production of cereal crops (often by several millennia). The first cultivated crops were wild in a genetic sense, but as selection pressures increased with human manipulation, they began to change their visual appearances and growth habits. Some have even become totally dependent on human management for survival, for instance some modern cereals such as maize (sweet corn) can no longer disperse their seeds by natural means when ripe. The relationship between humans and their domesticated food species is truly one of mutual dependence.

What happened in the interval between full foraging and full farming?

The above narrative will perhaps give the impression that the transition to agriculture was a fairly straightforward progression with few complications. Being ever optimistic and concerned with big pictures rather than minutiae, I normally tend to see it thus. Some of my colleagues do not. Why?

Clearly, some hunter-gatherers as ethnographically observed can be said to impose selective pressures on the species they exploit and occasionally to indulge in activities akin to cultivation (replanting, protection and the like). This means that hunters and farmers are not like chalk and cheese, ever separate in behaviour. All agriculturalists hunt and gather if and when they can—we still go fishing in the wild today and some people in modern urban societies are involved in recreational hunting practices. Hunters and gatherers can also exploit domesticated species that they acquire from adjacent farmers. Bruce Smith (2001) has coined the term 'low-level food production' to refer to such combinations of hunting, gathering and minor exploitation of domesticated crops and animals. If we apply such observations from the recent past to interpretations of deeper prehistory, they might give the impression that the development of successful food production was a drawn-out and very gradual process, in which populations laboriously increased their dependence upon produced food, perhaps by a few per cent per millennium.[4] I have doubts about such interpretations.

This is because there are important issues of historical contingency about low-level food production that must be considered. If we examine the ethnographic record of the past two centuries or so, we find that very few tribal populations existed in economies where hunting-gathering and farming were evenly mixed. This is also true of New Guinea, outside the Sepik Basin.[5] Furthermore, some ethnographic hunter-gatherer groups who followed such practices, for instance in the Great Basin of North America, did so because their ancestors were formerly

3 See Bocquet-Appel and Naji 2006 and Bellwood and Oxenham 2008 for discussion of increases in early farmer birth rates from skeletal and demographic perspectives.

4 One of the most significant reconstructions of this kind is for the origins of food production in Mesoamerica, derived from 1960s cave research in the Tehuacan Valley in Puebla (MacNeish 1967: Fig. 186).

5 See Murdock 1967 for documentation of ethnographic economies around the world. Roscoe 2002 discusses the Sepik populations who exploit wild stands of sago palms, as well as some domesticated fruits and tubers.

farmers in regions that became marginal for agriculture and so had to turn to hunting and gathering to survive.[6] Low-level food production only existed in agriculturally marginal circumstances where more efficient food producers could not compete, or where former food producers had switched to increased foraging in difficult environmental circumstances.

In my view, while early farmers had to undergo some kind of low-level food production transition from foraging into farming, the successful groups did not remain in this 'middle ground' situation for very long. 'Very long', of course, is a relative concept and I have already noted that domesticated crops perhaps took one or two millennia to develop from wild ones. But 2000 years is not a long time in the total span of human evolution, little more than a blink within a 50,000 year radiocarbon chronology. For New Guinea we still have very few data to throw light on this issue, especially in the early millennia of the Holocene. My working hypothesis would be that once a lifestyle based on cultivation had developed in the highlands, the momentum towards increasing dependence on cultivation would have grown rapidly. Richerson, Boyd and Bettinger (2001: 395) have used the graphic term 'competitive ratchet' to describe such situations. Once one group obtained a demographic advantage as a result of adopting systematic cultivation and planting, others would have followed rapidly, if only to maintain a *status quo*. New Guinea highlands ethnography reveals an intense level of competition that can hardly have developed since outsiders discovered the area in the 1930s. It is surely a fundamental human characteristic, here as amongst most other agricultural communities.

Because there is a lot of potential controversy over these issues, I think it is necessary to state clearly what my perspective on early agriculture involves, since it is likely to be very different from that presented in some other chapters of this book. I regard agriculture (with animal husbandry) as a relatively rare human development (hence the six, and perhaps a few more, regions referred to above) that, once developed, had remarkable abilities to expand. My reasons for taking this view depend not just on the archaeological record, but also on the historical implications of the subgrouping patterns within language families (a highly significant indicator of past human activity, but one ignored by many archaeologists) and the implications of human genetics research. My view is that agriculture spread mainly with its practitioners, rather than by universal *in situ* adoption by hunter-gatherers. I also regard language history as a more significant guide to recent human population history than the rather mute artefacts recovered by archaeologists. This is especially true for New Guinea, where regional stylistic patterns in the shapes and decorative features of artefacts do not survive in the archaeological record as richly as they do in some other archaeological homeland regions. Of course, this is not to suggest that such patterning was never present—the issue is largely one of survival of a perishable organic and aceramic material culture in a wet tropical environment.

Thus, the spread of farming in many, perhaps most, regions of the world went hand-in-hand with the spread of farmers and their languages (Diamond and Bellwood 2003; Bellwood 2005a, 2009). The significance of this observation will be reinforced below, since it might also be applicable to the New Guinea highlands situation, whether viewed from the perspective of genetics, Trans New Guinea languages or environmental significance. Admittedly for New Guinea, where cereals were not grown, the elements of causation could have been quite different from those in regions such as the Middle East and China. We simply know too little for dogmatism to prevail. But that should not stop speculation, to which I turn below.

6 For examples of this phenomenon in the Great Basin of North America see Hill 2002 and Bellwood 2005a: 37–39. Many former Fremont maize farmers in Utah eventually became hunter-gatherers as conditions for maize growing declined after AD 1300.

How does New Guinea fit into the picture of early agriculture?

The general region of Southeast Asia and New Guinea has given us a number of domesticated tubers, fruits and starch sources, such as coconuts, bananas, sugarcane, several species of yams and aroids (e.g. taro), breadfruit and sago. Some of the islands of Southeast Asia, from Sumatra to as far east as Sulawesi, also have native pig species and must therefore have contributed to the history of pig domestication. Yet this region was never involved with any significant indigenous domestication of cereals—rice and foxtail millet were introduced from China via Taiwan (Bellwood 2005a)—and, as far as New Guinea is concerned, no domesticated animals arrived until the pig, in association with the appearance of the Lapita culture in the Bismarck Archipelago shortly before 3000 years ago (Spriggs 1997: 88; on the dating see Summerhayes 2010: 13–24). Even so, the only evidence for a truly early and pristine origin of agriculture (devoid of any outside stimulus) in the western Pacific region comes from the New Guinea highlands. So far, there is absolutely no evidence to suggest that farming developed anywhere in Island Southeast Asia, where Neolithic populations with material assemblages deriving from the north (mainly southern China and Taiwan) first appeared around 4000 to 3500 years ago, absorbing and eventually replacing the material cultures of earlier foraging peoples.[7]

The discovery of early agriculture in the highlands of New Guinea came as a great surprise to many archaeologists, who had become accustomed to finding such phenomena in the monsoonal and Mediterranean-type climates of the world with very strong rainfall seasonality, typified by the Middle East, the African Sahel, the loess lands of China and the Mexican and Andean highlands. Only West Africa and the Amazon Basin have hints of early agriculture in relatively non-seasonal tropical climates like those of most of New Guinea, but for neither of these areas is there good evidence that the transition to agriculture was completely independent. However, the New Guinea highlands do have such evidence, thus making them interesting, even unique, for several reasons:

- The New Guinea transition was perhaps as old a transition as anywhere else in the world, and it was clearly pristine.
- It was focused on tree products, fruits and tubers, with no cereals (although sugarcane, like the cereals, is a member of the Gramineae family). The absence of cereals such as rice and foxtail millet (both native to China and normally cooked by boiling) is partly reflected in the absence of pottery in the New Guinea highland archaeological record, at least until recent centuries.
- In its early days, the New Guinea agricultural scene was without any domestic animals, until the pig was introduced from Indonesia, directly or indirectly, shortly before 3000 years ago, with dog and chicken perhaps later.
- The New Guinea region of early agriculture was relatively low in overall food productivity because of the absence of cereals and domestic animals. It did not produce the huge urban populations or continental-scale expansions of languages and societies that occurred out of some of the other regions, such as the Middle East, China, Mesoamerica and the northern Andes. On the other hand, population expansions within New Guinea and from the Near Oceanic region into those regions of Island Melanesia that lie beyond the Solomon Islands have undoubtedly occurred during the past 3000 years, during which time both agriculture and advanced navigational skills existed in coastal areas.

7 See Bellwood 1997 and Bellwood and Dizon 2008. Lipson et al. (2014) give an excellent presentation of current autosomal genetic evidence for the spread of Austronesian-speaking populations in Island Southeast Asia.

- Early agriculture in the New Guinea highlands involved the digging of channels to control water level, thus representing an interesting and unusual investment in technology. However, there is disagreement amongst the investigators about the time of its appearance, with estimates for the earliest artificial ditching ranging from 10,000 years ago by Hughes and Golson to only 4000 years ago by Denham, who argues that earlier channels were natural, not artificial (Denham, Golson and Hughes 2004: 293; see Chapters 11–13 here). Over subsequent millennia, characteristic New Guinea systems of agricultural intensification were developed in order to feed growing populations and to circumvent problems with loss of soil nutrients (see Chapters 14–16 here). Overall, this process of intensification has been successful, assisted no doubt by the introduction of the high-yielding sweet potato in recent centuries. But it was also interrupted on a local scale from time to time by periods of fallow and land abandonment, such as those suggested by the periodicity within the Kuk sequence.

Perhaps we can understand some of the possible reasons for early agriculture in New Guinea by taking a comparative look at other parts of the world. In my own view, the transition to a cultivator lifestyle in the New Guinea highlands occurred, as in the Middle East, after the very marked and rapid climatic fluctuations that occurred over much of the world at the end of the Pleistocene Ice Ages. In the Middle East, the situation of increasing plenty combined with periodic oscillations promoted moves towards food production. I suspect a similar trajectory in New Guinea, where the agricultural developments occurred especially in those highland regions in which many plants, such as taro, banana and sugarcane, would have moved upwards in altitude towards the limits of their growth ranges with the climatic amelioration. Such marginal locations would have favoured fluctuating food supplies as climates continued to oscillate back and forth, even with decreasing amplitude, from warmer to colder (with periodic frost), and perhaps also from wetter to drier. Such changes could have promoted the planting of useful species in protected areas (e.g. away from frost, or in swamps) in order to improve supply. This view focuses on the 'edge of the range' as a location where fluctuation can promote innovation.[8]

Some archaeologists do not agree with the above reconstruction, which implies, firstly, that fairly rapid changes in lifestyle occurred during the early Holocene and, secondly, that New Guinea agricultural origins occurred in the highlands rather than the lowlands. On the first issue, others (Groube 1989; Denham and Barton 2006) hold the view that New Guinea agriculture was the culmination of a much more drawn-out and continuous process of plant management, beginning with forest clearance soon after initial human settlement more than 40,000 years ago. In this regard, according to David Rindos (1984), plants have co-evolved with humans for as long as they have been exploited by them, adapting to the novel dispersal mechanisms provided as a result of human patterns of collection and discard. However, despite his gradualist views, Rindos (1984: 143, 191) still recognised that actual transitions to conscious cultivation (which he termed 'agricultural domestication') occurred in the various regions of early agriculture, perhaps rapidly, and probably driven by population increase. Co-evolution need not necessarily mean constant and gradual change through time, with no revolutionary episodes. In my view, the environmental changes in the New Guinea highlands after the end of the last glaciation were as rapid as and of equal magnitude to those in other parts of the world and I see no reason why New Guinea should *necessarily* have taken a different or more gradual trajectory towards agriculture than other regions.

On the second issue, whether agriculture in New Guinea began in the lowlands or in the highlands, my current opinion favours a highlands origin and in this regard I am in agreement with Denham, Haberle and Lentfer (2004). The highlands provide both archaeological evidence and a persuasive early Holocene environmental background for indigenous agricultural origins.

8 As proposed for the New Guinea highlands by Bellwood 1996: 485–486 and Haberle and Chepstow-Lusty 2000.

The New Guinea lowlands at present provide neither, although a spread of agriculture from the highlands into the lowlands, for instance down the Markham Valley or into the Sepik Basin, before the arrival of Austronesian-speaking populations in coastal New Guinea about 3000 years ago is very likely, in my view. Such an early spread of agricultural practices involving tuber cropping and arboriculture into coastal lowlands and adjacent islands would go far towards explaining why Austronesian settlement in New Guinea has been such a tentative phenomenon. The indigenous Papuan-speaking food producers spread first, at least in theory.

Some final observations

The degree of continuity of the human population from initial settlement to the present appears to have been very high in the region of western Melanesia generally, and especially in the New Guinea highlands. There are no signs of major population or language replacements from external sources during the Holocene, although internal expansions as a result of the acquisition of systematic agriculture are very likely, particularly from the perspective of linguistic evidence pertaining to the Trans New Guinea Family of languages.[9] There is no evidence of population replacements from outside penetrating the interior of New Guinea, which suggests that agricultural innovation has been a successful process there and that it has been driven from within, not from without. The ancestors who dug the sequence of Kuk ditches must take at least some of the credit for this.

So, what is special about New Guinea? Certainly, special features of the natural and cultural environment of the New Guinea highlands include closeness to the equator, providing a unique equatorial non-seasonal and cool tropical climate in world terms. There is also the factor of technological continuity, in archaeological terms, from the Palaeolithic to recent ethnography—there is no pottery, and ground axes are the only concessions to 'Neolithicisation'. As I have stated (Bellwood 2005b: 10) in reviewing the book *Papuan Pasts* (Pawley et al. 2005):

> To understand why New Guinea is so special we have to begin by thinking geographically. Open an atlas. At first sight, New Guinea looks just like an easterly extension to Indonesia, and one of the sad results of recent colonial hubris is that the western half of it indeed still belongs to Indonesia, while the other (the eastern part) forms the independent nation of Papua New Guinea. Yet, a closer look at the atlas will reveal that New Guinea is not a part of Indonesia in any geological sense, let alone any fundamental ethnological sense. As the northern landmass of the Greater Australian continent it is actually colliding with the eastern end of the Sunda-Banda volcanic arc, forcing back the latter into a sinuous retreat and in the process heaving its own continental rocks into a massive island-long cordillera of folded mountains that in places reach over 4500 metres in altitude. Any traveller can see at a glance that the chained but separate volcanoes of Indonesia bear little resemblance to the alpine structure of New Guinea. This is an island that is absolutely unique in geomorphological terms, with an equatorial location and a relatively iron-bound cordillera, with fertile hidden valleys between about 1400 and 1850 metres above sea level that the rest of the world did not discover until the 1930s. This cordillera is the clue to New Guinea's significance in prehistory and its achievement of indigenous agriculture early in the Holocene.

The excavations at Kuk give us a remarkable record of at least 6000 years of agriculture and swamp management in the New Guinea highlands, one so far unique in the world. To fill out this picture, and improve our understanding further, we need additional archaeological records similar to that from Kuk, especially for the first half of the Holocene. So far this exists mainly in limestone caves, places hardly well located to throw light on agricultural developments and the growth of sedentary villages. It is to be hoped that future social conditions in both halves of New Guinea will allow research to proceed in safety and a context of indigenous community goodwill.

9 On this issue see Pawley 2005: 97–99; Ross 2005: 41; Pawley 2007; cf. Denham 2005a: 351 and Golson 2005: 474.

3

Domesticatory Relationships in the New Guinea Highlands

Tim Denham

Introduction

Several characteristics of cultivation practices in the highlands are significant for understanding the emergence of early agricultural practices. Foremost for interpreting the multidisciplinary record, it is important to consider the range of subsistence practices across New Guinea today, with similar variability likely to have characterised the past (Bourke and Harwood 2009; Denham 2011). Despite this diversity, cultivation practices across New Guinea are, and are likely to have always been, predominantly vegetative. The effects of prolonged vegetative propagation on different plants, including what might be termed domestication traits, are poorly understood in the New Guinea context, as well as elsewhere globally. These themes are briefly reviewed here with respect to plant phenology and some of the most important traditional food plants in the highlands.

From gardens to landscapes

Highly variable subsistence practices occur across the island of New Guinea today, including hunting, gathering of invertebrates, fishing (largely confined to the lowlands), rearing of domesticated animals and the exploitation of plants. The exploitation of plants comprises a variable reliance on the gathering of wild plants, the collection of tree crops (often called 'arboriculture') and the cultivation of mostly vegetatively propagated root crops and vegetables ('horticulture' or 'agriculture'). The major staples, cultivation practices, intensity of cultivation—whether measured as frequency of use, labour inputs or technology—vary greatly from place to place (Brookfield with Hart 1971: 94–124; Powell 1976a; Bourke 2001; Bourke and Harwood 2009).

In the lowlands, there was traditionally a greater emphasis on tree crops supplemented by garden cultivation, hunting, gathering and marine resources. Many lowland groups are dependent on sago (*Metroxylon sagu*) and other tree crops as their staples. Nearly all lowland groups are also dependent to some degree on the cultivation of other plants, although many of their practices are difficult to classify because they fall between the rather clumsy categories of 'hunter-gatherer', or 'forager' and 'cultivator', or 'farmer' (Dwyer and Minnegal 1991; Roscoe 2002; Terrell 2002; Specht 2003). As in other parts of the world, intermediate concepts have been proposed, such as wild-food production (Harris 1989, 2007) and low-level food production (Smith 2001), to accommodate this 'middle ground'.

In the highlands and highland fringes of New Guinea, people are reliant to a greater degree on the vegetative cultivation of starch-rich staples, vegetables and other minor crops. Diets are supplemented by the periodic or seasonal exploitation of arboreal resources, where available. Cultivation practices vary greatly in type and intensity, including more intensive drainage of wetlands (e.g. Ballard 2001); semi-permanent, raised-bed cultivation on valley slopes (e.g. Waddell 1972); and shifting cultivation in rainforests (e.g. Clarke 1971). Even the most intensive agricultural practices in the highlands (Brookfield and Brown 1963; Powell et al. 1975; Powell with Harrison 1982) are supplemented by a repertoire of other strategies to diversify diets and reduce risk (e.g. Bowers 1968; Waddell 1972; Ballard 1995). For example, people living in the major inter-montane valleys may intensively cultivate artificially drained wetland margins, while also cultivating house gardens and dispersed mixed gardens on valley slopes, maintaining claims over fruit- and nut-bearing trees and exercising rights to hunt and gather in tracts of forest.

Concepts of cultivated and domesticated landscapes that transcend traditional terminology have been proposed to encompass the diversity of subsistence practices across New Guinea, as well as elsewhere (Yen 1989; Latinis 2000; Terrell et al. 2003; Kennedy and Clarke 2004; Denham and Haberle 2008). Landscape-based approaches are useful to understand cultivation practices in New Guinea because 'they lead us away from a focus on practices within gardens, plots and fields and towards understanding the strategies and range of practices people undertake to obtain food across the landscape' (Denham 2005b: 292). Just as the conceptual boundary between categories of 'hunting-gathering' and 'cultivating' becomes more porous in this context, so too the boundary between garden and forest can also begin to dissolve; people utilise 'wild' and 'cultivated' plants in diverse ways from a variety of environments. Instead of clear-cut demarcations, there are repertoires of practices that people deploy in different contexts (Latinis 2000; Denham 2009), gradients of intervention across the landscape (Terrell et al. 2003; Denham and Haberle 2008), and resultant degrees of domestication for plants under different forms of plant management and cultivation (following Yen 1985, 1990, 1991a; and Caballero 2004). Similar variability is likely to have existed in the distant past (Denham 2005b: 292):

> As with contemporary practices, early subsistence across New Guinea probably transcended traditional divisions between agriculture/hunting and gathering, wild/domesticated and forest/garden. Primary forest and gardens represent opposite ends of a resource exploitation continuum within a landscape. People engaged in a variety of practices, utilized a range of faunal and plant resources and impacted on the landscape in numerous ways. The resultant landscape was a mosaic of modified and utilized habitats, in which gardens represent an archaeologically visible and relatively intensive manifestation of co-occurring, constituent practices.

In seeking to understand how early agriculture emerged on the island in the past, the diversity of practices in the recent past suggests that it is not appropriate to conflate multidisciplinary evidence from across the island to generate a single macro-interpretation of early agriculture and plant domestication (see Denham 2009, 2011). Any such attempt would be liable to bring together plant exploitation practices and suites of domesticates that never co-occurred in the past; namely, the whole would create a false coherence for practices and plants that never actually co-occurred in the past (Denham 2011: S383). In order to avoid these types of issues, it is essential to construct a multidisciplinary record—comprising archaeology, archaeobotany, geomorphology and palaeoecology—from a single landscape to create a regional history of early agriculture and plant domestication. Such an approach has been adopted for Kuk Swamp, within the context of other wetland archaeological and palaeoecological sites in the upper Waghi Valley (Denham 2007a, 2009; Denham and Haberle 2008).

Vegetative reproduction

Vegetative propagation utilises a plant's capacity for asexual or clonal reproduction, whereas seed-based propagation harnesses a plant's capacity for sexual reproduction. Vegetative propagation entails the removal, transportation and planting of a reproductively viable part of a plant—whether a cutting of a branch, stem or stolon or a whole corm, sucker, rhizome or tuber (Hather 1996). The associated term 'vegeculture' is applied to forms of cultivation that are dependent upon vegetative propagation, as opposed to reproduction from seed (Hather 1996; Shuji and Matthews 2002). Vegeculture can also reflect a common orientation to the vegetative reproductive capacity of plant resources, an orientation that can be shared by foragers as well as cultivators and be associated with distinctive social practices (Barton and Denham 2011; see Textbox 25.3 here).

Cultivation practices in the highlands are, and probably always have been, predominantly vegetative and can be referred to as vegecultural. In the highlands, a wide range of plant types was vegetatively propagated for food and other uses (Powell 1976a), including:

- *Karuka* pandanus (*Pandanus julianettii*)
- Shrubs – *aibika* (*Abelmoschus manihot*)
- Grasses – edible *pitpit* (*Setaria palmifolia*/*Saccharum edule*) and sugarcane (*Saccharum officinarum*)
- Herbs – bananas (*Musa* spp.) and rungia (*Rungia klossii*)
- Root crops – greater yam (*Dioscorea alata*) and taro (*Colocasia esculenta*).

Even palms and trees are usually transplanted as seedlings, although they can also be reproduced through the planting of seed. For example, *Casuarina oligodon* tree-fallowing is thought to originate around 1200 years ago in the highlands (Haberle 2007; see Chapter 14 here).

Some more recently introduced crop plants, including the South American domesticates sweet potato (*Ipomoea batatas*) and manioc (*Manihot esculenta*), were readily amenable to incorporation in New Guinea cultivation practices because they are vegetatively propagated. However, New Guinea agriculture is not, and probably never has been, exclusively vegetative. For example, wax gourd (*Benincasa hispida*) is planted from seed (French 1986) and the earliest find dates to 3000–2000 years ago at Kana in the middle Wahgi Valley (Matthews 2003; Muke and Mandui 2003). Similarly, other crops reproduced from seed, such as maize (*Xea mays*) and even rice (*Oryza* sp.), are increasingly being adopted and inter-cropped in mixed gardens.

Even though people know that many vegetatively propagated plants can be reproduced from seed, cultivators in New Guinea propagate them vegetatively, a preference that has been documented elsewhere in the world (e.g. for *Ensete ventricosum* in Ethiopia; Hildebrand 2007). Vegetative propagation is preferred because it offers greater control over the gene pool and the best opportunity to reproduce desired phenotypic, often morphological, characteristics, such as colour, size, taste, toxicity and so on. On occasions when vegetatively cultivated crops adventitiously reproduce from seed, for example some traditional varieties of taro, cultivators may adopt the resultant lineage as a new variety within their vegetatively propagated stock (Kennedy and Clarke 2004; see Clement et al. 2010).

Domesticatory relationships under vegeculture

Domesticatory relationships refer to the ways in which people engage with plants in their world. The idea of characterising people–plant relationships in these terms is to avoid simplistic distinctions of 'wild' and 'cultivated', or 'domesticated', plants. Within the New Guinea context, these types of binary differentiation have little relevance for many plants under traditional forms of plant management and cultivation. Rather, it is more appropriate to view plants co-existing with people along gradients of domestication. These degrees of domestication reflect the cumulative effects of human interference in the life cycle and dispersal of plants.

The varying degrees of domestication evident in traditional New Guinea cultivars represent the accumulation of phenotypic and genotypic attributes derived from practices that have varied spatially and through time (Denham 2009, 2011). Stepped changes in the degree of human intervention in the life cycle of plants can be hypothesised to include, among others: selective exploitation of favoured ecotypes; management of favoured groves and stands; and both movement and continuous vegetative propagation beyond the natural range. The latter two practices result in the increasing reproductive (i.e. genetic) isolation of cultivated plants: movement beyond natural range prevents fertilisation of cultivated plants by wild plants of the same species, although sexual reproduction with other cultivated plants of the same species may still occur, and continuous vegetative propagation beyond the natural range completely isolates the gene pool of favoured varieties.

Prolonged asexual reproduction in a plant, whether humanly or environmentally induced, can lead to the suppression of characteristics important for sexual reproduction, resulting in further reliance on vegetative propagation. This has been noted for clonally reproducing plants generally, even though the precise mechanisms are poorly understood (Eckert 2002). For example, some clonally reproduced plants, such as greater yam (*Dioscorea alata* L.) and *marita* (*Pandanus conoideus* Lam.), have no known sexually reproducing wild progenitor. However, molecular analyses suggest sexual reproduction likely occurred in the past, such as for the greater yam (Lebot et al. 1998).

People may also have selected asexually reproducing plants because of the associated phenotypic traits. For example, reduced seed size and increased pulp size enhances the caloric yield of some fruits, such as bananas. Some of the important changes to the phenology of vegetatively propagated plants in New Guinea are briefly discussed here (extracted and amended from Denham and Barton 2014).

Parthenocarpy, namely the development of fruit to maturity without fertilisation, is a genetic mutation that has been selected for in numerous cultivated plants, including bananas (*Musa* spp.; De Langhe and de Maret 1999) and figs (*Ficus carica* L.; Condit 1947). Although parthenocarpic plants can often reproduce sexually if fertilised, such as occurs with some diploid banana cultivars (Perrier et al. 2011) and all cultivated figs (Denham 2007b), the development of parthenocarpy frees a plant from remaining within its natural range, as well as climates within which sexual reproduction is viable in terms of reproductive phenology, pollen sources and pollinators. Consequently, a parthenocarpic plant can be vegetatively moved beyond its natural range and can still be productive.

Sterility, namely the inability of a plant to reproduce sexually, is often achieved through polyploidy, such as the development of triploids in bananas (Perrier et al. 2011) and taro (Matthews 2004) and various polyploids in yams (Arnau et al. 2010). Triploid cultivars, although sterile, are often favoured because of greater starch production, as well as increased robustness and tolerance of environmental stress, pests and disease. Sterile cultivars are reliant on humans to be moved geographically, although they can self-spread given the right environmental conditions.

Effective sterility can also be achieved through the asynchronic flowering of male and female plants. This means that pollen production and fertilisation could feasibly occur but does not because male and female plants are sexually active at different times of the year. This has been noted in the greater yam (*Dioscorea alata* L.; Abraham and Gopinathan Nair 1991). No wild precursor of this cultivar has been found and it is not known whether asynchronous fertility is a result of human selection or not.

Seed suppression, namely the reduction in the size of seeds so that they are no longer viable, is selected for by people because it increases the size of the edible pulp or starchy part of the fruit. Seed-suppressed cultivars are no longer able to reproduce from seed and are reliant on vegetative means. For example, vestigial seeds are present in most of the major cultivar groups of banana (*Musa* spp.). In this respect, breadfruit and breadnut (*Artocarpus* spp.) are unusual (Zerega, Ragone and Motley 2004). Most widespread cultivars of breadfruit in the Indo-Pacific have been selected for edible pulp, with a concomitant reduction in size of the seeds, which are not eaten. In contrast, on the mainland of New Guinea people selected some *Artocarpus* sp. cultivars for the consumption of seeds. As a result, the seeds have increased in size and are eaten, while the pulp is discarded.

The cumulative effects of plant domestication in New Guinea have been achieved through prolonged vegetative propagation and include decreased acridity, toxicity and inedible seed sizes and increased edible portions. For most plants, the processes of domestication are not straightforward because many still interbreed with wild/feral plants and wild/feral plants are still planted in gardens (Kennedy and Clarke 2004). Consequently, the ways in which people continue to exploit many plants in New Guinea prevent them from being readily identified as 'domesticated', although some are. Others do not seemingly differ greatly from wild forms and yet others are considered 'semi-domesticated' (Yen 1990).

Similarly, and perhaps unsurprisingly, archaeobotanical data provide glimpses of the presence, processing and cultivation of many food plants. As yet, there is no clear morphological transformation of plant microfossils or macrofossils that might be expected to accompany the domestication process for any food plant through time (cf. Haberle 1995; Yen 1996). The absence of a robust archaeobotanically derived chronology does not necessarily reflect a lack of domesticatory relationships, but rather the nature of those relationships (as discussed above) and the low archaeobotanical visibility of likely domestication traits in many plants in New Guinea (as well as the relatively little systematic archaeobotanical research done on the island; see Chapter 10 here).

Even though the nature of plant domesticatory relationships in New Guinea is sometimes ambiguous, and despite the lack of clear domestication signatures in the archaeobotanical record, it is possible to use the multidisciplinary record to develop scenarios—effectively hypotheses—to understand the cumulative effects of prolonged cultivation on some of the most important food plants in the highlands.

Crop plants in the highlands

> We need to focus research on the evolutionary history of individual crops and regional crop associations, and to adopt a more rigorous approach to the identification and dating of archaeologically-recovered plant remains (Harris 1990: 15).

Until the last 20 years, New Guinea was considered a relatively minor area of plant domestication (Sauer 1952; Zhukovsky 1962; Hawkes 1983; Vavilov 1992; Balter 2007). Although a range of indigenous plant domesticates was known (Barrau 1955; Yen 1973; Simmonds 1976a, 1976b), most staples were inferred to have dispersed in ancient times to the island from Southeast Asia, or in post-Magellan times from the Americas. However, recent archaeological, genetic and linguistic research is beginning to reveal more complex histories of plant domestication in the

New Guinea region (following Lebot 1999). A new picture of New Guinea is emerging, in which the island is a major centre of plant domestication for a range of globally significant subsistence and cash crops (FAO 2012).

In this section, a brief overview of important traditional and exotic food plants cultivated in the highlands is provided (following Powell 1976a; Sillitoe 1983; Bayliss-Smith 1985a, 1988; French 1986; Schmid 1991; Kennedy and Clarke 2004; Bourke and Harwood 2009; see Chapter 4, Tables 4.1–4.4 for altitudinal tolerances of different plants). Given that communities traditionally exploited hundreds of plants for a variety of different purposes, the focus here is only on major food plants of highlands agriculture. The uses of each plant, major transformations inferred to result from prolonged cultivation (i.e. domestication traits) and the history of domesticated relationships are all indicated.

Bananas (*Musa* cvs)

Bananas are usually cultivated for edible fruit, although a variety of other uses is known (Kennedy 2009). In general terms, domestication has transformed wild, large-seeded forms with little edible pulp into cultivated, vestigially seeded forms with abundant edible pulp. Bananas are usually propagated vegetatively through the transplantation of suckers growing at the base of the plant pseudo-stem.

The predominant banana cultivars in the highlands are hybrids descended, to some degree, from *Musa acuminata* ssp. *banksii*, which is indigenous to the New Guinea region. Although a variety of banana cultivars are known, the most significant in terms of global food production are those descended from *M. acuminata* ssp. *banksii*. Edible diploids of this subspecies are thought to have undergone initial domestication in New Guinea, including the development of parthenocarpy. Subsequent westward dispersal to Island Southeast Asia has been reconstructed using genetic and linguistic lines of evidence, and major diploid and triploid cultivar groups are thought to have emerged within this maritime landscape through interspecific and inter-subspecific hybridisation to produce parthenocarpic, seed-suppressed and sterile forms (De Langhe and de Maret 1999; Kennedy 2008; Denham and Donohue 2009; Perrier et al. 2011).

Other groups of bananas occur on the island, including the highland *Musa ingens* (Ingentimusa section) and cultivated varieties descended from species of Callimusa section bananas (formerly Australimusa section). The starchy pith of the pseudo-stem of *Musa ingens* is sometimes eaten, although it is only a very minor food plant (French 1986). Of Callimusa bananas, Fe`i bananas are cultivated in the highlands for fruit, but they are more important in lowland New Guinea and the Pacific (Kennedy 2009).

Pandanus—*karuka* and *marita*

There are two main varieties of pandanus, or screwpine, cultivated on the island of New Guinea today (Stone 1982, 1984; Hyndman 1984; French 1986): highland *karuka* (members of the *Pandanus julianettii/iwen/brosimos* complex) grown for its calorie-, oil- and protein-rich nuts; and *marita* (*Pandanus conoideus*) grown for its energy and oil content. The classification of *karuka* is problematic, with multiple authors suggesting that a cline exists between 'cultivated' *P. julianettii* and 'wild' *P. brosimos*, with *P. iwen* as a possible intermediate form (Cook 1999). Both *karuka* and *marita* are periodically—and in many places seasonal—sources of food for groups in the highlands and lowlands of New Guinea (Bourke 1996; see Chapter 4 here).

These pandans have relatively discrete altitudinal ranges: wild *karuka* ordinarily occurs between 2400–3100 m, whereas cultivated *karuka* ordinarily occurs between 1800–2600 m; by contrast, *marita* is ordinarily cultivated between 0–1700 m, but is not important below 500 m and is common in mid-altitudes, with an upper altitudinal extreme of 1980 m (Chapter 4, Tables 4.3–4.4). Potentially, prolonged cultivation may have 'forced' the cultivation of *karuka* to lower altitudes, whereas *marita* was 'forced' into higher altitudes. As a result, an altitudinally intermediate pandanus, *P. antaresensis*, which ordinarily grows between 1000–2350 m, may have been replaced as a food source. Today, *P. antaresensis* is a minor food, partly due to the difficulty of extracting the nut from its kernel relative to other nuts, whereas archaeological excavations in the Wurup Valley (in the upper Wahgi) show that this species was utilised during the early Holocene (Christensen 1975; Donoghue 1989). Although speculative, altitudinal forcing may have led to the replacement of *P. antaresensis* as a food source in altitudes that were intermediate between the former altitudinal ranges of *karuka* (above 2400 m) and *marita* (below 1000 m) before prolonged cultivation extended their ranges.

Taro (*Colocasia esculenta*)

Taro is grown primarily for its edible corm, or enlarged underground storage organ, although in many parts of the world its leaves are also cooked as a green vegetable. The corm is abundant in starch, although it contains other compounds such as oxalates that make processing and cooking necessary prior to consumption. The transition between wild and domesticated forms is usually marked by increasing corm size and decreasing acridity. In part, these phenotypic changes are a function of growth environment. Diploid cultivars can reproduce sexually with each other and with wild plants, whereas triploid cultivars are sterile.

Wild-type taro (*Colocasia esculenta* var. *aquatilis*) occurs over a vast area from northern India to the New Guinea region and northern Australia (Matthews 1991, 1995). Taro is likely to have undergone multiple, possibly independent domestications within its natural range, including Southeast Asia and New Guinea (Lebot 1999). It is not known where taro was first cultivated or domesticated in New Guinea (Yen 1995; cf. Denham, Haberle and Lentfer 2004). Molecular analyses suggest limited genetic admixture, or gene flow, between geographical regions, such as between New Guinea and regions to the west (Lebot et al. 2004). Furthermore, traditional taro cultivars in New Guinea and the Pacific were diploids, whereas those in Southeast Asia include diploids and triploids (Matthews 2004). Taro was probably the major staple across much of the highlands before the introduction of sweet potato (cf. Chapter 4; for a revisionist view see Chapters 14 and 15). Over the last several decades, taro varieties recently introduced to New Guinea are replacing most traditional ones in many communities (personal observation).

Yams (*Dioscorea* spp.)

Yams are exploited for starch-rich tubers that usually occur underground, although they sometimes produce above-ground, or aerial, bulbils that can also be eaten. Multiple yam species can readily be cultivated in many parts of the highlands, including *Dioscorea alata, D. bulbifera* and *D. nummularia*, while others (*Dioscorea esculenta* and *D. pentaphylla*) approach the upper altitudinal range of cultivation around 1500–1600 m (Table 4.1). Prior to the introduction of sweet potato, yams were probably a more significant crop in the highlands and lowlands. Today, yams are rarely cultivated in the Kuk vicinity, although wild yams of unknown species have been recorded growing in the upper Wahgi Valley (Powell et al. 1975: 35).

The most significant and most widely grown yam globally is the greater yam, or water yam (*D. alata*). Although the precise locus of greater yam domestication is not known, and a wild-type or precursor has not been identified (Lebot et al. 1998), multiple lines of genetic and morphological evidence suggest the New Guinea region as a source (Denham 2010: 14):

> In the absence of clear genetic evidence, several lines of inference, or a triangulation method, can be used to assess where *D. alata* originated, which is likely to be the place of initial domestication. Firstly, AFLP-fingerprinting profiles show that *D. alata*, *D. nummularia* and *D. transversa* are closely related and that '*D. alata* may belong, together with *D. nummularia* and *D. transversa*, to a Southeast Asian-Oceanian genepool which is rather confined to the former Sahulian and Wallacean regions' [Malapa et al. 2005: 928], namely, Eastern Indonesia, New Guinea and Australia. Secondly, several authors have proposed New Guinea as the place of origin because it is the centre of greatest genetic diversity [Lebot 1999: 625]. Thirdly, Martin and Rhodes noted that primitive cultivar types [1977: 2], 'most bizarre and least improved types' [1977: 5], and most types found elsewhere [1977: 5] occur in New Guinea. Fourthly, '[b]ecause it [*D. alata*] flowers naturally in Melanesia, it might be assumed that its area of greatest diversity is also its area of origin' [Lebot 1999: 625]. Although circumstantial, these multiple lines of evidence suggest the New Guinea region as the place of *D. alata* origin and domestication, from which cultivar clones have dispersed widely across the globe.

Given these uncertainties, caution is needed when inferring where the plant was initially domesticated. The analysis of new accessions from eastern Indonesia in particular, and Island Southeast Asia generally, may radically alter current scenarios of yam domestication.

The greater yam, like other yams, is propagated vegetatively. The plant is effectively sterile due to asynchronic flowering. Genetic analyses have inferred sexual reproduction in the past, although the vast majority of genetic variability among greater yam populations represents somaclonal variation resulting from prolonged asexual, or vegetative, reproduction (Lebot et al. 1998; Malapa et al. 2005). Geographically discrete populations of greater yam are generally assumed to have become established through human translocation, even though plants can spread readily in some environments once established within a region.

Most yams exhibit considerable phenotypic plasticity, namely, the morphology of yam tubers can represent environmental controls as much as specific genetic traits. In West Africa, where these issues have been studied, there is no clear correspondence between morphological and genetic traits to differentiate 'domestic' from 'wild' plants once they have been brought into cultivation (Mignouna and Dansi 2003; Scarcelli et al. 2006). A working hypothesis is that the domestication of yams in New Guinea, as in other parts of the world, has sought to increase tuber size, as well as to promote culturally specific and idiosyncratic traits associated with colour, edibility, shape and taste.

Sweet potato (*Ipomoea batatas*)

Sweet potato is a South American domesticate that is primarily grown in tropical and subtropical locations for its edible, starch-rich subterranean storage roots. In Papua New Guinea, sweet potato is probably the most widely eaten food and fodder plant. Under cultivation, sweet potato is propagated vegetatively by taking a cutting of the vine, stem or slip, rather than using part of the underground storage organ as with English potatoes (*Solanum tuberosum*). The plant can also reproduce and disperse from fertilised seed, as suggested for the interior of New Guinea (Bulmer 1966).

Sweet potato is the dominant staple crop for people and pigs across vast tracts of the highlands today. Across much of its present-day range, sweet potato replaced taro because it provides higher yields on poorer soils in the highlands, although it is frost- and flood-intolerant. Even though the plant is probably a post-Magellan introduction to New Guinea, that is within the last 550 years (Roullier et al. 2013), the plant has enabled major social and environmental transformations. Sweet potato is accredited with increasing populations of pigs and people, with attendant social transformations to exchange practices and the development of the historically recorded 'big-man' institution (e.g. Modjeska 1982; Denham 2013a).

Manioc or cassava (*Manihot esculenta*)

Over recent decades, manioc or cassava (*Manihot esculenta*), another South American domesticate, has increasingly been cultivated for food and fodder in the highlands of New Guinea. Manioc adapts well to marginal environments, is drought-resistant and has a flexible growth cycle and relatively abundant yields per unit area of land (Lebot 2009). Manioc is usually reproduced vegetatively under cultivation; a portion of the stem is cut and replanted. However, cultivated manioc can also produce viable seed, which has been important for the domestication process and generation of cultivar diversity (Clement et al. 2010). Adventitiously generated seedlings can be incorporated into cultivated stock and subsequently vegetatively propagated.

Although the antiquity of manioc in New Guinea is uncertain, it was introduced ahead of direct European contact in some parts of the interior. People often say that they do not plant and eat manioc, even though it is inter-cropped in their gardens (Mike Bourke, pers. comm., 2010). The agronomic importance of manioc is likely to increase further in the future as a source of food and fodder because of its relatively high yields in marginal environments.

Sugarcane (*Saccharum officinarum*)

Of the various cane grasses domesticated in New Guinea, the most significant is sugarcane. Traditionally, sugarcane is cultivated vegetatively in order for the sugar-rich sap to be sucked from the stalk. Today, sugarcane is generally considered a snack food, although it was potentially a staple in drier areas of the eastern highlands in the past (Daniels and Daniels 1993).

The domestication history of sugarcane has not been fully reconstructed (Simmonds 1976b; Daniels and Daniels 1993; Lebot 1999; Grivet et al. 2004). Most authors suggest initial domestication of *Saccharum robustum* in New Guinea for its sugar-rich sap, with subsequent westward dispersal and interspecific hybridisation with *Saccharum spontaneum* in Island Southeast Asia to generate *Saccharum officinarum*. Alternative scenarios exist that shift the locus of domestication further towards Asia. Even though the initial stages of the domestication of bananas and sugarcane plausibly occurred in the New Guinea region, globally dominant cultivar groups are thought to derive from interspecific or inter-subspecific hybridisations in Island Southeast Asia before reintroduction to the island (Grivet et al. 2004; Perrier et al. 2011). Many indigenously derived cultivars of banana and sugarcane are, however, still cultivated on the island (Kennedy and Clarke 2004) and were probably more significant in the past.

Minor food plants

A variety of minor food plants are known to have been domesticated in New Guinea, some of which are indigenous to the highlands. Of these, several are still widely cultivated, including possibly winged bean (*Psophocarpus tetragonolobus*) and other legumes, edible cane grasses—*Setaria palmifolia* and *Saccharum edule*—and several leafy greens (collectively called *kumu*), including *aibika* (*Abelmoschus manihot*), *Ficus copiosa*, *rungia* (*Rungia klossii*) and *Oenanthe javanica*.

A number of other minor crops have been introduced to New Guinea at various times in the past. Some of these introductions are likely to be ancient, such as wax gourd (*Benincasa hispida*) dating to 3000–2000 years ago and bottle gourd (*Lagenaria siceraria*) potentially earlier (Powell 1970b; Golson 2002). However, the antiquity of many, such as kudzu (*Pueraria lobata*), still remain a mystery.

Kudzu is a legume that is generally considered to be an Asian domesticate, yet it is cultivated in the highlands for its tuber, which is slow-maturing and a ceremonial, reserve or famine food (Watson 1964b, 1968; Strathern 1969; Sillitoe 1983: 46–48). French (1986: 18) notes that wild forms can self-seed and usually grow between 30–1860 m, whereas cultivated forms are vegetatively propagated and are common at higher altitudes 'up to 2700 m'. A long time-depth for kudzu cultivation is implied by its ceremonial use, which suggests considerable cultural significance.

Animal domesticates

In contrast to plant domesticates, the three animal domesticates present in the highlands before the early 20th century—chicken (*Gallus gallus*; Liu et al. 2006), dog (*Canis familiaris*; Savolainen et al. 2004) and pig (*Sus scrofa*; Hongo et al. 2002)—all ultimately originate from mainland Eurasia. Although highlanders are known to periodically capture and raise cassowaries (*Casuaris* spp.), these animals are kept for exchange and consumption, rather than for rearing. Similarly, although marsupials were introduced to various islands in Wallacea and the Bismarck Archipelago in the Terminal Pleistocene and Holocene (Heinshohn 2010), these translocations represent resource improvement or stocking of landscapes with wild animals, rather than domestication in a classic sense.

The principal domesticates of New Guinea agriculture, chicken (*Gallus gallus*) and pig (*Sus scrofa*), together with the dog (*Canis familiaris*), were most likely introduced to New Guinea within the last 3500 years (O'Connor et al. 2011). All three are rare in archaeozoological assemblages in the highlands before c. 2000 years ago and mostly of uncertain provenance (Sutton et al. 2009). As Golson (1982: 125–130) observed for pigs, archaeological evidence sheds little light on the antiquity of animal domesticates in the highlands. Ethnographic accounts, however, suggest that the adoption of pig husbandry occurred relatively recently among some groups, perhaps within the last few hundred years (e.g. Riebe 1974 and Bulmer 1982).

Irrespective of antiquity, the adoption of animal husbandry would have represented a major shift in the way highlanders thought about their relationship to the environment, the things within it and, eventually, to each other. Previously, highlanders would have exchanged and kept wild animals for consumption, trade or curiosity, but this did not extend beyond the life cycle of an individual animal. Although similar rationales can be envisaged for the earliest introduced domesticates, namely that they were exchanged as wealth items or as curios, at some point people began to care for animals in an intergenerational sense. The social implications of this reorientation are unknown, but they plausibly had significance for a range of things: protein in the diet; community health and resultant demography; people's use of landscapes, potentially including a lower reliance on hunting especially in cultivated, grassland and degraded forest environments, although there were plausibly greater returns from hunting with dogs (Sillitoe 2002); and as a means of storing food surpluses, thereby intensifying exchange relationships and political stratification (Modjeska 1982).

Even today reproduction among some domesticates is only loosely controlled. For example, female pigs are kept and intensively managed, but they are often allowed to interbreed with feral boars. Similarly, reproduction among dogs is unregulated, although progeny of specific dogs may be selected for traits associated with their parents.

Animal domestication is not significant in terms of the periods associated with the genesis of agricultural practices in the highlands, whether at 10,000 years ago (Chapter 11) or with the initiation of mound cultivation by at least 6950–6440 years ago (Chapter 12) or with the advent of ditched field systems by 4400–4000 years ago (Chapter 13). However, animal domesticates became increasingly important during more recent ditched field systems, including those corresponding to Phases 5 and 6 at Kuk (Chapters 15 and 16). Potentially, the earliest archaeological evidence for pig husbandry in the highlands is the construction of fences along the edges of ditching to keep wild pigs out of cultivated plots (see Chapter 19).

Concluding points

While it has generally been assumed that early agriculture and the domestication of major staples, including bananas, taro and yams, initially occurred in the lowlands and moved to the highlands during the early Holocene (Golson 1991b; Yen 1995), this is uncertain (Denham, Haberle and Lentfer 2004). Although forcing plants under cultivation to higher altitudes is possible, it is not clear whether they could have grown wild in the highlands and been domesticated there. The ultimate loci of early cultivation are unlikely to be determined with any accuracy until additional multidisciplinary data is forthcoming from the lowlands. These data need to include a range of archaeological, ecological and genetic information.

Foremost, relatively little is known about the ecology of several major food plants, including their original habitats and natural ranges. Without such information, and in the absence of detailed genetic information on cultivar groups and wild populations across a vast area, it will not be possible to determine where plants were initially brought into cultivation and ultimately entered into domesticatory relationships with people.

Archaeobotany indicates that several plants—including taro, yams and other tuberous plants—have a long history of exploitation extending back into the Pleistocene across a vast area of Island Southeast Asia, New Guinea and Island Melanesia (Loy, Spriggs and Wickler 1992; Barton and Paz 2007; Summerhayes et al. 2010). However, with the exception of bananas (Perrier et al. 2011), there is a lack of detailed archaeobotanical evidence to ground genetic interpretations for plant domesticatory relationships in these regions. In part, the absence of archaeobotanical data is a product of the nature of the plants involved: they often do not produce the type of archaeobotanical remains that are readily preserved or identifiable (except with the advent of relatively new microfossil techniques); in part it is a result of limited systematic archaeobotanical investigation at sites on the island (see Chapter 10).

Irrespective of these concerns, perhaps the biggest problem facing our understanding of plant domesticatory relationships in the past are processes that are happening in the present. The genetic diversity of traditional crop plants is increasingly being eroded by replacement with introduced varieties of the same plants. The reduction in genetic diversity of indigenous cultivars is not only a loss for understanding agricultural history, it is a greater loss for crop improvement in the future.

4

Environment and Food Production in Papua New Guinea

R. Michael Bourke

Introduction

The physical environment plays a critical role in determining both where crops can be grown and how productive they are. The environment in which plants grow can be modified to some degree by people, for example, using drainage to reduce excessive soil moisture. Here the main physical environmental factors that influence crop growth in Papua New Guinea (PNG) are noted and their influence on crop distribution and productivity is reviewed. This research builds on the pioneering work of Harold Brookfield (1964) on the ecology of human settlement in New Guinea over half a century ago. The focus here is on those crops that were used in PNG before the recent adoption of numerous introduced species. Most of these new crops appeared after 1870 following sustained European contact, but sweet potato came into PNG via Southeast Asia about 300 years ago (Ballard 2005: 9; Bayliss-Smith et al. 2005: 109). Tobacco, another American plant, was present in west New Guinea about 400 years ago (Ballard 2005: 8).

I pay more attention to the impact of temperature as small differences can have a significant influence on both the distribution and productivity of crops, particularly near their environmental margins. Greater emphasis is also given to the PNG highlands than to the lowlands or the intermediate zone because the focus of this volume is on the Kuk archaeological site and the Wahgi Valley in the highlands. The environmental factors considered here, besides temperature, are soil moisture (including flooding), cloud cover, slope, day length and soil fertility.

The most important determinant of temperature differences in PNG is altitude. There are a number of other factors that have a minor influence on temperature, including distance from the equator, seasonal rainfall distribution, total land mass and aspect. But it is altitude that is the dominant factor, with temperatures declining in a linear manner with increasing altitude. With increasing altitude, the crop base becomes smaller, so that, at the upper limit for agriculture in PNG, people are dependent on a limited number of species, most of which are recent introductions.[1]

1 The upper limit of village agriculture now occurs at about 2700 m in the PNG highlands, as this is the upper limit for sweet potato production. In a limited number of locations, food gardens are made as high as 2850 m, while some foods are collected from wild plants as high as 3300 m, for example, wild *karuka* nut pandanus (*Pandanus brosimos*).

Available soil moisture for plants is determined by rainfall, slope, soil texture, soil depth, runoff, evaporation and drainage. Inundation or flooding is an extreme soil moisture condition that has a marked impact on both crop distribution and productivity. Deficiency of soil moisture can be corrected through irrigation (which is uncommon in contemporary PNG) and its excess through mounding or drainage, which are techniques widely used, particularly for growing sweet potato in the highlands (see Chapter 5).

Cloud cover is determined by both total annual rainfall and terrain. Excessive cloud cover limits crop productivity. Day length does not have a huge bearing on crop distribution or productivity in PNG, as most of the country lies within 12 degrees of the equator. Its main impact is to determine the flowering patterns of certain species, particularly fruit and nut crops. Soil fertility has a major influence on the productivity of plants. It is determined by the inherent fertility of the land, slope, fallow period, cropping period and human efforts to enhance it.

The food crop base before 1870

Our attention now turns to the crop base for subsistence food crop production before the introduction of sweet potato about 300 years ago and of numerous other food plants from the Americas, Europe and Africa, as well as elsewhere in the Asia Pacific region, after about 1870. The food crops can be grouped as staples (providing most of the food energy), vegetables, fruits and nuts. Between 1979 and 1984, I recorded the altitudinal range of 230 crop species in PNG (Bourke 2010). Some of these data, presented in Tables 4.1–4.4,[2] are utilised in the section on the influence of temperature on crop distribution and production. Data on the altitudinal range of three staple food crops (taro, banana and yam) are also used to draw conclusions as to whether these crops could grow in the Kuk area at different periods in the past.

The most important of the staple foods in PNG before the introduction of sweet potato and other crops from the Americas were *Colocasia* taro, banana, yam (*Dioscorea esculenta* and *D. alata*) and sago. Breadfruit was an important seasonal food in some locations. On the island of New Guinea, breadfruit seeds were roasted and consumed. On smaller islands, including those in the Bismarck Archipelago and Solomon Islands chain, and at a limited number of locations in New Guinea, breadfruit flesh was also eaten.

Sugarcane was a useful but minor source of food energy in many locations. Other minor species included swamp taro, used particularly on atolls and some of the larger islands, giant taro (*Alocasia*), *Amorphophallus* taro, three other species of yam (*D. bulbifera*, *D. nummularia* and *D. pentaphylla*) and pueraria, a minor and now unimportant tuber crop. Swamp taro, giant taro, *Amorphophallus* taro, sago and breadfruit do not grow in the highlands (Table 4.1). Of the species mentioned here, only sugarcane grows at more than 2400 m. Before the adoption of sweet potato about 300 years ago, the most likely staple food in the highlands over an altitudinal range of 1200 to 2200 m was taro, supplemented by banana and *D. alata* yam, (but see Chapter 14, where a case for the replacement of taro by yam and banana is argued for the period before the arrival of the sweet potato).

2 Some common names from PNG are used in the text. See the tables for botanical names.

Table 4.1 Altitudinal range of pre-1870 starchy food species in PNG.

Scientific name	Common name	Mean usual altitudinal range (m)	Extreme altitudinal range (m)	Number of observations/ standard deviation	
				Usual min.	Usual max.
Alocasia macrorrhizos[1]	Giant taro	0–?	0–?	-	-
Amorphophallus paeoniifolius	*Amorphophallus* taro	0–700	0–1230	-	4/50
Artocarpus altilis	Breadfruit	0–1250	0–1450	-	23/130
Colocasia esculenta[2]	Taro	0–2400	0–2760	-	17/150
Cyrtosperma chamissonis	Swamp taro	0–50?	0–?	-	-
Dioscorea alata	Greater yam	0–1900	0–2100	-	15/80
Dioscorea bulbifera	Potato yam	0–1900	0–2110	-	12/110
Dioscorea esculenta[3]	Lesser yam	0–1550	0–1670	-	4/120
Dioscorea nummularia	Nummularia yam	0–1900	0–2050	-	7/90
Dioscorea pentaphylla	Five leaflet yam	0–1500	0–1620	-	3/40
Ipomoea batatas[4]	Sweet potato	0–2700	0–2850	-	10/150
Metroxylon sagu	Sago	0–1150	0–1250	-	10/60
Musa cvs	*Fe'i* banana	0–1750	0–2060	-	8/160
Musa cvs	Diploid banana	0–1800	0–2030	-	19/70
Musa cvs	Triploid banana	0–2150	0–2580	-	30/130
Pueraria lobata	Pueraria	0–2300	0–2740	-	5/180
Saccharum officinarum	Sugarcane	0–2600	0–2760	-	8/160

Source: Bourke (2010), reproduced with permission.

Notes:

[1] Self-sown *Alocasia* sp. taro grows as high as 2640 m, but *Alocasia macrorrhizos* is planted as a food crop only at low altitudes.

[2] The figures for *Colocasia* taro are for single plants, but plots of taro are not planted as high as individual plants. The highest observed plot of taro plants was at 2370 m (Sau Valley, Enga) and the mean of six observations was 2250±100 m.

[3] *Dioscorea esculenta* yam is not common above 900 m.

[4] Sweet potato was introduced into PNG about 300 years ago (see Chapter 16). The usual upper limit of sweet potato (2700 m) is derived from the 10 highest observations.

A very large number of leafy green and other vegetables was consumed, including *aibika*, *Amaranthus tricolor*, cucumber, fern fronds, *Ficus copiosa* leaves and fruit, ginger, hyacinth beans, *Rorippa schlechteri* leaves, taro leaves, *tulip*, oenanthe, winged bean tubers and beans, rungia, lowland *pitpit* and highland *pitpit*. Many other species are now used as minor vegetables and some are likely to have been more important in the past. The number of species that could be grown above an altitude of 2200 m was limited, with *Rorippa schlechteri*, oenanthe, rungia and highland *pitpit* the most important of the pre-contact species now grown above 2200 m altitude (Table 4.2).

Some of the pre-1870 fruit species had a limited spatial distribution, for example *bukabuk* (*Burckella obovata*), which was eaten on the islands of Milne Bay, on New Ireland and the Gazelle Peninsula of New Britain, but had minor importance elsewhere. *Dracontomelon dao* was a significant fruit near Madang, as was *Pouteria maclayana*, but both were unimportant or absent elsewhere in the lowlands. Similarly *Parartocarpus venenosa* was mainly consumed on New Britain, although it was known and eaten in some other lowland locations. The most widely consumed fruits were traditional mango, *marita* pandanus, *ton*, golden apple and Malay apple. *Marita* pandanus was grown very widely on the island of New Guinea up to the lower highland valleys at an altitude of 1700 m, and it was the only significant fruit species in the highlands (Table 4.3). It was (and is) used to make a sauce rich in oil and Vitamin A to flavour bland root crops and banana.

Table 4.2 Altitudinal range of some pre-1870 vegetable species in PNG.

Scientific name	Common name	Mean usual altitudinal range (m)	Extreme altitudinal range (m)	Number of observations/ standard deviation	
				Usual min.	Usual max.
Abelmoschus manihot	*Aibika*	0–1900	0–2110	-	20/110
Amaranthus tricolor	Amaranth	0–1950	0–2050	-	11/50
Caryota rumphiana	Fishtail palm	0–1250	0–1600	-	10/70
Commelina diffusa	Wandering Jew	0–?	0–2390	-	-
Cucumis sativus	Cucumber	0–1950	0–2210	-	19/80
Cyanotis moluccana	-	0–?	0–2410	-	-
Cymbopogon citratus	Lemon grass	0–?	0–2140	-	-
Desmodium repandum	-	? –2250	1100–2350	-	6/80
Dicliptera papuana[1]	-	1000–2000	720–2660	6/220	5/170
Erythrina variegata	Indian coral tree	0–1550	0–2210	-	9/170
Ficus copiosa	*Kumu musong*	0–2200	0–2450	-	6/140
Ficus dammaropsis	Highland *kapiak*	800–2750	0–2820	5/300	3/60
Ficus pungens	-	0–1850	0–1900	-	5/60
Ficus wassa	-	0–?	0–2520	-	-
Gnetum gnemon[2]	*Tulip*	0–1100	0–1330	-	10/150
Graptophyllum pictum	-	0–?	0–1730	-	-
Lablab purpureus	Hyacinth bean	0–2000	0–2430	-	15/170
Lagenaria siceraria	Bottle gourd	0–?	0–2670	-	-
Oenanthe javanica[3]	Oenanthe	1050–2700	0–3400	9/220	3/40
Pipturus argenteus	-	0–1800	0–1950	-	5/90
Polyscias sp.	Valangur	0–1200	0–1230	-	4/30
Psophocarpus tetragonolobus[4]	Winged bean	0–1900	0–2070	-	28/90
Ricinus communis	Castor	0–2350	0–2760	-	5/100
Rorippa schlechteri[5]	-	750–2700	180–2850	4/120	4/120
Rungia klossii[6]	Rungia	950–2700	0–2760	10/170	4/40
Saccharum edule	Lowland *pitpit*	0–1800	0–2270	-	23/160
Setaria palmifolia[7]	Highland *pitpit*	0–2700	0–2760	-	4/40
Solanum americanum	Nightshade	0–2550	0–2800	-	6/190
Trichosanthes pulleana	-	0–2000	0–2200	-	3/80
Zingiber officinale	Ginger	0–1950	0–2200	-	15/80

Source: Bourke (2010), reproduced with permission.

Notes:

[1] *Dicliptera papuana* is given as *Hemigraphis* sp. by some authors.

[2] *Gnetum gnemon* produces both edible nuts and leaves over these altitudinal ranges.

[3] Oenanthe is planted in food gardens up to the altitudinal limit of gardening (about 2700 m) in Enga and Simbu. Self-sown plants occur as high as 3000 m in Enga and 3400 m in Simbu. The mean usual lower limit of 1050 m is for locations where oenanthe was traditionally grown. It is now commonly planted in coastal locations by highland migrants.

[4] The usual range for all plantings of winged bean is from sea level to 1900 m. This species is planted mainly for tuber production over the range of 1200–1900 m.

[5] *Rorippa schlechteri* is sometimes identified as *Nasturtium* sp.

[6] Rungia is planted up to about 2700 m, for example on the Sirunki Plateau and in the Kaugel, Wage and Chimbu Valleys. It is not common above about 2300 m.

[7] While *Setaria palmifolia* is grown between sea level and 2700 m, it is more commonly planted above about 500 m.

Table 4.3 Altitudinal range of some pre-1870 fruit species in PNG.

Scientific name	Common name	Mean usual altitudinal range (m)	Extreme altitudinal range (m)	Number of observations/ standard deviation	
				Usual min.	Usual max.
Burckella obovata	*Bukabuk*	0–?	0–390	-	-
Mangifera minor	Traditional mango	0–1750	0–1900	-	6/100
Pandanus conoideus[1]	*Marita*	0–1700	0–1980	-	37/90
Parartocarpus venenosa[2]	-	0–?	0–?	-	-
Pometia pinnata[3]	*Ton*	0–800	0–1120	-	7/160
Rubus moluccanus	Red raspberry	0–2150	0–2250	-	3/120
Rubus rosifolius	Red raspberry	950–2800	700–2900	8/180	5/60
Spondias cytherea	Golden apple	0–950	0–1070	-	4/110
Syzygium malaccense	Malay apple	0–850	0–1580	-	5/80

Source: Bourke (2010), reproduced with permission.

Notes:

[1] *Marita* pandanus is not usually planted near the ocean, but it is grown in inland areas at altitudes below 100 m, for example near Kiunga, Popondetta and Aitape and in the Gogol Valley. It is more commonly planted above about 500 m.

[2] The upper altitudinal limit for *Parartocarpus venenosa* is not known, but it is a lowland species.

[3] *Pometia pinnata* bears edible fruit up to a mean upper limit of 800 m, but the tree grows at higher altitudes. It has been recorded at about 1700 m in the Nipa area of the Southern Highlands Province.

Table 4.4 Altitudinal range of some pre-1870 edible nut species in PNG.

Scientific name	Common name	Mean usual altitudinal range (m)	Extreme altitudinal range (m)	Number of observations/ standard deviation	
				Usual min.	Usual max.
Aleurites moluccana	Candle nut	0–1800	0–2160	-	9/140
Artocarpus altilis	Breadfruit	0–1250	0–1450	-	23/130
Barringtonia procera	*Pao*	0–500	0–620	-	4/90
Canarium indicum	*Galip*	0–700	0–930	-	5/160
Castanopsis acuminatissima[1]	Castanopsis	700–2350	570–2440	6/80	8/110
Cocos nucifera[2]	Coconut	0–950	0–1310	-	20/190
Finschia chloroxantha	Finschia	0–1850	0–2000	-	4/110
Inocarpus fagifer	Polynesian chestnut	0–400	0–870	-	4/90
Pandanus antaresensis	Wild *karuka*	1000–2350	850–2460	4/110	9/90
Pandanus brosimos	Wild *karuka*	2400–3100	1800–3300	20/150	6/60
Pandanus julianettii	*Karuka*	1800–2600	1450–2800	50/110	18/100
Pangium edule	*Sis*	0–1050	0–1380	-	11/120
Terminalia catappa	Sea almond (*talis*)	0–300	0–460	-	4/100
Terminalia impediens	*Okari*	0–1000	0–1100	-	3/110
Terminalia kaernbachii	*Okari*	0–1100	0–1260	-	11/90

Source: Bourke (2010), reproduced with permission.

Notes:

[1] Self-sown *Castanopsis* is more common above about 1100 m, although the usual mean lower limit is 700 m.

[2] In the period 1980–82, coconut palms grew as high as 1760 m, but the highest altitude that they bore nuts was at Yonki, Eastern Highlands Province (EHP) (1310 m), and the Baiyer Valley, Western Highlands Province (WHP) (1220 m). By 1999, palms were bearing as high as 1370 m (Benabena, EHP), 1420 m (Korofeigu, EHP) and 1450 m (Wahgi Valley, WHP). By mid-2009, they were bearing as high as 1560 m (near Goroka, EHP). This trend is attributed to increasing temperatures associated with climate change. The information is taken from the author's field notebooks.

The most important nut-bearing plants were coconut, breadfruit, various pandanus and *okari*. Coconut was presumably an important source of food energy in coastal locations, given that it was (and continues to be) widely used for cooking there. Most of the other nut-bearing species did not produce above an altitude of about 1200 m. An important exception is the nut-bearing pandanus. Planted *karuka* nut (*Pandanus julianettii*) was an important food crop over an altitudinal range of 1800–2600 m and its relative, wild *karuka* (*P. brosimos*), over a higher range of 2400–3100 m (Table 4.4). Minor nut-bearing species in the highlands were castanopsis, sometimes consumed in the western and southern parts of the highlands, candle nut (*Aleurites moluccana*) and *Finschia chloroxantha*.

A number of important staple foods are now believed to be indigenous to and domesticated in the New Guinea region: *Colocasia* taro, banana, breadfruit, sago, sugarcane and two of the yam species, *Dioscorea alata* and *D. bulbifera* (Yen 1991a; Lebot 1999; Denham, Haberle and Lentfer 2004; see Chapter 3). Vegetables, fruits and nuts that were domesticated in the New Guinea area include oenanthe, rungia, lowland *pitpit*, highland *pitpit*, *Rorippa schlechteri*, *marita* pandanus, *bukabuk*, *ton*, *okari* nut and wild and planted *karuka* pandanus.

Some of the species that have been recorded since European contact as minor foods may have been much more important foods in the past. There are many examples of recently introduced species displacing or supplementing established ones since the 1870s (or some 200 years earlier in the case of sweet potato).[3] Newly adopted species, besides sweet potato, include cassava, *Xanthosoma* taro, maize, tobacco, peanuts, round cabbage, Chinese cabbage, *Amaranthus cruentus* and many fruits, such as mango, pineapple, pawpaw and mandarin. This suggests that people will readily adopt introduced foods that they consider to be superior, but do not completely discard the older species.

Sometimes there are indications that a species may have been adopted more recently than other species. For example, *Dioscorea esculenta* may have made a late appearance in the region and thus been used there for a shorter period than the other yam species. The evidence suggests that this occurred after the appearance of the archaeological Lapita culture in the Bismarck Archipelago some 3300 years ago.[4] The species is agronomically superior to other yam species in PNG, including *D. alata*, with fewer disease problems, a higher tuber yield per plant and tubers that are more easily prepared for cooking than those of most varieties of other species. It is also the most widely grown yam species in the PNG lowlands up to about 900 m altitude.[5] Despite this, it is less important for ritual purposes than the other yam species, particularly *D. alata*, suggesting that it has been adopted because of its ability to provide food energy, while the other species have been retained for other values and purposes.

3 See Bourke (2009) for a list of 180 food crops and stimulants in four groups according to the length of time that the crops have been in PNG.

4 This is because linguists cannot reconstruct a word for the species in Proto Oceanic (Ross 2008: 258, 263), the language of the Austronesian-speaking migrants who are thought to be associated with the beginning of the Lapita culture at this time (Spriggs 2010: 129; on the dating see Summerhayes 2010: 13–24). For another opinion on the history of *D. esculenta* in New Guinea see Chapter 10, footnote 1.

5 *Dioscorea esculenta* accounts for an estimated 4 per cent by weight of total production of staple foods in PNG compared with 2 per cent for *D. alata*. The most important staple foods in 2000 were sweet potato (64 per cent), banana (10 per cent), cassava (6 per cent), all yam species (6 per cent), *Colocasia* taro (5 per cent), *Xanthosoma* taro (5 per cent), coconut (2 per cent) and sago (2 per cent) (Bourke and Vlassak 2004). Sago makes a greater contribution to food energy because this figure is for dry sago.

Environmental influences on food crop distribution and production

Temperature

In New Guinea, temperature differences are largely determined by altitude. There is a close and linear relationship between altitude and temperature, with a decline in the maximum, mean and minimum temperature of 5.2°C for every 1000 m increase in altitude. This is known as the lapse rate. The average temperature can be predicted for any altitude in PNG. The following formulas can be used to calculate the maximum, minimum and mean temperatures for locations away from the coast:

$Y_{max.} = 32.67 – (0.0052 \text{ x } a)$

$Y_{ann.} = 27.32 – (0.0052 \text{ x } a)$

$Y_{min.} = 22.08 – (0.0052 \text{ x } a)$

where $Y_{max.}$, $Y_{ann.}$ and $Y_{min.}$ are mean maximum, mean annual and mean minimum air temperatures (°C) respectively and a is the altitude in metres (Allen and Bourke 2009: 68).

This relationship is modified near the coast because of the heat stored in the ocean. Hence the minimum temperature is somewhat higher and the maximum temperature is somewhat lower at coastal locations than would be predicted from the lapse rates. A number of other factors have a smaller influence on temperature differences. Seasonal differences are generally minimal, but are somewhat greater at locations further from the equator, particularly from about 8° south in Oro, Milne Bay and Central Provinces and the southern part of Western Province. Where the wettest part of the year coincides with the southern hemisphere winter, temperatures tend to be lower again in the winter. Even so, the maximum difference between mean temperatures in February and July does not exceed 5°C at any location.

The lapse rates tend to be somewhat less on the smaller islands, such as New Britain or New Ireland. This can be inferred from crop altitudinal limits. Diurnal temperature differences, namely the difference between day and night temperatures, vary somewhat between environments. At coastal locations on New Guinea, the typical diurnal temperature range is 7–8°C. This is greater in inland locations and is typically about 11°C in the highland valleys. The diurnal range tends to be less on smaller islands. For example, on Kiriwina Island, an atoll in the Trobriand group, the diurnal range is 4–6°C. Temperature influences the distribution and productivity of food plants in a number of ways, as discussed below.

Limits to growth

Minimum and maximum temperatures set altitudinal limits to where a crop will grow. Minimum temperatures more commonly set the limit, that is, a crop will grow up to a certain altitude where that minimum occurs. For some crops, it is the maximum temperature that sets a lower altitudinal limit. Because of the close association between altitude and temperature, it is possible to define the upper and lower altitudes at which crops grow.

As mentioned, between 1979–1984 I recorded the upper and lower limits for over 230 crop species in PNG. For each species the upper and lower usual and extreme limits were recorded at many locations. The usual limit for a location was defined as where the crop produced its economic product and was usually grown. An extreme limit was where the highest or lowest recording was made or where the crop was grown under unusual circumstances, for example, an isolated plant protected from cold by a building.

These recordings were made before current climate change had much impact in PNG. Temperature increases accelerated in the early to late 1970s. Since these recordings were made, temperatures have increased by up to 1°C and crops are bearing at higher altitudes in the highlands (Allen and Bourke 2009: 75–77). For the particular case of coconut see Table 4.4, note 2. The distribution of a particular crop at any given time will be influenced by adaptation, aided by human selection, as well as climatic conditions. The relative significance of these factors is generally unknown. However, climatic conditions are likely to have a more significant influence than adaptation at the margins of a crop's distribution. This would include climatic shifts during the Holocene that are the subject of discussion in Chapter 14, sections 'Responses to drought' and 'El Niño and Phase 4' and Chapter 15, section 'The wider context of mediaeval warming'.

The mean usual and extreme altitudinal ranges for 70 species of food crops that were present in PNG before 1870 are given in Tables 4.1–4.4. An example of how to use the tables is given for *aibika*, the first crop in Table 4.2. The mean usual altitudinal range is from sea level (0 m) to 1900 m. There were 20 observations made on the mean upper limit and the standard deviation was 110 m. So the mean usual maximum can be read as 1900±110 m. The highest plants observed that bore the economic product (leaves) were at 2110 m.

Most food crops grow from sea level to a defined altitude, but some of the 'highland' species do not normally grow near sea level. Thus in broad terms there are fewer available species with increasing altitude. Many of the tree crops cease bearing their economic product at about 800–1200 m, for example, breadfruit, sago, *ton*, golden apple, Malay apple, coconut, *Pangium edule* and *okari* nut. A limited number of species do not bear above 500–700 m, including *galip* and *pao* nut. A number of species cease producing in a band at about 1800–2000 m altitude, including three species of yam, cucumber, ginger, hyacinth bean, winged bean and lowland *pitpit* (Tables 4.1–4.4). These altitudinal bands where crops cease to grow provide the basis for the definition of altitudinal zones in PNG:[6]

- lowlands (sea level to 600 m)
- intermediate (600–1200 m)
- highlands (1200–1800 m)
- high altitude (1800–2400 m)
- very high altitude (2400–2800 m)
- uninhabited (>2800 m)

Irregular frosts occur in the New Guinea highlands and are usually associated with El Niño–Southern Oscillation (ENSO) events. While frosts have been recorded as low as 1450 m altitude, for example in 1997, they are uncommon below an altitude of 2000 m. Repeated and severe frosts, which occur at 2200 m and above, kill most food plants. Only a limited number of introduced species, such as round cabbage, can survive such frosts.

Productivity

The diurnal range has an influence on plant productivity. Where soil moisture and plant nutrients are not limiting growth, plants produce more where the diurnal range is greater. This is because plants convert carbon dioxide (from the atmosphere) into carbohydrate in bright sunshine in the day, but convert some of the carbohydrate back to carbon dioxide at night. These processes are

6 The high altitude and very high altitude zone are sometimes combined. The original zonation was developed by what at the time was the CSIRO Division of Water and Land Resources (Bellamy 1986: 84) and the cut-offs were in thousands of feet, for example the lowland zone was 0–2000 feet. Using 500 m instead of 600 m bands would have been equally valid.

dependent on temperature. A larger difference in temperature between day and night will result in greater net generation of carbohydrate. So the ideal conditions for plant growth are abundant soil moisture, plant nutrients, sunshine and a large diurnal temperature range.

In the PNG context, this means that the highland valleys have ideal conditions for high plant productivity. While time to maturity is somewhat slower than in the lowlands because of lower temperature (see below), productivity tends to be greater in the highland valleys, at least where rainfall is adequate but not excessive and soils are fertile. The Wahgi Valley meets all of these criteria and is one of the most productive environments in PNG, as is the Asaro Valley west of Goroka. Where diurnal temperature differences are very small, particularly on small islands, plant productivity is low.

Rate of growth

Temperatures influence the rate at which plants grow. For example, *Colocasia* taro matures in 6–9 months at 0–200 m, but requires 8–12 months at 1600–1800 m altitude. Similarly, sweet potato matures at 3–5 months at 0–200 m altitude, 5–8 months at 1600–1800 m and 8–12 months at 2200–2600 m.

A slower rate of growth is not necessarily a problem in the highlands. This is because insufficient bright sunshine may limit growth in PNG given the high levels of cloud cover. So where plants have a longer period to move through their growth cycle, there is more time for them to accumulate carbohydrate. Hence yields *per unit area* tend to be higher in the highland valleys than in the lowlands. Because the growing period is longer, the yield *per unit area per unit time* may be similar. For example, experimental yields of sweet potato are typically 12–18 tonnes/hectare (t/ha) on fertile soils in coastal locations, but 20–30 t/ha on fertile soils at 1600–1800 m in the highlands. In both cases, production is about 3.8 t/ha/month. However, because labour inputs do not change with a somewhat longer growing period, the returns to labour, measured as kilogram of food per person-day of labour input, are generally higher in the highlands.

Producing period

For a limited number of crops in PNG, temperature influences the producing period. One such crop is *marita* pandanus (*Pandanus conoideus*). This was and remains an important source of vegetable oil in most inland locations on the island of New Guinea up to the crop's altitudinal limit at 1700 m. *Marita* fruits more or less continuously near sea level, but the producing period declines in a linear manner with increasing altitude. Near the upper altitudinal limit at 1600–1700 m, fruit is available for about four months, typically from January to April.

It can be noted that the harvesting period for *marita* is quite predictable from year to year, unlike *karuka* nut pandanus (*P. julianettii* and *P. brosimos*), suggesting that flowering in *marita* is triggered by changes in day length (and perhaps temperature), but not soil moisture. The longer bearing period at lower altitudes is exploited by villagers who live on the highlands fringe or who have access to land in deep valleys. Because their *marita* fruit matures before that of people inhabiting higher altitudes (1500–1700 m), they are able to give *marita* fruit to trading partners or kin living there.

Soil moisture

Available soil moisture for plants is determined by rainfall, soil texture (with clay soils able to hold more available moisture), soil depth, runoff, evaporation and drainage. Rainfall is generally high to very high in PNG, ranging from 1000 to over 9000 mm per year. In some locations, more rain falls during the period November to March; in others, the wetter period is May to September; and in others, rainfall is distributed evenly throughout the year. Rainfall distribution is seasonal in the eastern part of the highlands, less so further west and non-seasonal further west again (Fig. 4.1). The driest part of the highlands is the Henganofi area in Eastern Highlands Province, which experiences five dry months per year and mean annual rainfall of 1800 mm per year.[7] Rainfall elsewhere in the northern part of the eastern highlands is somewhat higher and less seasonal, with 3–4 dry months per year. Rainfall increases in a westerly direction, so that the Wahgi Valley receives about 2600 mm per year, with no dry month. There is a zone with no seasonal rainfall distribution that extends west from the southern part of Simbu Province through the highlands to the Indonesian border (Zone A0 in Fig. 4.1).

Adequate supply of available soil moisture is vital for plant growth. Most of the food crops in PNG require high moisture levels, but there are significant differences between the major crops. Taro thrives where soil moisture is high and can be grown successfully under flooded conditions. In the lowlands it requires flowing water, but in the highlands it appears to grow well in stagnant water, for example, on the edge of flooded limestone dolines. In contrast, yams only grow and produce well in drier soils and are tolerant of mild water stress. Banana is a flexible crop regarding water needs and tolerates a range of soil moisture conditions. Banana is an important staple food in lowland locations where rainfall is continuously heavy, for example in inland Gulf and Western Provinces, as well as in locations that experience several months of water stress each year, for example in the Markham Valley of Morobe Province and coastal Central Province. They are also an important food in locations where there is only mild water stress, such as on the Gazelle Peninsula of New Britain.

In the PNG lowlands villagers used different combinations of their staple foods to maintain a continuous food supply throughout the year, given that only yam and sago can be stored post-harvest. This strategy continues in the lowlands, although provision of a continuous food supply has been made much easier since the widespread adoption of sweet potato, cassava, *Xanthosoma* taro and consumption of purchased rice and wheat-based foods. Where rainfall was high and there were no dry months on average each year, taro was the main staple food. At locations where the rainfall was somewhat lower and rainfall distribution seasonal, people planted more yam (*Dioscorea esculenta* and *D. alata*) and banana. The proportion of yam and banana increased as seasonality increased. Such a cline could be observed in many lowland locations, for example from Madang to Bogia or on the Gazelle Peninsula of New Britain or in southeast New Guinea. In some locations, sago was used to fill the gap.

It is no longer possible to observe these combinations of taro, banana and yam in the highlands because of the dominance of sweet potato. Nevertheless, the strategy of using a combination of food crops is still practised in seasonally dry parts of the highlands. In the northern parts of Eastern Highlands Province, where rainfall seasonality is greater and there is a longer dry season (D2 and C1/C2 on Fig. 4.1), yam (mainly *D. alata*) is grown to supplement sweet potato. In recent decades, cassava and maize have been widely adopted in this environment as both provide food when sweet potato is less available.

7 A dry month is defined as one in which the mean monthly rainfall is less than 100 mm.

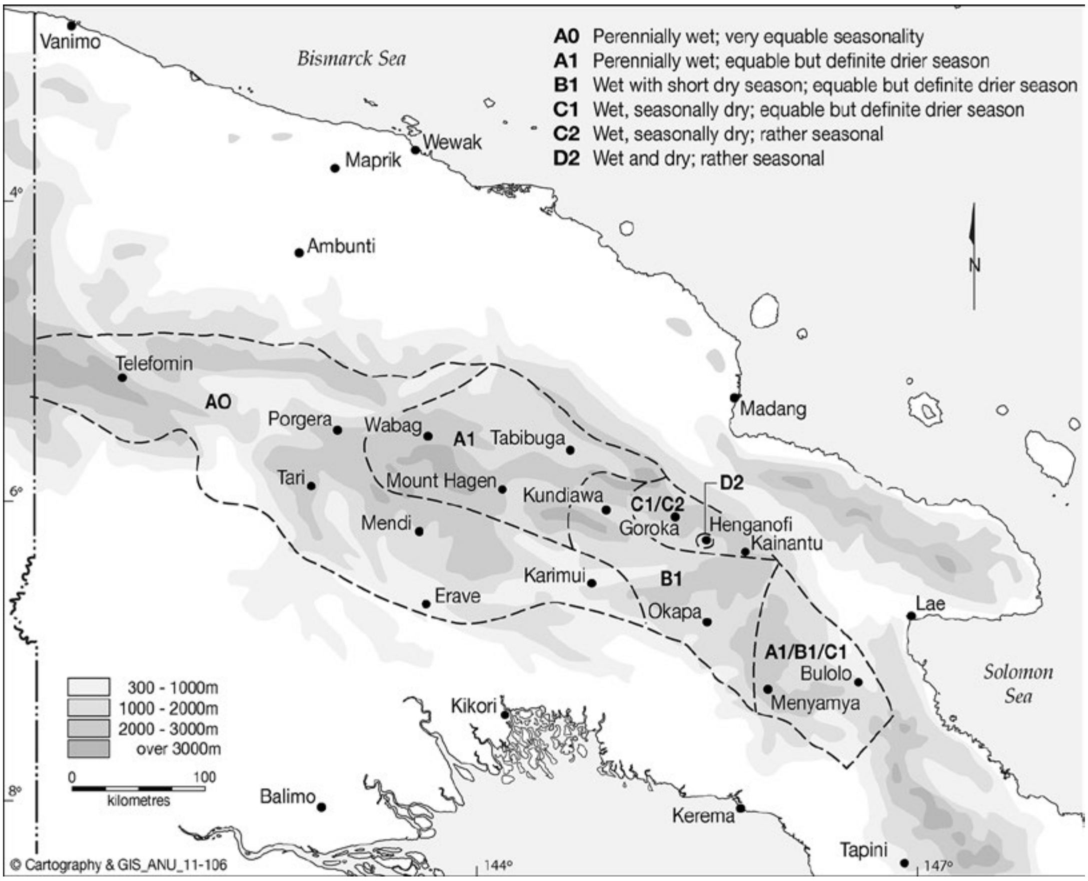


Figure 4.1 Climatic types in the PNG highlands based on rainfall seasonality.
Source: Keith Mitchell, Cartography, College of Asia and the Pacific, ANU.

In this drier area of the Eastern Highlands Province, the staple food before sweet potato would have been taro supplemented by yam and banana. In those locations with 3–5 dry months each year, irrigation of taro would have resulted in a more even supply of food throughout the year. Taro irrigation has been recorded in a number of locations in the Eastern Highlands Province over the past 50 years, including the Lamari Valley and adjacent valleys near Okapa. It is now a minor practice, but it is likely to have been more significant in the past before sweet potato became an important food in recent decades. In the Arona Valley east of Kainantu it seems that people once targeted natural terraces that retained water from surface runoff and subsoil seepage for growing taro. This is inferred from the presence of modest ditching systems predating the sweet potato that enhance water collection and distribution in an area where taro is not an important crop today (Golson and Gardner 1990: 410). Further west, including in the Wahgi Valley, there would have been less need to grow significant amounts of yam and banana as the supply of taro would have been more constant throughout the year.

Regular or irregular periods of lower rainfall lead to water stress in plants. Such stress stimulates flowering in many plant species. Given the high rainfall in most of PNG, even mild water stress can lead to flowering. This is the case for *karuka* nut pandanus (*P. julianettii*). In the eastern highlands, flowering and fruiting is somewhat irregular, but approximates to an annual pattern, with fruit maturing from about February. In the western part of the highlands where annual water stress is slight or absent, fruiting is more irregular and does not follow an annual pattern (Bourke et al. 2004: 40). Large harvests of *karuka* nut generally occur after droughts, such as those in 1972, 1979 and 1982.[8] Both the size and timing of the nut harvest vary considerably from year to year and between locations in the western part of the highlands. Thus the fruiting period for planted *karuka* nut (*Pandanus julianettii*) and the wild species (*P. brosimos*) cannot be predicted from year to year.

Cloud cover

Cloud cover is determined by total annual rainfall, local patterns of cloud build-up during the course of a day, and terrain. High levels of cloud cover reduce the amount of bright sunshine, which is needed for optimum plant growth. Cloud cover is generally high in the highlands and the highlands fringe in New Guinea, but there is less cloud cover and hence greater plant productivity in some of the main valleys, including the Wahgi Valley.

Slope

Much of PNG is mountainous and hence much of the landscape has a steep slope. Slope influences a number of other environmental factors that affect plant growth. These include soil depth, and hence soil fertility, with deeper soils generally being more fertile, as well as moisture retention and runoff, with greater runoff on steep slopes and more infiltration on gentle slopes. Steeper land is commonly used in preference to flat land for sweet potato production as sweet potato is intolerant of excessive soil moisture and steep land is better drained. In contrast, taro tolerates higher levels of soil moisture, so there is no advantage in using very steep land for its cultivation.

Day length

Seasonal differences in day length are slight near the equator, such as on Manus Island, and somewhat greater at 8–12° south, that is in Milne Bay, Oro and Central Provinces and the southern part of Western Province. The difference between the length of the longest and the shortest day at Lorengau (2°1'S) is only 14 minutes, whereas at Port Moresby (9°27'S) it is 66 minutes (McAlpine et al. 1983: 119).

Differences in day length influence flowering of some species, including *marita* pandanus, *Pangium edule*, lowland *pitpit* (*Saccharum edule*) and probably breadfruit. Breadfruit bears in a regular seasonal manner at 8°S and further south, but not at locations nearer the equator in PNG. Seasonal differences in day length do not influence crop distribution or productivity of taro, banana, yam or sago. The producing period of *marita* pandanus fruit and *Pangium edule* nuts at a particular location is predictable, thus both species can be relied upon as seasonal food sources.

Soil fertility

Soil fertility has a major influence on productivity of plants. It is determined by the inherent fertility of the land, slope, fallow period, cropping period and human inputs. Soil fertility is usually maintained by natural fallows. People enhance it using a number of techniques, including placing green manure on the soil surface, which may be covered with soil (as is done in the composted mound systems in the highlands) or without being covered by soil (as is done in taro plots on atolls). Other techniques used include planting nitrogen-fixing trees, particularly *Casuarina oligodon* in the highlands, so that fallow periods are reduced, and rotating root and leguminous crops in a sequence.

8 There was not a large crop of *karuka* pandanus nuts after the major drought of 1997. It seems that this drought was so severe as to inhibit flowering.

Soil fertility has minimal influence on the distribution of food crops in PNG. Where soil fertility is very low, taro and yam may not yield. This is now the situation on a number of very small islands where population pressure is very high and soil fertility has been reduced by extended periods of cropping without adequate fallows. However, this is a recent phenomenon and is unlikely to have been a limiting factor until recent times.

In contrast, differences in soil fertility have a major influence on plant productivity. The most productive soils in PNG are those derived from volcanic ash and alluvium. The deep soils in the Wahgi Valley, formed on these materials, are among the most productive in PNG.

Discussion

Temperature, which is largely determined by altitude, is the most important factor determining where crops can be grown in PNG. This is because it sets the absolute limits to growth. The other major environmental factors of soil moisture, cloud cover, day length and soil fertility have a greater influence on plant productivity, but they are in general less critical in determining where crops can be grown. However, inundation does limit agriculture and where land is inundated for extended periods, only a limited number of food crops grow, sago being the most important.

The current altitudinal distribution of food crops can be used to make inferences about crop distribution under different temperature regimes in the past. Taro, supplemented by banana and yam (*Dioscorea alata* with some *D. bulbifera* and *D. nummularia*), is likely to have been the most important food in the highlands before the adoption of sweet potato about 300 years ago. In the early 1980s, monocultures of taro were uncommon above 2200 m altitude, although individual plants were grown up to 2400 m and occasionally as high as 2760 m (Table 4.1). Some types of banana yielded at up to 2150 m and occasionally as high as 2580 m. *D. alata* yam and the other two species grown in the highlands yield at up to 1900 m, and occasionally as high as 2100 m (Table 4.1).

Based on these observations, it is concluded that, when temperature conditions were similar to those prevailing in about 1980, the upper limit for agriculture in PNG occurred at about 2200 m, and occasionally as high as 2400 m, before the adoption of sweet potato. A limited number of other crops, including sugarcane and some vegetables, such as *Rorippa schlechter*, oenanthe, rungia and highland *pitpit* could have been grown at higher altitudes, but they would not have been sufficient to meet the energy needs of people (Table 4.2). The cultivated and wild form of *karuka* nut pandanus (*P. julianettii* and *P. brosimos*) grow up to 2600 m and 3100 m respectively (Table 4.4). These would have provided valuable vegetable oil and protein in people's diets for part of the year, but the producing period was not reliable from year to year, particularly in the western part of the highlands where rainfall seasonality is weak or absent.

The upper Wahgi Valley, including the Kuk archaeological site, lies at about 1600 m altitude, that is, it is about 600 m lower than the suggested upper limit for agriculture based on taro, banana and yam. If the mean minimum and maximum temperatures were 3°C lower than they were in 1980, then the upper Wahgi Valley would have been at the upper limit for agricultural production. If temperatures were 5°C lower than the 1980 means, Kuk would have been too cold for taro, banana or yam production. During the last glacial maximum at around 21,000 years ago, the highland valleys between 1500–1700 m altitude were as much as 7°C cooler than their mean temperatures in about 1980, with frequent frosts and drought (Hope and Haberle 2005). Thus the highland valleys could not have supported taro and banana at that time. Warming in the Late Pleistocene period after about 15,000 years ago would have meant that taro and banana could grow as high as 1600 m once temperature increased to a point where it was no more than 3°C lower than that at around AD 1980.

The upper Wahgi Valley has an ideal environment for agricultural production, with an adequate but not excessive rainfall; mild temperatures in which crops mature more slowly and have time to accumulate more carbohydrate; less cloud cover to limit plant growth; and very fertile soils, particularly when swamps are drained of excessive water. Plant productivity is high in the valley, with good yields per unit area recorded for sweet potato, taro and cassava (Bourke et al. 2009: 149, 153). Perhaps it is not surprising that the upper Wahgi Valley is the site of some of the earliest documented agriculture in the world.

Acknowledgements

I am grateful to Jack Golson for guidance on the focus of this chapter; and to Chris Ballard, Jack Golson and two anonymous referees for comments on earlier drafts.

5

The Wetland Field Systems of the New Guinea Highlands

Chris Ballard

Introduction

This chapter provides an ethnographic and historical overview of the various traditional practices of wetland drainage and wetland field systems documented across the New Guinea highlands during the period since initial contact with colonial administrations in the 1920s and 1930s. The distribution and hydrological settings of these wetland drainage systems are mapped, differences in the technologies of drainage and wetland gardening are described, and the varying social contexts that create the demands for their use are addressed. The chapter concludes with some consideration of the genesis of these historical or ethnographic wetland field systems: are they the outcome of independent processes of invention and modification in different highlands locations or is there evidence that knowledge of wetland drainage techniques might have diffused from a single location or a limited number of centres within the region, or even from the New Guinea lowlands or coast? And, in the context of the Kuk Swamp finds, might these ethnographic examples offer possible analogues for the more recent phases (5 and 6) of the archaeological sequence of the Wahgi wetland drainage systems?

There has been a surprising paucity of ethnographic research into wetland field systems in New Guinea, and very little comparison drawn between different systems. While detailed accounts exist for wetland gardening practices in a few locations, they tend to be treated individually. This chapter is a first attempt at a systematic review of the different wetland drainage systems of the highlands. The term 'drainage' is used here as shorthand for water management practices more generally, ranging from true drainage through to irrigation. The advantages conferred by drainage and other water management practices include greater control over environmental factors, a higher crop yield per hectare than comparable dryland systems and increased potential for further intensification (Spriggs 1990). Drainage 'systems' are composed of contiguous fields where some degree of cooperative activity beyond the simple construction of an individual plot is responsible for the creation of a network of linked plots or fields.

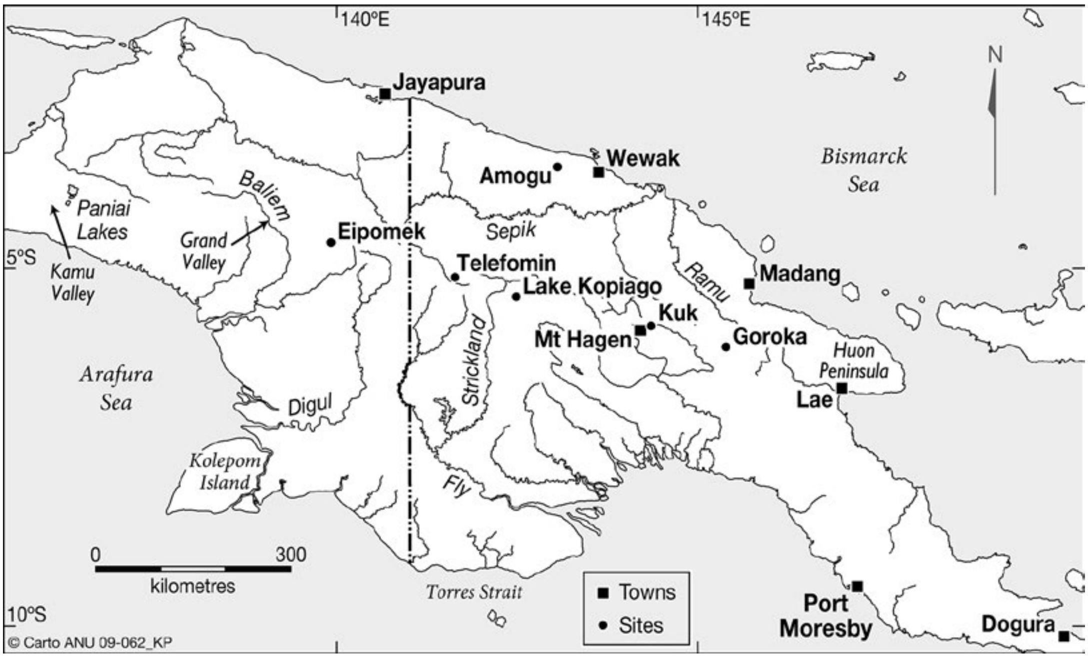


Figure 5.1 Distribution of wetland management systems across New Guinea.

Source: Karina Pelling, CartoGIS Services, College of Asia and the Pacific, ANU.

The field systems on which this chapter focuses are all located in the central highlands of New Guinea; Figure 5.1 shows locations across the main island of New Guinea referred to here, while Figure 5.2 provides more detail on locations within the highlands region of Papua New Guinea (PNG). The distribution of drainage as an agricultural technique across PNG has been mapped by The Australian National University's Mapping Agricultural Systems Project (Allen et al. 1995), which demonstrated the fairly tight restriction to the highlands region of drainage as an important technique within local systems (Fig. 5.3). Smaller and more localised drainage systems are also found in the New Guinea lowlands—most notably on the south coast between the Fly River and Digul River estuaries and on Kolepom Island in west New Guinea (Serpenti 1965; Harris and Laba 1982; Barham and Harris 1985; Manembu 1995; Harris 1995; Hitchcock 1996) and on the Amogu floodplains in the middle Sepik area (Allen 2005: 613; Swadling and Hide 2005: 315)—as well as in some of the neighbouring regions of eastern Indonesia and Island Melanesia (see the overviews by Damm 1951 and Spriggs 1990). However, there are no obvious connections between these systems and those of the highlands in terms of crops, techniques or methods of production. Similarly, no further consideration is given to irrigation techniques practised in moisture-deficient locations, as at Dogura in Milne Bay Province (Kahn 1985, 1986) and in the Lamari Valley (Loving 1976), both of which involve the long-distance transport of water by bamboo aqueducts (see Gorecki 1979a for notices of small-scale taro irrigation in the highlands). This chapter also focuses on water management for agricultural production rather than damming for fish or eel production (Dosedla 1984: 1130–1131) or for purely ritual or ceremonial purposes, as in the case of the dams of the Huon Peninsula (Vial 1938; Holzknecht 1998).

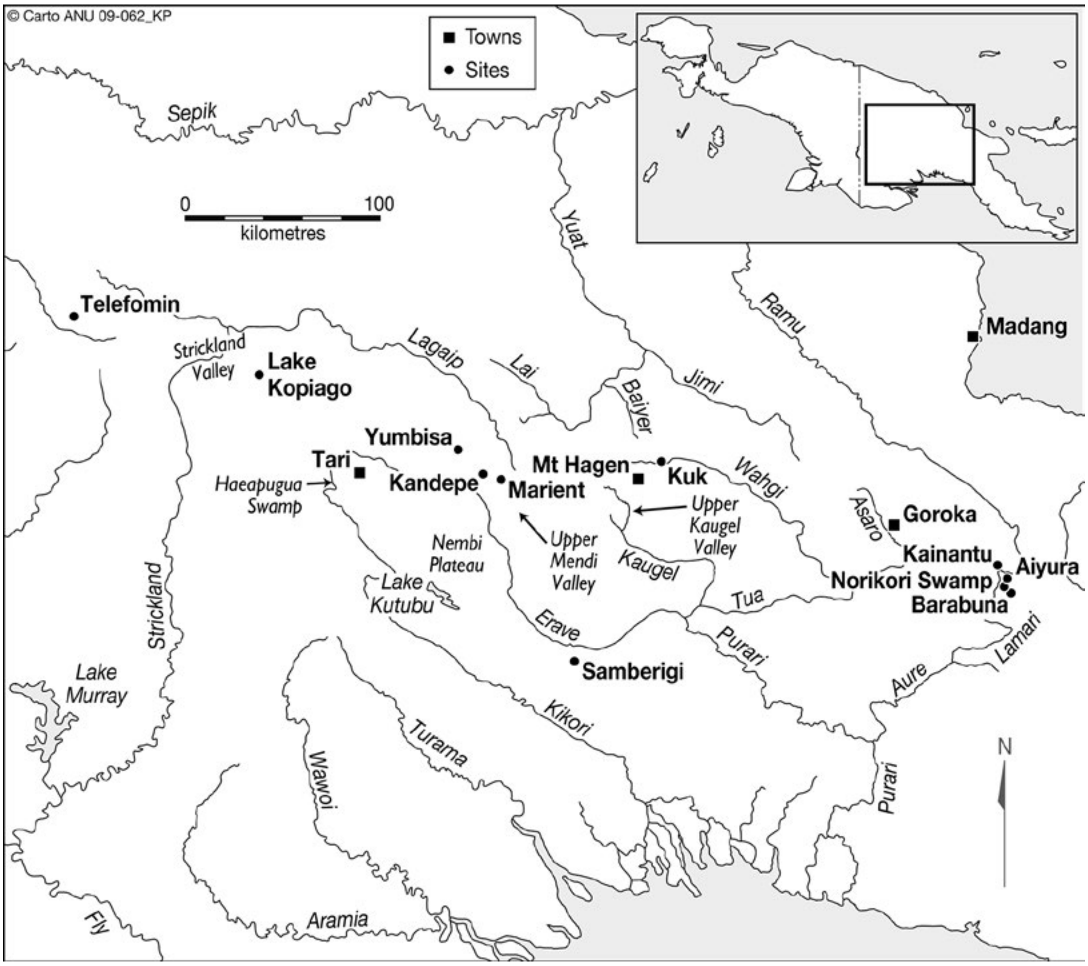


Figure 5.2 Distribution of wetland management systems in the highlands of PNG.
Source: Karina Pelling, CartoGIS Services, College of Asia and the Pacific, ANU.

The highlands focus of this review evidently presumes some degree of relationship amongst the different highlands wetland field systems, but the argument made here is that this relationship holds only at the widest level of cultural and technological relatedness. What the wetland field systems of the highlands appear to share, beyond the constraints of a suite of similar local environmental conditions, is a common crop repertory, a limited range of agricultural technologies and broadly parallel demands on production, particularly in relation to the raising and exchange of pigs as items of wealth and transaction. In the place of any evidence for diffusion of a single wetland field system, as a set of techniques and cultural contexts, we find a process that might be described as broadly common throughout the highlands: early field systems, which are developed initially along the highly productive and partially clear margins of swamps, are subsequently extended both into swamp centres and up onto adjacent dryland slopes.

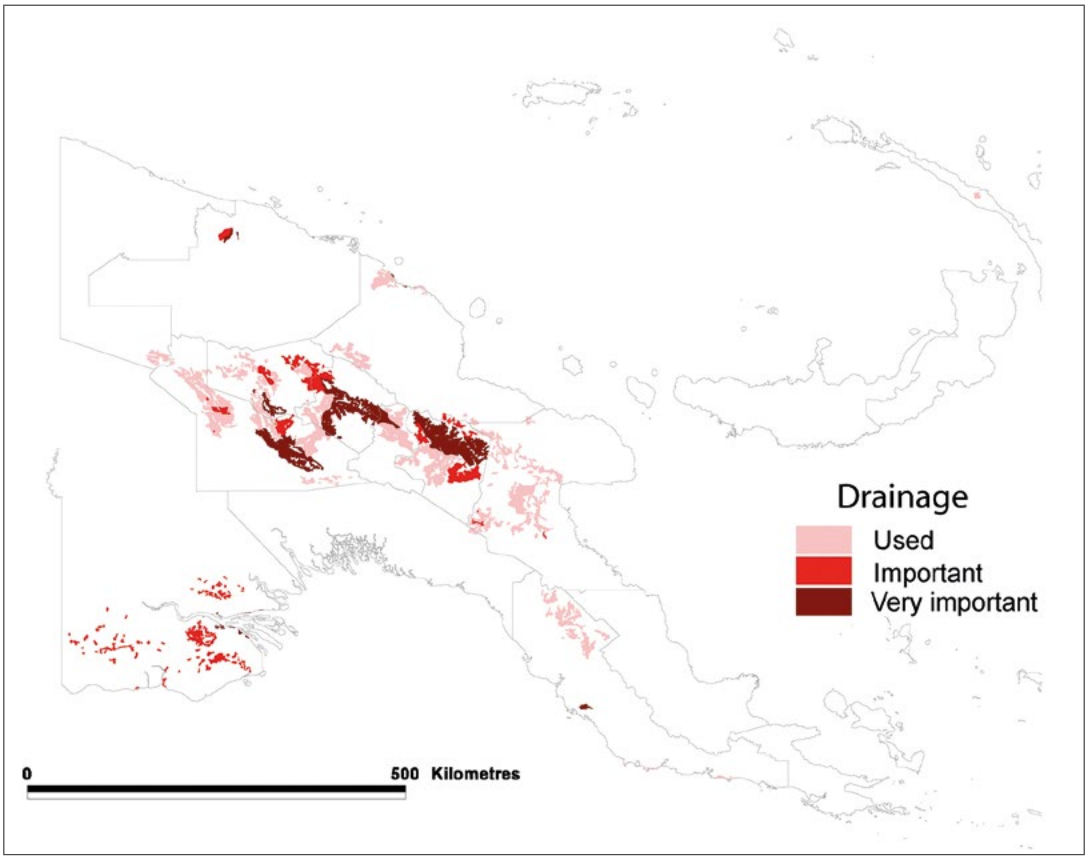


Figure 5.3 Distribution of drainage as an agricultural technique across PNG.

Source: Bourke and Allen (2009: 261, Fig. 3.12.1), courtesy of the Land Management Group, Department of Human Geography, ANU.

Swamp hydrology and catchments

In order to appreciate the nature of any particular wetland field system, the specific context of its hydrological conditions must first be determined, along with the constraints and opportunities that these conditions present for wetland use. For the purposes of this chapter, wetlands are defined as essentially a human artefact, referring to a modified intermediate zone between natural dryland and unreclaimed swampland (Gorecki 1982: 223). The boundary between dryland and swampland represents a critical margin, usually marked by a sharp vegetation break. With minimal additional investments of labour, gardeners in this marginal zone gain access to an exceptionally productive environment, which also serves as a moisture reservoir during seasonal or exceptional dry periods. As demands on agricultural production increase, wetlands can be expanded, usually involving incrementally higher inputs of labour as the wetter areas of swampland are reclaimed.

Most highlands swamps are created by natural impediments to natural drainage, such as tectonic uplift or landslip processes (Chambers 1987: 6). Though there are more elaborate schemes (e.g. Ingram 1983), most of the swamps can be classified as either perfluent, low-lying areas around a major watercourse that are prone to flooding, or lake-margins, where the scope for drainage tends to be restricted by the presence of a static body of open water. The hydrology of individual swamps may be altered over time either by natural processes, such as earthquakes or the gradual erosion or removal of the impediments generating the swamp, or by human intervention, such as drainage or clearance in the catchment and a consequent increase in sedimentation.

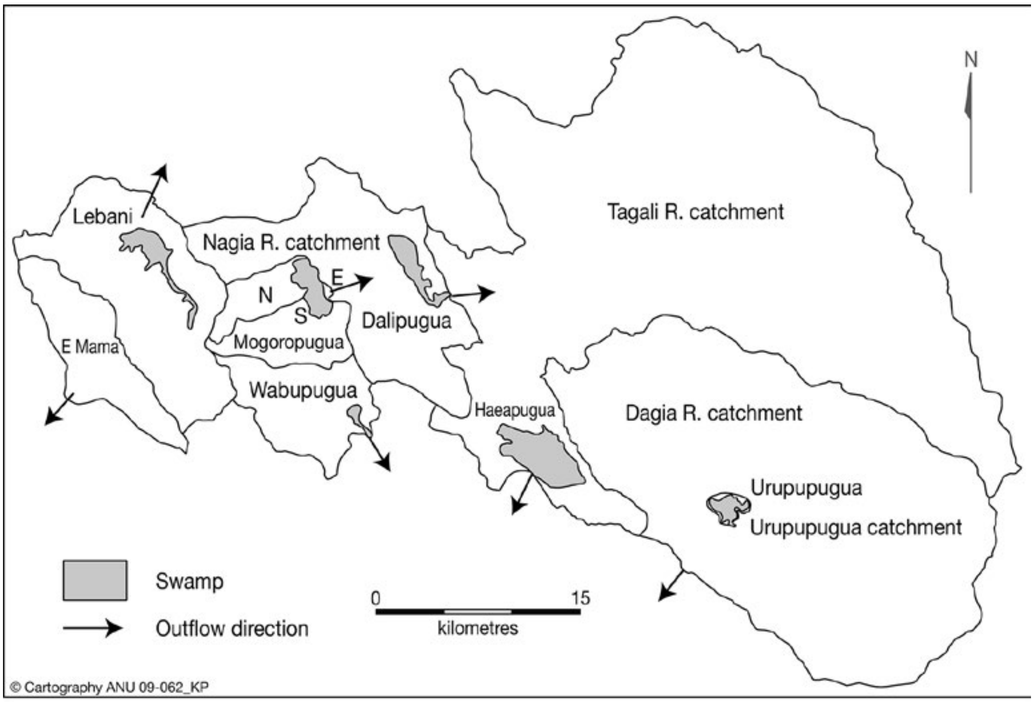


Figure 5.4 Swamps and catchment areas in the Tari region.

Source: Karina Pelling, CartoGIS Services, College of Asia and the Pacific, ANU.

Significantly, human drainage initiates changes in hydrological regimes that can ultimately undermine the wetland field systems that it seeks to enable. Shrinkage of swamp peats following drainage can lower the swamp surface dramatically and render the initial drainage channels ineffective (Hartley 1967; McGrigor 1973). At the same time, increases in dryland clearance can exacerbate the scope for flooding in low-lying wetlands; under different conditions, increased clearance can result either in the scouring and destruction of drains by higher-velocity flow or the silting up of channels with excessive sediment loads.

Comparison of a 'nested' series of catchments and drained wetlands in the Tari region reveals some of the complex relationships governing the hydrology and scope for drainage of highlands swamps (Ballard 1995, 2001). A 'cascade' effect, in which water from higher catchments flows through to lower and larger catchments, directly influences the variable scope for wetland drainage at individual swamps. Contrary to expectations based on population pressure, the central parts of the largest swamp, Haeapugua, which lies closest to the historic centre and highest density area of the local Huli population in the Tari Basin, appear to have been drained later than the more distant swamps of Mogoropugua and Dalipugua, which have far smaller catchments, but feed one into the other and then both into the Haeapugua catchment (Fig. 5.4). The ratio of swamp to catchment areas, which yields a coefficient of dryness for the individual swamps (Table 5.1), indicates the highly variable scope for drainage of the different swamp areas, with Haeapugua revealed as a much wetter and more challenging environment for drainage. However, it is argued that one consequence of the adoption of sweet potato was the migration of large numbers of people into the uplands of the Tagali River catchment and the rapid clearance and degradation of this fragile environment. A further, inadvertent consequence of the dramatic increase in soil erosion in the upper reaches of the catchment was the generation of sufficient sediment to finally stabilise the levee banks of the Tagali River where it flows through Haeapugua Swamp (Fig. 5.5), thus rendering the swamp centre available for drainage. Evidently, hydrological conditions at individual wetlands need to be determined, and to be considered within the context of entire catchment areas, before arguments about population density or demands on agricultural production can be entertained.

Figure 5.5 The Haeapugua Swamp wetland field system.

Source: Karina Pelling, CartoGIS Services, College of Asia and the Pacific, ANU.

Table 5.1 Catchment/swamp area ratios for swamps in the Tari region.

Swamp	Elevation (metres)	Catchment area (km^2) [C]	Swamp area (km^2) [S]	Catchment/swamp ratio [C/S]
Lebani	2250	143.83	7.77	18.5
Mogoropugua	1870	63.58	7.60	8.4
North	1870	24.28	4.11	5.9
South	1870	38.69	2.87	13.5
Wabupugua (Yaluba Basin)	1790	63.91	1.32	48.5
Dalipugua (Koroba Basin)	1700	231.44	6.97	33.2
Haeapugua	1650	1075.99	17.10	62.9
Urupupugua (Tari Basin)	1610	5.11	3.32	1.5

Source: Ballard (2001: Table 2).

Distribution of wetland field systems

The distribution of wetland drainage in the highlands suggests that demands on production from relatively dense populations play a critical role in the decision to commit resources to the creation of drained field systems. The upper limit to taro-based or pre-Ipomoean agriculture in the New Guinea highlands is between about 2200 m and 2400 m (see Chapter 4). The adoption of sweet potato has extended this range to about 2700 m, but population densities tend to decline markedly above about 2200 m; a few communities reside and have drained swamps at higher altitudes, such as the Yumbisa Valley in western Enga at 2550 m (Wohlt 1978). At the lower end of the highlands range, an altitude of about 1300 m commonly marks the upper limit of endemic malaria, which tends to curb population growth. Almost all of the documented drained wetlands in the highlands fall within the altitudinal range from 1300 m to 2200 m. There is little evidence to suggest that available wetlands in settled areas below 1300 m, such as those around Lake Kutubu at 800 m, have been drained in the recent past. The one major exception is the Samberigi Valley of Southern Highlands Province, at 980 m, where extensive drainage networks were described in the 1920s but not in further detail since (Beaver 1920: 262; Saunders 1923–24: 29; Bourke et al. 2002: 100).

A survey of the major wetland field systems of the highlands suggests that most of the major accessible swamps within the 1300–2200 m altitudinal band have been exploited. These major wetland field systems are listed in Table 5.2, along with the principal documentary sources for each system, and their distribution is mapped in Figures 5.1 and 5.2. In the western half of New Guinea, the two major areas of highlands swamp—in the Paniai region comprising the Paniai Lakes Basin and the adjacent Kamu Valley, and the Grand Valley of the Baliem River—have both been drained and heavily utilised; no other extensive wetland field systems are known from western New Guinea (Ploeg 2005). A large gap in distribution is accounted for in part by the absence of major intermontane basins between the Grand Baliem Valley and the Strickland Valley. Raised-bed cultivation of sweet potato, with use of the mud and mulch from the inter-bed drains or hollows similar to techniques employed in the Grand Baliem Valley, is practised by Mek-speakers of the Eipomek Valley (Röll and Zimmerman 1979: 19ff; Michel 1983: 59, Figs 52, 53), though the valley's steep topography does not allow for the development of wetlands. However, from the Strickland Valley to the eastern highlands of PNG, most of the major valleys contain swamp areas and the majority of these have been drained in the recent or prehistoric past.

There has been no comprehensive review of highlands swamps and their use that might allow us to determine precisely the proportion of swamps that have remained unexploited agriculturally and to plot their distribution. The only significant examples for which there is currently no ethnographic or archaeological evidence for intensive use are some of the smaller wetlands of the eastern highlands of PNG, but this apparent anomaly may reflect a lack of archaeological enquiry, as digging sticks have recently been recovered from a small wetland area in the Asaro Valley (Tim Denham, pers. comm., 2008). Swamps in the Kainantu region, at the very eastern end of the central highlands, appear to have been used only at their margins, if at all, prior to colonial administrative contact (Schindler 1952; Grossman 1984; Bourke 1992; Haberle 1996). The marked seasonality and dry periods experienced in the eastern highlands (see Chapter 4; see also Bryan and Shearman 2008: 111, Fig. 64) might be expected to have rendered wetland use even more attractive than at other locations. However, it is possible that a strong cultural commitment to existing seasonal crop repertoires, and especially the cultivation of yam during dry periods, may have militated against more extensive wetland drainage. Grossman (1984: 153–154) also records strongly held fears of swamplands amongst eastern highlanders at Barabuna, which appear to have operated as a brake on wetland use.

Table 5.2 Wetland agricultural systems of the New Guinea highlands.

Region	Locale	Ethnic community	Altitude (masl)	Principal sources
Paniai region	Paniai Lakes Basin	Me	1640–1740	Le Roux 1948–50; Barrau 1955; Pospisil 1963; Ploeg 2000
	Kamu Valley	Me	1500	Pospisil 1963
Grand Valley, Baliem River		Grand Valley Dani	1400–1500	Brass 1941; Heider 1970, 1997; Soenarto 1987; Schneider et al. 1993; Purwanto 1997; Soenarto and Rumawas 1997
Tari region	Lake Kopiago	Duna	1320	Robinson 1999
	Haeapugua	Huli	1650	Powell with Harrison 1982; Wood 1984; Ballard 1995, 2001
	Dalipugua	Huli	1700	Ballard 1995
	Mogoropugua	Huli	1870	Ballard 1995
North Mendi, Western Enga, Kaugel	Upper Mendi Valley	North Mendi	1950	Mearns 1986
	Marient Basin	Enga-North Mendi	2420	Clarke 1989
	Kandepe Basin	West Enga	2340	Wohlt 1986
	Yumbisa	West Enga	2550	Wohlt 1978
	Upper Kaugel Valley	Kakoli	2100–2200	Bowers 1968; Bayliss-Smith 1985a
	Wahgi Valley	Melpa	1580	Vicedom and Tischner 1943–48; Powell et al. 1975; Gorecki 1982;
Eastern highlands	Aiyura	Gadsup	1600	Schindler 1952; Bourke 1992
	Norikori Swamp	Tairora	1750	Haberle 1996
	Barabuna	Tairora	1670	Grossman 1984

Source: Data collated by Ballard.

Technologies of wetland drainage

Given environmental conditions that might allow for wetland drainage, the development and particular form of individual drained field systems tend to reflect several additional factors, including available techniques, crop suites and their requirements, local demands on production and the social organisation of production.

The technologies of highlands wetland field systems are not markedly different in most respects from those used on drylands adjacent to swamps. Significantly, there is no evidence for wetland agriculture without a dryland counterpart. Technologies developed on the dryland margins of swamps are extended both to the surrounding dryland slopes and to the wetter swamplands. This dryland marginal context for wetland technology is physically evident in the form of wetland drains, field systems and digging implements.

Wetland drains

Across the highlands, wetland drains represent a deepening and widening of adjacent dryland margin ditches. Thus the narrow and shallow ditches of the Grand Baliem Valley dryland *wen alobaga* gardens, typically 0.5–0.75 m wide and 0.5–1.0 m deep, are substantially expanded as drains for the wetland *wen imah* gardens, which range from 1.0– 2.5 m in width and 1.5– 2.0 m in depth (Purwanto 2004). There is considerable variation in wetland drain dimensions within and between individual highlands field systems, reflecting local hydrological conditions, but drains are commonly 1.0–3.0 m wide and 0.5–2.0 m deep (see Table 5.3). The exceptional depths recorded for drains in the Tari region reflect the fact that ditches in this area extend uninterrupted from dryland slopes through wetland margins and into the swamp centres. On dryland in the Tari region (where their function is primarily related to land boundary marking, defence and keeping pigs out of gardens), ditches up to 4 m in depth are not uncommon, generating a dense grid of irregular form laid over much of the inhabited and cultivated landscape.

Table 5.3 Wetland drain dimensions.

Location	Drain width (m)	Drain depth (m)
Paniai region	n.a.	0.5–1.0
Grand Baliem Valley	1.0–3.0 (major drains 5.0)	0.6–2.0
Tari major drains	2.0–5.0	2.0–3.0
Tari minor drains	1.0	1.0–1.4
Marient	n.a.	Up to 2.0
Upper Wahgi	1.0–1.5	0.6–1.6
Barabuna (eastern highlands)	1.2–2.0	0.9–1.3

Source: See Table 5.2 for sources from which the data were taken.

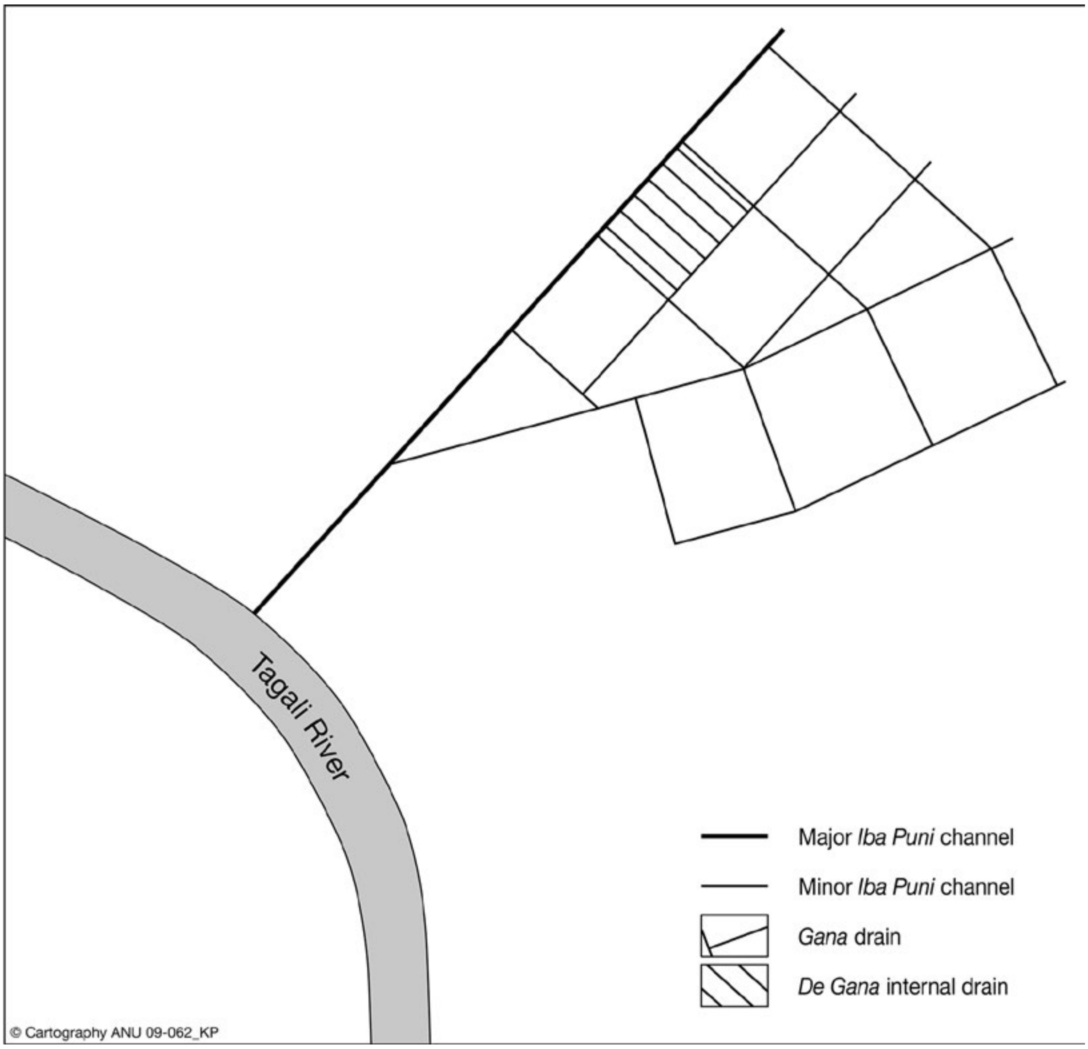


Figure 5.6 Drain hierarchy at Haeapugua Swamp, Tari region.

Source: Karina Pelling, CartoGIS Services, College of Asia and the Pacific, ANU.

In the more elaborate wetland field systems, a hierarchy of drain sizes and functions can be discerned and is often identified and named in local language. Dani people of the Grand Baliem Valley have developed a wide range of terms for the different elements of their intricate and highly variable field systems and discriminate between smaller drains (*ikala*) and the larger drains that enclose a family group's garden beds (*wen panla*) (Purwanto 1997: 355–356). In the Tari region, Huli people distinguish between small ditches within individual garden blocks (*de gana*), deeper drains surrounding garden blocks (*gana*) and the largest drains (*iba puni*), into which empty the *gana* drains of an entire clan or subclan territory (Fig. 5.6).

Wetland field systems

Wetland field systems range in scale from isolated individual plots, such as the taro gardens in boggy sinkhole depressions of the Nembi Plateau (Sillitoe 1996: 187) or the cultivated drainage depressions of the Kainantu region (Bourke 1992), through to networks such as those of the Grand Baliem Valley or the Tari region that encompass the gardens of multiple clans. Very few field systems have been mapped beyond the level of individual gardens; extensive maps that allow for detailed comparison are available only for Lake Kopiago (Robinson 1999), Haeapugua Swamp in the Tari region (Ballard 1995; Fig. 5.5 here), Yumbisa Valley in western Enga (Wohlt 1978), the upper Kaugel Valley (Bayliss-Smith 1985a; Fig. 5.7 here) and the reconstructed field systems for archaeological Phases 5 and 6 at Kuk Swamp (Bayliss-Smith et al. 2005). All of these mapped field systems conform broadly to the rectilinear, coaxial pattern illustrated for Haeapugua Swamp in Figures 5.5 and 5.8.

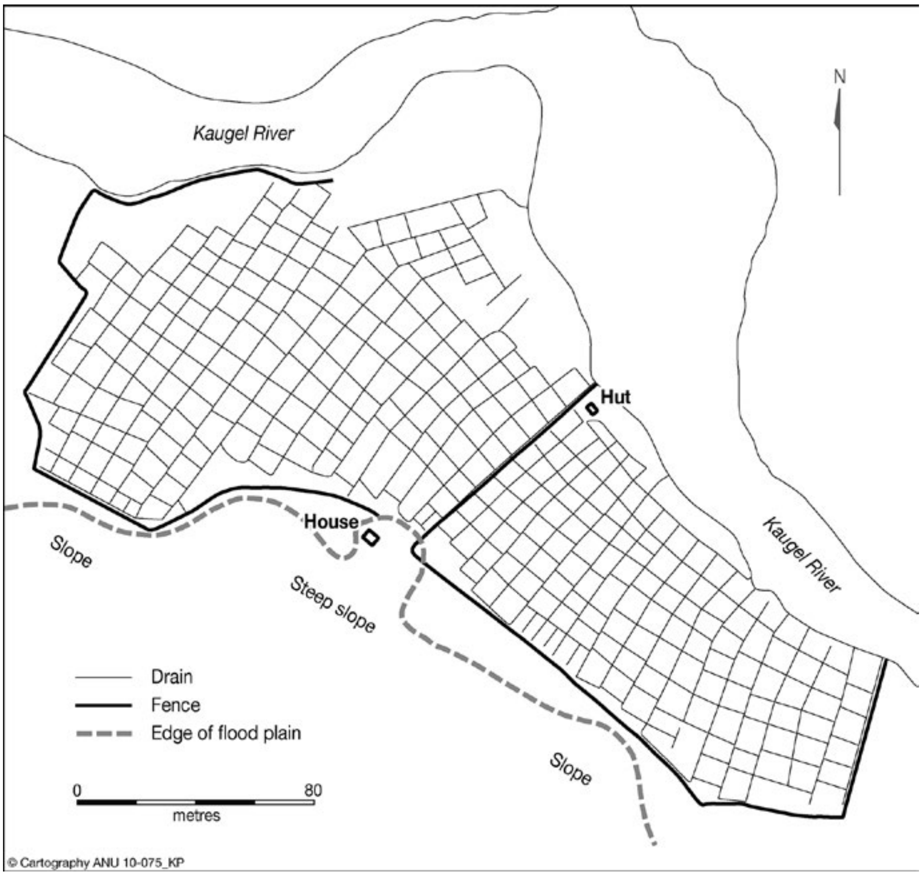


Figure 5.7 Drainage system for mixed taro gardens at Kiripia, upper Kaugel Valley.

Source: Karina Pelling, CartoGIS Services, College of Asia and the Pacific, ANU.

Figure 5.8 Aerial photograph of wetland field systems, Haeapugua Swamp, 1978.

Source: Mapmakers Pty Ltd, reproduced with permission.

On this admittedly slender basis, a number of features common to highlands wetland field systems can be proposed. Brookfield and Brown (1963: 44–45) have suggested that drainage grids 'tighten' with increasing moisture, but this is an observation made from the perspective of dryland field systems, where individual field sizes are generally larger than those on swamp margins, which require a closer network of drains. As wetland field systems extend into swamp centres, the fields actually grow larger in area again, reflecting their shorter lifespan and a more limited commitment to maintaining drainage in an environment so exposed to flooding (for data on contrasting field sizes in different parts of Kuk Swamp, see Bayliss-Smith et al. 2005: Table 3). This is clearly illustrated in the map of the Haeapugua Swamp field system (Fig. 5.5), where those fields closest to the swamp's centre near the main Tagali River are also the largest in area.

Another general observation is that increasing moisture tends to be associated with an increase in the regularity and linearity of drain networks. This presumably reflects both the hydrological advantages of removing excess water as efficiently as possible via straight drains and the scope for conformity in the plan and layout of a pioneering field system in a flat and newly colonised space. The one challenge to this generalisation comes from the convoluted form and seemingly infinite variety of the field systems of the Grand Baliem Valley, of which examples are shown in Figures 5.9 and 5.10. The hydrology of the Grand Baliem Valley remains poorly documented, however, as do its field systems, and it seems probable that the reticulate form of local drains is designed to trap and manage occasional overbank flows from tributaries of the Baliem River; it would be interesting to determine whether the flood-prone field systems closer to the Baliem River are more linear in their layout.

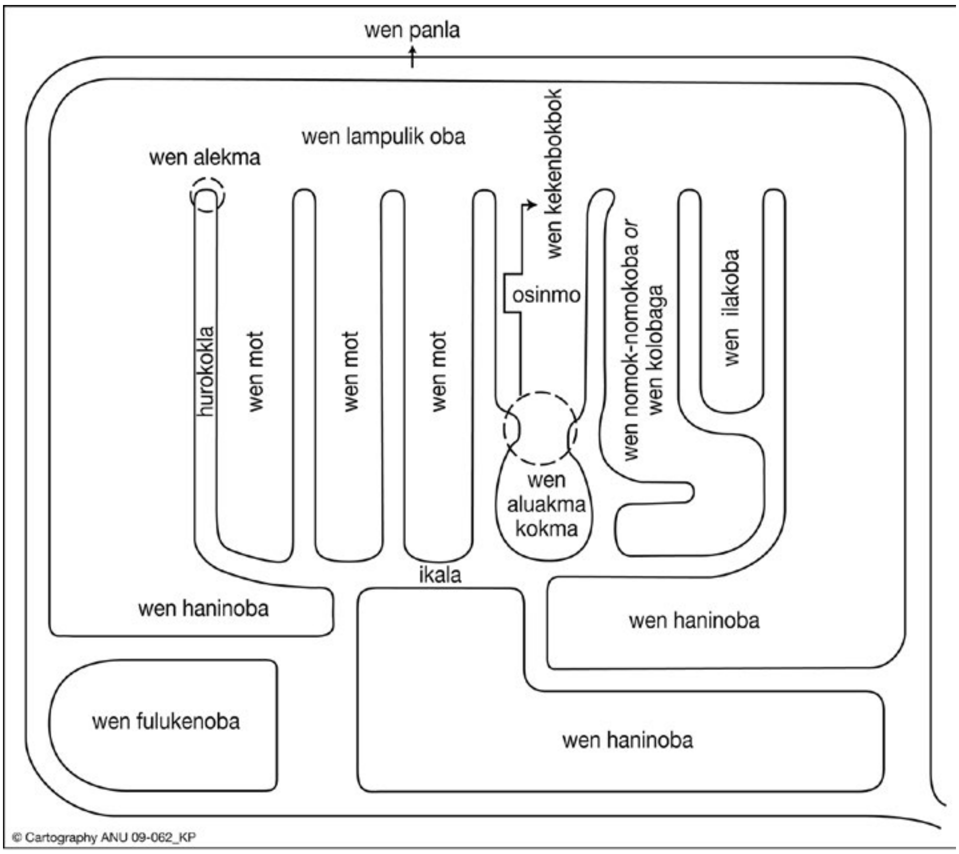


Figure 5.9 Dani terms for components of the field system in the Grand Valley of the Baliem River.

Source: Karina Pelling, CartoGIS Services, College of Asia and the Pacific, ANU.

Figure 5.10 Aerial photograph of Dani wetland field systems, Grand Valley, 1987.
Source: Photograph by Chris Ballard.

Local convention certainly plays some role in the variability evident amongst different wetland field systems, most obviously in the case of the Dani elaboration of forms in the Grand Baliem Valley, but also amongst Huli of the Tari region, where there is a commitment to ditches and drains that far exceeds the needs of water management. A particular Huli aesthetic is brought to bear on the construction of drains and the symmetry and smoothness of drain walls are subject to public appraisal; Huli initiates were formerly shown model landscapes, carefully crafted in mud, which served to display an ideal harmony in the layout of field systems and the locations of different house forms (Ballard, fieldnotes, 1990). There is also evidence from several locations of an enduring conservatism in field systems, as successive generations of drain excavators seek out the lines of earlier drains and reexcavate them in conscious imitation of known ancestors, identified by name as the first to have dug a particular drain (e.g. Ballard 1995: 96; see also Purwanto 1997: 358 on similar Dani practices). Although there is often considerable labour involved in removing the sloppy fill of an old drain, there is at least the certainty that the drain has functioned in the past and that the same claims to land are being activated (Fig. 5.11). At Kuk Swamp, archaeological Phase 6 drains appear to replicate the Phase 5 network, suggesting the observance of a similar practice in the recent past (Bayliss-Smith et al. 2005: 114).

Figure 5.11 Clearing a major channel at Haeapugua Swamp with traditional wooden rakes, 1991.
Source: Photograph by Chris Ballard.

The larger wetland drains serve a range of functions in addition to their role in the management of water: as a wetland equivalent of dryland garden fences, to keep pigs out of garden blocks; as roadways for both people and pigs; as social boundaries from the level of individuals through to clans; as boundaries between secular and sacred space; as temporal markers of local history and proofs of land ownership; and as defensive barriers during warfare (Williams 1940: 44; Ballard 1995: 95–98). Most drains serve many of these functions simultaneously.

Close attention to the layout of wetland field systems can also disclose the traces of earlier networks that allow for the reconstruction of relatively recent historical sequences of network development. At Haeapugua two different forms of earlier field systems are evident. The first consists of remnants of 'covert' drains within the existing wetland field system, aligned along different axes that have since been largely effaced (Fig. 5.12). The second, earlier field system is 'fossilised' along the wetland/dryland margins, where drains identified with some of the earliest clan ancestors (many of them now enclosing ritual spaces) take a more circular or 'lobate' form, composed of clusters of incomplete oval or lobate fields developed around even earlier oval fields (Fig. 5.12). It would be wrong, however, to draw the conclusion that lobate field forms necessarily precede rectilinear forms or that rectilinear field forms represent in themselves a particular developmental stage in the history of highlands agriculture. Rather the lobate fields resemble those employed by pioneer gardeners operating in a forested environment and less even topography, while the rectilinear forms are largely necessitated by the dictates of local hydrological conditions as gardeners push further into the swamp.

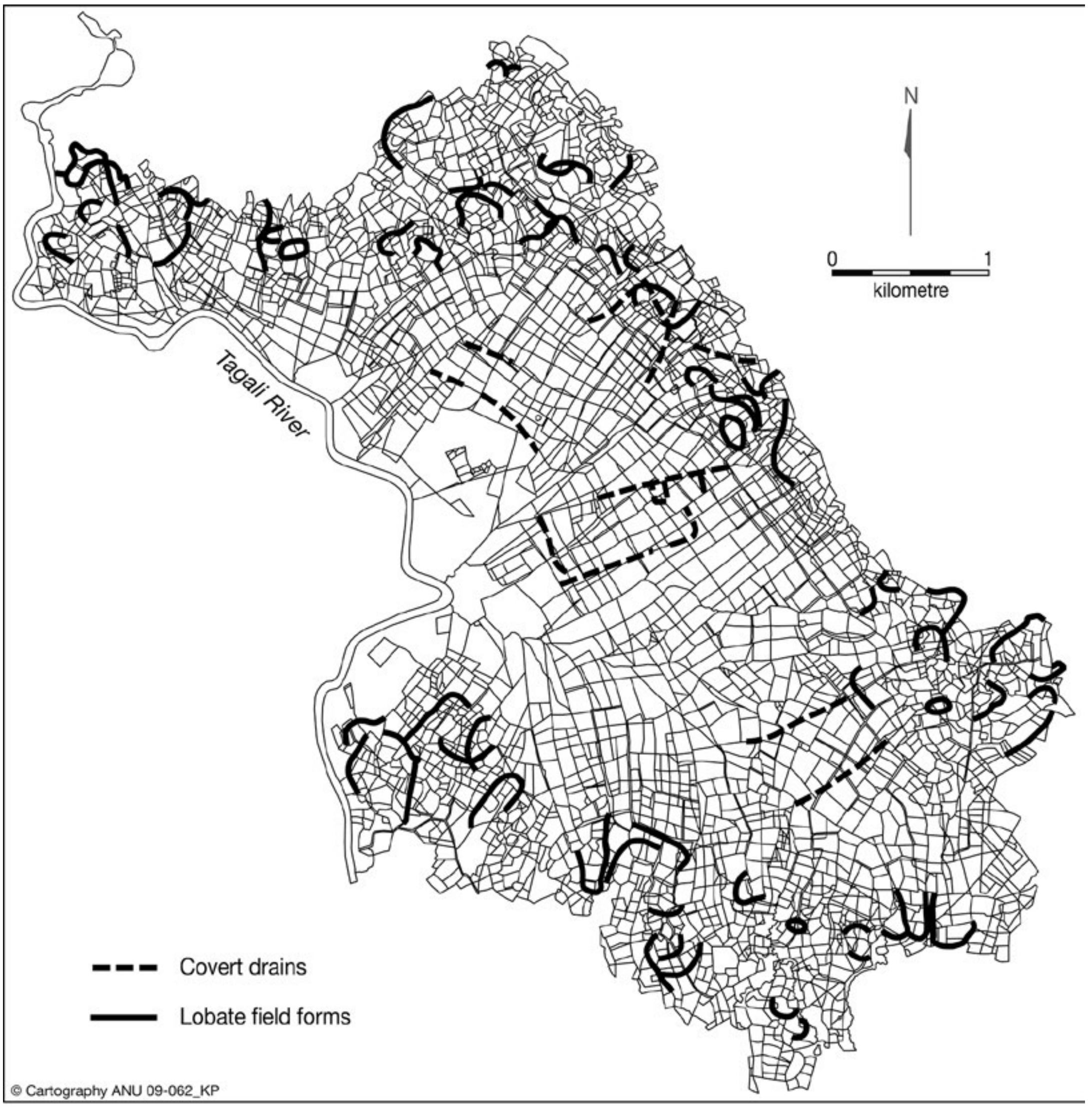


Figure 5.12 Early lobate field forms and fossil field systems at Haeapugua Swamp, Tari region.
Source: Karina Pelling, CartoGIS Services, College of Asia and the Pacific, ANU.

Digging implements

The repertoire of wooden implements employed in wetland drainage and agriculture at the time of colonial contact was fairly uniform across the highlands region (Powell 1970a: 35–36; 1974; Gorecki 1978; Steensberg 1980: 71–100; Golson and Steensberg 1985), with only a few local specialisations evident. Certain tools appear to be unique to specific locations, such as the *ma habono* taro-dibbling club of the Tari region (Ballard 1995: Table B12) or the *patau* 'earth-knife' of the Paniai region (Le Roux 1948–50, vol. 1: 290–291; Pospisil 1963: 105), which seems to have served many of the functions of the wider range of digging sticks and spades found elsewhere.

Golson (1977a: 629–630) has argued that the long-handled spades (with single or double spade-ends) used to cut fresh drain faces from a standing position above the drain wall and also to lift fertilising material up from the base of a drain, may have been developed initially in the context of swamp agriculture before being applied to dryland gardens (see also Golson and Steensberg

1985: 350–353, 360–361; Gorecki 1985: 342). Following the general argument of this chapter, an alternative way of framing this hypothesis would be in terms of a wetland technology suited to the swampland/dryland margin and capable of application to both swampland reclamation and dryland cultivation. Agricultural tools are discussed in further detail in the context of the Kuk investigations in Chapter 19.

Wetland crops and garden sequences

Within the altitudinal range of highlands agriculture, and subject to the individual limitations of particular crops (as outlined in Chapter 4), the suite of crops cultivated in wetland gardens varies little throughout the highlands region. Sweet potato now totally dominates the crop repertoire, by every measure. In pre-Ipomoean times, it is presumed by archaeologists (and assumed by many highlands people) that taro played a similar if slightly reduced role.

The contemporary garden sequence at Haeapugua Swamp, which may be taken as broadly representative of wetland sequences elsewhere in the highlands, opens with drain excavation or clearance, followed by a period of up to two years during which the area is allowed to drain (Powell with Harrison 1982). An initial wetland swidden (*lara*) sequence consists of grass clearance, the excavation of smaller internal boundary ditches and then two successive crops of taro and sweet potato, with vines dibbled directly into the garden surface. A second phase (*tabu*) sees fallow vegetation cleared and burnt, with the compost material generated forming the core of heaped soil mounds into which sweet potato vines are inserted. Following the first harvest from this *tabu* phase, the garden enters a third, mature phase as an established garden (*mabu*). Other crops traditionally cultivated in wetland gardens during the early part of this mature phase include sugarcane (*Saccharum officinarum*), yam (*Dioscorea alata*) and green vegetables such as *Rungia klossii*, *Oenanthe javanica*, *Rorippa schlechteri*, *Amaranthus* spp., *aibika* (*Abelmoschus manihot*) and cucumber (*Cucumis sativus*), all of them regarded by Huli as present in their repertoire well before direct contact with Europeans (Ballard 1995: 82–83). Post-contact additions include pumpkin, maize, choko (*Sechium edule*), various beans, pineapple, cassava, Chinese cabbage, onion and *Solanum* potato.

As wetland gardens age, the proportions of all crops other than sweet potato and sugarcane decline to the point where there is effectively a sweet potato monoculture. After a period ranging from about five years through to near-permanent reclamation, the length being contingent principally upon the needs of the garden's owners and their ability to maintain the surrounding drains, the garden reverts first to long fallow and, if not brought back into use, ultimately to swamp. The progression from swidden to burning of the cut grass for ashy compost, succeeded by mounding or bedding in an established garden, follows closely the sequence for a dryland garden, the two forms of garden thus sharing a common template.

The fertility and productivity of wetlands are probably sufficient to account for the attraction they hold for highlands communities. Table 5.4 gives figures for the yields of sweet potato from dryland and wetland gardens in the same locations. Although the estimates for yield in tonnes per hectare per year vary considerably amongst locations, the contrast between wetland and dryland productivity is relatively constant, suggesting that productivity from wetland gardens can be as much as twice that of dryland gardens. Based on Pospisil's (1963: Table 8) data, gardening in reclaimed swampland, which requires 217 hours of labour per tonne (hrs/t) of produce in the Paniai region, is also considerably more efficient than dryland agriculture (Pospisil's 'Extensive Shifting Cultivation'), at 360 hrs/t, but less efficient than wetland agriculture on swamp margins (Pospisil's 'Intensive Shifting Cultivation'), at 145 hrs/t (as calculated by Modjeska 1977: 153–155). But in terms of yield per square metre, wetland cultivation is the most productive of the three forms, generating 1.69 kg/m^2, compared with 1.38 kg/m^2 from intensive dryland and 0.81 kg/m^2 from extensive dryland cultivations (Pospisil 1963: Table 24). Bayliss-Smith (1985a) also suggests that, despite labour inputs that are three to four times greater than those per unit area of forest swidden, wetland taro cultivation in the upper Kaugel produces yields that are two to three times greater. Figures for wetland taro yields vary widely, from 12 t/ha to as much as 30.6 t/ha for specific cultivars, with an average from crop trials near the Kuk Swamp site being 17.1 t/ha; generally, however, these figures compare favourably to taro yields from swidden gardens on slopes of 4.0–7.8 t/ha (Bayliss-Smith 1982: 137). Where the necessary labour inputs are available, wetland agriculture thus appears to be considerably more productive and efficient than its dryland counterparts, both for sweet potato and for its presumed precursor staple, taro (see Chapter 14, section 'Labour and yields in Phase 4').

Table 5.4 Sweet potato yields on dryland and wetland (tonnes per hectare per year).

Location	Dryland	Wetland
Paniai region	8.1–13.8	16.9
Grand Baliem Valley	10.0	20.0–25.0
Tari region	5.1–8.2	11.3–13.8
Upper Mendi	1.4–8.8	24.3

Source: See Table 5.2 for sources from which the data were taken.

A further significant difference between wetland and dryland systems has to do with the reduced crop repertoire cultivated in wetland gardens. The tendency to a virtual monoculture of sweet potato in established wetland gardens has major implications for the overall agricultural production of the gardening community. The balance sought in daily diets between sweet potato and leafy green vegetables (Pospisil 1963: 376ff; Powell with Harrison 1982: 93ff) is not reflected in this apparent imbalance in agricultural production, though the imbalance is partly offset in some highlands communities through the consumption of sweet potato leaves (particularly amongst Dani of the Grand Baliem Valley, Purwanto 1997: 215). Nor does population fluctuate proportionally with the large wetland areas brought into and out of use. During the 33 years between 1959 and 1992, the total area of wetland in use at Haeapugua in the Tari region fluctuated both up and down by as much as 43 per cent; yet over the same period the population resident in the area rose inexorably, almost doubling (Ballard 2001: 298). Why then is labour committed to wetland drainage, if the resulting wetland production is linked directly neither to population growth nor to the dietary needs of humans, and how is that labour marshalled?

Social contexts for wetland drainage

In most highlands societies, political autonomy is fiercely defended and individual men and their immediate families guard closely their right to garden independently of others. Wetland drainage can be undertaken successfully by individual families, but more commonly involves larger groups acting communally, at least in the construction of the garden. The advantages of working in a larger group include wider political and defensive support for what are often contested claims to areas of swampland that are vulnerable to attack, as well as the benefits of a more speedy completion of the initial tasks of drain excavation and garden construction.

Estimates of the labour required to create wetland fields are based on a variety of calculations at different locations and range from 7 m^3/man-day in the Tari region (Ballard 1995: 187, over a 7.5 hour period) to 7.25 m^3/man-day in the Paniai region (Pospisil 1963: 106, assuming 5 hours of labour per day) or 6 m in length of excavated drain per man per day in the Wahgi Valley (Gorecki 1985: 340–341, assuming 4.0–4.5 hours per day), though all three sets of figures presume the use of modern steel spades. Experimental data from a range of sites relating to excavation with wooden spades (Bayliss-Smith and Golson 1992a: 15, 21) suggests a slower rate of 2.5 m^3 or 1 m in length of drain per day (Bayliss-Smith and Golson 1999: 222), assuming an average volume of 2.5 m^3 per metre of drain, removed at 0.5 m^3 per hour for a maximum of 5 hours per day. As the total length of the visible drain network in the wetlands at Haeapugua (Figure 5.5) is calculated at just over 205 km, the rough 'wooden tool' rate of 1 m/man-day yields an estimated total of 205,000 man-days for the entire network; but does this represent the labour of 14 men working continuously, and improbably, over 40 years or, equally implausibly, of 561 men working every day for one year? Local oral traditions at Haeapugua suggest that most of the drain network was in fact created over little more than 40 years (Ballard 1995: 187), at an average of about 5 km/yr, while Gorecki (1985: 341; see Chapter 23 here) notes that drainage of the South Kuk wetlands was achieved over a period of 17 years, at an average of just over 3 km/yr. While such figures and estimates offer only a very general guide to labour investments, they do serve to stress the difficulty of deducing actual labour group sizes, or the time taken to establish a drainage network, simply from the scale of a field system, as well as the challenge of 'reading' social organisation from the form of a field system.

The ethnographic evidence for the social organisation of wetland production is invaluable here and it suggests that communal labour inputs, if not essential, are the common rule. Dani work parties in the Grand Baliem Valley of up to 15 men and boys are assembled by a garden owner and fed during the period of their labour, in the knowledge that they will call on his labour on their fields in turn (Heider 1970: 39); larger enterprises are initiated and coordinated by lineage heads (Schneider et al. 1993: 20–21; Purwanto 1997: 358). Huli work parties in the Tari region are coordinated in much the same way as for any other communal project—such as warfare or compensation payments—by one or more identified 'owners' (*anduane*) or 'sources' (*tene*) of the project. The capacity of project owners to marshal labour for wetland drainage, drawing on immediate family, affinal kin, friends and allies, is acknowledged as testament to their ability as leaders and contributes substantially to their prestige within the community. By the same measure, the longevity of a wetland garden project is a test of the capacity of a project leader to sustain the cohesion of his work party by ensuring that the drains are regularly maintained and the garden's viability repeatedly secured.

If the question of 'how' a wetland garden project is pursued is relatively simply observed and documented ethnographically, the corresponding question of 'why' wetland gardens are initiated is less easy to resolve. Disaggregating consumption of produce from wetland gardens from all other agricultural production is difficult, but interviews with wetland garden owners at Haeapugua suggest that wetland projects are usually directed towards some identifiable goal to which other project members might be recruited. Rather than simply alleviating shortfalls in dryland garden production, wetland projects are initiated with the goal of producing a surplus of sweet potato, a substantial proportion of which is reserved as fodder or forage for pigs. Estimates of the overall proportion of sweet potato production fed to pigs in several highlands societies range from 23 per cent to 70 per cent, but most commonly fall around the 50 per cent mark (Hide 2003: 63–70). The production of pigs, as the premium item of exchange in most highlands societies, whether for marriage or various forms of compensation, as well as for ritual sacrifice, requires a degree of long-term planning (Hide 1981: 561) Haeapugua Huli have described their wetland projects as initial steps in the process of preparing for major payments, or even in covert anticipation of conflict. To the extent that uncultivated wetlands are a common source of forage for pig herds, especially for earthworms (though introduced earthworm species appear to be more attractive for pigs than endemic species, Hide 2003: 71–72), wetland cultivation is thus in part a means of intensifying pig production within the same area.

Comparisons

This brief ethnographic overview of wetland field systems documented during the period since colonial contact suggests extensive similarity in techniques, crops and methods of production across much of the highlands region of New Guinea. There is evidence for considerable variability within individual systems (see, for example, Heider 1970: 42), sometimes greater than that between systems from different locations. However, the local continuities between dryland and wetland systems are sufficiently strong that these similarities should probably be interpreted as evidence for a broad agricultural heritage shared across the highlands, for continuities in environmental context and for the common hydrological requirements of drainage systems. However, this argument for an essential regional uniformity comes with an important proviso, articulated by Spriggs (1990: 184): individual wetland systems need first to be understood at the specific level, in terms of each of the factors discussed here, such as the characteristics of local hydrology and catchments and the local forms of demand on production and of labour organisation.

Denham (2005a) has argued that the rectilinear fields of archaeological Phases 3–6 at Kuk Swamp represent an invention indigenous to the highlands, which precedes and thus cannot be attributed to the influence of the arrival along the coasts of New Guinea of Austronesian-speaking communities. While the claim that wetland drainage has developed independently in the New Guinea highlands now appears secure, the argument about the rectilinear form of the wetland field systems is probably not required, as rectilinear drains are a measure that is largely dictated by hydrological requirements and by the nature of land subdivision in a novel environment. There is certainly no support for an exogenous origin for highlands wetland drainage evident in the tool repertoires or the various highlands vocabularies for wetland agriculture, all of which are embedded firmly in the wider technologies and lexicons of local dryland agriculture (Ballard 2000). For the later Phases 5 and 6 at Kuk, the ethnographic analogues of the 20th century discussed here offer real interpretative possibilities, identifying anthropogenic wetlands along the dryland/swampland margins as the agricultural powerhouses of production and innovation and confirming the role of pig production and the intensification of social exchange as critical stimuli for communities confronted with the social and technological challenges of swampland reclamation.

Acknowledgements

This chapter has benefited considerably from the comments of Bryant Allen, Tim Bayliss-Smith, Mike Bourke, Robin Hide and Anton Ploeg.

Part Two: Kuk Swamp and its Store of Evidence

6

Kuk Swamp

Philip Hughes, Tim Denham and Jack Golson

The Wahgi Valley

Kuk Swamp lies at around 1580 m altitude in the upper Wahgi Valley, a large intermontane basin between the Sepik-Wahgi Divide to the north and the Kubor Range to the south, both of which rise to 4000 m or more above sea level. Today the basin is largely drained by the east-flowing Wahgi River, but formerly the western part drained westwards. This drainage was reversed with the damming of the valley by a massive volcanic debris avalanche from the Mt Hagen stratovolcano, which today dominates the western end of the basin, rising about 2000 m above the surrounding landscape (Löffler 1977: 26–27, 73; Pain et al. 1987). The avalanche responsible for this blockage occurred at least 80–100,000 and possibly 400,000 years ago (Pain et al. 1987: 275).

The Wahgi Basin is filled with extensive fan and terrace deposits that, at the western end of the valley, at the point where it is widest, are capped with swampland in the ponded area between the footslopes of Mt Hagen and the higher fans and terraces to the east (Haantjens et al. 1970: 22; Löffler 1977: 105–107; Pain et al. 1987: 269, Fig. 2). In their natural state, these swamplands were more than 250 km^2 in area (Haantjens, Reiner and Robbins 1970: 64–65; Pain et al. 1987: Fig. 2). They covered large areas of floodplain along the upper reaches of the Wahgi River and its tributaries and accumulated as extensive back swamps between the floodplain and adjacent higher ground (Fig. 6.1 below). Over much of the area, the swamplands were discontinuous and relatively shallow (probably <2 m). There are two major swamp basins, the huge North Wahgi Swamp and a smaller swamp basin to the south, of which Kuk Swamp is part (Pain et al. 1987: 271, Fig. 2). These two basins are separated by a major bedrock ridge called Ep. Being virtually surrounded by water, Ep Ridge was called the 'island' by the first Europeans to enter the upper Wahgi (cf. Leahy 1936: 248; Gorecki 1979b: 26).

Beginning in the 1950s, large parts of the Wahgi swamplands were progressively drained and the land developed for agricultural purposes, mainly tea and coffee plantations. The Kuk Tea Research Station was established at Kuk Swamp in 1969.

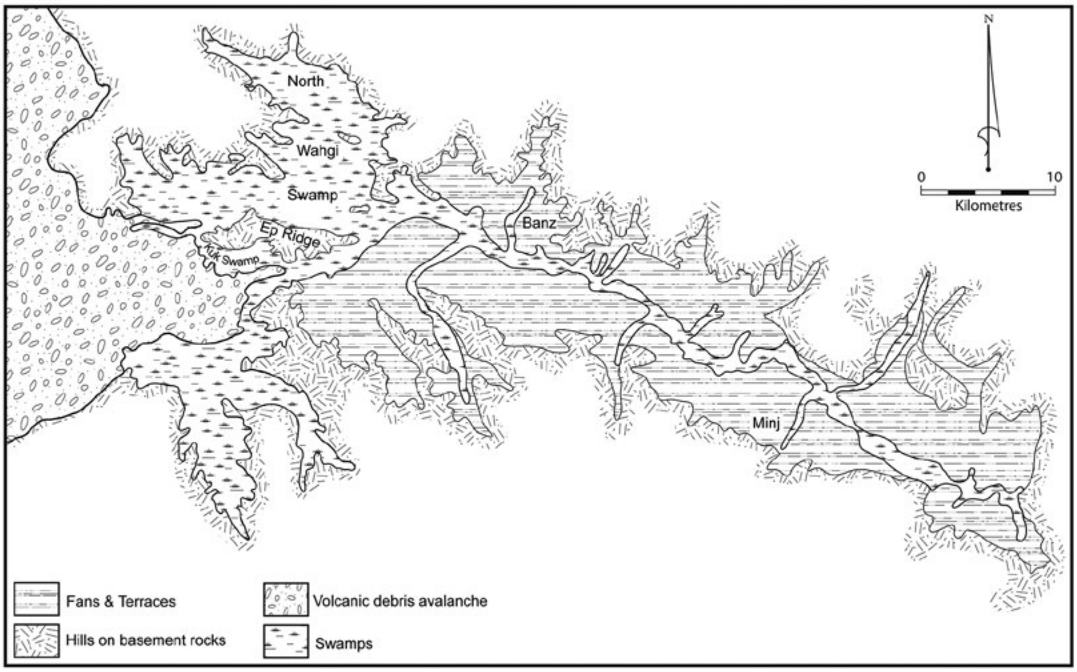


Figure 6.1 The swamplands of the Wahgi Valley before large-scale drainage began in the 1950s.
Source: After Pain et al. (1987: Fig. 2). Drawing by Kara Rasmanis.

Kuk Swamp in its local setting

To the immediate north of the swamp, the steep slopes of Ep Ridge rise 150–350 m above it (Figs 6.2 and 6.3). To the south are low hills formed on volcanic debris avalanche (lahar) deposits derived from Mt Hagen to the west (Blong 1986a; Pain et al. 1987; Figs 6.1, 6.4, 6.5, 6.6 and 6.7 here). These lahar deposits are capped by a sequence of up to nine volcanic ash (or tephra) formations older than 50,000 years, all most probably derived from Mt Hagen (Pain and Blong 1976). The tephra cover on the hills is commonly less than 1 m, but it is much thicker on their flanks. In the east of the Station, the gently undulating tephra-mantled land surface dips northwards, and then also northwestwards, beneath the deposits of the swamp, with a few low rises or hills of about 1 m local relief (Figs 6.2, 6.4 and 6.5). In the southwest of the Station, the tephra-mantled land surface is visible as an extensive area of slightly higher ground narrowing to the north (Fig. 6.4).

The swamp surface slopes down a couple of metres from the southern boundary of the Station, relatively steeply at first, then almost imperceptibly, to its lowest point about two-thirds of the way across the swamp. Northwards of this it rises quite sharply over the toes of the fans at the base of Ep Ridge (Figs 6.4, 6.8 and 6.9). This situation reflects the greater influence on depositional processes in the swamp basin of water coming from the southern catchment than that of the very much shorter but steeper northern catchments on Ep Ridge (Fig. 6.2).

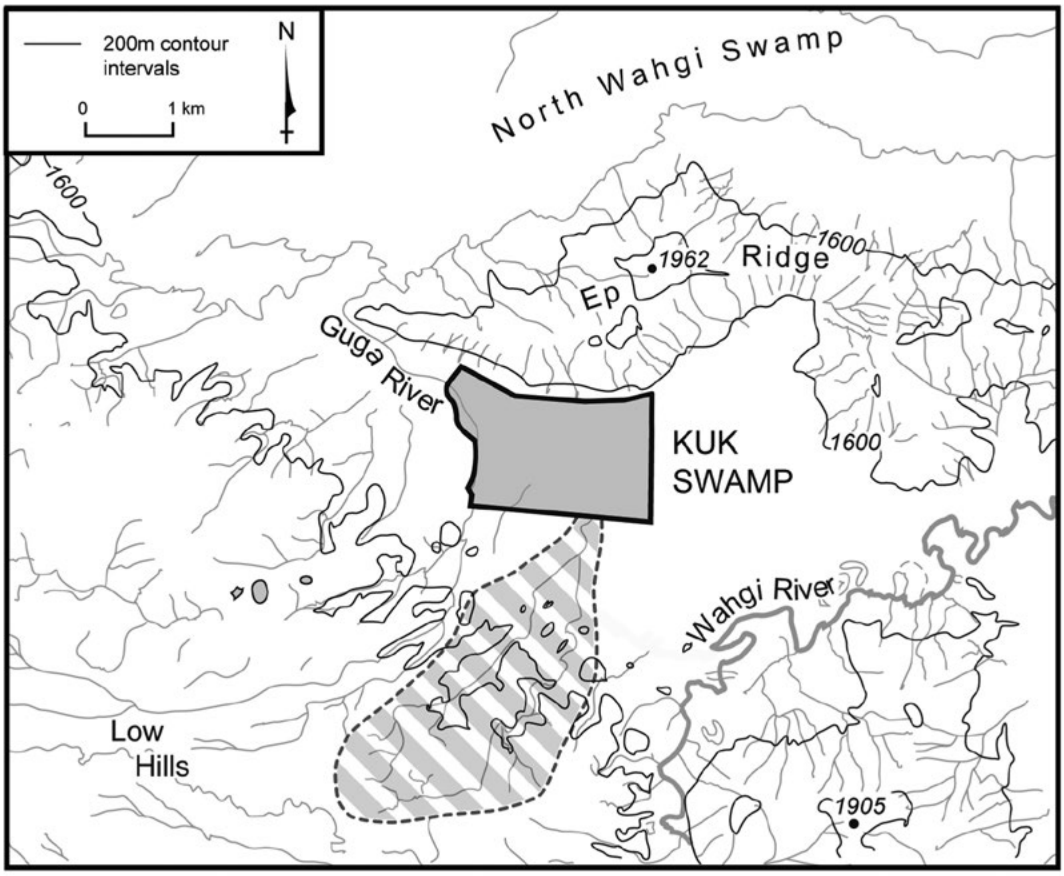


Figure 6.2 Kuk Research Station and its landscape setting, showing the southern catchment of Kuk Swamp (shaded).

Source: Drawing by Harrison Pitts.

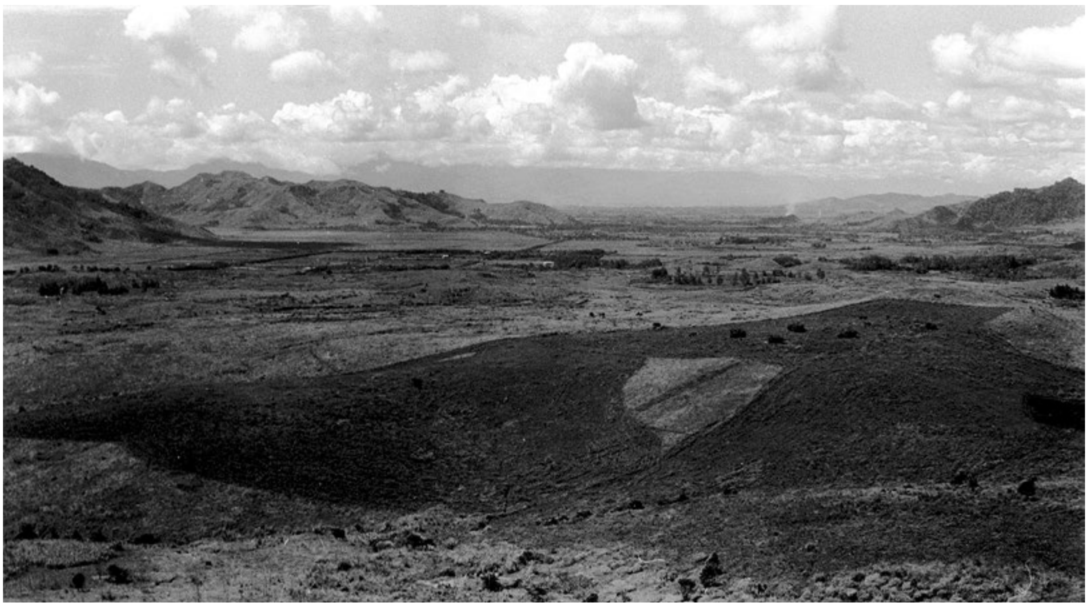


Figure 6.3 Looking east down the Wahgi Valley to Kuk from Mt Ambra. The slopes of Ep Ridge are on the extreme left edge.

Source: Photograph by Ole Christensen, Kuk archive, 1973.

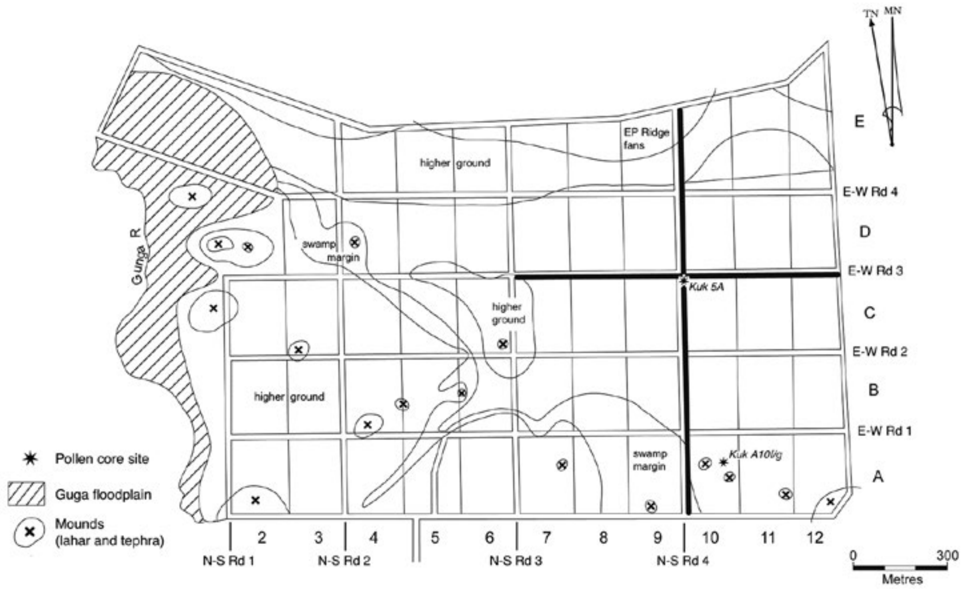


Figure 6.4 Landforms of Kuk Swamp.

The black lines show the location of the stratigraphic profiles illustrated in Figure 6.9. The north–south profile marks the approximate position of the watershed. The locations of the two pollen cores, Kuk 5A and Kuk A10f/g (Powell 1984), described in Chapter 9 are also shown.

Source: Drawing by Winifred Mumford.

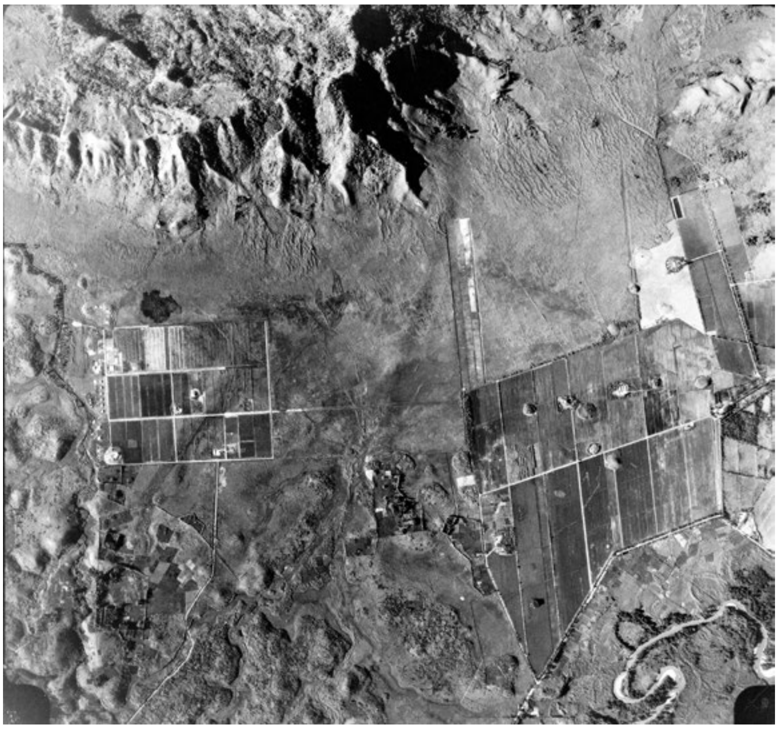


Figure 6.5 Vertical aerial photograph of Kuk Swamp and its surrounds in 1970, including Ep Ridge to the north and the low hilly catchment to the south.

The SW part of the agricultural station is under development and to the SE is Tibi tea plantation. Some of the hills to the south and west of Kuk are lahar mounds and there are several prominent lahar mounds at the northern end of Tibi plantation.

Source: Qasco aerial photograph, 5 October 1970, Film NG 127, Run 4, reproduced with permission.

Figure 6.6 Oblique aerial photograph of the Kuk Swamp southern catchment, looking NE over the Station's southern boundary drain.

The southern end of the most westerly of the Station drains cuts into a lahar mound we called 'Blong's Nob'. The two close-set drains to the east are the flanking drains for the future N–S Rd 4 of the Station grid. At the top left of the photograph is E–W Rd 1.

Source: Photograph by Russell Blong, Kuk archive, 1972.

Figure 6.7 Oblique aerial photograph of the Kuk Swamp southern catchment, looking SSW over the southern boundary drain. Blong's Nob appears just above the bottom right corner of the photograph.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

Figure 6.8 Looking south from the foot of Ep Ridge along drain E7f/g towards the line of trees bordering E–W Rd 1. Drain D7f/g is in the background.

Source: Photograph by Philip Hughes, Kuk archive, 1975.

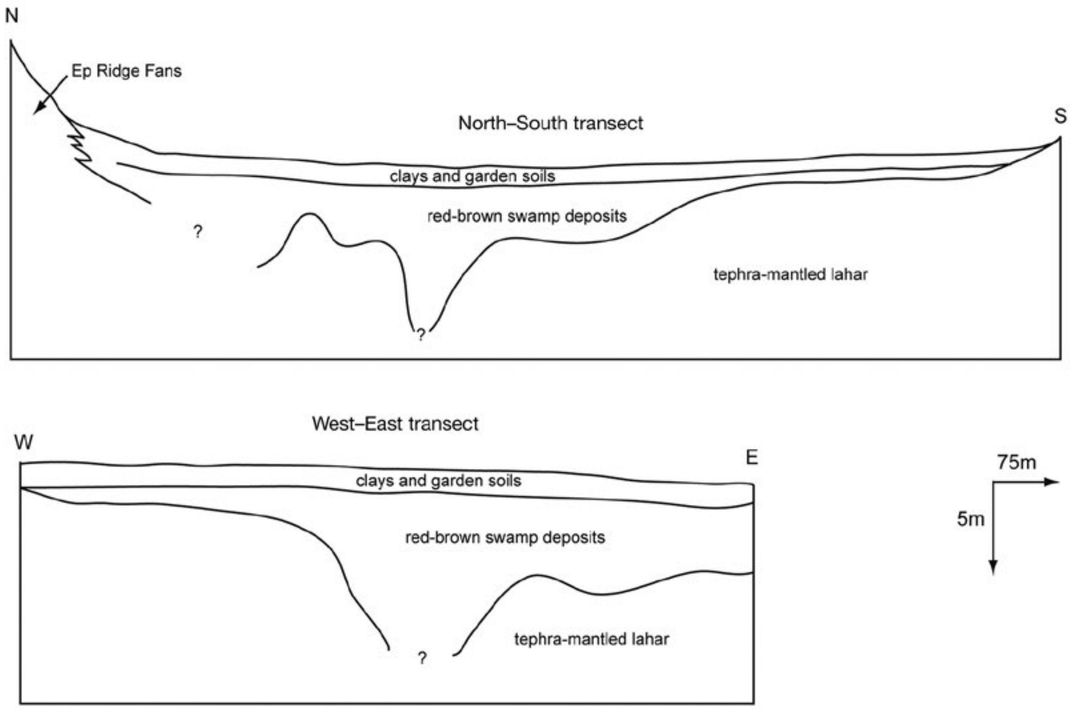


Figure 6.9 Stratigraphic profiles across the eastern half of Kuk Station, showing the thickness of the swamp deposits.

The north–south transect is along the eastern drain of N–S Rd 4 and the east–west transect along the southern drain of E–W Rd 3 (see Fig. 6.4).

Source: Kay Dancey, CartoGIS Services, College of Asia and the Pacific, ANU.

There is a watershed running north across the widest part of the swamp in the eastern part of the Station (Fig. 6.4), imperceptible to the naked eye but known to some of the older Kawelka residents of the area. Under natural conditions the water that drained eastwards flowed across the large tracts of adjacent swampland, known locally today as Tibi, Tibi Residue and Baisu, and thence along a shallow valley through higher ground and into the Wahgi River (Fig. 6.2). Water draining westwards moved via the Guga River to the Gumants River, which in turn flowed through the vast North Wahgi Swamp, eventually reaching the Wahgi River well downstream to the east (Figs 6.2 and 6.4). The existence of this watershed was recognised during early planning for the Kuk drainage scheme (McGrigor n.d.).

During this planning phase some areas of the swamp were found to be over 10 m deep, making them amongst the deepest such deposits in the Wahgi Valley (McGrigor n.d.). The thickness of swamp deposits overlying the tephra-mantled basement was documented in cores by Jocelyn Powell in the early stages of the Kuk Project; the reconstructed cross-sectional profiles show that before the present swamp formed, a shallow valley at least 6 m (and probably more than 10 m) deep and 100 m wide had been cut by stream action into the plain that existed at that time (Fig. 6.9). The reasons why this and any other streams draining the basin ceased to flow freely, thus allowing swamp to accumulate, are not known. It could have been caused by landslides or accumulating fan deposits from Ep Ridge that blocked the Guga River outlet to the west and deposition on the Wahgi River floodplain that cut off drainage to the east (Fig. 6.2).

Overall, Kuk Swamp is a shallow basin (Figs 6.2, 6.4 and 6.9) into which sediment was washing from the surrounding hills for more than 50,000 years, along with the decayed remains of plants that grew in the swamp. In the process, the swamp deposits have come to consist of a sequence of distinctive layers of organic and inorganic sediments: deeper deposits reflect changing regional and local climatic and hydrological conditions; shallower deposits primarily reflect the impacts of human landuse in the dryland catchments of the swamp and in the swamp itself over the last 10,000 years.

The stratigraphy of the swamp has been recorded along more than 15 km of modern drainage ditches over an area of about 100 ha covering many parts of the Station, especially the eastern half (Fig. 6.4). The ages of the stratigraphic units shown in Figure 6.10 have been determined from widespread radiocarbon dating and from the swamp-wide correlation of a number of thin, highly distinctive airfall tephras that are preserved in the deposits (see Chapter 7). In the southeastern part of the swamp, the increasingly inorganic sediments deposited after about 20,000 years ago comprise a fan deposit (Fig. 6.11), thickest at the southern margin of the swamp, which formed from sediments washed in from the low tephra-mantled hills to the south (Figs 6.2 and 6.5). Numerous similar but smaller and steeper fans deriving from Ep Ridge protrude into the swamp from the north.

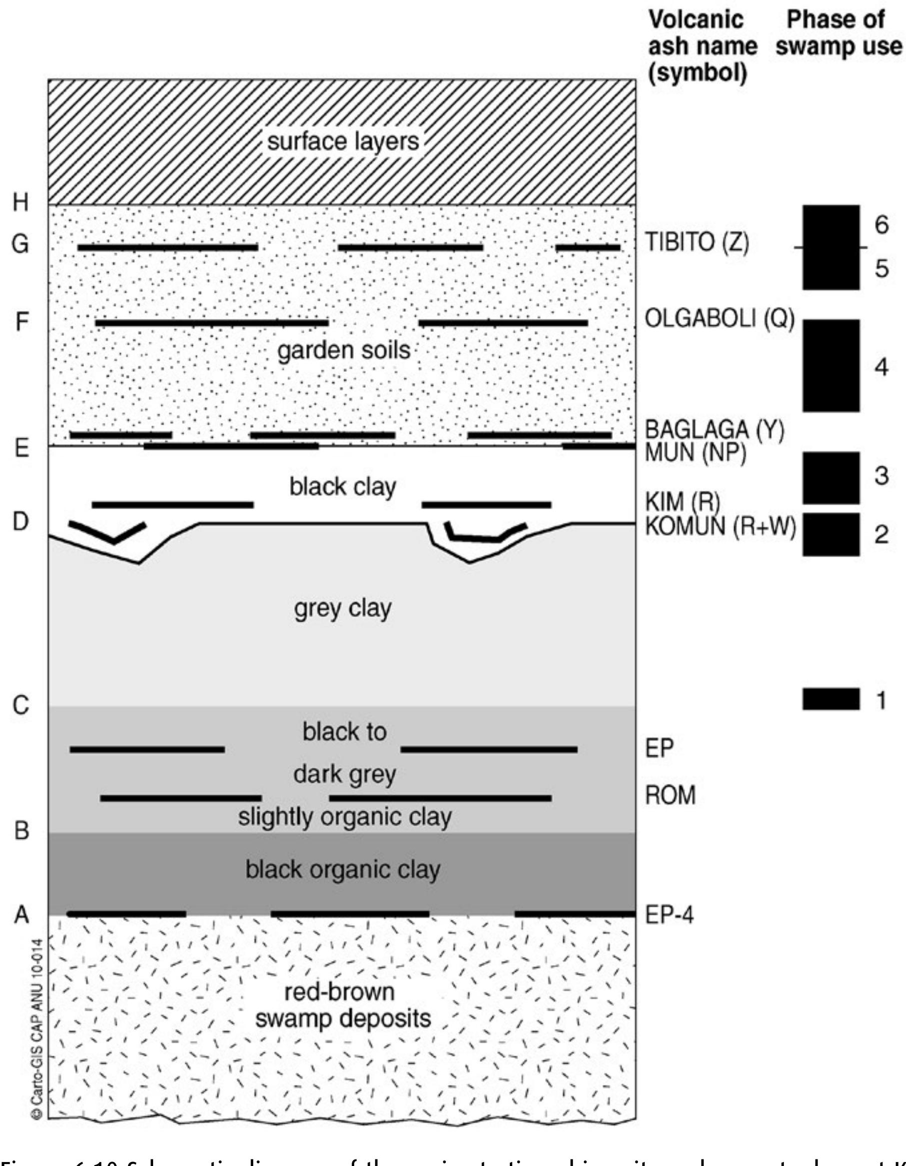


Figure 6.10 Schematic diagram of the main stratigraphic units and some tephras at Kuk Swamp.
Source: Kay Dancey, CartoGIS Services, College of Asia and the Pacific, ANU.

Main stratigraphic units at Kuk

There are seven main stratigraphic units and nine tephras identified at Kuk (Figure 6.10). With the exception of G, the chronology in the discussion that follows is based on radiocarbon dates calibrated to years Before Present (BP) at two standard deviations. See Table 7.2 for dates of B, F and G. The ages of the main stratigraphic units and their associated tephras are described as follows:[1]

- A is the transition from red-brown swamp deposits to black organic clay, marked in places by a volcanic ash (or tephra) called Ep-4. A generalised minimum age of 35,000 years for the transition, and thus for Ep-4, is argued in Appendix 6.1.
- B marks the transition from black organic clay to black to dark grey slightly organic clay, which on drain D7d/e is spanned by a 150 mm diameter log some 15 m south of the north end of the drain. The log is dated by ANU-3186 to between 24,650 and 23,380 BP (see Rom tephra in Chapter 7).
- C marks the start of grey clay deposition between a date in the range 10,220–9910 BP for the top of the fill of channel 101, which the grey clay overlies, and one in the range 10,230–9780 BP from near the base of the grey clay itself (see Denham et al. 2003: Table S2; Table S1 gives the individual radiocarbon dates).
- D, the horizon between grey and black clay, falls between a date in the range 7420–7210 BP near the top of grey clay (Denham et al. 2003: Table S1, OZD931) and one in the range 6950–6440 BP near the base of black clay (Denham et al. 2003: Table S2; see Table S1 for the individual radiocarbon dates).
- E, the horizon between black clay and garden soils, is marked in places by Mun (Niupela) tephra. The ashfall is undated, but occurred between a date in the range 2730–2360 BP for a late phase of black clay formation and one in the range 2710–2120 BP for the surface on which Baglaga (Y) tephra fell (Denham et al. 2003: Table S1, ANU-8056 and 8057 respectively). A new date is in the range 2700–2340 BP for the surface below Baglaga at nearby Mt Ambra crater (Sniderman, Finn and Denham 2009: Table 2, OZF145). For Baglaga dates see Table 7. 2.
- F is Olgaboli Tephra (Q), dated between 1230 and 970 BP. At around this level in the profile, the garden soils change in texture from finer to coarser.
- G is Tibito Tephra (Z), dated between 304 and 154 BP by radiocarbon (the calibrations in this case not rounded off) and AD 1665/1666 on other evidence.
- H is the base of the surface layers of peat, and its decay products, that formed over the swamp after gardening ceased. This was shortly before the fall of Tibito Tephra in the deeper swamp and in the early 20th century elsewhere at Kuk.

From broader geomorphic investigations across the entire Station, it was possible to map areas comprising what were referred to in the field as 'true swamp', 'swamp margin' and 'higher ground' (Fig. 6.4). 'True swamp' was that area where the basement deposits were mantled with red-brown swamp deposits older than about 35,000 years, as described below. 'Higher ground' referred to that part of the Station where, if they occurred at all, any overlying swamp deposits were thin (<0.5 m) and had been converted into garden soil over the last 2500 years or so. 'Swamp margin' was the land between these two. Also mapped were 'mounds' (Fig. 6.4; cf. Figs 6.5 and 6.12), small hills formed from tephra older than 50,000 years. The cores of some of these were seen to consist of lahar deposits and therefore they can properly be called 'lahar mounds' (Fig. 6.6; cf. Fig. 6.5). At least one other low hill, which was exposed in section to a depth of almost 3 m, consisted of tephra-derived clay without any sign of lahar material (Fig. 6.13). This, and other possible examples of the same type, may be residual features formed by erosion of the original volcanic landscape.

1 The tephras were named after localities in the Wahgi Valley. Most of them originally were given fieldnames (shown here in brackets after the formal names), which, because these were used in many of the earlier Kuk publications, are reproduced here for consistency. For the use of upper case T for Tephra following Olgaboli and Tibito see Chapter 7.

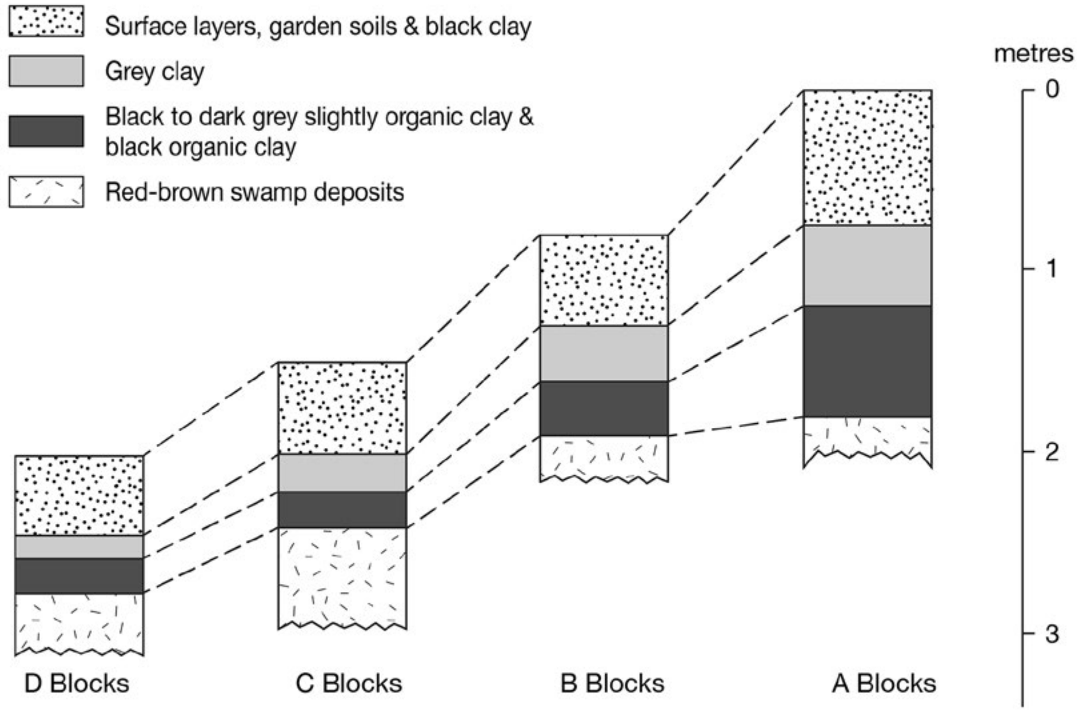


Figure 6.11 The relative disposition of major stratigraphic units in the SE part of Kuk Swamp.

Based on records taken along Station drains in blocks to the east and west of N–S Rd 4. See also Figures 6.17, 6.18 and 6.19.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Figure 6.12 Oblique aerial photograph of two tephra mounds in block A10 (arrows A and B), view to NW.

The straight line to the east of the mounds is the course of Simon's Baret (arrow C), a disposal channel of Phases 5 and 6 running NNW from beyond the Station southern boundary.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

Figure 6.13 Stratigraphy viewed from the north in drain A10f/g, which was dug through the tephra hill marked B in Figure 6.12.

Source: Photograph by Philip Hughes, Kuk archive, 1974.

Kuk Swamp and its drainage for the Research Station

The following description of Kuk Swamp and its drainage for the establishment of a Tea Research Station in 1969 by the Australian administration's Department of Agriculture, Stock and Fisheries is based on two unpublished documents by Alan McGrigor (n.d., 1969), who was responsible for the drainage works. They give different figures for the area of the Station: 770 acres in an undated document, which converts to 311.6 ha, and 318.4 ha in the other. We adopt 311 ha for the area, since this is close to the figure others have used (e.g. Ketan 1998: 18; Moutu 1998: 20). Some 75 per cent of the property was described as peat swamp under a cover of either phragmites (*Phragmites karka*), sedge (probably several species including *Eleocharis sphacelata)* or both. The remaining 25 per cent consisted mainly of slightly elevated land in the southwest sector, still only poorly drained at best, and the lower slopes of Ep Ridge within the Station, which would have been relatively well drained. There were no watercourses as such on the block, only sluggish flow lines. McGrigor (1969: 2) estimated that at least 50–60 per cent of the area would have been permanently under water. Conditions over much of the block were such that the surface would not support the weight of a person, but there was a firm 'bottom' between about 0.3 m and 2 m below the surface. As discussed below, in many places the swamp surface apparently consisted of floating mats of vegetation.

Before beginning the internal drainage of the Station, it was necessary to collect and dispose of the water entering the block from outside its boundaries. According to McGrigor's estimates, Ep Ridge contributed the runoff from some 120 ha of catchment above the northern boundary, most of which was taken by small incised streams down the steep slopes. Most of the runoff from 464 ha of undulating country beyond the southern boundary, on the other hand, was carried by two creeks; the eastern one, Tibi Creek, draining a much larger area than the western one, Tibito Creek. The southern boundary drain of the Station was dug to intercept the eastern creek (Figs 6.6 and 6.7). Water was taken by the southern and eastern boundary drains into the Tibi drainage system and eastwards across Baisu to the Wahgi River. The flow of the more westerly of the two creeks was formalised to take its water along internal drains of the Station and into the Guga Creek at its western boundary (Fig. 6.14).

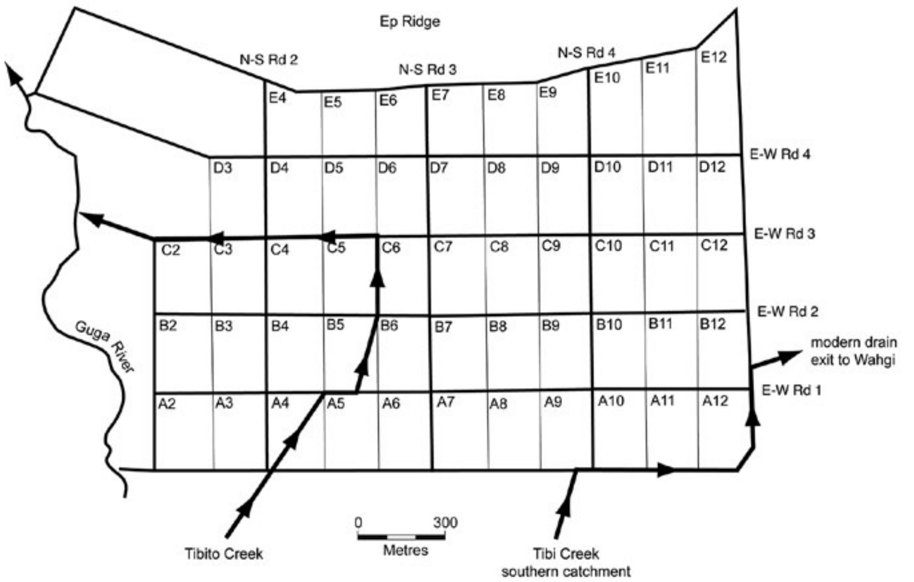


Figure 6.14 Schematic map depicting the road and block grid at Kuk Research Station. The main outlet drains diverting flow to the east from Tibi Creek and to the west from Tibito Creek are also shown.

Source: Kay Dancey, CartoGIS Services, College of Asia and the Pacific, ANU.

Textbox 6.1 Alphanumeric code for roads, drains and blocks

Philip Hughes and Jack Golson

The four east–west roads were designated E–W Rd 1 to 4 from south to north and the four north–south roads N–S Rd 1 to 4 from west to east (Fig. 6.4). The main 4.5 ha blocks were labelled A to E from south to north and 2 to 12 from west to east, i.e. from A2 in the southwest corner of the station to E12 in the northeast corner (Figs 6.4 and 6.14)

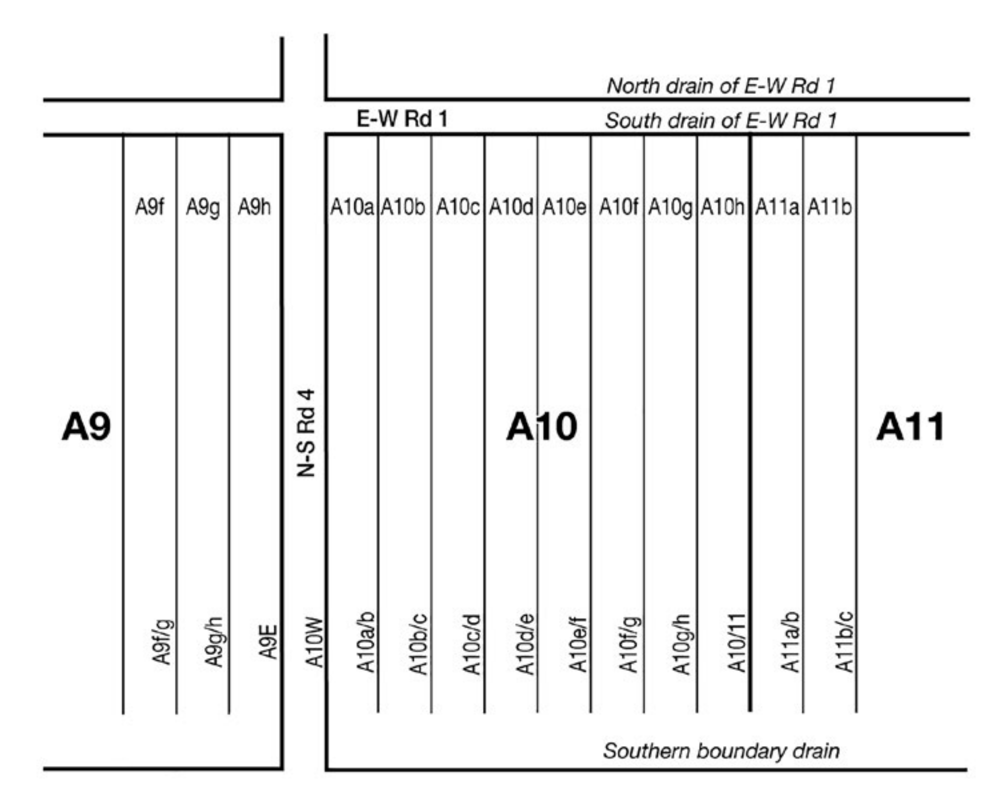


Figure 6.T1.1 The alphanumeric code illustrated.

Source: Drawing by Harrison Pitts.

Within each of the main 4.5 ha blocks (block A10 is the example illustrated here) the eight sub-blocks were labelled a to h from west to east, i.e. A10a to A10h. The north–south drain between two main blocks, in our example blocks A10 and A11, was labelled A10/11. The minor north–south drain between two sub-blocks, A10b and A10c for example, was labelled A10b/c, and that between A11a and A11b, A11a/b.

The drains flanking the east–west roads, in our example E–W Rd 1, were referred to as the north drain and south drain of E–W Rd 1. Those flanking the north–south roads, in our example N–S Rd 4, were referred to, in the case of the eastern drain, as A10W (i.e. the western boundary of block A10) and for the western drain as A9E (i.e. the eastern boundary of block A9).

McGrigor's plan for development within the boundaries of the Station aimed to combine adequate drainage of the property with a grid of access roads that provided individual blocks as uniform in size as possible (Fig. 6.15). Figures 6.4 and 6.14 indicate the alphanumeric code by which the Station management identified roads, drains and main blocks throughout the property (see also Textbox 6.1). Four east–west roads with flanking drains, built at 265 m intervals, supplied the framework of the scheme. The roads and their two associated drains were 15 m wide, which left strips 250 m wide between them for cultivation. North–south drains subdivided these strips into 4.5 ha blocks (250 m x 180 m), with north–south roads and flanking drains at intervals between them. Minor north–south drains, spaced at 22.5 m, 45 m or 90 m, allowed further subdivision according to the drainage requirements of each location. All drains were dug by hand (Fig. 6.16).

The Station code was adopted and extended by the members of the archaeological research team in the course of their work, which took place east of N–S Rd 3 and operated there in terms of the Station drainage plan (Fig. 6.14). An example is block A9, where archaeological work started in 1972. Figure 6.6 is an aerial view over part of this block, looking northeast from village land in the foreground and across the southern boundary drain complex of the Station, which forms the southern boundary of the block. Its northern boundary is the southern drain of the tree-lined E–W Rd 1 in the upper-left corner of the picture, while its eastern boundary is the western drain of N–S Rd 4, which is under construction in the centre top. This western drain we called A9E because it formed the eastern boundary of A9 and on the same principle we called the other drain of N–S Rd 4, 25 m to the east, A10W, because it formed the western boundary of the yet undrained block A10.

Figure 6.15 Developing the Station drain and road network east of N–S Rd 3, which runs across the middle of the picture.

These infrastructural developments were undertaken in 1972 solely to enable archaeological investigations in the eastern half of the property. All drainage for archaeological purposes was done in accordance with the Station drain and road plan. The first drains dug for the archaeology team, in block A9 in late June and July 1972 appear at the top right of the photograph. For a closer view see Fig. 6.6.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

Figure 6.16 Digging the eastern boundary drain of Kuk Station in the course of the development of the drain and road network shown in Figure 6.1.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

Figure 6.6 shows five of the seven minor N–S drains dug by workmen at 22.5 m intervals to remove water from the block north to the E–W Rd 1 southern drain. The eight strips into which block A9 was thus subdivided were called A9a to A9h from west to east and the minor drains responsible for the subdivision became A9a/b to A9g/h. The western boundary of the block was a larger N–S drain separating it from block A8 and known as drain A8/9. Like the minor internal drains of A9, the block-dividing drain A8/9 was connected to the southern drain of E–W Rd 1 to the north and stopped short of the southern boundary drain.

In the ways described above, block A9 is typical of all the blocks east of N–S Rd 3 and south of E–W Rd 4, just south of which the swamp surface reaches its lowest point after its gentle but continuous fall from the southern boundary. To the north of this, in the E blocks, there is a marked rise of ground surface at the foot of Ep Ridge (Fig. 6.8) so that all N–S drains fed south into the north drain of E–W Rd 4.

Formation processes and swamp deposits

We describe the character of the deposits and present an account of their depositional history and the post-depositional changes (cultivation, bioturbation and soil-formation processes) to which they have been subjected. In addition to field descriptions, a wide range of laboratory methods has been used to characterise and interpret these deposits, including thin section description (Textbox 6.2) and X-radiography (Textbox 6.3).

Three major types of sediment comprise the swamp deposits at Kuk: alluvial deposition of sediments eroded from the catchment, aeolian deposition of airfall tephras and on-the-spot formation and deposition of organic material during lacustrine periods and in abandoned channels. Basal red-brown highly organic swamp deposits several metres thick formed during the Pleistocene before the Last Glacial Maximum (LGM), which peaked at about 21,000 years ago (Reeves et al. 2013). These are capped by formations up to 1.8 m thick consisting of black to grey organic and inorganic clays and garden soils, which represent alluvial deposition and soil formation since the start of the LGM. Tephra deposition has occurred episodically throughout the Pleistocene and Holocene.

These different types of alluvial, organic and volcanic accumulation have been subject to periodic soil-formation processes that are largely determined by drainage. Soil formation (pedogenesis) occurs in freely drained portions of the stratigraphy and ceases, or is severely retarded, within saturated portions. Soil formation comprises biological, chemical and physical processes, including (Dent, Browning and Rogaar 1976; Collins and Lavney 1983):

- bioturbation, or mixing, of free-draining portions of the sediment profile by faunalturbation, e.g. by earthworms, termites, ants and other soil fauna (Paton, Humphries and Mitchell 1995: 33–68), and floralturbation, e.g. root activity;
- chemical weathering of primary (pyroclastic) and secondary (clay) minerals, with increasing alteration through time; and,
- dewatering and aeration following initial drainage of organic sediments, with subsequent compaction, decomposition and oxidation of organic matter and resultant wastage and subsidence of the deposit (Burton and Hodgson 1987: 22–24).

The nature of soil-formation processes at Kuk has varied greatly, spatially and through time. The ‘higher ground’, comprising the tephra-mantled land surface predating 50,000 years ago, has always been well drained and exhibits highly weathered soils that have been subject to prolonged pedogenesis. By contrast, areas of the swamp exhibit variable pedogenesis depending primarily on the extent and duration of prehistoric drainage, as well as variability in watertables along the ‘swamp margin’ in response to changes in climate.

Textbox 6.2 Thin section description

Tim Denham

The description of soil and sediment thin sections, termed micromorphology, is a sedimentological technique widely used by archaeologists to augment their understanding of deposits at agricultural and habitation sites (Courty, Goldberg and MacPhail 1989).

Thin section analysis is usually employed on undisturbed samples collected from archaeological sites, namely samples that are collected in the field using special sampling tins (called Kubiena or Brewer tins) for impregnation with resin in the laboratory. Thin sections, each comprising a 25–30 μm thick slice of sediment mounted on a glass slide, are prepared from the impregnated block, examined under a microscope and described using standard terminology (Bullock et al. 1985; Stoops 2003).

At Kuk, the technique was applied selectively to provide high-resolution interpretations of Phase 1, 2 and 3 palaeosols (literally 'old soils'), feature fills and stratigraphic units (Fig. 6.T2.1). The technique provided a means to understand how deposits formed, and particularly to identify soil characteristics associated with past human activities on the wetland and past hydrological conditions, which are a major determinant of soil formation processes.

Thin section description at Kuk enabled:

- primary and secondary attributes of deposits to be differentiated, namely those attributes associated with initial formation as distinct from those acquired following formation and burial;
- pedofeatures, essentially microscopically visible features within the soil, to be interpreted with respect to soil formation processes and past human activities on the wetland; and
- the processes involved in the formation of minor and major stratigraphic units to be clarified.

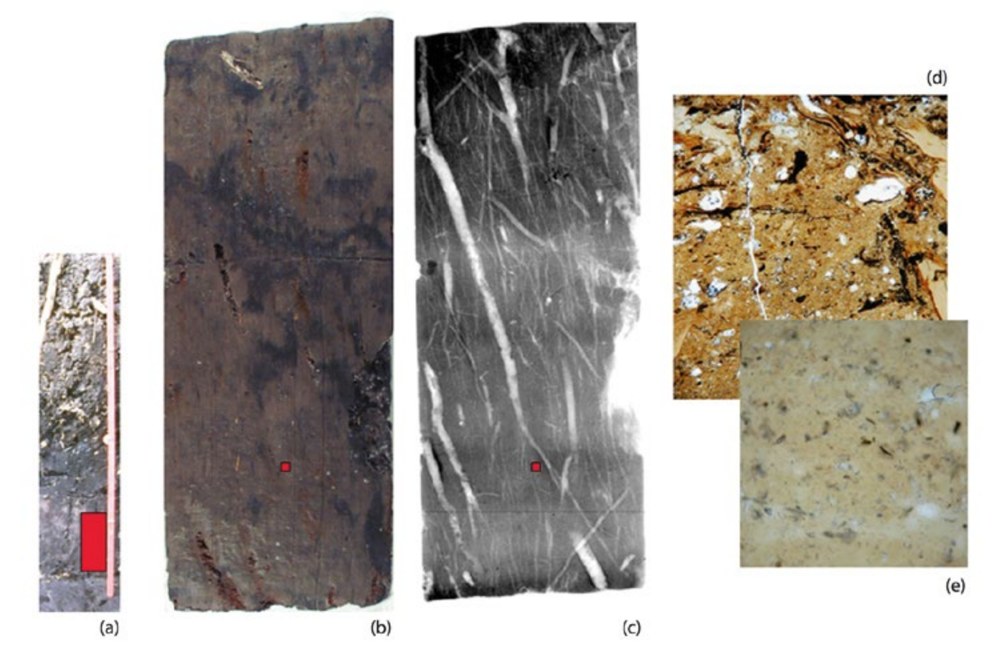


Figure 6.T2.1 From field description to thin section description: linking macro-, meso- and microlevels of stratigraphic analysis.

(a) Field photograph of stratigraphic column from surface to base of grey clay. The area in red shows the location of a sampling tin. See main chapter for description of the stratigraphic column. (b) Photograph of the grey clay sediment column within a sampling tin. Note the marbling effect of grey and black clays and ferric staining along recent voids. The area in red shows the location of (d). (c) X-radiograph of the same grey clay sediment column photographed in (b). Note the clear depiction of vertically oriented channels (curvilinear voids caused by roots and soil mesofauna). The lighter and darker banding across the image is caused by fluctuations in sample thickness. The area in red shows the location of (d). (d) Photomicrograph of pedofeatures within grey clay (image width of c. 2.5 mm). Pedofeatures include voids filled with downward percolated clay, or argillans, along the right-hand side of the image and ferric staining around the edges of filled voids. Recent voids are unfilled white areas in the image. (e) More detailed photomicrograph of grey clay comprising a fine fraction of dusty to impure clay and a coarse fraction of phytoliths and microcharcoal fragments (image width of c. 0.6 mm).

Source: Photographs (a)–(b) and photomicrographs (d)–(e) by Tim Denham, X-radiograph (c) by Alain Pierret.

Textbox 6.3 X-radiography

Alain Pierret and Tim Denham

Radiography refers to imaging techniques in which a penetrating radiation is used to produce an image of the internal structure of materials. The use of X-radiography in geology and soil sciences was introduced by Hamblin (1962) and Krinitzsky (1970), who showed that 'thick bedded' or 'massive' sedimentary deposits really contain many complex primary structures that are visible with X-rays but are otherwise poorly expressed or invisible (Krinitzsky 1970: 47). Typically, such structures correspond to variations in porosity, chemical/mineral composition and water content.

Practically, a thin slab of soil (c. 20 mm thick) extracted from an undisturbed monolith collected in the field is positioned in front of an image detector (e.g. photographic film) and exposed to the beam of an X-ray tube. X-radiography's main limitation is that it is restricted to soil types from which 10–20 mm thick slices can be conventionally extracted, i.e. soils with sufficient cohesion and few coarse elements such as gravel. Special care must be taken to ensure that soil slabs are uniformly thick because variations in thickness show up in the images. Provided access to an existing facility is granted, X-radiography is inexpensive. If required, output images can be quantified by means of image analysis (e.g. Pierret and Moran 1996). The principal advantage of the technique is that it provides virtually immediate insight into soil arrangement at the meso-scale (i.e. resolution of features 0.1 to 1 mm in size, depending upon the imaging system used) without the need for complex sample preparation. The meso-scale investigation of soil and sediment characteristics using X-radiography provides the essential, though often missing, link between macroscale field descriptions and detailed micromorphological studies, i.e. thin section analysis.

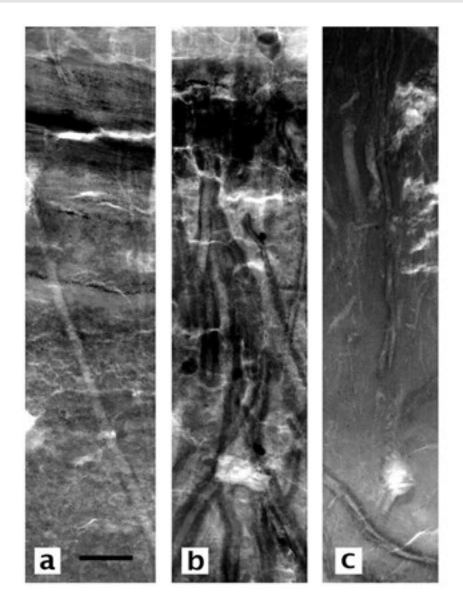


Figure 6.T3.1 X-ray absorption images of samples from Kuk.

Showing: (a) a high degree of preservation of stratification within a palaeochannel fill with only a few recent vertically oriented channels (light, rectilinear areas); (b) intense bioturbation of preexisting stratification with redistribution of material from the dark layer at the top of the image along channels; and (c) well homogenised stratigraphic unit with superimposed channels (lighter areas) representing recent root and faunal activity. Black horizontal line in (a) represents 10 mm.

Source: X-radiographs by Alain Pierret.

Recently, X-radiography has been used on archaeological sediments to detect soil structures and pedoturbation, to reveal tephra lenses within peats and to assess rapidly primary and secondary attributes of deposits prior to subsequent analysis (Barham 1995). At Kuk Swamp, Denham (2003a) used X-radiography to detect former palaeosols and assess the degree of pedogenic homogenisation within a sample (Fig. 6.T3.1). The differentiation of deposits that retain their original stratification, as opposed to those that were subject to extensive post-depositional pedogenic modification, has proven essential for choosing samples for subsequent analysis, understanding site formation processes and interpreting analytical results (Denham 2003a; Denham, Sniderman et al. 2009).

Red-brown swamp deposits

The basal swamp consists of red-brown highly organic swamp deposits (commonly 40 per cent or more organic matter), predominantly organic muds with variable amounts of original fibrous organic matter and wood. There are numerous exposures of thin tephras, including one that seems to occur at or within a few millimetres of the top of the red-brown unit (Fig. 6.17). In the field this was called 'Ep-4', originally meaning the fourth tephra below Ep Tephra (see Table 7.1). The surface of the basal swamp is nearly horizontal. It falls about 0.4 m from the southern end of blocks A10 and A11 to the northern end of these blocks and only another 0.4 m to the lowest part of the swamp in the D blocks, a total distance of about 1 km. The surface of this unit then rises about 0.4 m in the E blocks, where it is covered by at least 2.5 m of fan deposits from Ep Ridge.

The red-brown colour of the deposits throughout the swamp, the generally good preservation of plant remains (including wood) and the widespread presence of thin horizontal bands of tephra show that the deposits formed under swampy or lacustrine conditions and have remained permanently saturated and relatively undisturbed since they accumulated. Timber was uncovered during the digging of Station drains, in the form of roots, fallen logs and occasional stumps apparently in growth position. It proved to be from trees prominent in the upper reaches of the lower montane forest like beech (*Nothofagus*) and conifers (see Chapter 9), indicating that at least in the later stages of red-brown swamp accumulation climatic conditions were generally colder than today.

Figure 6.17 The organic/inorganic transition in the swamp stratigraphy shown in the west wall of drain D7f/g in the lowest part of the swamp.

Notes: a) the tephra called Ep-4 (arrow A) at the transition between the underlying red-brown swamp deposit and the overlying black organic clay; b) the grey clay that is so prominent a feature of the swamp stratigraphy to the south (see Figs 6.18 and 6.19) is here barely discernible in this low part of the swamp; and c) the pegged feature is a Phase 5 field ditch.

Source: Photograph by Philip Hughes, Kuk archive, 1975.

The swamp probably began accumulating more than 50,000 years ago. About 35,000 years ago, there was an abrupt change from red-brown swamp mud to black organic clay that was referred to in the field as the organic/inorganic transition. These ages are based on an evaluation of radiocarbon dates from relevant levels of the stratigraphy, in which dates on charcoal and wood were favoured over those on materials of organically more complex origins (see Appendix 6.1).

Clay deposits

Black organic clay and black to dark grey slightly organic clay

The organic/inorganic transition is a change that for the most part took place over a few millimetres. The lie of what appeared to be the same tephra (Ep-4), at or just below the stratigraphic change, suggested that this occurred at the same time across the swamp.

In the southeastern part of the swamp, the black organic clay is on average 170 mm thick and has a mean organic matter content of 22 per cent. It grades upwards over the space of a few millimetres into a black to dark grey slightly organic clay. This unit is increasingly lighter in colour and less organic upwards. Its average thickness is 150 mm and mean organic matter content 11 per cent. Two major tephras occur in this unit, Rom (10–20 mm thick) at or near its base and Ep (20–50 mm thick) towards its top (see Appendix 6.1 and cf. Tables 7.1 and 7.2).

In contrast to the underlying red-brown swamp deposits, the two later units contain few if any macroscopic plant materials like sedges and grasses or the leaves and seeds of trees growing at the time they were laid down. Pieces of wood are also very uncommon. It appears that plant remains decayed rapidly due to oxidation, presumably because of periodic drying out of the deposits as they accumulated. Both units are heavily penetrated by younger roots. The frequent presence of long exposures of Rom and especially Ep Tephras indicates that deposition probably occurred in standing water and that the sediments have undergone relatively little post-depositional disturbance, especially in their deeper levels.

The beginning of black organic clay deposition is part of the organic/inorganic transition, dating to around 35,000 years ago, as discussed in Appendix 6.1. The end of the black to dark grey slightly organic clay into which it grades is marked by the formation of a conspicuous grey clay starting around 10,000 years ago (Fig. 6.10C). Within this 25,000-year-long period, chronological markers are provided by Ep and Rom, though the dating of these tephras is imprecise (Table 7.2). A 150 mm diameter log 30 mm below Rom provides a maximum calibrated age of close to 25,000 years not only for the tephra but for the change from black organic clay to black to dark grey slightly organic clay which it straddles (Fig. 6.10B).

Hughes, Sullivan and Yok (1991: 233–234) have estimated that the accumulation of inorganic sediment in the two units under discussion represented an average erosion rate that lowered the ground surface in the southern catchment 1.5 mm per 1000 years or removed 1.2 tonnes of soil/km^2/year. This is an extremely low rate and indicates that the catchment was very stable, probably under relatively undisturbed forest cover. The deposition of dark grey slightly organic clay ceased 10,000 years ago when Phase 1 of swamp use began (see Chapter 11).

Grey clay

The relatively short period of Phase 1 cultivation some 10,000 years ago was associated with the operation of a disposal channel, which in the field was called Kundil's Baret after one of the workmen; Tim Denham has subsequently called it channel 101 in his register of features. Hughes and Golson consider this to have been an artificial channel, whereas for Denham it is a natural feature (Denham, Golson and Hughes 2004: 269–274; see Chapter 11). When cultivation ceased, this channel was sealed with a distinctive grey clay (Figs 6.18–6.22), which also filled holes and basins resulting from plant management on the palaeosurface, as well as other depressions not necessarily artificial in origin. This grey clay was washed in from the catchments of the swamp and over the next 3000 years or so accumulated across it. The clay that derived from the southern catchment forms a subdued fan in which it is thicker (~300 mm), less organic (~6 per cent) and more dense (~0.8 tonnes/m^3) at the apex than along the distal margins (~200 mm, ~10 per cent and ~0.65 tonnes/m^3 respectively). The fan-like nature of deposition is even more pronounced on the northern side of Kuk, where the thickness of grey clay washed in from the steep slopes of Ep Ridge decreases markedly over a few hundred metres, from up to 600 mm in the E blocks to less than 100 mm in the D blocks.

Figure 6.18 Stratigraphy looking SSW at the west wall of drain B10c/d, where the grey clay is conspicuous, midway between the lowest part of the swamp and the southern boundary drain.

The four stratigraphic elements of Figure 6.11 are depicted here for one of the B block drains: the grey clay (C) is perched midway down the drain wall, with black clay (B) and garden soil (A) above and black organic clay (D) below to the base of the drain. The surface of grey clay is penetrated by a minor Phase 4 ditch to the left of the ranging pole and the layer is totally removed by a bigger Phase 4 ditch with Olgaboli (Q) Tephra to the right. The ranging pole is graduated at 200 mm intervals.

Source: Photograph by Sam Garrett-Jones, Kuk archive, 1974.

Figure 6.19 East wall of drain A11d/e in the area where grey clay is thickest, view to SSE.

In this A block drain the stratigraphic profile is almost totally made up of the upper three of the four major stratigraphic units, with garden soil and black clay above grey clay at the bottom of the drain wall and only the very top of the underlying black organic clay exposed at the base of the drain. The ranging pole is graduated at 200 mm intervals.

Source: Photograph by Barbara Greaves, Kuk archive, 1974.

Figure 6.20 Looking at the west wall of drain B10e/f towards its southern end, where the black clay above grey clay thickens to fill a Phase 2 cultivation feature in the grey clay surface.

The distinctive lens that sits on the black clay surface above and outside the cultivation feature is Mun (Niupela or NP) tephra. The ranging pole is graduated at 200 mm intervals.

Source: Photograph by Philip Hughes, Kuk archive, 1974.

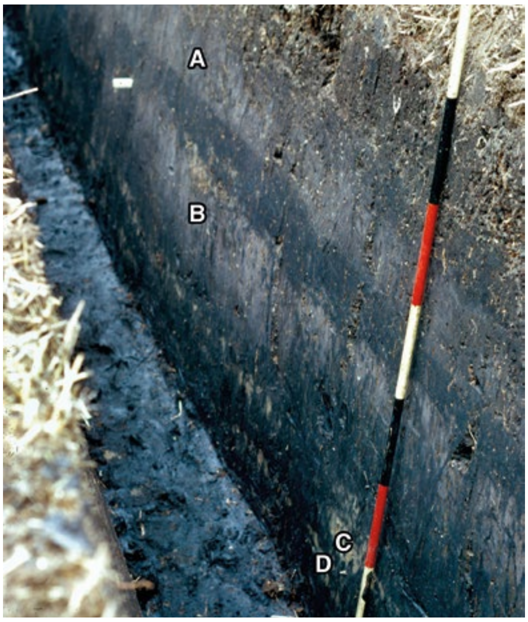


Figure 6.21 The place of 'new grey clay' (A) in the stratigraphy of drain A10g/h west wall looking SSW.

The 'red and white' material that we call Kuman fills a Phase 2 cultivation feature in the surface of grey clay (B) and there are discontinuous lenses of Ep (C) and Rom (D) tephras in the black organic clay at the base of the drain. The ranging pole is graduated at 200 mm intervals.

Source: Photograph by Philip Hughes, Kuk archive, 1974.

Figure 6.22 Looking WSW at the stratigraphy of the west wall of drain A11a/b, showing the garden soil (A) above the black clay (C) and the grey clay (D) underneath.

A striking feature here and elsewhere in the northern 60 m of the drain is the extended presence of Olgaboli (Q) Tephra and Baglaga (Y) tephra in the stratigraphy, the former stretching between the pegs at the left and the right margins of the image. The level of the latter, c. 100 mm below Olgaboli, is marked by the second lowest peg in the column to the right of the ranging pole. Baglaga tephra sits almost immediately above the top of black clay (C) and Olgaboli in the garden soils (A). Between them is an 'intermediate' horizon (B) that is believed to mark the beginning of soil tillage at the site. The ranging pole is graduated at 200 mm intervals.

Source: Photograph by Jim Rhoads, Kuk archive, 1973.

From the outset, Golson and Hughes (1980; also Hughes, Sullivan and Yok 1991) interpreted the grey clay as the product of accelerated erosion in the dryland caused by forest clearance for cultivation. This interpretation has been confirmed by the work of Haberle and others (see Chapter 11, section 'Landuse'; cf. Wilson 1985: 96–97). Hughes, Sullivan and Yok (1991: 233–234) have estimated that the accumulation of grey clay derived from the southern catchment represented an average erosion rate that lowered the landscape 12 mm per 1000 years or removed 10 tonnes of soil/km^2/year. Although this was almost a tenfold increase in the average erosion rate over that of the preceding 20,000 years, it nevertheless was comparatively low for humanly impacted landscapes in the tropics (Hughes, Sullivan and Yok 1991: 235–237). Deposition of the grey clay ceased about 7000 years ago when Phase 2 use of the swamp began (see Chapter 12).

Black clay

The black clay accumulated during and after the operation of Phases 2 and 3 in the swamp between 7000 and 2500 years ago, the latter being an estimate of the age of Mun or Niupela (NP) ash, which marks the end of black clay deposition (Fig. 6.10E; cf. Fig. 6.20). The clay was derived from ongoing soil erosion in the surrounding landscape and it is likely that much of this material was intercepted and carried beyond the limits of the swamp when the various disposal channels servicing Phases 2 and 3 were operating.

The black clay, which is on average 100 mm thick, has the same consistency as the grey clay. Surprisingly, it is low in organic matter (<10 per cent), iron and manganese, all of which could have accounted for the dark colour. We think that organic matter in the form of decomposed organic soil material and finely divided charcoal, perhaps derived from gardening, has 'stained' and bonded with poorly ordered clay minerals to give the black colour.

The upper fills of the Phase 3 channels in the southeastern part of the Station are also usually black clay, but in some situations lenses of grey clay occur within it. In a few cases, these grey clay lenses extend for a few metres to tens of metres beyond the banks of channels. These localised occurrences of younger grey clay are referred to as 'new grey clay' (Fig. 6.21). They were probably deposited in floodwaters particularly rich in sediment derived from erosion of the tephra-covered hills in the southern catchment.

The sharpness of the break between the black clay and the underlying and overlying units, together with the relatively frequent occurrence of the formation known as Komun (Red and White, R+W) in the base of Phase 2 basins and of Kim (R) tephra in the stratigraphy above them, indicate that the black clay has not undergone major post-depositional disturbance. (For the status of Komun see Chapter 7, section 'Field investigations of volcanic ash at Kuk'.)

Garden soils

The deposits that accumulated from about 2500 years ago, after the abandonment of Phase 3, were collectively referred to in the field as 'crumby black' because they contained clearly distinguishable soil aggregates that were absent from the underlying clay sediments. For simplicity, the 'crumby black' came to be called 'garden soil' for reasons discussed below (Fig. 6.22). These garden soils average about 300 mm thick and on the southern side of the swamp they thicken to about 350 mm towards the southern catchment, which was the major source of sediment from which they were formed.

The first unit of the garden soil, immediately overlying the black clay, is a soft silty clay that contains fine soil aggregates. This highly distinctive formation grades upwards into firmer clayey material characterised by coarser soil aggregates to about the level of Olgaboli (Q) Tephra where this is present. Where Baglaga (Y) tephra occurs in the profile, it is the finely textured component of the soil that separates it from the black clay lying a few millimetres below. The last Phase 3 ditches to be abandoned have this soil as a prominent element of their fill, with Baglaga tephra dipping deeply into them (see Fig. 13.9).

Hughes and Golson consider that the consistent lie of this finely textured material in relation to the black clay, Baglaga (Y) tephra and the late Phase 3 ditches whose upper fill it forms, together with the very sharp nature of the contact between it and the underlying black clay, demonstrates that the abrupt change from clay to soil aggregates was depositional in origin and not the result of post-depositional soil formation. Golson and Hughes (e.g. Golson 1977a: 621–622) have attributed this change to the onset of a new practice in dryland cultivation, namely soil tillage, with a consequent change in the character of the erosional products washing into the swamp, from clay to a more silty clay deposit that contains soil aggregates (see Chapter 14, section 'Soil tillage as an innovation').

In contrast, Denham (2003a: 282–283) considers the unit to result from soil formation on slowly accumulating sediments. Soil formation was sufficient to develop aggregates within recently deposited alluvium, but it was insufficient for deeper bioturbation to remove traces of the Baglaga (Y) tephra band within the stratigraphy as a whole. Similar types of aggregates within abandoned ditches are likely to result from a combination of erosion of adjacent land surfaces and soil formation.

The garden soil above the finely textured soil discussed above consists of undifferentiated dark brownish clayey sediment with large soil aggregates. At its base there would have been an input of coarser-textured soil from the digging of the field ditches of Phase 4. Most of it, however, resulted from the making of raised garden beds with the spoil from the grid of garden ditches dug during Phases 5 and 6 of the agricultural sequence. Despite disturbance by intensive root penetration and the burrowing of small invertebrate animals such as beetles, lenses of Olgaboli (Q) (between about 1250 and 950 years old; see Fig. 6.10F) and especially Tibito (Z) (about 350 years old; see Fig. 6.10G) commonly survive because they were covered over by raised garden beds, and protected from being disturbed. Tibito Tephra is always above Olgaboli, which in turn is always above Baglaga. This demonstrates that despite considerable post-depositional disturbance, evidence for progressive net accumulation of sediment across the swamp between phases has survived in these garden soils.

Surface layers

As we saw at the beginning of the section about Kuk Swamp and its drainage, much of the surface was peat-like material formed by roots and other plant remains. Often this would not support the weight of men laying out survey lines and they had to swim or use a boat because any firm 'bottom' was too deep. In such areas, the surface consisted of floating mats of vegetation separated by water from the firm 'bottom' formed by the garden soil of the swamp stratigraphy.

As it was drained, the swamp underwent rapid shrinkage due to drying, oxidation, compaction and the loss of the buoyancy effect of the groundwater (McGrigor 1973: 34–39). In a trial area in the B blocks, McGrigor found there was an average shrinkage of 2 feet (about 0.65 m) in the first three months following drainage. Most of this shrinkage would have occurred in the soft surface peat-like material. By the time the first archaeological and geomorphological investigations were carried out in the 1970s, this drained surface 'peat' was already rapidly degrading and was seldom more than 200 mm thick. Normally, this modern peat consisted of two components, an underlying very soft, highly organic clay (referred to in the field as 'greasy black') and an overlying horizontally bedded layer of compacted fibrous plant material, mainly roots (referred to as 'felted peat') (Fig. 6.23). In some places, only one or the other of these two components was present and in others neither. The 'greasy black' is sapric peat, i.e. humified plant material derived from the decay of the overlying fibrous or 'felted' peat.

Figure 6.23 The surface layers (A and B) on drain A9E, west wall, cap garden soil (C) and seal in a Phase 6 ditch. The two components, which can be clearly distinguished, are 'felted peat' (A) and 'greasy black' (B). The scale is graduated at 100 mm intervals.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

Summary

The Pleistocene red-brown organic swamp deposits older than 35,000 years at Kuk accumulated in a ponded area abutting the debris avalanche deposits from Mt Hagen and the slopes of Ep Ridge, where they have remained waterlogged since they were formed and unaltered to any significant degree by soil-forming processes. The interpretation of the post-LGM organic clay sediments laid down before cultivation of the swamp began 10,000 years ago is more complicated. Although these too were probably deposited in standing water and have undergone relatively little post-depositional disturbance, most of the plant remains associated with them appear to have decayed rapidly due to oxidation, presumably because of periodic drying out of the deposits as they accumulated. One possible reason for this change to periodic drying and oxidation is that by 35,000 years ago the ponded Kuk basin had largely filled with sediment and become more freely drained. Alternatively, or additionally, streams like the Guga, into which the swamp drained, may well have become entrenched by this time, leading to conditions of freer drainage. This latter explanation would better account for the abrupt change from the red-brown swamp to the overlying black organic clay.

The characteristics of the deposits that accumulated after 10,000 years ago reflect the influence of changing landuse activities in the swamp and its catchments, as well as post-depositional processes associated with soil formation such as bioturbation and weathering. Between the relatively short phases of swamp cultivation described in subsequent chapters, sediment that washed in from the surrounding catchments accumulated under waterlogged conditions and remained relatively undisturbed, as evidenced by the widespread occurrence of stratified tephra layers and the preservation of the garden systems that they overlay. The grey clay deposited in the swamp between 10,000 and 7000 years ago is interpreted as the product of accelerated erosion in its dryland catchments caused by forest clearance for cultivation. The sediments that accumulated after 7000 years ago reflect erosion rates that were at least as high, if not higher, than in the preceding period (Hughes, Sullivan and Yok 1991: Table 2). By this time, the catchments would have been transformed into the open landscapes of garden, grassland and managed regrowth that are characteristic of the Wahgi Valley today. Present activities on the dryland such as gardening, ditching and pig-rooting, which can be seen to be contributing sediment to the streams that flow into the swamp today (Hughes, Sullivan and Yok 1991: 235), would similarly have been agents of erosion in the prehistoric past.

During periods of swamp cultivation, accumulation of sediments would have been interrupted because those coming in from the catchments would have been captured by the various water-disposal channels used for drainage and carried out of the system. At the same time, drainage of those parts of the swamp being used for cultivation would have lowered the watertable. It was during these periods of cultivation that the deposits were subjected to the most intense post-depositional disturbance, particularly in Phases 5 and 6 from perhaps 750 to 100 years ago, when raised-bed gardening was practised (see Chapters 15 and 16).

Appendix 6.1: The Age of the Red-Brown Swamp Deposits and the Earliest Human Presence at Kuk

Philip Hughes and Jack Golson

The age of the organic/inorganic transition as around 35,000 calendar years

Six samples of organic mud were used to date the top of the organic swamp and three samples of the overlying black organic clay to date the beginning of this formation. The results are given in Table A6.1. They do not reveal a sufficient number of overlaps, even at two standard deviations (2 sd), to indicate the organic/inorganic transition as a time horizon at the site, as suggested in Chapter 6. As discussed below, they are, at the same time, much younger than dates on wood and charcoal from the equivalent levels. For these reasons the radiocarbon dates in Table A6.1 have not been calibrated.

By far the most striking difference from anything else in Table A6.1 is the date for the clay fines, fraction C, of sample ANU-1458 from immediately above Ep-4 ash at the base of black organic clay at drain A10f/g. This is much older than the dates for the same fraction of the other samples in the table, which are all from the same stratigraphic stratum, the black organic clay, or the underlying one, the red-brown organic mud. The ANU-1458C date seems reliable, since wood fragments from the same sample gave an even older mean date, ANU-1458B (Table A6.2), marginally overlapping with ANU-1458C at 2 sd.

Table A6.1 Radiocarbon ages (at 1 sd) on samples of organic mud from the base of black organic clay (upper set) and the top of red-brown organic mud (lower set).

Drain A9E		Drain A10f/g		S Drain E–W Rd 1		Drains C10a/b & C10W*		S Drain E–W Rd 3	
ANU No.	**Date**	**ANU No.**	**Date**	**ANU No.**	**Date**	**ANU No.**	**Date**	**ANU No.**	**Date**
bottom of clay		**bottom of clay**				**bottom 20 mm of clay**			
3767A	17,970±740	1458(A)	20,000±450			3389A	13,650±140		
3767B	20,530±250	1458C	28,400±850			3389B	18,150±210		
3767C	21,080±280								
top of mud		**top of mud in Ep-4**		**mud 50+ mm below top**		**top 20 mm of mud**		**top of mud 100 mm thick**	
3768A	23,050±350	3388A	22,600±360	1437B	19,700±400	1587A	9,850±140	1439A	3,540±550
3768B	23,200±400	3388B	22,350±350			1587B	18,000±300	1439B	21,700±650
3768C	24,900±450								
		mud just below Ep-4							
		3390A	20,350±180						
		3390B	22,350±230						
A=coarse fraction, acid wash B=fines NaOH soluble C=fines NaOH insoluble		(A)=fibrous fraction A =coarse fraction B =fine fraction C =fines NaOH insoluble		B=mud and fibrous material		A=coarse fraction B=fine fraction		A=fibrous fraction B=fine fraction	

Source: Data collated by Hughes and Golson from their fieldnotes and ANU Radiocarbon Dating Laboratory report sheets.

The calibrated ages of these two samples, and others on wood and charcoal pertinent to the age of the organic/inorganic transition, are presented in Table A6.2 below, rounded off to the nearest 10. All are calibrated at 2 sd, using CALIB 6.0 calib.qub.ac.uk/calib/calib.html; Reimer et al. (2009) and are shown with the per cent probability that the true date falls within the indicated age range.

Three samples of charcoal were collected at the base of black organic clay and the surface of the underlying swamp along a 10 m stretch of drain A9E some 60 to 70 m from its northern end (ANU-1195, ANU-3187 and ANU-3188) (Table A6.3). To test the date of the organic/inorganic transition, yet again samples of organic sediment were taken from the west wall of drain A9E using a sampling tin across the interface between black organic clay and organic mud at the southern end of the investigated 10 m stretch. The ages for the two samples, ANU-3767 for the black organic clay and ANU-3768 for the organic mud (Table A6.1), were again discrepant with the three wood and charcoal dates (Tables A6.2 and A6.3). Another dated charcoal concentration (ANU-1056) some 110 m to the west, on the line of drain A9c/d, correlates with charcoal dates from A9E. This concentration was 10 mm thick and 130 mm above the base of black organic clay, which here lay not on swamp but on basal volcanic ash.

Table A6.2 Calibrated ages of wood, charcoal and mud relating to the age of the organic/inorganic transition.

Lab no.	Material	Calibrated age (cal. BP)	% Probability	Drain
ANU-1458B	Wood	40,660–34,430 BP	(100%)	A10f/g
ANU-1458C	NaOH insoluble fines	34,590–31,320 BP	(100%)	A10f/g
ANU-1195	Charcoal	35,650–31,480 BP	(96%)	A9E
		36,260–35,830 BP	(4%)	
ANU-3187	Charcoal	36,850–31,200 BP	(100%)	A9E
ANU-3188	Charcoal	36,520–32,240 BP	(100%)	A9E
ANU-1056	Charcoal	37,430–33,020 BP	(100%)	A9b/c

Source: ANU Radiocarbon Dating Laboratory reporting sheets.

Collectively, these six dates, four on charcoal, one on wood and one on NaOH-insoluble fines, indicate a minimum age for the organic/inorganic transition of between 41,000 and 31,000 years ago, on the basis of which we suggest a generalised date of 35,000 years ago. The dates on clay and mud that, with one exception (ANU-1458C), are more recent than the wood and charcoal samples are rejected on the grounds of younger contamination. Bulk organic samples collected for dating are more susceptible to contamination because they may contain a mixture of organic particles from unknown sources of carbon, which of course could be younger, older or both.

The earliest human presence at Kuk

We think that the four occurrences of charcoal dated to between about 37,000 and 31,000 cal. years BP (ANU-1056, ANU-1195, ANU-3187 and ANU-3188) are likely to be evidence of the earliest human presence at the swamp at Kuk. One of them, ANU-3188, was collected from what was interpreted as a scoop hearth. All occur along what would have been the southern margin of the swamp at the time.

Golson (2000: 242) has argued a case for pandanus exploitation at Kuk in the Late Pleistocene, on a number of grounds. In samples from the black organic clay, Powell (1984) had found evidence of firing of the vegetation and identified pandanus pollen there, as well as in the underlying organic swamp, where, in addition, a few drupes of *P. antaresensis* were discovered during drain digging. Also found during drain digging, more likely, it was thought, on the top of the organic swamp rather than in it (Golson 2001: 192), was the butt end of a waisted axe, an implement plausibly associated with pandanus exploitation (Golson 1991a: 87–88). More recent work supports this interpretation of the Late Pleistocene evidence at Kuk (see Chapters 9 and 10) and the radiocarbon data reviewed above have supplied a firmer chronology.

The organic/inorganic transition, for which we propose a date of around 35,000 years ago on the basis of the consistent charcoal and wood ages of around 30,000 radiocarbon years, may reflect the appearance of a different depositional regime at the swamp that made its margins habitable.

Younger wood dates at the organic/inorganic transition

There are two additional dates on wood (cellulose), however, that are much younger than 35,000 years, ANU-1437A and ANU-1438 of Table A6.4. The wood samples were both from the top of the organic swamp and they date appreciably closer to the mud and clay samples at the organic/inorganic transition (Table A6.1) than to the wood and charcoal samples (Table A6.2). Both are from the south drain of E–W Rd 1. Sample ANU-1437A was close to the eastern boundary of the Station at block A12e and ANU-1438 was further west at block A12b. Henry Polach, who was then head of the ANU Radiocarbon Laboratory, wrote on the laboratory report sheet that ANU-1437A was not significantly different, statistically, from the date for ANU-1437B obtained from the mud and fibres in which the wood had been embedded (Table A6.1). This, he said, was because of the large statistical error associated with the cellulose result, ANU-1437A.

Table A6.3 Radiocarbon ages (at 1 sd) on wood or charcoal from the bottom of black organic clay.

Drain A9c/d		Drain A9E		Drain A10f/g	
80 m S of E–W Rd 1		collection area as in Table 1		collection site as in Table A6.1	
ANU No.	**Date**	**ANU No.**	**Date**	**ANU No.**	**Date**
1056x	30,740±980	1195x	29,400±1,100	1458B	32,350±1,450
		recollection of above			
		3187y	29,650±1,440		
		from scoop hearth a few m to the S			
		3188x	30,000±950		

x=charcoal, acid wash | x=charcoal, acid wash; y=charred wood, acid wash | B=cellulose fraction

Source: Data collated by Hughes and Golson from their fieldnotes and ANU Radiocarbon Laboratory report sheets.

Table A6.4 Radiocarbon ages (at 1 sd) on cellulose from wood at the top of red-brown organic mud on E–W Rd 1.

ANU No.	Date	Collection point
1437A	23,950±1,600	90 mm diameter log lying 50 mm below top of swamp (cf. ANU-1437B of Table A6.1)
1438	23,100±600	Root at base of tree stump over which the swamp mud/black clay boundary arches, as does Rom ash, which is displaced upwards by 100 mm

Source: Data collated by Hughes and Golson from their fieldnotes and ANU Radiocarbon Laboratory report sheets.

One possible explanation is that these two younger samples of wood have intruded from above into older deposits. This could easily be the case if they were the roots of trees growing in younger deposits above. It is perhaps worth noting that at the collection sites of ANU-1437 and ANU-1438, the ash identified as Rom was 70 mm and 40 mm respectively above the top of the swamp mud, which is much less than at other collection spots recorded: around 200 mm at A9E, 300 mm at A10f/g and about 200 mm at D7d/e. There are a number of possible reasons for this, including a slower local rate of deposition or the local occurrence of erosion at the collection sites of ANU-1437 and ANU-1438 on E–W Rd 1, or the possibility that the transition itself may have varied in date in some places in the swamp.

The age of the underlying swamp as >50,000 calendar years

This age is based on ANU-1440, on a sample of cellulose from the wood of a 100 mm diameter log at block C7b on E–W Rd 3 lying about half a metre below the organic/inorganic transition. The ANU laboratory reported the age in September 1975 as 'background', i.e. beyond the range of radiocarbon dating, a result about which Henry Polach wrote in pencil on the report sheet 'older than 50,000'.

7

Volcanic Ash at Kuk

Russell Blong, Thomas Wagner and Jack Golson

Introduction

Layers of volcanic ash, or tephra, to use a more technical term, are deposited in an instant of geological time. As most thin (<100 mm) ash layers are probably deposited in around 24 hours, this is pretty close to an instant of human time as well. In an environment such as Kuk Swamp where there is little else to provide absolute (or sometimes even relative) time markers, accurate identification of tephra remnants is of fundamental significance to interpretation of features resulting from both human activities and biophysical processes. Without the numerous layers of volcanic ash at Kuk, it would be much harder to interpret the history of swamp agriculture.

The rapid deposition of ash in a very short period of time means that if we can determine the age of an ash remnant at one site with reasonable certainty and then positively correlate that remnant with other remnants of the same ash, we have established a *chronostratigraphic* marker—a time horizon that can have value far beyond the confines of the Kuk archaeological site.

This chapter discusses the nature of thin falls of volcanic ash and the ages of the ash deposits at Kuk. It then explores a really big question—where did these tephras come from? Which volcanoes in PNG produced such large eruptions?

Volcanic ash or tephra

Almost all eruptions produce tephra. This is erupted from the vent, forming a rising column with rock, gas and water. As the hot mass rises, it mixes in the surrounding air and continues to rise—sometimes, in a big eruption, reaching 20 to 30 km above the earth's surface. Most of the ash is composed of new volcanic material, fragmented by explosions and vesiculated (punched full of small holes) by expanding gases. The frothy new magma fragments are chilled rapidly by contact with the atmosphere, taking on a glassy appearance (Fig. 7.1), but some of the new magma cools more slowly so that it is crystalline rather than glassy.

Most ash lands within a few kilometres of the vent and contributes to the typically conical shape of volcanoes (see Mt Ambra in Fig. 7.2). The usual pattern of ash deposition is elliptical around the vent, with the long axis of the ellipse indicating the dominant wind direction. At distances of more than a few tens of kilometres from the vent, ash falls more gradually through the atmosphere, with larger and denser particles deposited earlier and closer to the vent. Winds in the boundary layer (just above the ground surface) may sweep ash into eddies and against topographic and other obstacles. As fine ash particles form ideal surfaces for the condensation of water vapour, rainfall during ashfall is not uncommon. Rain may also flush the ash from the atmosphere, increasing deposition here and reducing deposition there.

Figure 7.1 Vesicular glass shard from the eruption of Vulcan, Rabaul, 19 September 1994. The shard is less than 0.1 mm in length, about the same as the median size of those from Tibito Tephra at Kuk.
Source: Photograph by Linda Coates.

Figure 7.2 The small, beautifully preserved Mt Ambra, 3 km west of the Kuk site, view to north.
Source: Photograph by Russell Blong, 1971.

In most parts of PNG, volcanic ash falls from the atmosphere onto a vegetated ground surface. Acid aerosols attached to the ash may make the particles sticky so that they cling to the vegetation in one area, while tropical downpours may wash much of the ash through the vegetation onto the ground surface in another. Ash that arrives fluffy and loose like fresh snow quickly compacts under the impact of raindrops. Some ash is eroded and deposited elsewhere.

Chemical processes alter the ash almost as soon as it has been deposited. Potassium, sulphur and other plant nutrients are released and vegetation such as grasses and crops quickly sprout. The glassy components of the ash break down and form new minerals such as clays. This process is enhanced by mechanical and biological activities. In tropical environments with intense rainfalls and very high rates of biological activity, a 1–2 mm deposit of light-coloured ash, readily identifiable immediately after deposition, can become all but invisible within a matter of weeks. Such deposits are preserved only in environments where the rate of biological turnover is exceptionally low—for example, on high (cold) mountains and on the bottoms of lakes. Ash deposits a few centimetres thick will survive much longer but are gradually reworked and destroyed as an identifiable layer by the growth and decay of plants, the burrowing activities of soil organisms, the rooting of pigs and the gardening activities of humans. As time passes, fewer and fewer remnants of the ash layer remain, with identifiable deposits restricted to short lenses of reworked ash sandwiched between older and younger deposits with different characteristics and different origins.

Field investigations of volcanic ash at Kuk

Thin layers of volcanic ash were identified at Kuk on our first visit in 1970, when the Research Station was at an early stage of development and there were long stratigraphic exposures in the walls of newly dug drains. Subsequently, we found reference to the occurrence of thin tephras in cores taken for pollen analysis from swamps near Wabag (Flenley 1967) and Mt Hagen (Powell 1970a) in the middle and later 1960s respectively, under the auspice of a project on the vegetation history of the New Guinea highlands directed by Donald Walker of ANU. Thus Flenley (1967: 229, 273) refers to thin bands of 'silt' in his cores, samples of which were subsequently identified as volcanic ash under laboratory examination (cf. Powell 1970a: Tables 9.1–9.5).

Over the next seven years at Kuk, extended efforts were made to determine the characteristics and chronology of the volcanic ash record. As deeper sections of the swamp were drained and the exposure of new drain walls stretched to tens of kilometres, new ash layers were identified, characterised, placed in stratigraphic position and, where possible, dated by radiocarbon analyses of associated deposits.

Correlation of the thin tephras was no simple matter. Rarely were there remnant layers more than 1–2 m long exposed in the walls of drains or excavation trenches and only occasionally were more than three or four tephras revealed in a single exposure. Nonetheless, it is now believed that there are at least 20 separate tephra layers preserved at the Kuk site. Table 7.1 summarises present knowledge of tephras at Kuk in stratigraphic order and in terms of their field characteristics, including colour, texture and consistency. Occasionally, other properties like the appearance of samples under low magnification, mineralogy and magnetic susceptibility signatures have been used to assist identification. The descriptions reflect grain sizes, admixture of adjacent organic materials, reworking characteristics, pedological alteration and the degree of weathering. Rarely is one characteristic sufficient to uniquely identify a tephra remnant.

The most distinctive and best known tephras at Kuk are Tibito, Olgaboli, Kim and Ep. The first three named occur relatively high in the sequence and have distinctive appearances and stratigraphic positions. Ep Tephra is the thickest tephra layer in the swamp. Below Ep Tephra the various ash layers are poorly known. They are similar in appearance with few distinguishing characteristics and, as they are deep in the swamp, there are few exposures. The tephras below Ep are not considered much further in this discussion because they are very much older than those associated with the archaeological evidence for use of the swamp dating from the last 10,000 years (Table 7.2) and which are the focus of this chapter.

Higher in the sequence, it is often difficult to make a certain identification of individual tephra remnants because many of their physical characteristics are similar. This is the case, for example, with Kenta and Kuning tephras in many exposures, where firm identification as one or the other is only possible when a remnant of Olgaboli Tephra is also present. There is also the question of Komun tephra, characterised by red-and-white speckled clay root-fillings and small pellets. It is possible that at the time when Komun was deposited, Kuk Swamp was a poor site for tephra preservation. However, it is also possible, following the analyses of Tim Denham (2003: Appendix E4.8, Appendix E5), that the soil layer called Komun in Table 7.1 is not a tephra at all since the characteristics of the clay mineralogy are different from those of all other presumed tephras, except Kuning (Sandy 2). Denham (pers. comm., 2004) is also inclined to doubt that Kuning is a tephra. So even above Ep Tephra we are unsure of the exact number of eruptions that have deposited volcanic ash at Kuk. If Komun and Kuning are not tephras, however, we have no clear idea what they might be.

Table 7.1 lists a range of names for tephras at Kuk, incidentally giving a potted history of our understanding of the tephra sequence. As we became more confident of our identifications of the tephra remnants and their associated characteristics, we used approved stratigraphic procedure, with each tephra being assigned a local name. For example, Tibito was named after the small Tibito Creek that flows through Kuk Swamp. Tibito Creek was also the first site where this tephra was identified. The names we applied to two of the thin tephras at Kuk, Tibito and Olgaboli, are on the Australian Stratigraphic Units Database as members of a list of names that have formally been reserved for use with PNG tephras (Colin Pain, Geoscience Australia, pers. comm., 2009). This means that the formal names are Tibito Tephra and Olgaboli Tephra, with Tephra having an uppercase T (see www.ga.gov.au/data-pubs/data-standards/reference-databases/stratigraphic-units). The same applies to Tomba Tephra and Bune Tephra, which are mentioned later.

Table 7.2 sets out best estimates of the ages of the thin tephras identified at Kuk. In some cases, multiple age estimates are available. With one exception, Tibito b), in the decade of the AD 1660s, all age estimates in the table are based on radiocarbon dates on associated organic material calibrated to calendar years BP. The tephrochronological record at Kuk has been developed through intensive investigation of many kilometres of exposure. The record is not perfect and is still subject to reinterpretation, but it is certainly one of the finest records of thin tephras available anywhere in the world. Although there are questions about the number and character of tephras preserved in deeper parts of Kuk Swamp, we can be confident that at least 10 thin tephras have been deposited since Ep Tephra fell between about 18,500 and 14,500 years ago. Tibito and Olgaboli Tephras have been identified in the field over wide areas since 1970 (Blong 1982; cf. Haberle 1998a: Appendix 1). This, with support from geochemical fingerprinting, makes it possible to draw isolines of distribution and thickness. Figure 7.3 does this for Tibito Tephra.

Table 7.1 Stratigraphic characteristics and descriptions of tephras at Kuk.

Tephra name & original field names	Stratigraphic context (see Chapter 6)	Colour	Texture	Thickness (mm) (when not reworked)	Frequency of occurrence	Mineralogical and other characteristics
Tibito Z	Garden soil	Greyish olive green	Fine sand, often coarser downwards	<50 mm, often 60–80 mm when reworked	Frequent	Slightly allophanic tephra. Mineral fraction dominated by subequal grains of pale to medium green pyroxene and plagioclase, but most sand grains are unaltered, angular, colourless, highly vesicular, pumiceous shards.
Kenta Sandy 1	Garden soil	Creamy fawn with some red colouration	Clayey fine sand	Variable	Infrequent	Small ash pellets mixed with organic pellets and often associated with a red clay. Some glass. Good magnetic signal from one sample. Very similar to Kuning tephra.
Olgaboli Q	Garden soil	Dark grey	Silty sand to fine sand	Up to 50 mm, often thicker when reworked	Frequent	Forms firm, blocky aggregates with visible iron-oxide films on surfaces of both aggregates and individual grains. More strongly cemented than Tibito Tephra, with oxidised red-brown surfaces; some suggestion of vertical cemented columns towards base. Often increasingly darker in colour and coarser in texture from top to bottom. Colourless, angular, vesicular, oxidised glass dominates the sand fraction with plagioclase and minor amounts of pale green augite the most common mineral grains. Sharp upper and lower boundaries.
Kuning Sandy 2	Garden soil	Creamy white, sometimes with reddish coatings	Clayey fine sand	Variable	Infrequent	Stained red where cemented into blocks by iron oxides (Fe). Occurrence at Kuk is usually as small balls of ash, often with associated balls of organic material and very thin (0.1 mm) stringers of bright red clay, probably following root hairs. Very similar to Kenta tephra.
Baglaga Y	Finely textured component towards the base of the garden soil	Light to medium brown	Fine sandy silt	<20 mm	Moderately frequent	Sometimes has two-tone colour. Often occurs as flat-lying continuous layer.
Mun Niupela NP	Interface between garden soil and black clay	Creamy grey with some reddish colouration	Gritty	Up to 50 mm	Infrequent	Ash pellets that also have reddish root-hair lines through them. Easily confused with Komun. No glass found in microprobe analyses, but abundant fine-grained quartz.
Kim R	Black clay	Variable yellowish grey	Fine sandy silt	Up to 20 mm	Moderately frequent	Soft nodules with thin iron-clay linings (cutans) along root channels. Pyroxene and magnetite present.
Komun Red & White R+W	Black clay, a few mm above base of Phase 2 basins and channels in grey clay	Creamy white with red speckles	Clay	Variable, up to 60–70 mm	Moderately frequent	Occurs rarely as a clear lens but is concentrated in basins; pedologically reworked to form diffuse layer of whitish-creamy root fillings and small (<2 mm) clay balls. Often just a series of pale-coloured creamy root fillings with occasional reddish flecks. No radiographic density difference was found between ash and surrounding material at one location tested. One sample has no glass present, but unidentifiable greenish grains in reflected light. Numerous tiny quartz grains. It has been suggested that this is not a tephra (see text).

Tephra name & original field names	Stratigraphic context (see Chapter 6)	Colour	Texture	Thickness (mm) (when not reworked)	Frequency of occurrence	Mineralogical and other characteristics
Remnants of 3 tephras	In the fill of large ditches of Mek's Complex in a different stratigraphic setting: placed here on the basis of ^{14}C dating. Not further discussed					
Occasional remnants of unknown number of tephras	Grey clay. Not further discussed					
Ep[1]	Black to dark grey slightly organic clay	Variable: light green, olive green, light yellow-brown. Dries olive green	Sandy	20–50 mm, up to 140 mm when reworked, as in exposures at the base of Ep Ridge.	Frequent	Frequently preserved as soft nodules in lenses 250–400 mm long. Glass fragments are angular, translucent to smoky green, with spherical vesicles. High-K, low-Si andesite. Mean particle size ~0.28 mm in one examined sample. Under microscopic examination, light yellow-brown open porous fabric with some zones of darker red-brown clay mineral that forms stronger clusters sometimes lining or filling vesicles. Some void fillings are light yellow in colour. SEM shows grains are sharp-edged and platey, generally with few vesicles, some of them clay-filled. Grains appear weathered, but exterior walls are relatively smooth.
Between Ep and Rom[1]	Very rare occurrence of at least one tephra named Ep-1					
Rom[1]	Black to dark grey slightly organic clay	Brown, pale-coloured when dry	Clay	10–20 mm	Frequent	Boundaries diffuse and root-penetrated. No indication of fine nodules or denser grains on one radiograph. Lower part may have more dark-coloured mineral grains than upper part.
Ep-2 & Ep-3	Black organic clay. Not further discussed					
Ep-4	At or just below the transition from red-brown swamp deposits to black organic clay; not further discussed, but see Appendix 6.1					
Ep-5 & at least 4 tephras	Red-brown organic swamp deposits; not further discussed					

Source: Descriptions of tephra by Blong and of their stratigraphic characteristics by Blong, Golson and Hughes from their fieldnotes.

Note:

[1] Originally the next recognised ash below Ep was a conspicuous ash that was given its own name, Rom. When a rare occurrence of ash was later noted between the two this was called Ep-1. The name Rom was retained for the underlying conspicuous ash and numbering of the ashes below Rom started with Ep-2.

Table 7.2 Chronology of tephras at Kuk.

Tephra	Date of ashfall (in cal. yr BP, where BP = Before Present and Present = AD 1950)	Source
Tibito	a) Between 169–154 BP (35%)[2] Between 304–282 BP (65%)[2]	a) Chapter 8 here, pooled mean of five radiocarbon dates
	b) In the decade of AD 1660s	b) Chapter 8 here
Kenta	Between 930–310 BP[3]	Radiocarbon dates:
	a) Between 680–310 BP	ANU-3909, 520±120, on peat immediately above the ash
	b) Between 930–690 BP	ANU-3823, 890±70, on carbonised wood some 300 mm below the ash Gillieson et al. 1989: Fig. 6.3, at Yeni Swamp, Jimi Valley
Olgaboli	Between 1190–970 BP (97%)[2] Between 1230–1210 BP (3%)[2]	Pooled mean of three radiocarbon dates, Haberle 1998a: 13 and Appendix 2
	Between 1330–800 BP	Radiocarbon dates:
	a) Between 960–800 BP	a) OZF140, 1040±40, above the ash
	b) Between 1330–1180 BP	b) OZF141, 1400±40, above the ash Sniderman et al. 2009: Table 2, at Mt Ambra crater 3 km from Kuk
	Between 1280–940 BP	Coulter et al. 2009: Table 1, using the radiocarbon data of Sniderman et al. 2009
Kuning	Between 1690–930 BP	Radiocarbon dates:
	a) Between 1120–930 BP	a) OZF-142, 1150±40, above the ash
	b) Between 1690–1420 BP	b) OZF-143, 1710±40, below the ash Sniderman et al. 2009: Table 2, at Mt Ambra crater 3 km from Kuk
	Between 1560–1040 BP	Coulter et al. 2009: Table 1, using radiocarbon data of Sniderman et al. 2009
Baglaga	Between 2650–1950 BP	Denham et al. 2003: Table S2, Y ash: Table S1 for contributing dates
	Between 2700–1820 BP	Radiocarbon dates:
	a) Between 2110–1820 BP	a) OSF-144, 2030±50, above the ash
	b) Between 2700–2340 BP	b) OZF-145, 2450±40, below the ash Sniderman et al. 2009: Table 2, from the crater of Mt Ambra 3 km from Kuk
	Between 2400–1980 BP	Coulter et al. 2009: Table 1, using radiocarbon data of Sniderman et al. 2009
Mun	Between 2730–2120 BP	Chapter 6 here, note E following Fig. 6.10, citing Denham et al. 2003
Kim	Between 3980–3630 BP	Denham et al. 2003: Table S2, R ash: Table S1 for contributing dates
	Between 4140–3690 BP	Radiocarbon dates:
	a) Between 4140–3730 BP	a) OZF-146, 3680±50, above the ash
	b) Between 3980–3690 BP	b) OZF-147, 3610±50, below the ash Sniderman et al. 2009: Table 2, from the crater of Mt Ambra 3 km from Kuk
	Between 3970–3870 BP	Coulter et al. 2009: Table 1, using radiocarbon data of Sniderman et al. 2009
Komun	Between 6440–5990 BP	Denham et al. 2003: Table S2, R+W ash: Table S1 for contributing dates

Tephra	Date of ashfall (in cal. yr BP, where BP = Before Present and Present = AD 1950)	Source
Remnants of three tephras in ditches of Mek's Complex	Between 7430–5990 BP	Radiocarbon dates:
	a) Between 6440–5990 BP	a) the limiting dates of Komun (see above), which is later than Mek's
	b) Between 7430–6640 BP[3]	b) radiocarbon date ANU-1704, 6150±180, on cellulose from wood at the base of a ditch at the complex
Rare remnants of unknown number of ashes in grey clay	Between 10,230–6440 BP	Radiocarbon dates for grey clay:
	a) Between 7420–6440 BP	a) end of grey clay deposition, Chapter 6 here, note D following Fig. 6.10, citing Denham et al. 2003
	b) Between 10,230–9780 BP	b) start of grey clay deposition, Chapter 6 here, note C following Fig. 6.10, citing Denham et al. 2003
Ep	Between 18,480–14,920 BP[4]	Radiocarbon dates:
	a) Between 16,400–14,920 BP	a) ANU-1461D, 12,890±140, NaOH-insoluble fraction of clay sample from immediately above the ash at Kuk
	b) Between 18,480–17,010 BP	b) ANU-3215, 14,510±230, on lake mud 80 mm below the ash at a small pond near Mt Ambra 3 km from Kuk
Ep-1[1]		
Rom	Between 24,500–18,900 BP[4]	Radiocarbon dates:
	a) Between 20,030–18,900 BP	a) ANU-1460, 16,320±220, on clayey peat 0–50 mm above the ash
	b) Between 24,500–23,380 BP	b) ANU-3186, 20,070±230, on wood from 150 mm diameter log 30 mm below the base of the ash
Ep-2 and -3		
Ep-4 at the organic/inorganic transition	Minimum age between 40,660–31,200 BP[4]	Range of five dates from four samples from the base of black organic clay at drains A9E and A10f/g; see Appendix 6.1
Ep-5 to -8		

Source: Where not specified in the table, from data collated by Golson from his fieldnotes and ANU Radiocarbon Laboratory report sheets.

Notes:

[1] See note 1 of Table 7.1.

[2] Percentage (%) probability of the true age falling within the calibrated age range; all the ranges indicated by notes 3 and 4 are 100%, except for one in the final entry, Ep minus 4.

[3] Calibrations by Simon Haberle using Calib 6.0.0 (Stuiver and Reimer 1993); a calibration for ANU-1704 is published here for the first time.

[4] Calibrations by Simon Haberle using IntCal09 (Reimer et al. 2009) of radiocarbon dates published here for the first time.

The detailed investigation of the volcanic ash layers at Kuk summarised in Table 7.1 has spawned two related studies. The rest of this chapter is the subject of one: the question of which volcanoes were the sources for the tephras preserved at Kuk. Chapter 8 deals with the second study, the relationship between Tibito Tephra and widespread stories of a Time of Darkness (*taim tudak*), and its date.

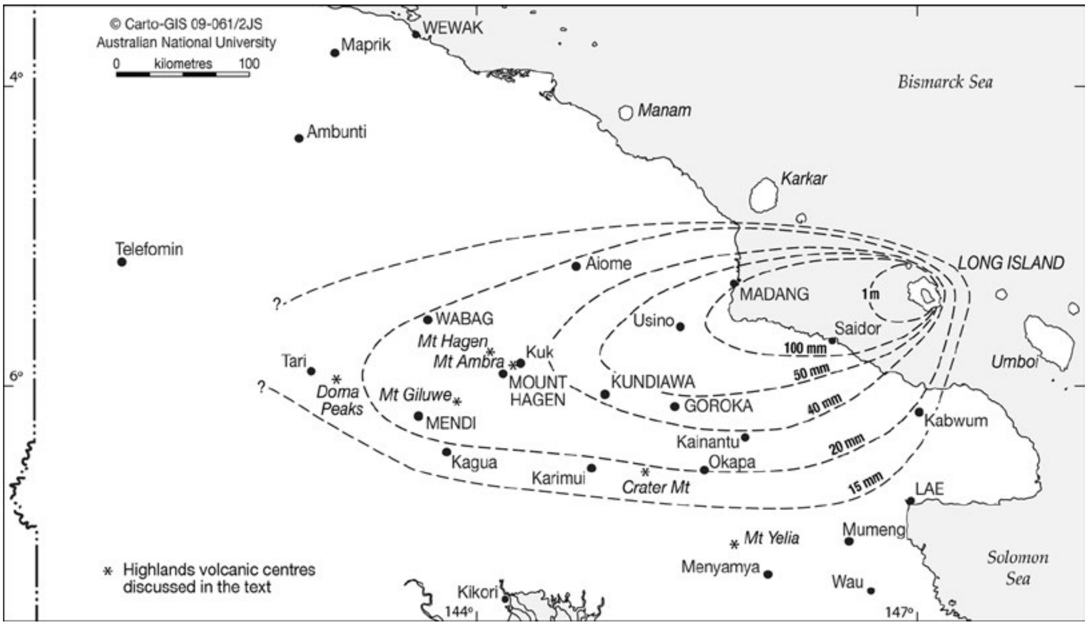


Figure 7.3 Distribution of Tibito Tephra based on extensive fieldwork.

Source: Drawing by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU, based on Blong (1982: Fig. 29), reproduced with permission.

Sources of the thin tephras found at Kuk

So where did the Kuk tephras come from? This is an important question because these volcanoes might still be active today. With dozens of volcanoes in the New Guinea region (Fig. 7.4) to choose from, we needed a variety of methods to narrow down the selection, including fieldwork and chemical analysis.

As a start, New Guinea volcanoes can be divided into groups based on their geologic setting, as follows: volcanoes of the highlands, the area within which the Kuk site is situated (Fig. 7.3); the Bismarck volcanic arc, a long chain of volcanoes off New Guinea's northern coast (Fig. 7.4); and more distant sources such as the volcanoes of eastern Papua, the Admiralty Islands, the Tabar-Feni arc and Bougainville (Fig. 7.4). Some of these areas can be eliminated from further consideration based on the eruptive history of the volcanoes and the physical characteristics of the tephra layers.

Another consideration is that as a tephra deposit becomes progressively thinner with distance from its point of origin (see Fig. 7.3), we should be able to trace it back to the source volcano. Extensive fieldwork, however, shows that the tephras do not thicken toward any of the volcanoes near Kuk. This evidence is consistent with other indications that highlands volcanoes ceased erupting tens of thousands of years before the Kuk tephras were deposited. For example, Mt Ambra (Fig. 7.2), located just 3 km away (Fig. 7.3), has the Kuk tephras in its summit crater, meaning the tephras are younger than Mt Ambra's last eruption. The larger nearby volcanoes such as Mt Hagen and Mt Giluwe (Fig. 7.3) are also too old to have produced the Kuk tephras. The last major eruption of Mt Hagen produced Tomba Tephra at the same time as Mt Giluwe produced Bune Tephra. The massive Tomba Tephra mantles all of the major eruptive centres in the western highlands, including Mt Ambra and at least some of the apparently youthful cones south of Mt Giluwe. These deposits are certainly older than 50,000 years (Pain and Blong 1976).

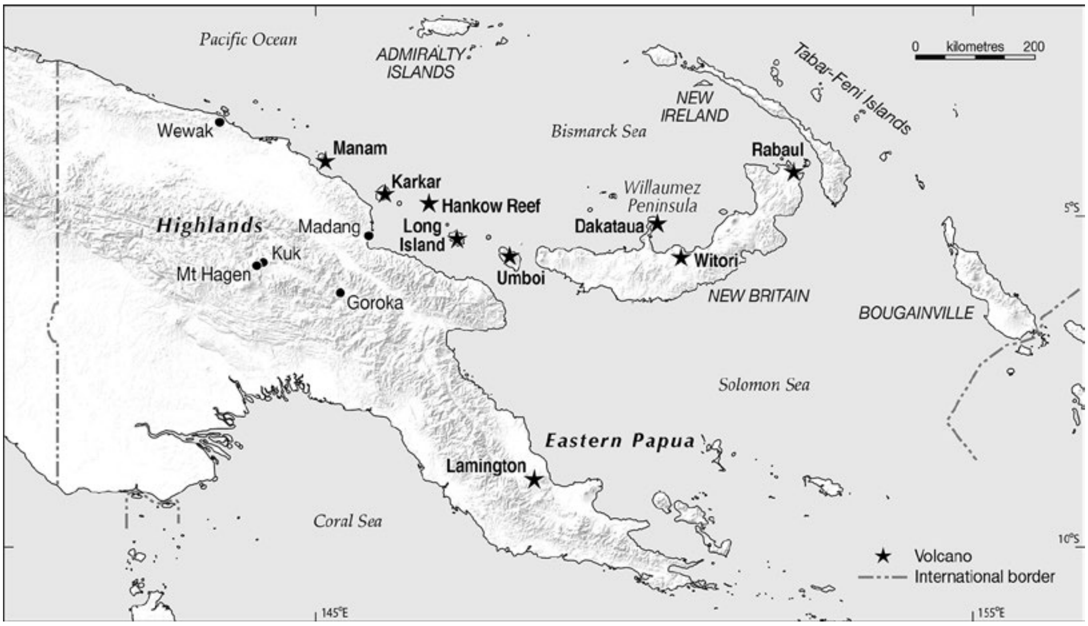


Figure 7.4 Map of volcanic areas in PNG. The Bismarck volcanic arc comprises the eruptive centres along the north coast from Wewak to Rabaul.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Highlands volcanoes located further away from Kuk are also unlikely sources. Doma Peaks, near Tari in Southern Highlands Province (Fig. 7.3), is often cited as the youngest possibly still active volcanic centre in the highlands. Though it has fumaroles—hot gases seeping from the ground—in the crater and other sites nearby (Taylor 1971), the deposits from its last eruption are covered by those of Tomba Tephra from Mt Hagen (Colin Pain, pers. comm., 2007). Southeast of Kuk, the major highlands volcanoes are Crater Mountain and Mt Yelia, about 100 km and 200 km distant, respectively (Fig. 7.3). Little is known about the eruptive history of Crater Mountain, but the last significant eruption of Mt Yelia occurred after 17,500 years BP (SUA-835) but substantially earlier than 5000 years BP (SUA-836) (Blong, fieldnotes, 1977). Nevertheless, none of the Kuk tephras thicken towards the east-southeast. This observation also eliminates Mt Lamington and the eastern Papua volcanoes from consideration as sources for the Kuk tephras (Fig. 7.4).

Since the tephrostratigraphic information suggests that none of the thin tephras found at Kuk after the fall of Ep, between about 18,500 and 14,500 years ago, erupted from volcanic centres on the New Guinea mainland, it is necessary to look elsewhere. The next nearest group of volcanoes is formed by those of the Bismarck arc.

Possible Bismarck arc sources

The Bismarck arc is a 1000 km long string of volcanoes that stretches along the north coast of PNG from near Wewak in the west to Rabaul at the eastern end of the island of New Britain (Fig. 7.4). The arc contains over 30 volcanic centres, many of which have been active in historical times. An ash cloud of sufficient size to deposit tephra at Kuk would require a very large eruption of a Bismarck arc volcano, one that would probably collapse a significant portion of the volcano's edifice. We briefly consider the known eruptions of large magnitude along the Bismarck arc over the last 20,000 years. Kuk lies generally west or southwest of all of them. We recognise that this discussion is likely to be incomplete as the eruptive histories of some volcanoes are poorly known.

The volcanoes nearest Kuk are Karkar Island and Long Island, 230 km and 320 km away respectively. Both volcanoes have central collapse features (calderas) and stratigraphic records of large explosive eruptions during the period under review—three at Karkar and three at Long (Pain, Blong and McKee 1981; Pain and McKee 1981). Local legends (Mennis 1981) suggest that another volcano, active in the last few thousand years but now submerged, lies between these two. Called Yomba, the volcano's peak could have been destroyed during a large eruption, leaving just a submarine reef. Although Mennis (1981) proposed Hankow Reef as the site of ancestral Yomba, recent underwater mapping shows topographic features that imply the last eruption at Hankow Reef is substantially older than the Yomba legend (Silver et al. 2009).

Witori and Dakataua, respectively 710 km and 670 km from Kuk, are volcanoes on Willaumez Peninsula on the island of New Britain that have produced major eruptions. Five such eruptions occurred at Witori in the last 6000 years, one at Dakataua (Machida et al. 1996; Petrie and Torrence 2008; McKee, Neall and Torrence 2011). At the eastern end of New Britain, Rabaul caldera, 930 km from Kuk, also has a record of massive eruptions (Nairn et al. 1996), the major ones being two within the last 10,000 years and another three in the previous 10,000 years. Hargy volcano, also on the north coast of New Britain, had two major eruptions between about 14,000 and 11,000 years ago (McKee, Neall and Torrence 2011).

All of the caldera-forming eruptions under discussion injected vast amounts of tephra into the upper atmosphere and the generally southwest-flowing upper airstream could have deposited it at Kuk. However, Rabaul, Hargy, Witori and Dakataua are so far away (930 km, 800 km, 710 km and 670 km respectively) that truly enormous eruptions would have been required to deposit tephra at these distances from the source volcano. Consequently, Karkar and Long Island seem the most likely sources for the tephras at Kuk. However, our understanding of the eruptive histories of these volcanoes is imperfect. The uncertainties and overlaps in the dates for tephra deposition at Kuk and the cataclysmic eruptions of these volcanoes are too large to allow precise correlations. So we have tried something else—chemical fingerprinting. Just as people have individual fingerprints, volcanoes have fingerprints in terms of the chemical composition of the magmas that they produce. By analysing the tephras we can compare them against a database compiled by Dr Wally Johnson (accessed 1998), the foremost authority on PNG volcanism, of chemical analyses of tephras and lavas from potential source volcanoes.

Geochemical characterisation of the Kuk tephras

Characterising the Kuk tephras geochemically is not straightforward. Lying in a swamp for hundreds to thousands of years, the tephras react with groundwater in a way that alters their chemical composition. On the positive side, this alteration produces the fertile soils of the highlands (see Chapter 8, section 'Soil replenishment') by changing volcanic glass to clay and releasing key plant nutrients like potassium and sodium. However, for fingerprinting, we need a technique that looks beyond the alteration process. Using an electron microscope, we can image and analyse the tephras on a very fine scale, down to millionths of a metre (see Fig. 7.1). This allows us to preferentially select and analyse pristine shards of volcanic glass. Figure 7.5 displays the most important results of this work. The fields represent many analyses of the glass shards from 16 samples of Tibito Tephra and 13 samples of Olgaboli Tephra.

The data in Figure 7.5 show that Olgaboli Tephra represents a simple eruption of basaltic-andesite of almost uniform composition. Tibito Tephra, on the other hand, contains a wider range of magma types, highly variable by volcanic standards, extending from basalt to dacite and forming a much broader field on this graph. The other major tephras found at Kuk, Kim and Ep, are not shown in Figure 7.5, but are similar in composition to Tibito Tephra.

The remaining Kuk tephras have compositions similar to either Tibito or Olgaboli Tephras (Fig. 7.5), but some display the intriguing characteristic of being split between the two groups. Based on a variety of evidence, these split tephras may be physical mixtures of two or more tephras at the Kuk site. These and other major findings are summarised in Table 7.3. However, we emphasise that these conclusions are tentative because in several cases only single samples (but multiple grains) have been analysed. A great deal of further work is required before we are able to provide unique matches between the tephras at Kuk and specific deposits on the source volcanoes.

The compositional variation shown in Figure 7.5 also tells us some interesting things about the volcanic sources. The wide range in composition displayed by Tibito Tephra was probably produced by cooling and partial solidification of magmas in the volcano prior to eruption. This variability implies tapping of a complicated volcanic system with diverse pockets of magma in various stages of solidification. The eruption was probably very large and collapsed major portions of the volcano. Because they are similar in composition to Tibito Tephra, two earlier tephras, Kim and Ep, which erupted between about 4000 and 3500 years ago in the first case and about 18,500 and 14,500 in the second (Table 7.2), were almost certainly produced by the same source as Tibito. This would mean that the same behaviour was repeated on timescales exceeding a few thousand years.

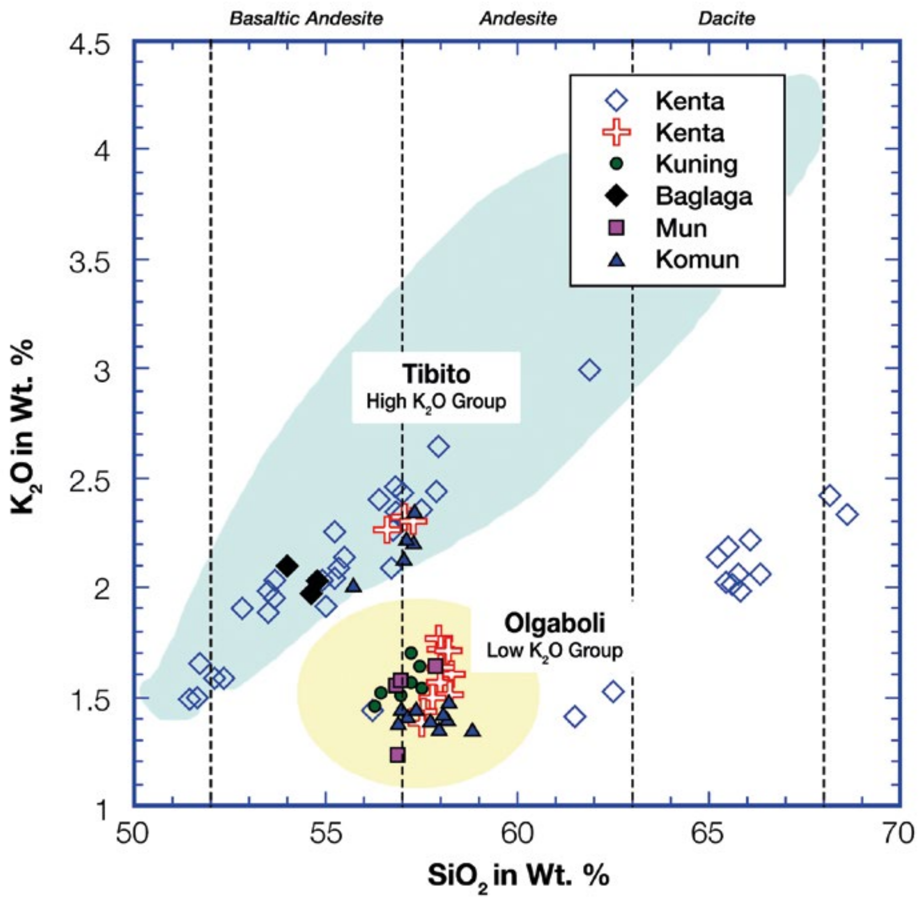


Figure 7.5 Analysis of shards of volcanic glass for tephras at Kuk. Blue field represents analyses of over 80 individual glass shards from Tibito Tephra.

Yellow field represents analyses of over 40 individual glass shards from Olgaboli Tephra. Other tephras are noted in the legend; each data point represents a single glass shard.

Source: Drawing by Tom Wagner.

Table 7.3 Compositional characteristics of tephras at Kuk.

Tephra name	Characteristics	Volcanic source
Tibito	Highly variable composition—basalt to dacite—but generally forming trends consistent with magmatic differentiation processes	Long Island
Kenta	Probably represents a mixture of Tibito- and Olgaboli-like tephras. Two samples analysed, one of which also displays a unique low-K_2O trend not observed in other samples, but which appears consistent with magmatic differentiation	Long Island or Karkar
Olgaboli	Basaltic-andesite of restricted composition, with lower K_2O contents than Tibito	Karkar
Kuning	One sample analysed, similar to Olgaboli, low K_2O group	Karkar
Baglaga	One sample analysed, basaltic-andesite that falls on Tibito trend	Long Island
Mun	One sample analysed, similar to Olgaboli, low K_2O group	Karkar
Kim	Five samples analysed, all on Tibito trend, limited to basalt-andesite and andesite	Long Island
Komun	Two samples analysed and probably represent a mixture of Tibito- and Olgaboli-like tephras. They display some anomalous compositions in other elements. If Komun is a tephra, these samples may have been affected by alteration	Long Island
Ep	Five samples analysed, most on Tibito trend, limited to basaltic-andesite to andesite, but some have very high K_2O contents off the trend. These may be alteration effects; there is very little fresh glass and it is difficult to find unaltered fragments	Long Island

Source: Samples of tephra collected by Blong and analysed by Blong and Wagner.

By comparison, as already noted, the volcanic system that produced Olgaboli Tephra was simpler. With little variation in composition, the eruption tapped a single magma body or at least a generally less differentiated system overall. In addition, this system also repeats its behaviour, but on shorter timescales of less than a thousand years, as evidenced by the similarity between Olgaboli and two of the minor tephras, Kuning and Mun, which erupted respectively between around 1700 and 900 years ago and 2750 and 2100 years (Table 7.2). In addition, these tephras are not as thick as those in the Tibito group, which implies production by smaller or more distant eruptions, or that the wind directions were different.

Identifying the volcanic sources

To identify the source volcanoes for the Kuk tephras, we compared them to chemical analyses of tephras and lavas with known sources. We focused primarily on the large eruptions from Bismarck arc volcanoes as only large eruptions are likely to have deposited tephra as far away as Kuk. Nonetheless, we also searched Wally Johnson's database of New Guinea volcanics (accessed 1998). The results indicate that all of the recent tephras found at Kuk were probably erupted from volcanoes in the Bismarck arc.

Figure 7.6 compares the Kuk tephras with samples collected from the Bismarck arc volcanoes by grouping individual chemical components into mineral units to facilitate interpretation, using the method of Grove (1993). The Kuk tephras form fields in the centre of the diagram. The major Rabaul eruptions all plot near the bottom of the diagram, far from the majority of the Kuk tephras. Other Rabaul data are scattered across the diagram, and while there is some overlap of these with the group at the bottom of the diagram, there are only a few glass shards from Kuk tephras in this area. As in the case of Rabaul, major Witori and Dakataua eruptions form fields in the bottom left of the diagram, away from the Kuk tephras, though some analyses of samples from these volcanoes are more scattered.

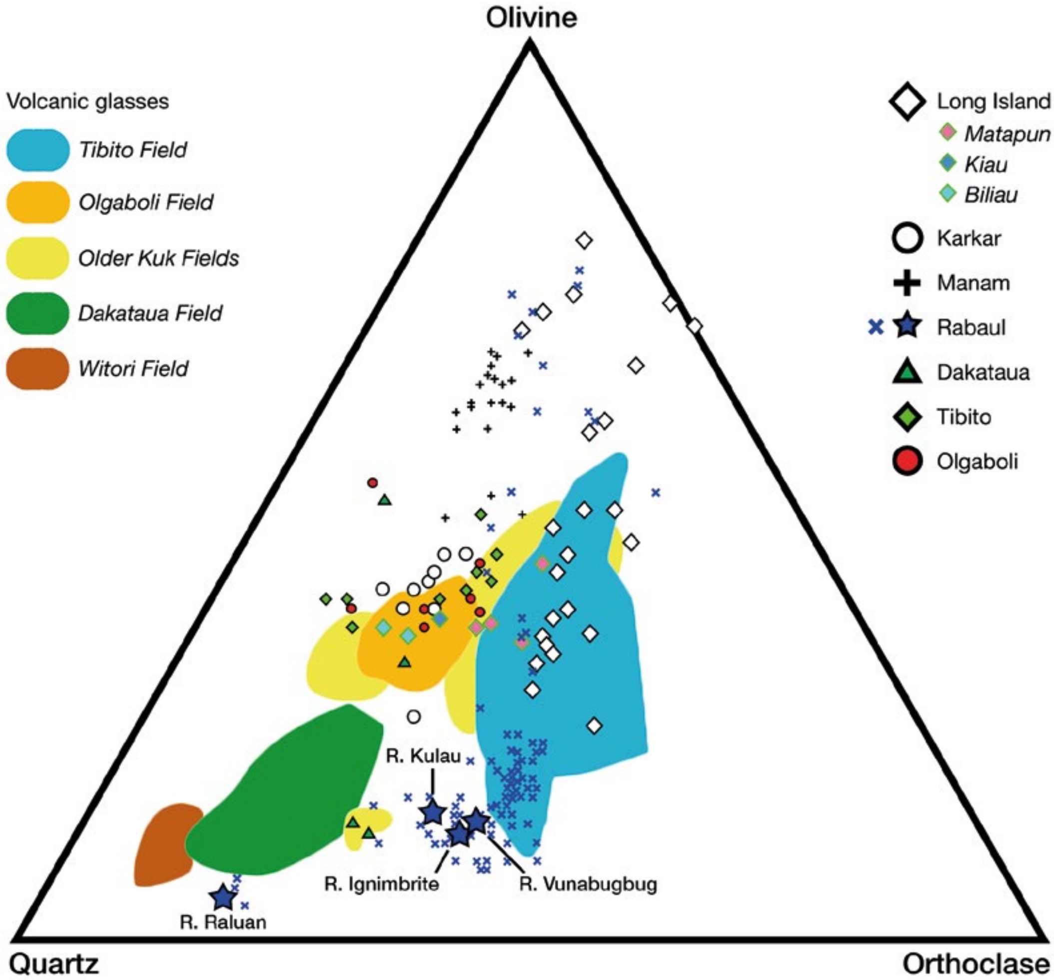


Figure 7.6 Mineralogical composition of some Kuk tephras and various Bismarck arc volcanic samples.

Volcanic glasses from the Kuk tephras are shown by the blue (Tibito), orange (Olgaboli) and yellow (others) fields. The volcanic glasses in the Kuk tephras were analysed as individual glass fragments by Electron Microprobe. Systematic differences are to be expected. Data points show volcanic rocks from New Britain, Karkar, Long Island and Manam volcanoes; different symbols for the one volcanic source refer to different beds. Generally, the volcanic samples are from whole rocks analysed by X-Ray Fluorescence (XRF). Samples from only four of five major explosive Witori eruptions have been analysed here. Similarly, samples from only four of the five such eruptions of Rabaul volcano have been analysed. Dakataua and Witori fields are based on unpublished data provided by Robin Torrence, reproduced with permission.

Source: Drawing by Tom Wagner.

The overall point to take away from Figure 7.6 is that the Bismarck arc volcanoes that are located very far from Kuk—Rabaul, Witori and Dakataua (Fig. 7.4)—show significant compositional differences from the Kuk tephras and are unlikely to be their source. This is despite there having been very large eruptions from these volcanoes in the last 15,000 years or so (Machida et al. 1996; Nairn et al. 1996; McKee, Neall and Torrence 2011).

The western half of the Bismarck arc hosts a number of potential sources (Fig. 7.4). The Kuk tephras are most similar to eruptive products from Long Island and Karkar volcanoes in terms of both major elements and the critical minor elements K_2O (potassium oxide) and TiO_2 (titanium oxide). The Kuk tephra samples are also similar to some samples from Umboi, Langila and Cape Gloucester (on and near the western end of New Britain, see Fig. 7.4), though there are relatively few analyses available for these volcanoes and no evidence that they have experienced cataclysmic caldera-forming eruptions. Table 7.3 lists the likely source or sources for each Kuk tephra.

Conclusions

Numerous thin tephra units have been identified at Kuk and at a number of other sites across the highlands, providing unique chronostratigraphic markers that are absolutely essential to understanding the history of the Kuk site. Extensive fieldwork has eliminated the possibility that any highlands volcanoes were the sources of these tephras. Based on stratigraphic work around several volcanoes along the Bismarck arc, the ages of major eruptions there (Pain, Blong and McKee 1981; Pain and McKee 1981; Polach 1981) and analyses of wind speeds and directions (Blong 1981), it is clear that Karkar and Long Islands are the most likely sources for all the tephras found at Kuk younger than and including Ep (Table 7.2).

Compelling arguments also come from the compositional characteristics of eruptives from Karkar and Long Island volcanoes, which match the geochemical properties of the Kuk tephras. Figure 7.6 shows that many Long Island samples overlap with the Kuk tephras, including both the Tibito and Olgaboli groups. It also shows that the Karkar samples have less overall compositional variation than the Long Island samples. These characteristics are consistent with Karkar being the source for the Olgaboli group and Long Island for the Tibito group and some other tephras. However, there is still much research to do, particularly on the source volcanoes and on tephras identified at a range of sites across the highlands, before we can uniquely correlate each of the Kuk tephras to a well-dated eruption.

Acknowledgements

Major contributions were made to the tephrostratigraphy at Kuk over a period of years by Wal Ambrose, Philip Hughes, the late Ron Lampert, Frank Oldfield, Colin Pain, Jocelyn Powell, Marjorie Sullivan and various more temporary members of the Kuk team. We thank particularly Philip Hughes and Colin Pain for their major contributions to Tables 7.1 and 7.2. We also thank Wally Johnson and Robin Torrence for access to unpublished data on New Guinea volcanics.

8

Tibito Tephra, *Taim Tudak* and the Impact of Thin Tephra Falls

Russell Blong

Introduction

The cataclysmic eruption of Long Island that produced Tibito Tephra probably occurred in the decade of the AD 1660s. The eruption, in terms of the volume of tephra produced, was equal in size to the eruption of Krakatau in 1883, devastating Long Island and spreading the tephra across the north coast and highlands of Papua New Guinea (PNG). Some 85,000 km^2 of land area were covered by up to 10 mm of ash. Despite the size of the eruption, one of the 10 largest anywhere in the world in the last thousand years, it appears not to have been recorded anywhere in written form.

Dozens of groups of people across PNG retain stories about a *taim tudak*, when darkness prevailed for several days and sand or dust fell from the sky, ruining crops, killing birds and animals, collapsing some house roofs and killing a few people (Fig. 8.1). The available legends are presented in full in Blong (1979b) and an extended interpretation can be found in Blong (1982). Only a few aspects of the stories are considered here. The Time of Darkness story and its variants are summarised and comparisons made with what we know of the effects of modern tephra falls. In most aspects, the *taim tudak* stories are essentially accurate accounts of the consequences of a thin tephra fall, though there are aspects of some accounts that appear exaggerated or erroneous. The chapter ends by outlining the likely outcomes if a similar fall of tephra were to occur today.

In total, about a hundred versions of the *taim tudak* legend have been collected by (mainly) anthropologists and missionaries. At least 56 of these versions come from the area where we can be confident that Tibito Tephra is the uppermost tephra and, therefore, the almost certain inspiration for the *taim tudak* story (Fig. 8.1) (Blong 1979b, 1982). While we might surmise that there have been minor dustings of tephra, of only a couple of millimetres or less, subsequent to the fall of Tibito Tephra in at least some of these areas, there is no current stratigraphic or historical evidence that such minor falls have occurred in the last few hundred years. Most of the accounts of the *taim tudak* were collected more than 300 years after Tibito Tephra fell.

Some of the legends report the fall of more than one tephra. Minor dustings might be included here, but the Kuk investigations reveal the presence of many older thin tephras that fell during the last 14,000 years or so. While we have no direct evidence of the impact of these earlier falls, we can assume that they produced rather similar consequences to those described for Tibito Tephra and contained in the *taim tudak* stories.

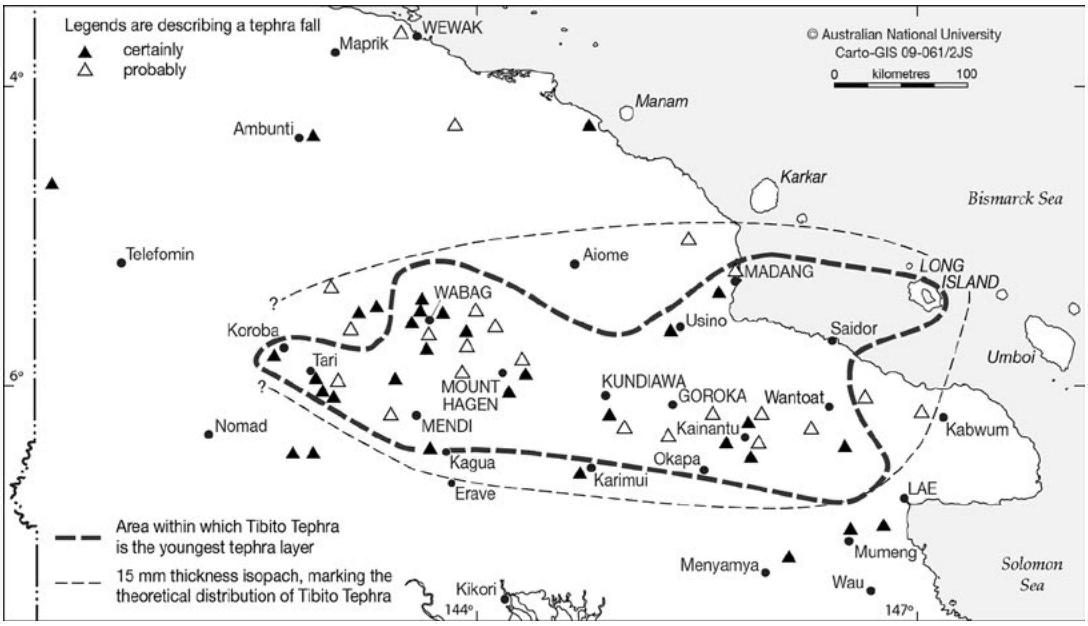


Figure 8.1 Location of Time of Darkness legends, shown in relation to the area within which Tibito is the youngest tephra.

Source: Drawing by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU, based on Blong (1982: Figs 35 and 31), reproduced with permission.

While the impacts of tephra falls on other aspects of everyday life are examined, this chapter focuses on the impact of thin tephra falls on plant resources, animals and insects. In reality the effects cannot be separated—a food resource might flourish because of the extermination of an insect predator, or it might be decimated because a pollinating insect comes close to local (and temporary) extinction.

It is important to recognise that we know too little about the effects of tephra falls on plants, animals, buildings, people and societies in the PNG region or, for that matter, anywhere in the world. We must also recognise that perceptions are just as important as realities, confounding what we think we know. For example, about two weeks after a fall of less than 10 mm of tephra on Karkar Island in 1979, subsistence farmers reported taro tubers were rotting in the ground as a result (personal fieldwork observation). Local agricultural officers believed that taro blight, unconnected with the eruption, was the cause of the decay. Perception and reality are intertwined in at least some of what follows.

The *taim tudak* legend

As implied by Figure 8.1, there are numerous versions of the *taim tudak* legend. The one given below was collected in the 1930s by the German Lutheran missionary Georg F. Vicedom (Vicedom and Tischner 1943–48, vol.1: 91) from Melpa-speaking inhabitants of the upper Wahgi Valley around the present Mount Hagen town, to whom the Kuk people are related and who speak the same language. Its early collection date may be the reason why it is less affected by the mixing of different events that is evident in later versions. The translation of Vicedom's German text is by Andrew Strathern (Vicedom 1977: 67):

> Once upon a time, in olden days, men saw to the south the whole land was covered with dark clouds. A storm was on its way and there was a rustling and a whistling in the air. They asked what this meant, and heard that it was raining ashes in those parts, so that the people could not go out

> to dig up their food crops. So they themselves went out and gathered in supplies. The ash-storm reached them and they had to stay inside their houses for four or five nights. By this time they were either terribly hungry or else they actually did starve to death. They were badly shocked by the event and were sure they would all be annihilated and that their spirits had deserted them, although they continued to pray. Gradually over a two day period it grew light again, till they were able to emerge and saw their crops and fields were ruined. They were in great need, as their stores were finished and they had to plant new crops while they were still hungry. After a month nearly all of them died. A few remained and through time increased again. The plants we grow were handed down to us from those survivors. People today do not know that the ash-storms once took place. Men have increased again and it is said that a new race of men lives.

Characteristics of the tephra fall

Almost all the *taim tudak* legends refer to the fall of ash or dust or sand. Four accounts describe falling stones and one of these includes falling trees (Blong 1979b, 1982). Of the 43 accounts that contain some information about the thickness of the tephra fall, 36 describe it as only a dusting, or thick enough to cover plants, or thick enough to break down houses and trees. Most of the seven describing thicker falls occur in the western part of the area represented in Figure 8.1. One of these, collected by Keith Briggs, a Summer Institute of Linguistics worker, from among the Kaluli people near Mt Bosavi, suggested the tephra was so thick it was 'up to the eaves on houses six feet off the ground' (Blong 1982: 101). Another series of accounts from the same language group and located only a few kilometres distant from the first group, was collected by the anthropologists Buck Schieffelin and Steve Feld in the same year (1977). These accounts say the fall of sand was not thick enough to form a layer, but just filled the nodes between the leaves on plants.

Inferences or statements about the duration of the darkness or the duration of the tephra fall are contained in 37 of the accounts. Thirty-one of these estimate the duration as four days or less, with 3–4 days the most common answer. Four accounts suggest that darkness or tephra fall lasted longer than two weeks, with two accounts stretching the period to at least three months.

Thin tephra falls are those less than 100 mm in thickness. The density of freshly fallen tephra is quite low but it is also highly variable, compacting to a bulk density of around 1.3 to 1.8 g/cm^3. These changes in density with compaction also imply a change in thickness. A reasonable rule of thumb is that thickness on the ground halves with time. If rainfall occurs, compaction is likely to be rapid. We can assume that in areas like the PNG highlands, most compaction occurs within a few days of deposition.

Rainfall washes ash particles off leaves and other surfaces, moving them closer to the ground, thereby representing initial reworking of the volcanic ash. Often, the ash surface forms a semi-impermeable layer that encourages runoff and erosion of the ash. Thus, even when ash falls as a continuous layer of even thickness, it is likely to be quickly altered to form a discontinuous layer of uneven depth within days.

Figure 7.3 shows the compacted (present-day) thickness of Tibito Tephra based on both field measurements and theoretical considerations. Compacted thicknesses in coastal Madang are more than 100 mm, thinning westward to less than 20 mm around Tari. Given that the freshly fallen thicknesses are likely to have been about twice these values, that tephra drifts in the wind against obstructions, and that it can be quickly eroded and redeposited, most of the legends provide reasonable estimates of thickness. Perusal of the European literature on tephra fall thickness suggests that the *taim tudak* legends are as accurate in this respect as written accounts from Alaska, Indonesia, the Philippines, the Caribbean and elsewhere (Blong 1984).

In the upper Wahgi Valley, the median particle size of Tibito Tephra is fine sand in the range 0.1 to 0.15 mm diameter. The available analyses underestimate the proportion of finer particles, but descriptions in the legends that suggest 'dust' or 'sand' are fairly accurate. Conversely, the available particle size analyses indicate that the largest fraction of Tibito Tephra that fell over mainland PNG was less than 2 mm in diameter (Blong 1982). Thus, accounts suggesting that stones or trees fell from the sky appear exaggerated. Reference to 'stones' may only indicate problems in translation from local languages or confusion of the *taim tudak* legend with falls of hailstones, while 'falling trees' could refer to limbs broken from trees by the weight of tephra (see Table 8.1).

Table 8.1 Effects of tephra falls on crops.

Tephra fall thickness	Effects on crops
<10 mm	burnt leaves; minor damage to corn and hay; strawberry plants flattened, increasing fruit rot
10 mm	hay crop less because of prostration; banana, wheat, mulberry, tobacco and vegetable crops flattened; scarring of blueberries; breadfruit, apples, cotton dropped
15 mm	hay windrowed before tephra fall unusable
20 mm	30% loss of lentils; loss of wheat, barley, peas, grass seed; mandarins, mulberry crop and vegetables considerably damaged
25 mm	damage to sweet potatoes, yams and tannias; sugarcane prostrated in patches; branches broken off young breadfruit trees
30 mm	some plants unable to push through tephra crust
40 mm	50% loss of lentils; 15–30% loss of wheat, spring barley, peas and hay
50 mm	banana plants damaged; 'forced ripening' of some crops
100 mm	some branches break under tephra load; palm fronds broken

Source: Based on Blong (1984) and Dale, Delgado-Acevedo and MacMahon (2005).

Examination of the rather sparse literature on the duration of darkness and tephra falls suggests a mean rate of tephra accumulation on the ground of 4–5 mm/hour. Blong (1982: 144–145, Fig. 55) displays the relationship between uncompacted thickness of tephra and the duration of darkness, the standard deviation from this relationship and the quality of the darkness reported in the *taim tudak* legends. The plot suggests that the duration of the tephra fall/darkness is exaggerated in almost all accounts. At Kuk, for example, where Tibito Tephra is <50 mm compacted thickness, darkness probably lasted less than 24 hours (assuming compacted thickness is half the original thickness). Even if we assume that Tibito Tephra fell at only half the 'average' rate, the duration of darkness would still have been substantially less than two days.

Effects on plants

That nearly all of the *taim tudak* accounts describe deleterious effects on crops is hardly surprising given the central role of subsistence agriculture in the highlands economy. Most accounts mention that leaves were burnt or spoiled, leaves were stripped or tubers rotted (Blong 1979b, 1982). Many accounts describe more than one of these effects. A Huli version mentions that all leaves on trees were dried/burnt and fell off, though there was no permanent damage (Blong 1982: Table 19). Leaves on sweet potato (*Ipomoea batatas*), sugarcane (*Saccharum officinarum*), bananas (*Musa* spp.), dryland and wetland grasses and the like were burnt brown. It was not possible to eat sweet potato because of the taste, leading to famine. However, most accounts are less specific. A few versions of the story emphasise, not the destruction, but the fertilising effect of the tephra fall (see the section on 'Longer-term impacts' below).

Examination of the literature on the effects of tephra falls on plants indicates that four major factors are important: the thickness of tephra falls, the physiognomy of the plants, the season in which tephra fall occurs and the aerosols attached to the tephra.

The thickness of tephra falls

Table 8.1 sets out a range of reported effects on crops for tephra falls of compacted thicknesses (though this is not always specified in the original accounts). Although only some of the crops listed are tropical, the wide variety of effects provides insights into potential consequences and indicates how little we know about specific plant responses to tephra fall. It is also clear that many of the types of effects described in the table are similar to those reported in the legends.

The physiognomy of the plants

Plant physiognomy is an important influence on plant response. For example, the growth position of crops is of obvious importance: crops that grow close to the ground, like strawberries, are more likely to be adversely affected by even thin tephra falls than those that grow on trees. Similarly, hairy leaves and fruits retain tephra and experience reduced photosynthesis, while smooth leaves and fruits are more likely to shed tephra during windy or rainy periods.

The crop production of some plants may be adversely affected by even a small loss of flowers. Others, for example cocoa, can experience more than 90 per cent destruction of flowers without a marked effect on fruit/pod production (Blong and Aislabie 1988). Alternatively, even a reduction in the number of fruit may still result in a larger crop (fewer but larger fruit).

The season in which tephra fall occurs

Seasonality of tephra fall is obviously important in terms of crop growing season. Tephra fall can promote flower drop or prevent pollination. Young plants may be particularly susceptible to tephra fall. Seasonality of tephra fall may also be important where there are marked wet and dry seasons. In dry seasons, fine tephra blows readily in the wind, forming small drifts with the minute angular glassy fragments abrading delicate plant stems and foliage. Periods of heavy rain, on the other hand, will wash foliage clean, limiting damage from reduced photosynthesis and acid aerosols, but perhaps exacerbating consequences downstream through tephra deposition and plant burial or increased stream turbidity.

The aerosols attached to the tephra

Aerosols and acid rains are commonly attached to tephra particles. Aerosols may be an important influence on plant growth and survival even in areas where tephra falls are very limited. Coatings on particles may have a pH as low as 4.0, or even less, producing burning of foliage, blossom drop or poor fruiting. Burnt leaves may have a limited effect or may lead to rotting of tubers and fruit. The amount and frequency of rainfall, and the humidity, may limit or exacerbate the effects of acid aerosols.

Despite the chemically inert glassy silica that makes up the bulk of tephra falls at distances greater than tens of kilometres from the source volcano, trace elements in the glass and in the attached aerosols are likely to include sulphur and potassium, which act as natural fertilisers. On the other hand, elements present in trace amounts might include arsenic, cadmium, copper and molybdenum, which can have deleterious effects on plants at specific growth stages.

Thus, without any analysis of specific versions of the legend, it is clear that the general descriptions of ruined gardens, the burning, stripping or spoiling of leaves and the rotting of tubers in the ground are in accord with the sorts of evidence produced in European accounts of tephra falls around the world (Blong 1984; Dale, Delgado-Acevedo and MacMahon 2005).

Effects on birds, animals and insects

Many of the *taim tudak* stories report effects on animals and birds. An account from amongst the Daribi, near Karimui in Simbu Province, notes that domestic pigs and cassowaries had their bristles or feathers so full of ash that they could not move, while wild pigs were unable to run away and men killed many of them (Blong 1982: Table 20). Pigs and cassowaries that slept under fallen trees or in holes escaped. Many accounts draw distinctions between domestic animals, which were in the houses and escaped relatively unharmed, and wild animals and birds that died or were bewildered, easily caught and eaten as food.

There is an amazing variety of consequences of tephra fall reported in the literature, mainly because there is an amazing variety of animals and insects. Some ashfalls have had marked adverse effects on crickets, cockroaches, flies, grasshoppers, honeybees and other pollinators. Tephra can be abrasive to insect cuticles, even after only a few hours of exposure (Edwards 2005). Animals can be adversely affected by loss of grazing habitat, tephra-caused increase in tooth wear, eye problems, ingestion or inhalation of ash or poisoning by acids attached to particles (Vanderhoek and Nelson 2007).

However, seasonality of the tephra fall is likely to be an important influence. Earthworms, other insects and even animals that spend time below ground level (or hibernating) may be little affected by many tephra falls. But the dominant control on animal and insect survival may well depend most on the survival or disappearance of insects and animals higher and lower in the food chain. Similarly, the effects of tephra falls on plants may disrupt the feeding patterns of some animals and insects but not others.

The size of the area affected by tephra fall may also be important. Exterminated species of birds or animals may be replaced by recolonisation within a few months or years if food becomes available, while the habitat redevelops if the affected areas are limited.

Again, the general effects on birds and animals recorded in most of the *taim tudak* legends are in good accord with the general comments in the literature for relatively thin tephra falls (Blong 1984). In most cases, this aspect of the legends has an air of veracity and is relatively free from exaggeration, so far as can be told.

Effects on buildings

About 24 of the *taim tudak* legends collected refer to the effects on houses (Blong 1982: Table 18); about a quarter of these specifically state that houses were not affected by the ashfall. The others refer to the collapse of houses (sometimes many houses, sometimes a few) or to the deformation or collapse of the roof. More than one quarter of the accounts refer to bumping the roof or cleaning the roof to dislodge the tephra. A few indicate that such action would be taken the next time a tephra fall occurred.

At first glance, one might be surprised that a fall of less than 100 mm of tephra can cause the collapse of house roofs, but the legends are essentially in accord with the experience reported in the literature (Blong 1982). Even modern buildings can collapse under quite thin loads of wet ash; for example, it was noted around Vesuvius after the 1906 eruption that 100 mm of tephra fall was sufficient to collapse some flat roofs, though steeper roofs were usually less damaged (Perret 1950). Thatch roofs may be more susceptible than, for example, metal roofs, as the lower angles of sliding friction on the latter aid tephra removal. Certainly, the roofs that are most likely to collapse are those with large spans and those on older buildings where the supporting structure may be weaker. The various structural components of a timber building are quite variable in their ability to carry loads, as the strength of timber beams is not consistent (compared with, say, that of steel girders); the failure of one key component can lead to the collapse of the entire building.

While there is little pattern in the legends that suggests roof damage was concentrated where tephra falls were thicker, it is worth noting that none of the accounts from Enga describe roof or building collapse. As the *taim tudak* story has been intensively investigated in Enga by Mai (1981), we can probably conclude that houses did not collapse in this area. As 20–30 mm of (compacted) tephra fell across Enga and as similar amounts produced reports of house collapse elsewhere in the highlands, it is intriguing to speculate that Enga houses were more strongly built or that the roofs had shorter spans than elsewhere.

Effects on human health

Of the 56 versions of the *taim tudak* considered here, a little over half make no mention of human deaths as a result of the fall of Tibito Tephra (Blong 1982: Table 21). As this would be a most surprising omission, we can be reasonably confident that no deaths resulted from the tephra fall in those areas for which deaths are not mentioned. A further 11 accounts specifically mention that no human deaths occurred. The remaining versions report deaths during the fall as a result of collapsing houses or falling stones or afterwards as a result of hunger. Only two accounts, one from amongst the Melpa (see the version given at the beginning of this chapter) and one from the upper Wage in western Enga, suggest that few people survived the tephra fall and its aftermath. Notably, not one of the accounts collected refers to human injuries as distinct from deaths.

Tephra falls are not the most deadly of volcanic phenomena. However, there are numerous cases of deaths and injuries resulting from roof collapse following thin tephra falls. It is rarely possible to determine the number of deaths as a proportion of the population at risk, but it appears to be usually small unless a large proportion of the populace has gathered in a large structurally weak building (such as an old church) where the roof collapses.

Reports of famine and food shortages are common in the aftermath of large eruptions, but it is not clear that starvation occurs often where tephra falls are thin. Perhaps sweet potato and other tubers are particularly susceptible to rotting or disease resulting from tephra fall—we simply do not know.

Despite these shortcomings in our knowledge, most of the *taim tudak* accounts can be regarded as reasonably accurate in that few deaths are reported and significant food shortages are not often mentioned. The modern literature concerned with the consequences of thin tephra falls is focused on respiratory problems, usually relatively minor psychological issues and the possibility of longer-term effects including pneumonosilicosis and fluorosis (Baxter and Horwell 2015).

Dating the Time of Darkness

Many of the *taim tudak* accounts provide information that can be used to estimate when the fall of tephra occurred. Usually the information refers to an ancestor in whose lifetime the event took place. A date for the event is then estimated allowing, say, 30 years for each generation.

The most consistent estimates come from Mai's (1981) work in Enga, which cluster around the mid-19th century. Estimates from accounts elsewhere group around the mid to late 19th century, but also extend to as early as AD 1700 (Blong 1982). Estimates based on the legends from Long Island suggest the eruption occurred in the range AD 1810–1840.

Blong (1982) examined several additional lines of evidence:

- radiocarbon dates on wood and peat samples from Kuk, from other highlands sites and from Long Island;
- lead-210 dates from highlands lake sediments;
- palaeomagnetic secular variation in lake sediments;
- Dampier's AD 1700 sighting and description of Long Island and subsequent reports by other European navigators; and
- the likely time necessary for recolonisation and revegetation of Long Island (20–30 years) after the eruption.

After weighing the evidence, Blong (1982: 193–194) concluded that the radiocarbon ages provided the soundest evidence and that a mid-17th-century date (between AD 1630 and 1670) was the most likely for the eruption of Long Island, the emplacement of Tibito Tephra and the origin of the *taim tudak* legends.

More recently, the detailed work of Thornton (1996, 2000) on the revegetation of Krakatau following the 1883 eruption suggests, if Krakatau is a suitable analogue for Long Island, that an allowance for recolonisation of 40–50 years is more appropriate than 20–30 years.

The original analysis relied on the Stuiver (1978) calibration for translating radiocarbon dates into calendar years. Haberle (1998a) used the revised calibration curve of Stuiver and Reimer (1993) on five highlands samples to show that a date between AD 1645–1680 had a probability of 45 per cent, between 1755–1805 a probability of 38 per cent and between 1935–1950 a probability of 17 per cent. In 2001, Caspar Ammann (pers. comm.) applied the CALIB 4.3 of Stuiver et al. (1998) to the same five samples, producing new estimates of between AD 1646–1668 (probability 65 per cent) and between 1781–1796 (35 per cent). Using nine samples from the highlands and Long Island produced calendar year ages between 1636–1675 (probability 58 per cent), and between 1776–1801 (31 per cent). Haberle's (1998a: 3) comment still stands: 'while the somewhat later possibility in the eighteenth century cannot be totally dismissed, the weight of independent evidence points to the seventeenth century AD range'.

Two additional lines of evidence have also become available. The first is that large volcanic eruptions push huge quantities of sulphur and chlorine gases into the upper atmosphere. The sulphur dioxide reacts with water in the stratosphere to form sulphuric acid, some of which is eventually deposited on the Greenland and Antarctic ice sheets where its presence can be detected as a spike of electrical conductivity (Bradley 1999). Hammer, Clausen and Dansgaard (1980) showed there is a marked spike in a Greenland core for the years 1666 and 1667 that could not be assigned to any known eruption. As reported earlier, the 17th-century Long Island eruption is one of the 10 greatest eruptions of the last millennium; thus it should be represented in the Greenland ice core.

The second line of evidence stems from the tree ring density chronologies that record year by year temperature changes in the northern boreal forest zone. Briffa et al. (1998) first made the connection between the anomalously cold years of 1666 and 1667 and the eruption of Long Island. Reference to the boreal forest temperature curve shows that AD 1666 had the 12th largest negative temperature anomaly in the last 600 years.

The Greenland ice core and the tree ring temperature curve are not in themselves evidence that the Long Island eruption occurred in AD 1665 or 1666, which allows up to a year after the eruption for the effects to be registered in ice cores and tree rings. However, we know that such a large eruption would have produced substantial effects. If this was not in 1665 or 1666, then it is necessary to find other unassigned years for the Long Island eruption. As no other unassigned years exist, the most economical hypothesis is that the Long Island eruption, the emplacement of Tibito Tephra and the birth of the *taim tudak* legends all occurred in 1665 or 1666. We should recognise, however, that there remains some possibility that this hypothesis is incorrect. Until further analysis becomes available, it is preferable to say that the Long Island eruption occurred 'probably in the decade of the AD 1660s'.

Longer-term impacts

Amongst people belonging to a number of language groups in Southern Highlands Province, but particularly among the Huli, there seems to be a strong belief that the *taim tudak* will occur again. All of the language groups in question are more or less adjacent and there may be an element of diffusion as a result. Glasse (1963, 1965) reports that the Huli at Tari have made at least two ritual attempts to encourage the recurrence of what is called *bingi*, because they regard the fall of tephra as beneficial. Similarly, the Enga groups where Mai (1981) recorded the *taim tudak* story see the tephra fall as culturally beneficial, responsible for an increase in the complexity of tribal dances, the broader spread of pig exchange and technological improvements in fences and housing styles. However, attempts to bring about a recurrence of the ashfall have not been reported in Enga; in fact, the Mae Enga used to make placatory offerings to their ancestors in the hope of ensuring that such untoward events would not recur (Meggitt 1973).

It is also instructive to ask how different things would have been for the various peoples affected by the tephra fall and the *taim tudak* had they not occurred. We have no complete answer, but it seems likely that the millenarian cult manifest among the Ipili in the 1940s would not have had an emphasis on the coming of a great darkness, with spells to invoke the help of the sun to disperse the cloud of darkness (Meggit 1973). Similarly, the Kilibob-Manup myth among the Yabob south of Madang might not have included the prophecy of a fall of ash that would destroy the gardens and lead to war and cannibalism (Lawrence 1964). The Huli would have been without an important part of their highly structured ritual and the Paiela cycle of world renewal after tephra fall would have been different (Aletta Biersack, pers. comm., 1978). The preparations made by some eastern highlands groups for a 1962 solar eclipse following the warnings of five minutes of darkness by patrol officers (Du Toit 1969) would surely have been less elaborate.

While the suggested connections between the 17th-century eruption of Long Island, the *taim tudak* stories and belief and behaviour among recent populations are plausible, it is more difficult to establish cause and effect. We know little enough about the direct effects of ashfall on communities and even less about the extent to which environment, culture and people were susceptible or amenable to changes induced by the event. As Grattan, Michnowicz and Rabartin (2007: 172) note, 'mere coincidence is not enough'.

Soil replenishment

Volcanic soils are commonly regarded as extremely fertile (Mohr and van Baren 1954), especially on islands such as Java where dense populations live on the slopes of numerous active volcanoes. A large number of accounts describe the fertilising effects of falls of volcanic ash, with crops and other plants growing more strongly in the aftermath of an ashfall (see Blong 1984: 348–350). The Huli account of *bingi* would seem to support this view. But we should note that the fertilising effect is likely to be mixed and vary from nutrient to nutrient, species to species, site to site and across relatively small areas, especially for very thin tephra falls (cf. Cronin et al. 1997).

Similarly, various authorities have assumed that occasional falls of volcanic ash across the highlands of PNG have had a fertilising effect by replenishing soil nutrients. Hope, Gillieson and Head (1988), for example, suggest that volcanic ashes have produced a macronutrient boost to peat bogs and that a sudden supply of nutrients facilitates increased dominance by particular species for a few generations. This view has been extended to suggest that falls of volcanic ash across the highlands of PNG raised soil fertility, in contrast to the Indonesian part of the island where soil fertility is believed to be lower because the ashfalls did not reach this far (Haberle, Hope and DeFretes 1991).

However, this hypothesis needs to be treated with caution. Many of the accounts of increased plant growth after an ashfall fail to make it clear whether the 'bloom' results from the increased availability of plant nutrients, a decline in competition because some plant species have not fared well, or because insect predators have been decimated by the ash.

Certainly, many ashfalls provide readily available plant nutrients, but we have remarkably little information on how long this increased supply might continue. At Kuk the average interval between now identifiable ashfalls is more than a thousand years—does increased nutrient availability last for all of this period? At Kuk, the total compacted thickness of the thin ash beds in the last 14,000 years or so is probably less than about 220 mm, or about 15 mm per 1000 years on average. At Tari, the rate of ash accumulation would be about half that. Are these rates of ashfall sufficient to replenish the fertility of soils? Or is soil fertility provided by Tomba Tephra and other massive tephra falls deposited more than 50,000 years ago across enormous areas of the highlands of PNG?

Furthermore, Humphreys (1998) reports that even soils developed on the widespread Chim Formation from which volcanic ash has been removed by erosion are quite fertile. Interestingly, Wood's (2002) investigation of garden ages, using genealogical dating, shows that soil fertility and sweet potato yield decline less on soils adjacent to swamps and on floodplains around Tari after 100 years of cultivation than on volcanic ash soils after fewer than 50 years. Whatever the differences in edaphic factors from site to site, presumably all received roughly the same inputs of thin tephra falls over the last few thousand years as all the sites are a similar distance from the potential source volcanoes.

Different plants and different crops have different nutrient requirements. Sweet potato is generally considered to have a low requirement for available phosphorus, but potassium is recognised as an important sweet potato nutrient (Goodbody and Humphreys 1986). We do not know enough about available nutrients and thin tephras to say which plants would respond best, or for how long, to the falls of volcanic ash that have affected the highlands. Soil replenishment by thin falls of volcanic ash remains nothing more than an interesting hypothesis, albeit one deserving more penetrating investigation.

Additional impacts of tephra fall on a modern society

What would happen if a tephra fall of up to 100 mm occurred again across the PNG highlands, covering an area of tens of thousands of square kilometres with fluffy but abrasive volcanic ash and bringing darkness to the region for 24 hours or so? Such a scenario is not unrealistic, as evidenced by the fall of Tibito Tephra and the numerous earlier ashes found at Kuk. At this site and probably across a wide area, we might expect such a fall of tephra every 1000–2000 years on average, with occasional lighter dustings occurring.

Many of the effects of tephra fall reported in the *taim tudak* legends would occur again: a few house roofs, on both traditional and western-style houses, would fall in, resulting in some deaths and injuries. Traditional agriculture would suffer, as would the forests and animal life. In some areas electricity, and the lifelines dependent on it, including water supply, sewerage services, storm water drainage and communication systems, would fail. Air transport would be halted for days over a very large area and road transport would be difficult because of the clouds of dust in dry areas and the extremely slippery surface in areas where rain fell. Engines would be damaged where the air filtration systems were not well maintained and many electrical goods, including computers, would be affected, often beyond repair. Even where ashfall is very thin, perhaps only a millimetre, corrosion of exposed metal pipes and roofs might become obvious within a few weeks.

In urban areas, cleanup of the ash and its disposal would be likely to be major problems. For example, a 50 mm compacted fall of tephra represents about 75,000 tonnes/km^2; finding somewhere to put even a fraction of this mass and the means to transport it is not a trivial task.

Conclusions

The cataclysmic eruption of Long Island and the fall of Tibito Tephra occurred, most probably, in the AD 1660s. The fall of tephra across more than 85,000 km^2 of mainland PNG to a depth of up to 100 mm gave rise to an amazingly diverse legend about a Time of Darkness when sand fell from the sky, crops were destroyed, some houses collapsed and a few people as well as animals were killed. As far as we know, a version of the *taim tudak* legend was first written down, nearly 300 years later, in the 1940s (Vicedom and Tischner (1943-48, vol.1: 91). While details, and the emphasis, vary across the highlands and while individual elements in some accounts are undoubtedly embellished, the legends, viewed as a whole, provide a largely accurate version of the likely effects of a fall of up to 100 mm of ash. While the duration of the darkness or the thickness of the ashfall is commonly exaggerated, and the length of time elapsed since the tephra fall occurred is seriously underestimated, most details are plausible, indeed likely.

The *taim tudak* legends and the fall of Tibito Tephra are important for a number of reasons:

- the fall of Tibito Tephra was the result of one of the 10 largest volcanic eruptions anywhere in the world in the last thousand years;
- the legends provide the only accounts of the eruption and ashfall;
- they also provide one of the few bodies of information on the effects of tephra fall on a range of subsistence agriculturalists;
- they demonstrate that oral traditions can contain a large amount of reliable information when judged against modern observations;
- the *taim tudak* accounts prove that essentially accurate oral traditions can be handed down over periods of at least 300 years; and
- the *taim tudak* provides a chronological marker across a very large area and the only one that predates the arrival of Europeans in the region.

The connection between the *taim tudak* legend and Tibito Tephra was first raised at Kuk and then substantiated there (Blong 1982). Although we have numerous versions of the legend, there are still opportunities to undertake detailed collection and analysis, similar to the excellent work of Paul Mai and his colleagues in Enga.

9

Palaeoecology

Simon G. Haberle, Carol Lentfer and Tim Denham

The nature of palaeoecology

Palaeoecology is the branch of ecology that studies the relationship of ancient plants and animals to their environments and as such can reveal the nature of environmental change through time.

This chapter reviews the history of human–environment interactions at Kuk as determined through the examination of subfossil evidence, mainly pollen and charcoal, for environments of the past. The palaeoecological results are interpreted below with respect to change through time with a focus on the archaeological phases. These results are then considered in terms of the palaeoecological records for the upper Wahgi Valley regionally and New Guinea more widely: the differentiation of climatically and humanly induced changes to environments in the past, changes in landuse pattern through time and resource availability.

In the upper Wahgi region of the Papua New Guinea (PNG) highlands, palaeoecological research has focused on the analysis of pollen and charcoal in sediment samples as a way of determining vegetation and fire response to past environmental (mainly climatically and humanly induced) change. The impact of people on the environments of highland PNG is most clearly documented by the replacement of primary rainforests and swamp forests with grasslands, secondary forests and gardens at times when other possible drivers of change, like climate, do not provide an adequate explanation (Fig. 9.1; Haberle 1994; Hope and Haberle 2005). Valley infill, eroded slopes and altered waterways may also at times be caused by human actions, together with the deliberate creation of terraced slopes and ditched plains. This is not to deny that dramatic climate change has also impacted upon the landscape and affected human societies over the same period. The separation of natural from human factors in landscape change is one of the key problems that is current in palaeoecological research.

Several different palaeoecological techniques have been used to reconstruct past environments for the Kuk wetland and its immediate environment. These include:

- pollen analysis (palynology) (Bennett and Willis 2001; see Textbox 9.1 here)
- charcoal analysis (Whitlock and Larsen 2001; see Textbox 9.1 here)
- entomological analyses (Porch 2008; see Textbox 9.2 here)
- diatom analyses (Battarbee et al. 2001; see Textbox 9.3 here)
- macrobotanical analyses (Fairbairn 2008; see Textbox 10.1 here)
- phytolith analyses (Piperno 2001; see Textbox 10.2 here)

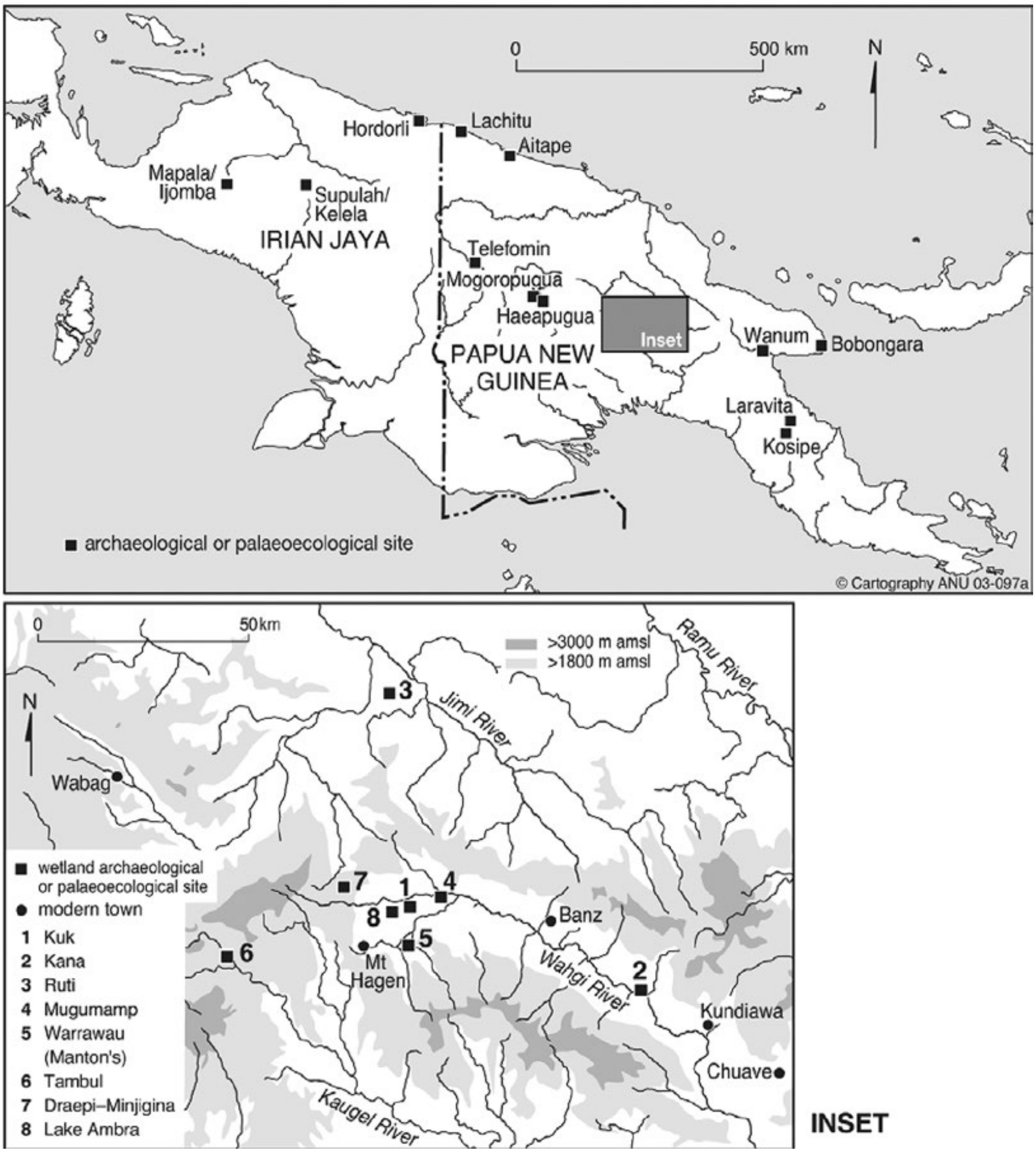


Figure 9.1 Map of New Guinea showing the location of important archaeological and palaeoecological sites. The inset depicts wetland sites in the PNG highlands.

Source: Denham (2005a: Fig 1), reproduced with permission. Drawing by Kay Dancey, CartoGIS Services, College of Asia and the Pacific, ANU.

Textbox 9.1 Pollen and microcharcoal analyses

Simon G. Haberle

Pollen

The study of pollen and charcoal preserved in sediments is one of the main ways we can reconstruct past vegetation patterns and changes to the landscape through time (Bennett and Willis 2001). The techniques have been in use for nearly a century in the study of climate change, archaeology and human impact on the environment through to industrial application in petroleum geology.

Pollen grains are plant parts that play a role in fertilisation during plant reproduction and are found in the flowers of angiosperms and gymnosperms. Pollen is dispersed from one plant to another in many ways, but the most common are by wind (anemophilous) and by insects (entomophilous). Pollen grains are usually spherical or elliptical and vary in size from approximately 10 µm (0.01 mm) to 100 µm (0.1 mm). Their shape and surface texture can be used to identify them to a parent plant family, genus and sometimes even species. The tough structure of pollen grains means that they are readily preserved in anaerobic (low oxygen) environments, such as bogs and lakes (Fig. 9.T1.1). The sediments are sampled by coring and the pollen grains extracted from them using a series of chemical and physical treatments that concentrates them (along with other inert organic fractions such as microscopic charcoal). They can then be identified and quantified using light-transmitted microscopy (400–1000x magnification, Fig. 9.T1.2).

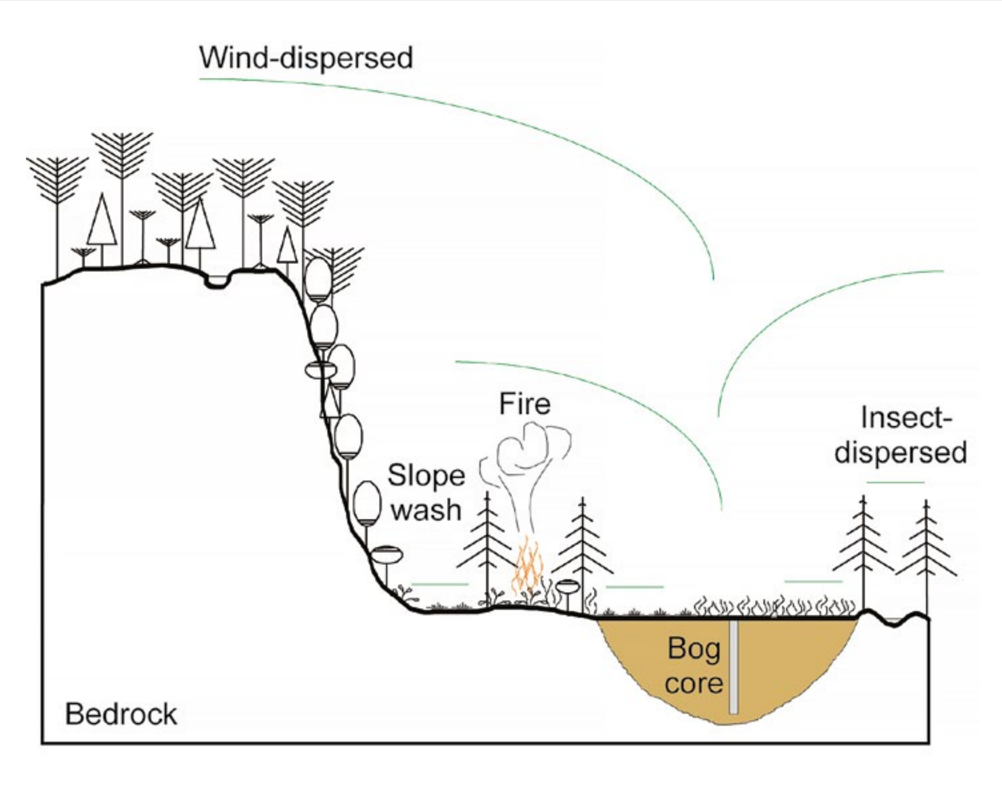


Figure 9.T1.1 Model of pollen dispersal mechanisms from the source plant to the point of deposition. Microcharcoal is dispersed in a similar fashion. Sediment cores are extracted from suitable anaerobic sites in the landscape.

Source: Drawing by Simon Haberle.

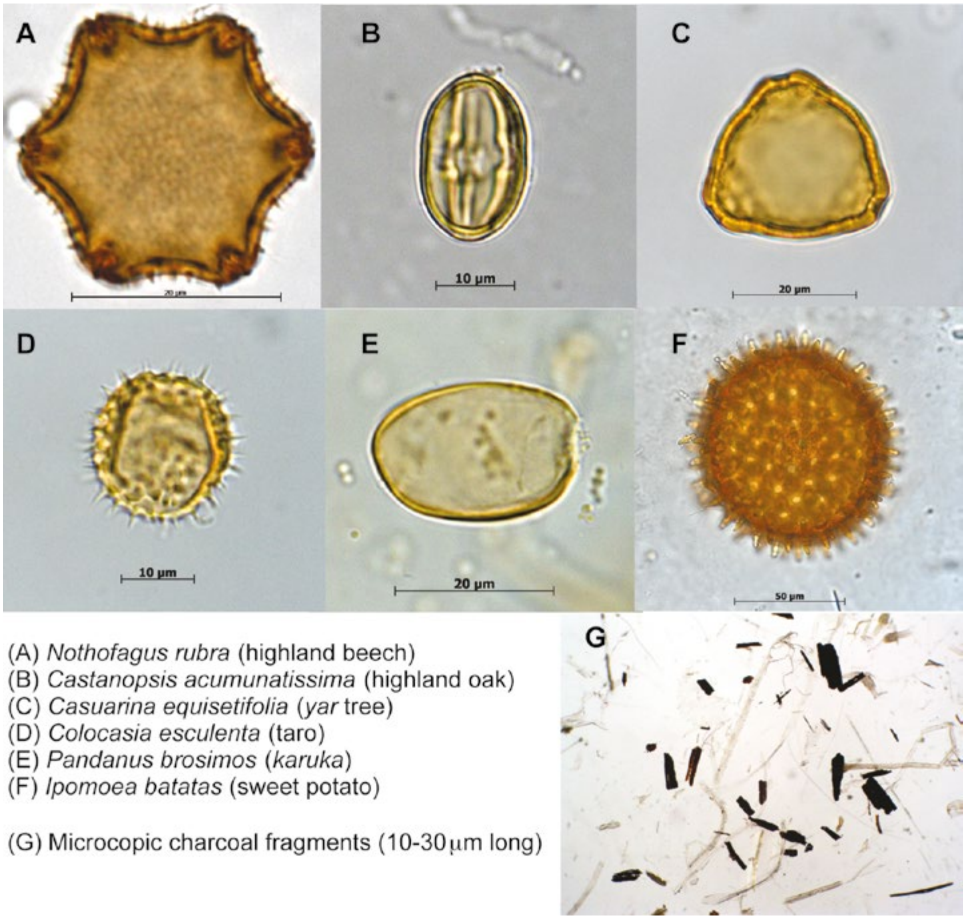


Figure 9.T1.2 Common pollen grains and microscopic charcoal from the highlands of PNG.

Source: Photograph by Simon Haberle.

By looking at the proportion of each pollen type that is preserved in sediments of known age, we can produce an ‘index’ of the vegetation surrounding the site. A time series of pollen spectra can be constructed by examining samples at intervals down a sediment profile. This provides us with a window into past vegetation changes at a particular point in the landscape (Fig. 9.T1.3).

Microcharcoal

Fine fragments of charcoal are preserved alongside pollen remains in sediments and can be used to reconstruct fire occurrence through time in the landscape (Whitlock and Larsen 2001). Microcharcoal is generally considered to be the fraction between approximately 5 µm (0.005 mm) and 100 µm (0.1 mm) and is quantified alongside analysis of the pollen. Peaks in charcoal abundance are interpreted as representing fire episodes in the past that may have contributed to changes in vegetation recorded in the pollen record. In some cases, increased charcoal occurs when forest pollen proportions are reduced, which may indicate that people have been clearing and burning the local forest (Fig. 9.T1.3).

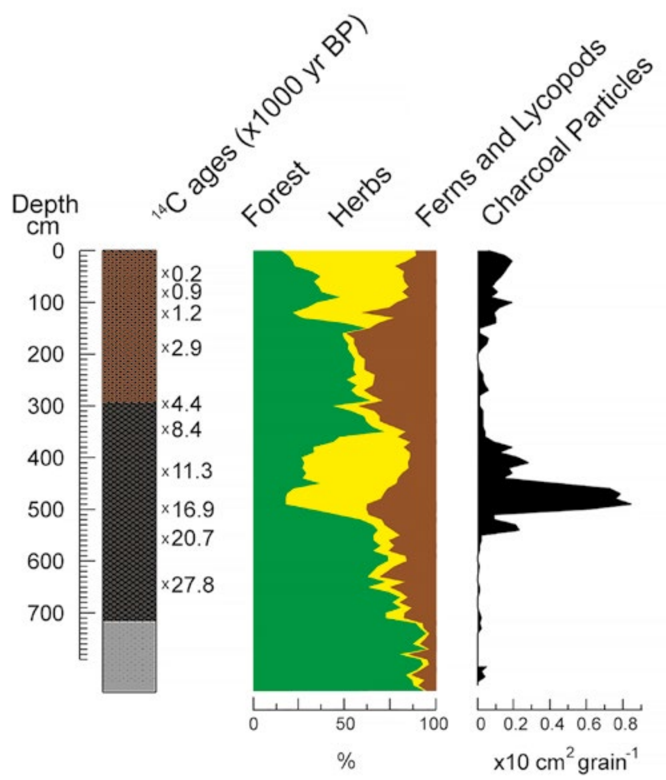


Figure 9.T1.3 Example of a pollen spectrum derived from the Tari Basin.

The summary pollen record shows the changing proportion of pollen from forest, herbs and fern taxa through time (the last 30,000 years). Microscopic charcoal fragments have been quantified.

Source: Drawing by Simon Haberle.

Textbox 9.2 Insect assemblages from Kuk

Nick Porch

The use of insect remains—especially of beetles—in palaeoecology is well established in the temperate areas of the northern and southern hemispheres (Elias 1994; Porch and Elias 2000; Marra 2003). Tropical assemblages have been largely ignored for a range of reasons: the focus of palaeoecological and palaeoclimatic research on temperate regions; the perceived lack of suitable sites; and, perhaps, the understandable fear that the overwhelming diversity of tropical insects would render the task of identification and interpretation impractical. The analysis of Holocene insect faunas from Kuk was, at the time it was undertaken, a first for Quaternary entomology in the tropics.

Insect remains were recovered by Porch from samples (Table 9.T2.1) of basal ditch fill sediment using standard techniques that included sieving and kerosene flotation (Elias 1994). Insects were picked from floated residues under a binocular microscope and stored on micropalaeontological slides or, for fragile specimens, in ethanol. Figure 9.T2.1 shows a typical example of an insect assemblage composed of many different species and body parts, freshly picked from the floated sample. Identifications were made by comparison with material in the Bernice P. Bishop Museum, Honolulu, or with reference to publications describing the New Guinea fauna.

Table 9.T2.1 Summary of age, origin (bag, name of channel and location) and size of Kuk insect samples (total weight 21.598 kg).

Phase	Approximate Age (cal. BP)	Bag	Name of Baret	Location	Weight (g)
5/6	750–100	39	Simon's	A10g	1667
4	2000–1100	41	Ketepa's	A10f/g	2256
4	2000–1100	42	Ketepa's	A10f/g	2475
4	2000–1100	7	Neringa's	A10f	1850
3	c. 2800	-	Nema's	A10d	1739
3	c. 3000	18	Kui's	A10f/g	1684
2/3	c. 4000	43	Kum's	A10f/g	2305
2/3	c. 4000	19	Kui's	A10f/g	1602
2/3	c. 4000	26	Joseph's	A10f/g	2150
2/3	c. 4000	27	Joseph's	A10f/g	1800
1	10,000	20	Kundil's	A10f/g	2070
				Total	21,598

Source: Data collated by Porch.

Assemblage types

Not all sediment samples yielded equally diverse assemblages: older samples were richer and better preserved, whereas the youngest samples had fewer species and often poorly preserved individuals, reflecting intensive oxidation of material either before it was incorporated into the site or subsequently.

There are essentially two assemblage types with little overlap in composition:

a. The single sample from Phase 1 is quite different from other samples.
b. Samples from Phases 2, 3 and 4 are more similar to each other than they are to the Phase 1 sample; the single Phase 5/6 sample had a very small and poorly preserved fauna and is not discussed further.

Figure 9.T2.1 A typical subfossil insect assemblage including beetles, ants, bugs and mites.
Source: Photograph by Nick Porch.

What do the differences mean?

The Phase 1 sample contains a wide range of saproxylic and saprophilic beetles; saproxylic organisms are associated with dead and decaying wood (Grove 2002) and saprophiles live in decaying organic matter, often but not always on the forest floor. The abundance of these taxa, especially some that are obligate forest beetles, indicates that the assemblage is derived from closed forest. This is supported by the abundance of plant-eating taxa (phytophages), especially the presence of several platypodine and cossonine weevils that bore into living—often stressed—trees. There are relatively few aquatic or riparian taxa in the Phase 1 sample; those that are present are relatively uninformative in regard to the specific nature of the aquatic environment, but are consistent with a pool in forest. The absence of the flowing water species that characterise later phases implies that the channel from which the sample was derived did not have abundant flowing water.

In contrast to Phase 1, the samples from Phases 2–4 are dominated by aquatic and riparian taxa and contain a limited saprophilic fauna. A range of taxa indicates open environments, especially in the vicinity of the ditches. In these ditches, the presence of the elmid beetle *Austrolimnius* shows that clean, well oxygenated water flowed over sand/gravel, while other taxa suggest a mosaic of faster water and slower weedy habitats. Several riparian taxa are found predominantly on open sunny sand and mud beside running or standing water. The absence of platypodine and cossonine weevils and saproxylic taxa further supports the interpretation of open environments in contrast with the Phase 1 sample.

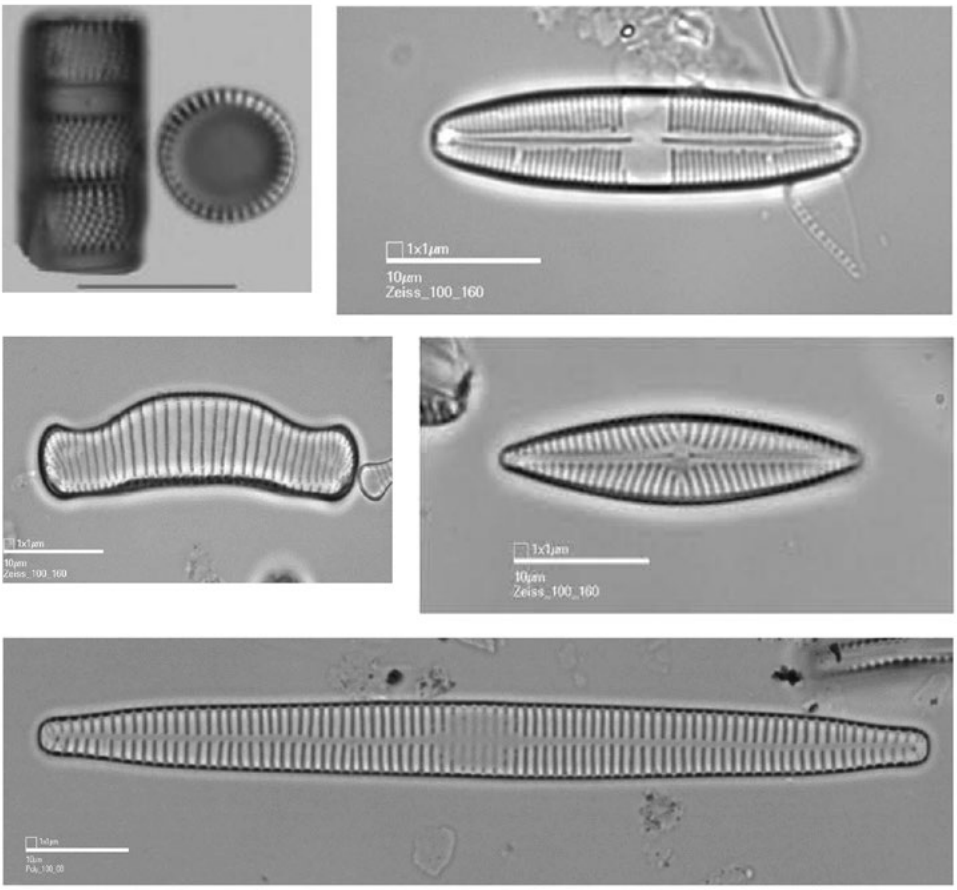
Textbox 9.3 Diatom analysis at Kuk

Krystyna M. Saunders

Diatoms are unicellular algae with a siliceous cell wall that preserves well in most sedimentary environments (Battarbee et al. 2001). They occur in all types of aquatic habitats and are highly sensitive to changes in their environment (Fig. 9.T3.1; Stoemer and Smol 1999). As a result, they are excellent indicators of a wide range of water types and quality, such as nutrient concentrations, pH, salinity, temperature and water depth (Stoemer and Smol 1999). However, diatoms have not been widely used in archaeological studies, despite several authors highlighting their potential value (e.g. Battarbee 1988) and their widespread use in palaeoecological studies (Smol 2008).

Diatom analyses have formed part of the multi-proxy palaeoecological analyses at Kuk (Denham, Sniderman et al. 2009). The major diatom taxa identified in the fills of Phase 1, Phase 2 and early Phase 3 features indicated that there were substantial changes, particularly from open water conditions in the Late Pleistocene to saturated and exposed soil conditions by the mid Holocene (Phase 2; Fig. 9.T3.2). A short-lived drying event c. 10,000 years ago (Phase 1) was associated with formation of an immature soil profile on the wetland margin. A marked transition occurs at the time of mounded cultivation at 6950–6440 cal. BP (Phase 2), when aerophilous, soil diatoms dominate.

Although mid to late Holocene assemblages are dominated by aquatic taxa, the assemblages are distinct from those of the Late Pleistocene when Kuk was an open water environment. High proportions of *Aulacoseira* sp. 1, and to a lesser extent *Synedra ulna* and *Eunotia praerupta*, are common to both periods, but overall diatom compositions vary. These variations represent, in part, differences between an open water system (Late Pleistocene) and standing water environments within abandoned palaeochannels and ditches (Phase 3; mid to late Holocene). The lower abundance of species tolerant of high nutrients, pollution and turbidity in the mid to late Holocene also represents, in part, better water quality within the abandoned waterways. The retention of fine stratification within the fills of channel 107 indicates that they have remained waterlogged, whereas the fills of ditch 353 are shallower below ground surface, drier and have been admixed by a variety of soil formation processes.



1. *Aulacoseira italica* (Ehrenberg) Simonsen[1]
2. *Caloneis bacillum* (Grunow) Mereschkowsky[2]
3. *Eunotia praerupta* Ehrenberg[2]
4. *Navicula cryptotenella* Lange-Bertalot[2]
5. *Synedra ulna* (Nitzsch) Ehrenberg[2]

[1]Diatoms of the United States
[2]Kelly et al. (2005)

Figure 9.T3.1 Common diatoms in the Kuk Swamp palaeoecological record. Scale bar is 10 microns.

Sources: 1. Diatoms of the United States (2013); 2. Kelly et al. (2005), reproduced with permission.

Substantial shifts have also been observed in an unpublished study of diatom assemblages at Kuk, as results of analyses undertaken by Barbara Winsborough (2003), in an appendix in Denham's doctoral thesis (2003a). These were undertaken for a range of archaeological and stratigraphic contexts dating to the early (Phase 1), mid (Phase 2) and late (Phase 3) Holocene. As noted above, the taxa associated with the late Holocene are distinct from taxa associated with the early and mid Holocene (with the exception of *Aulaoseira* sp. 1, *Synedra ulna*, *Eunotia praerupta* and *Luticola mutica*). Consequently, the diatom assemblages enable the local palaeoenvironments for different periods to be characterised: the early Holocene (Phase 1) was characterised by higher nutrients, and acidic and wetter conditions, likely reflecting at least some periods of standing water; whereas, the mid Holocene (Phase 2) was characterised by a dominance of 'soil' diatoms and drier conditions.

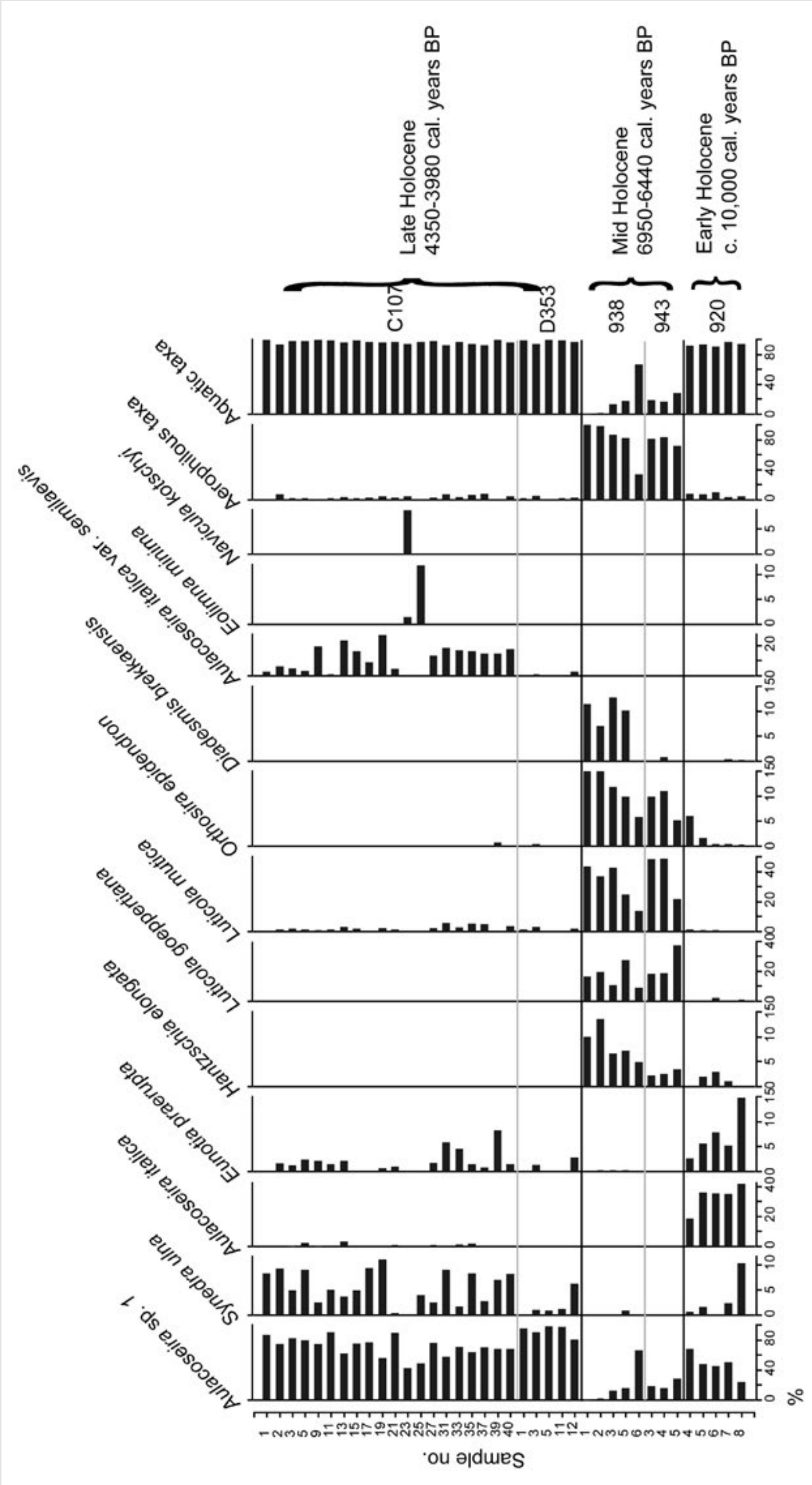


Figure 9.T3.2 Summary of dominant diatoms (× 10% relative abundance) and the proportion of aerophilous and aquatic taxa in the Kuk Swamp palaeoecological record over the last c. 10,000 years.

Source: Drawing by Krystyna Saunders.

Although each technique provides a different type of record, the results complement one another to build up a coherent picture of past environments for the local Kuk wetland and its catchments. At present, the most comprehensive palaeoecological information is available for early and mid Holocene contexts (Phases 1–3), which were considered most significant for understanding the emergence and nature of early agricultural practices. There is limited information on the more recent archaeological phases at Kuk, i.e. Phases 4, 5 and 6.

Palaeoecological reconstruction at Kuk

Pollen and charcoal data have been used to reconstruct the palaeoecology of the Kuk wetland and catchments from the Late Pleistocene to late Holocene. The data are derived from a number of studies that have documented past vegetation in the region with a focus on understanding the timing and nature of past human influence on vegetation (Powell 1970a, 1976b, 1982a, 1982b, 1984; Denham et al. 2003; Denham, Haberle and Lentfer 2004; Denham and Haberle 2008; Denham, Haberle and Pierret 2009; Denham, Sniderman et al. 2009; Haberle et al. 2012). The nature and chronology of early and mid Holocene vegetation change and human impacts were established using palynology corroborated and supplemented by paired phytolith data (Denham et al. 2003). Seed and wood data have also been of some value for inferring environmental change (Powell 1970a, 1982a). Here we outline the environmental changes as interpreted primarily from pollen and charcoal preserved at Kuk Swamp and the wider Wahgi Valley from before 25,000 years ago to the present.

Sites selected for palaeoecological reconstruction in the Wahgi Valley were chosen to provide insight into the nature and timing of human impacts, including forest clearance, burning and the management of cultivated and non-cultivated plants (Table 9.1 and Fig. 9.1 for locations). These sites generally lie close to archaeological excavations, like Lake Ambra, or are directly associated with archaeological features, like the infilled ditches and pits on palaeosurfaces at Kuk Swamp. One of the limitations of the sediment sequences investigated lies in the apparent time gaps in the records. Most of the sites have continuous sedimentation from 5000 years ago to the present, but prior to this date there are major gaps in the records back to the Late Pleistocene. More recent analysis of samples from already dated sections of the Kuk Swamp sedimentary sequence belonging to the late glacial period and the early Holocene has allowed a more complete pollen record for the basin to be constructed (Denham et al. 2003; Denham, Haberle and Lentfer 2004; Denham, Haberle and Pierret 2009; Denham, Sniderman et al. 2009).

Table 9.1 Palaeoecological sites in the Wahgi Valley.

Site	Map ref. no. in Fig. 9.1	Altitude	Age range years ago	Reference
Kuk	1	1580 m	30,000–16,000; >9000–present	Powell 1984; Denham et al. 2003; Denham, Haberle and Lentfer 2004; Denham and Haberle 2008; Haberle et al. 2012; and this chapter
Warrawau (Manton's Baret)	5	1590 m	5000– present	Powell 1982a, b
Kindeng	4	1600 m	2000– present	Powell 1982a, b
Lake Ambra	8	1620 m	32,000–25,000; >5000–present	Powell 1982b
Ambra Crater	8	1680 m	4000–500	Sniderman, Denham and Finn 2009
Draepi-Minjigina	7	1890 m	36,000–18,000; >5000–present	Powell 1976b, 1982b

Source: Data collated by Haberle.

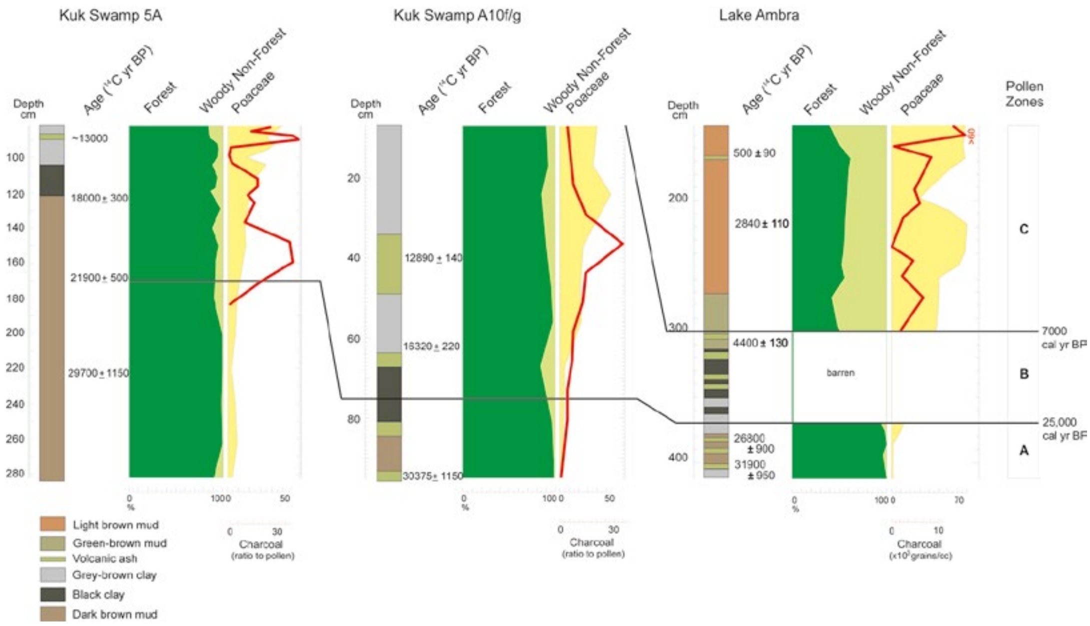


Figure 9.2 Late Pleistocene to late Holocene stratigraphy, radiocarbon ages and summary pollen diagram (pollen sum based on total forest and woody non-forest taxa) based on two cores from Kuk Swamp.

The Kuk 5A site is in C10W, the east drain of N–S Rd 4, 5 m south of its junction with the south drain of E–W Rd 3. The Kuk A10f/g site is 89 m south of E–W Rd 1 in the west wall of A10f/g. Their locations are shown in Chapter 6, Figure 6.4. The Pleistocene radiocarbon dates from the cores are on peats/organic muds which are prone to younger contamination and are therefore minimum age estimates (see Appendix 6.1 here).

Sources: Drawing by Simon Haberle. Kuk 5A and Kuk A10f/g cores redrawn from Powell (1984); and the Lake Ambra core redrawn from Powell (1982b). Reproduced with permission.

Visual or statistical comparison of pollen assemblages preserved in these sites across time and space makes it possible to group assemblages that reflect similar plant communities, such as rainforest or grassland, into pollen zones. This approach allows us to assess the extent and timing of change from one vegetation community to another and, in the present case, develop an understanding of the changes in vegetation community composition preceding and following the development of early agriculture in the area.

Based on the statistical analysis of pollen assemblages from palaeoecological sites in the Kuk Swamp region, we can present an account of the vegetation history of the region spanning the Late Pleistocene to the present. This time span can be divided into three broad periods comprising the Late Pleistocene (prior to 25,000 years ago), the Last Glacial Maximum (LGM, 25,000–18,000 years ago) to early Holocene (before 7000 years ago) and the mid to late Holocene (7000 years ago to the present). These periods are identified in Figures 9.2–9.4 as distinct pollen zones (Zones A–C), generally recognisable across the Wahgi Valley and applying specifically at Kuk Swamp. Analysis of the pollen from the three cores tells a parallel story of vegetation composition and change, which is divided into three shared episodes that register this: Pollen Zone A (before 25,000 years ago), Pollen Zone B (25,000–7000 years ago) and Pollen Zone C (7000 years ago to present).

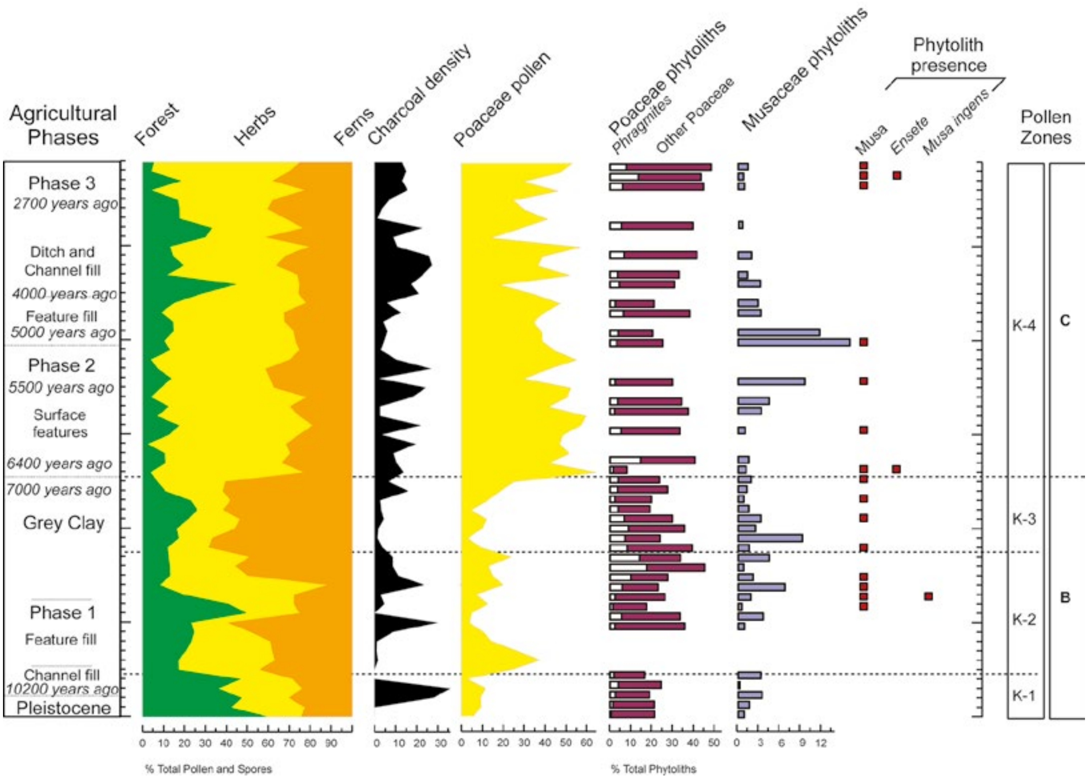


Figure 9.3 Terminal Pleistocene to late Holocene composite pollen diagram of archaeological and stratigraphic contexts at Kuk Swamp, primarily of early and mid Holocene age.

The diagram shows selected pollen, spore and phytolith taxa plotted according to sample age and association with agricultural phases/features (left of diagram): gaps in the phytolith record relate to samples that have not been analysed; charcoal density refers to microscopic charcoal particle concentration from pollen samples. Four significant pollen zones are recognised, K-1 to K-4. Comparable pollen assemblages found throughout Kuk Swamp sediments are assigned to Pollen Zone B (25,000–7000 years ago) and Pollen Zone C (7000 years ago to present). See also Figures 9.2 and 9.4.

Source: Drawing by Simon Haberle.

Late Pleistocene, Pollen Zone A, before 25,000 years ago

Pollen records from Kuk Swamp from core 5A and drain A10f/g, in combination with that from nearby Lake Ambra, document vegetation change from before 25,000 years ago through to the late Holocene (Fig. 9.2). The summary pollen and charcoal records from these three sites show that prior to 25,000 years ago the valley floor was covered in almost 100 per cent mixed montane forest. This forest was dominated by a canopy of *Nothofagus* and *Castanopsis* with an understorey of Cunoniaceae and gymnosperms such as *Podocarpus*. The lack of charcoal particles and very low percentages of grass pollen and woody non-forest pollen point to an environment subject to little or no disturbance. Climatic conditions in the highlands prior to 25,000 years ago are considered to have been essentially cool, probably 2–4°C cooler than present, wet and relatively stable (Haberle, Hope and van der Kaars 2001).

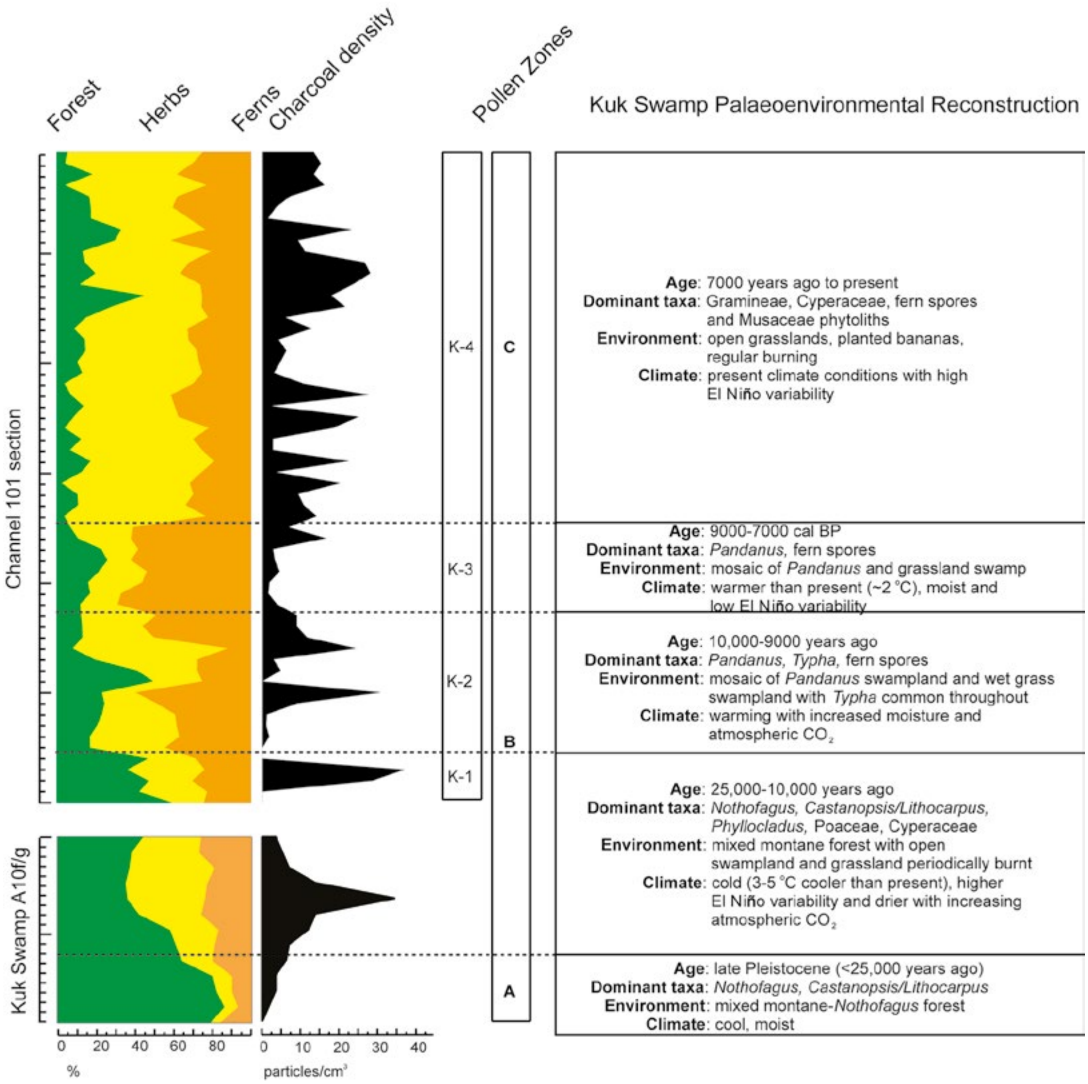


Figure 9.4 Palaeoenvironmental reconstruction for the Kuk Swamp basin based on the composite pollen, charcoal and phytolith record in Figure 9.3, plus drain A10f/g from Figure 9.2 (% based on total pollen and spore sum excluding aquatics for both sections).

Comparable pollen assemblages found throughout Kuk Swamp sediments are assigned to Pollen Zone A (before 25,000 years ago), Pollen Zone B (25,000–7000 years ago) and Pollen Zone C (7000 years ago to present). See also Figures 9.2 and 9.4. Climate summaries follow Haberle, Hope and van der Kaars (2001).

Source: Drawing by Simon Haberle.

While the earliest indications of people in the Wahgi Valley date to around 37,000–31,000 years ago (see Appendix 6.1), the Kosipe area of the Owen Stanley Range has given archaeological evidence of human occupation as early as 49,000–44,000 years ago (Summerhayes et al. 2010). It is entirely possible that people were present in the Wahgi Valley, if only temporarily or seasonally, by this time, but without so far registering in the palaeoecological records. At Kuk Swamp there is a suggestion that people may have been having an impact on the valley floor vegetation as early as 25,000 years ago from the palaeoecological evidence, which shows an increase in woody non-forest pollen and charcoal around this time in the 5A core (Fig. 9.2). This would suggest a shift towards a more sustained use of the region by people that was significant enough to register in the vegetation history record.

The Last Glacial Maximum to the early Holocene, Pollen Zone B, 25,000–7000 years ago

LGM, 25,000–18,000 years ago

While our knowledge of climatic conditions during the period of earliest settlement in the highlands is extremely sketchy, there is a better understanding of LGM to early Holocene climates, thanks in part to long environmental records from marine sediments, coral cores and glacial records (Hope et al. 2004). From these archives it is known that the Ice Age climates of New Guinea were drier than the present, grasslands and savannah probably extended right across the Torresian Plain, the land exposed between New Guinea and northern Australia during periods of low sea level. The climate at high altitudes was also colder, with ice caps on many mountains along the central ranges. Long-term climatic and environmental trends based on the dynamics of equatorial glaciers and pollen records of treeline fluctuations indicate that conditions were dry and possibly as much as 5–7°C cooler during the Last Glacial Maximum (Haberle and David 2004) than at the beginning of the Holocene when a modern temperature regime took hold.

Alpine vegetation covered over 50,000 km^2 above 2700 m at the height of the glaciation about 25,000–18,000 years ago (Hope 1996), compared to some 800 km^2 today above 3900 m. Apart from changes in plant species composition through time, the vegetation boundaries on the lower mountain flanks and northern coasts may not have changed very much. Pollen evidence from peat sections near Mt Trikora (Hope, Flannery and Boeardi 1993), Kosipe (Hope 2009) and Lake Sentani (Hope and Tulip 1994) provide records back 50,000 years or more. These data suggest that closed tropical and montane forests have continuously occupied many areas from before the likely arrival times of people. The wet conditions that supported the rainforests seem to have been maintained all along, indicating that the tropical waters of the Western Pacific Warm Pool north of New Guinea persisted through the Late Pleistocene (Thunnell et al. 1994), providing moisture to the high inland regions of New Guinea. Under these conditions it might be expected that the highland valleys lying below the altitudinal treeline would have maintained their forest cover throughout the LGM to the early Holocene. However, this is not the case, as at least two pollen records, from Tari (Southern Highlands Province, Haberle 1998b) and Kuk Swamp (Denham et al. 2003), have evidence for episodes of increased burning and loss of forest cover during the LGM to the early Holocene. Details of these vegetation changes at Kuk Swamp are presented here in Figures 9.3 and 9.4.

The period of postglacial warming, 18,000–10,000 years ago

The Kuk Swamp region in the period from 18,000–7000 years ago is very dynamic in terms of vegetation change, including a loss of the montane forest cover with shifts in forest composition towards a dominance of understorey and light-demanding components represented by genera like *Trema*, *Acalypha*, *Macaranga* and *Dodonaea*. The period saw the first evidence for major burning events followed by grassland expansion, showing that grasslands had expanded under the influence of fire. This process of punctuated forest loss, burning and changing forest composition continues to the end of the early Holocene, suggesting a dynamic pattern of forest and grassland persisted through this period. The reasons for these changes are not clear, though it is possible that people may have been responsible for an increase in the frequency of fire events. Alternatively, regional palaeoclimatic indicators point towards rapid and high-amplitude changes in temperature and precipitation, extended dry periods and high-frequency El Niño–Southern Oscillation (ENSO) events from around 18,000–10,000 years ago (Haberle, Hope and DeFretes 2001; Denham and Haberle 2008), that may have been of sufficient magnitude in the highland valleys to impact upon natural vegetation cover and fire regimes.

The argument for people being a factor in vegetation change in the Wahgi Valley from the LGM to the early Holocene is limited to inference from what is known of the nature of human occupation and resource exploitation in the region during this period and the changes recorded in the pollen records. The human occupants of the Wahgi Valley during the LGM inhabited a largely forested valley floor, with a gradually decreasing proportion of upper montane forest (dominated by *Nothofagus*) and a corresponding increase in the proportion of lower montane forest (dominated by *Castanopsis-Lithocarpus*) through time. In addition to faunal resources, the landscape offered ready access to the nutritious members of the high-altitude *Pandanus brosimos/iwen/jiulianettii* complex (Haberle 1995), as well as to diverse resources of the lower montane forests (Golson 1991a).

Rather than merely passively gathering resources, it may be suggested that people were already opening up patches in the forest using fire and, arguably, stone tools to ringbark and clear vegetation (after Groube 1989). People possibly focused on gaps in the forest canopy, such as those caused by tree-fall and landslides, as well as riverbank and wetland ecotones, where resources may have been different and potentially more diverse than those found under the forest canopy (Denham and Barton 2006; Haberle 2007). Some gaps in the forest would have been maintained through fire and clearing and patches of grassland would potentially have formed adjacent to wetlands and along river corridors due to localised and sustained forest disturbance. As patches became maintained foci of activity, so too the resources within those gaps—including herbs (*Musa* spp.), tuberous plants (potentially including taro and yams), grasses (*Saccharum* spp. and *Setaria palmifolia*) and a wide variety of leafy vegetables—were brought under increasing management (see Table 10.1). Although people may not have resided permanently in the Wahgi Valley at this time, there are many reasons to believe that mobile groups lived permanently within the forested interior of New Guinea during the Pleistocene (Denham 2007c).

The early Holocene, 10,000–7000 years ago

This period has been a particular focus of recent palaeoenvironmental research at Kuk (Fig. 9.3, Zone K-2 to K-3) because of a lack of information about it in the upper Wahgi Valley in general. The situation was remedied by targeting samples from a continuous series of monoliths extending from the Late Pleistocene to the late Holocene, as well as by collecting and radiocarbon dating samples from the fills of palaeochannels and palaeosurface features (Denham, Sniderman et al. 2009). This has enabled detailed reconstructions of palaeoenvironments during both the early and mid Holocene (see Fig. 9.3 for detail). In addition, a composite diagram from Kuk Swamp is reproduced here to illustrate the vegetation history from before the LGM to the present (Fig. 9.4).

In the first thousand years of the early Holocene (Fig. 9.3, zone K-2), mixed montane forest was replaced by a more open forest environment, with local swamp forest dominated by *Pandanus* (probably *P. antaresensis*) and *Schefflera*. The deposition of a massive grey clay unit across the swamp surface (Fig. 9.3, zones K-2 and K-3) occurred at a time when grasslands and fern flora increase at the expense of forest under the influence of periodic fire episodes. At the same time, the catchment forest became more open, with subcanopy taxa, particularly *Pandanus*, dominant. The grey clay unit has long been considered a result of erosional processes associated with catchment destabilisation due to forest clearance under shifting cultivation (see Chapters 6 and 11). However, increased sediment mobilisation due to natural processes associated with increased precipitation and vegetation destabilisation at the end of the period of postglacial warming cannot be ruled out.

Denham (2005b: 301) discusses the nature of agricultural practices at this early period and suggests that the earliest gardens were likely to have been small areas of specially prepared ground, actively planted for only a short time and characterised by the vegetative propagation and intercropping of plants from wild and heavily tended sources. The most significant evidence for the emergence of more intensive forms of plant exploitation is associated with microscopic remains from two major edible plants present in the Kuk vicinity at this time, namely *Colocasia* taro and Musa (until recently Eumusa) section bananas (Denham et al. 2003; see Table 10.T2.1 for bananas and Fig. 10.T3.2 for taro; on the change of section name in banana see Table 10.1, note 7).

Banana phytoliths are present at the base of the grey clay unit (see Fig. 9.3). Their frequencies within later grey clay contexts are significant, with intact phytolith chains indicating that the parent plant was growing on the spot (Table 10.T2.1). *Colocasia* taro has been identified from starch residues on the cutting edge of a flake collected from the fill of an early Holocene feature (see Fig. 10.T3.2). The same is true of artefacts collected from within grey clay (see Chapter 20, section 'Between Phases 1 and 2'). There were starch grains of yam, *Dioscorea* sp., on a used stone from the base of the Phase 1 palaeochannel (see Fig.10.T3.3), while a felsic volcanic core tool low down in the grey clay above the Phase 1 palaeosurface had residues of both yam and taro starch (Chapter 20, section 'Between Phases 1 and 2'; Fullagar et al. 2006: 605).

Mid to late Holocene, Pollen Zone C, 7000 years ago to present

At the beginning of the mid Holocene, around 7000 years ago (Figs 9.3 and 9. 4, Pollen Zone C), there was a rapid loss of forest together with increased burning at Kuk and an open grass and sedge swampland was established. These developments were associated with the beginnings of archaeological Phase 2, a period of mound cultivation that represents the earliest evidence for more intensive forms of plant exploitation, in the context of swidden agriculture and extensive foraging and gathering (Denham et al. 2003; Denham, Sniderman et al. 2009; cf. Chapter 12 here). The evidence for similar mound cultivation at Mugumamp and Warrawau at a somewhat late date (Denham 2003b: 173–174) suggests that forest clearance, widespread use of fire and the establishment and maintenance of disturbed environments were regional processes in the upper Wahgi Valley, reflecting the emergence of an agricultural landscape from around 7000–6500 years ago. This predates Powell's (1982b: 218) pollen record from Warrawau, but when the latter does begin, around 6000 years ago (calibration of ANU-252, Powell 1970a: 146), it shows the environmental changes that we are discussing to be well under way.

The emergence of more intensive plant exploitation at Kuk in the form of mounded cultivation is associated with further microscopic evidence for *Colocasia* taro and Musa section bananas, two major edible plants that were identified in early Holocene Phase 1 contexts at the site, as discussed above. Relatively high frequencies of banana phytoliths, including those of the Musa section, in early Phase 2 contexts are, in view of their association with the mound technology, especially significant (Denham et al. 2003: Fig. 3; Table 10.T2.1 and Fig. 10.T2.1 here). Given the low productivity of phytoliths in bananas relative to grasses, elevated frequencies in Phase 2 contexts have been interpreted as indicating the cultivation of bananas on the wetland margin within a landscape degraded to grassland (Denham et al. 2003: 191–192). *Colocasia* taro starch has been identified on an artefact found in the fill of a Phase 2 feature (see Chapter 20, 'Phase subdivision 2C'; cf. Fullagar et al. 2006: 607).

During the mid Holocene, plant exploitation is likely to have been extremely diverse and have included gathering, patch creation, swidden cultivation and intensive forms of mounded cultivation. These practices would all have co-occurred across the landscape, with a gradually increasing reliance on plot cultivation as access to primary or disturbed forest became more restricted for groups inhabiting the valley. Following several thousand years of persistent forest disturbance, most of the valley floor and slopes were degraded to grassland (Figs 9.2–9.4). A major loss of high-diversity valley-floor swamp forests (Haberle 2007) and the expansion of dryland environments are indicative of persistent agricultural activity during this period. By around 2500 years ago, only isolated pockets of disturbed forest survived within the valley, with stands of heavily utilised primary forest confined to the higher slopes above 2000 m. The extensive grasslands carpeting the floor of the Wahgi Valley were periodically burned and would have been depauperate in large to medium-sized mammals and in edible plants. Within this highly degraded but intensively settled landscape, people had less access to land for swidden cultivation and foraging. Although these activities were still likely to have been practised by people living on the valley floor where and when possible, such people became increasingly reliant on intensive forms of cultivation, mounds and other types of raised bed cultivation on dryland and ditched field systems in wetlands.

Several archaeological sites of wetland drainage for cultivation besides Kuk are on record for the upper Wahgi Valley and adjacent regions, like Kana, Mugumamp, Warrawau, Draepi-Minjigina and Tambul (Fig. 9.1 inset), with Mogoropugua and Haeapugua further afield in Southern Highlands Province (Golson 1982; Denham 2003b, 2005a, 2007a). Rectilinear ditch networks like those of Kuk Phase 3 were in use in the Wahgi and at Tambul by 4000 years ago, the Tambul site producing an early wooden agricultural implement of that date (Golson 1996), while there is evidence at a number of sites of phases of abandonment and reuse on the Kuk pattern (Denham 2005a: Table 2). Current evidence suggests that these developments were indigenous (Chapters 5 and 13; cf. Denham 2005a). Not only would the drainage of wetlands to create ditched field systems have greatly increased the area available for cultivation, but the drained land, particularly compared with heavily weathered valley slopes, would have been extremely fertile, amenable to cultivation for several years without fallow and relatively resistant to the increased frequency of ENSO-induced droughts.

Complementary developments in the dryland sphere are discussed for Phases 4 and 5 in Chapters 14 and 15, respectively. They comprise the adoption of soil tillage around 2500 years ago, *Casuarina* agroforestry techniques around 1200 years ago and raised-bed cultivation sometime between 1000–500 years ago. All these represent strategies to alleviate the consequences of forest loss followed by soil nutrient depletion. In the case of deliberate planting of *Casuarina* close to settlements, this development would have removed the need for further forest destruction for timber and thus reduced the resource loss that such destruction entailed.

A final word

The story of agricultural development in the highlands of New Guinea is one of continuing indigenous innovation in agricultural techniques in the face of increased land degradation and climate change (cf. Haberle 1994; Haberle and David 2004). Further insights into how agriculture transformed these highland valleys can be gained through application of new approaches such as high-resolution sampling and multi-proxy palaeoenvironmental reconstructions (Denham, Haberle and Pierret 2009; Denham, Sniderman et al. 2009). These insights bring us one step closer to understanding how people adapted to major environmental perturbations such as changing climates, land degradation and volcanic eruptions.

10

The Archaeobotany of Kuk

Carol Lentfer and Tim Denham

Introduction

The study of plants in archaeology—archaeobotany—is key to discovering how and when people exploited, cultivated and domesticated plants in the past, influenced their dispersal and effected their present-day biogeographic distributions. Archaeobotanical study incorporates a complex of methodologies, often reliant on carefully planned and executed sampling strategies and dependent on good preservation of various plant remains (Pearsall 2000).

Traditionally, the method for studying plant remains in archaeological deposits has been the analysis of macro remains of hardy material such as seeds, wood and nutshell (Textbox 10.1). These can provide direct evidence for human/plant association. However, they are not always available for study, being best preserved in extremely dry and cold environments, as well as in anaerobic conditions such as waterlogged deposits. Generally, macrobotanical remains are poorly preserved in well drained, acidic environments, particularly in the wet tropics, unless they have been burnt and converted to charcoal; even after burning it is usually only the hardy types of material that are preserved. Consequently, macrobotanical remains are limited in what they can tell us about the finer details of changing environments, plant distributions, manipulation and human exploitation because preservation in the wet tropics, when it does occur, is inconsistent, favouring some plants and/or plant parts over others.

It is often the case, therefore, that other analytical techniques are required to complement and enhance the analysis of macroremains or fill the gap in instances where they are not preserved. As well as firmly established pollen/spore and microcharcoal analyses, a host of microscopic techniques have been developed and applied to tropical archaeobotany over the last three decades of the 20th century (see Hather 1994), involving plant fibres, parenchyma and other plant tissues, as well as phytolith, starch and raphide analyses. These techniques enable the identification of a broader array of soft tissues than is usually preserved at archaeological sites, including the microscopic remnants of fruits, roots, rhizomes and tubers. Besides microscopic analysis, a number of chemical, spectrographic and other biomolecular techniques have potential to identify plant residues like resins, proteins, enzymes, lipids and fatty acids preserved on stone tools, pottery and other artefactual material (see Denham, Atchison et al. 2009 for a review). Additionally, techniques have been developed for ancient DNA (aDNA) analysis of plant remains and are presently being developed for identifying plant residues in sediments and on artefacts (Schlumbaum, Tensen and Jaenicke-Despres 2008).

Textbox 10.1 Plant macrofossils: Seeds, fruits and wood

Andrew Fairbairn and Peter Matthews

What are plant macrofossils?

These are relatively large (>0.25 mm) parts or fragments of plant material preserved in sediments that can come from short-lived annual herbs or longer-lived perennials (herbs, shrubs and trees) (Fig. 10.T1.1). Macrofossils can be derived from many different plant parts: seeds, fruits, leaves, stems and roots. They are usually visible to the human eye, but their identification often requires the use of a microscope.

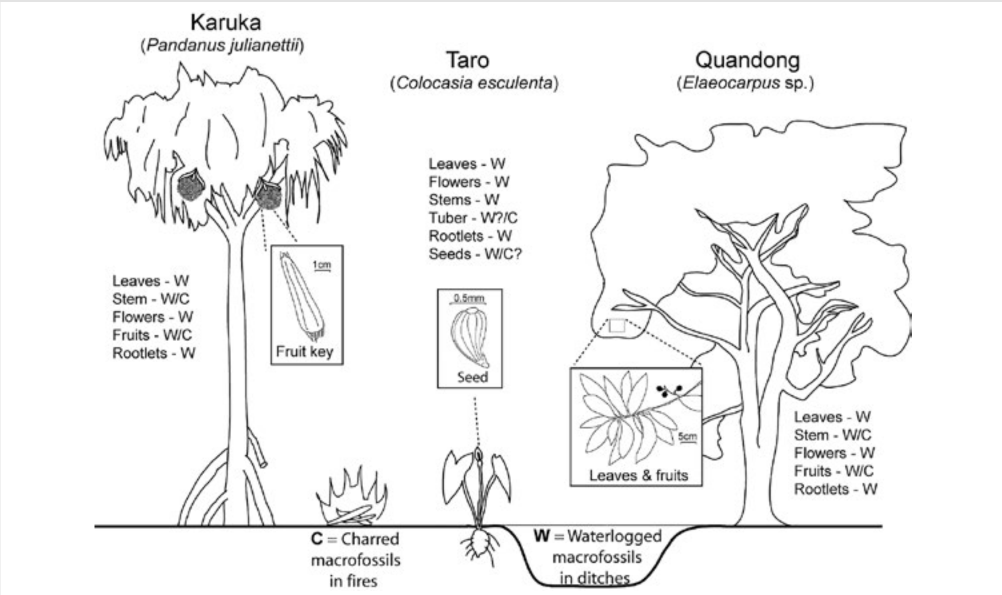


Figure 10.T1.1 Potential macrofossil preservation in three highlands plants.

Source: Drawing by Andrew Fairbairn.

How are macrofossils preserved?

Plant materials can be preserved if they are:

- buried in low-oxygen environments, such as the waterlogged sediments at Kuk;
- partially burnt, charred or carbonised;
- deposited in a constantly dry location, such as inside a cave;
- resistant to decay, e.g. the hard fruit stones of hackberry (*Celtis* spp.).

Waterlogging can preserve most plant parts. Charring favours tougher parts (seeds, wood and fibrous tissues) and can destroy more fragile parts (the soft tissues of fruit and leaves).

What can macrofossils tell us?

Seeds are often starchy food sources and their preservation can provide information about the occurrence and use of food plants. Wood charcoal can tell us what trees were used as firewood or for building houses. Different plants grow in different environments and plant macrofossils can be used to reconstruct the environmental conditions and local flora that existed in the past. Macrofossils are usually deposited close to where the living source plants were growing and can often be identified to the species taxonomic level. They are thus complementary to the evidence provided by microfossils such as pollen and phytoliths, which are more easily dispersed over long distances (in the air or in eroding soils) and which are often more difficult to identify to species level.

How are macrofossils collected?

Some macrofossils can be collected directly by excavation with a trowel or by sieving dry sediments, but most are collected through flotation. The flotation technique is best for charred remains, which are very buoyant. Any organic remains that float can be collected in a sieve after mixing excavated sediment with water (Fig. 10.T1.2).

Figure 10.T1.2 Herman Mandui (left) of the PNG National Museum demonstrates wet sieving in Sandaun (formerly West Sepik) Province, PNG.

Source: Photograph by Andrew Fairbairn.

How are macrofossils studied?

Macrofossils are identified by comparison with known living plants. We compare:

- morphology (shape, size and surface structure), using low-powered microscopy (5–50x magnification); and
- anatomy (the internal tissue structure), using high-powered microscopy (50–5000x magnification).

Seeds can often be identified to species level using morphology. Anatomical study is required to identify fragments of wood or other parts that lack a diagnostic morphology and wood is commonly identified only to family or genus level. Changes in the quantity of macrofossils (counts or weights) over time are used to interpret economic and environmental changes.

Example 1: Prehistory of nut pandanus

Highlands pandanus nuts, including those of the type denoted by the pidgin term *karuka*, such as *P. brosimos* and *P. iwen*, are important foods that are likely to have been used since the time of earliest human presence in the mountainous interior of New Guinea. The oldest charred archaeological nutshells to be radiocarbon dated are from the Ivane Valley in the Papuan highlands and fall between about 36,000 and 34,500 years ago (Fig. 10.T1.3; Fairbairn, Hope and Summerhayes 2006: 379; Summerhayes et al. 2010: 78).

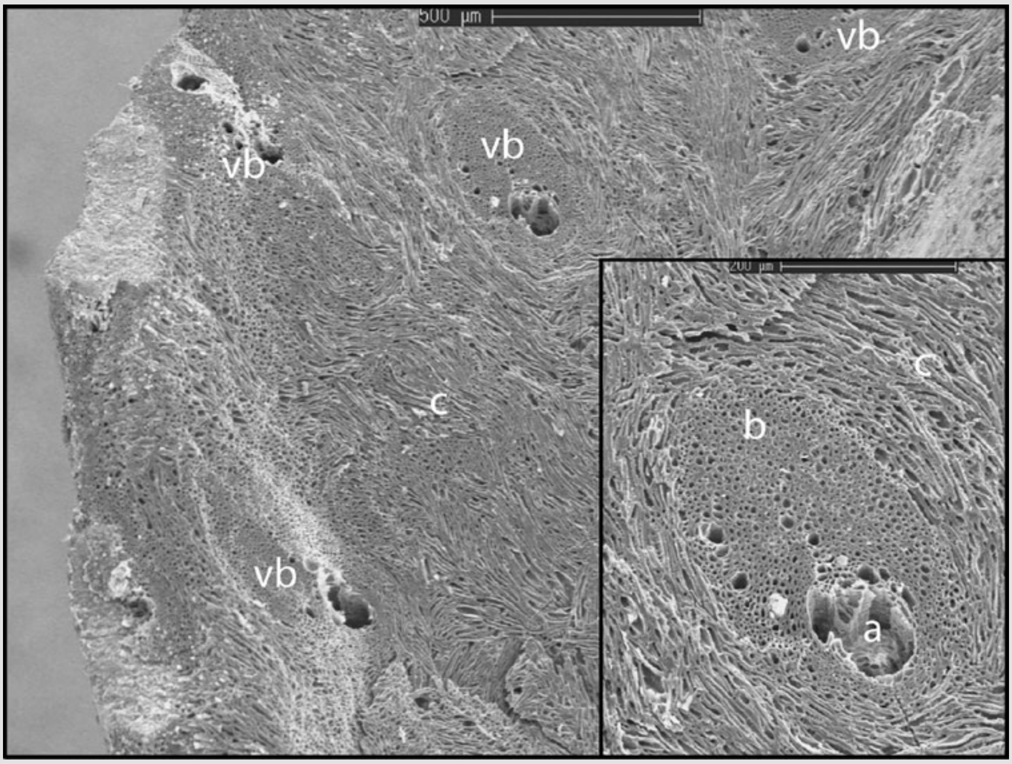


Figure 10.T1.3 Transverse section through a burnt 30,000-year-old *karuka*-type nutshell from Kosipe with vascular bundles (vb) highlighted; inset shows vascular bundle anatomy, a = vascular elements; b = bundle sheath, c = ground tissue. Photographs were taken using a scanning electron microscope.

Source: Photograph by Andrew Fairbairn.

Nutshells found in archaeological sites in the Manim Valley near Mount Hagen (Christensen 1975; Donoghue 1988) show the use of another pandanus species, *P. antaresensis*, from wild or managed stands, from first occupation before around 12,000–10,000 years ago to just after 7000–6000 years ago. After this its use declined, perhaps due to a greater reliance on cultivation (see Chapter 14, section 'Forest foraging and high-altitude cultivation').

Example 2: Plants cultivated in the wetlands

At the Kana site, excavators recovered the remains of a single gourd buried in mud, with seeds still associated with pieces of gourd skin (Fig. 10.T1.4; Matthews 2003). These seeds were identified by comparing them with published pictures and herbarium specimens of seeds from other plants in the same family (the cucumber family, Cucurbitaceae). The identification of wax gourd (*Benincasa hispida*) is important because it confirms the presence (and likely cultivation) of a plant that in modern times has had multiple uses as food and as container.

Some very small seeds from Kuk were found only by chance, when sediment samples were processed by Tara Lewis to allow Nick Porch to look for small insect remains (see Textbox 9.2). The seeds are big enough to see by eye (0.5–1 mm approximately), but were not found until a low-magnification microscope was used. They were too small to describe without using the more powerful scanning electron microscope (SEM) (Fig. 10.T1.5). At present, we are not sure what plants these seeds came from. We do know that they come from more than one kind of plant because they have very different shapes. One of the plants may be an aroid, from the Araceae, a family that includes taro (*Colocasia esculenta*), but we are unsure—other plants may produce similar seeds.

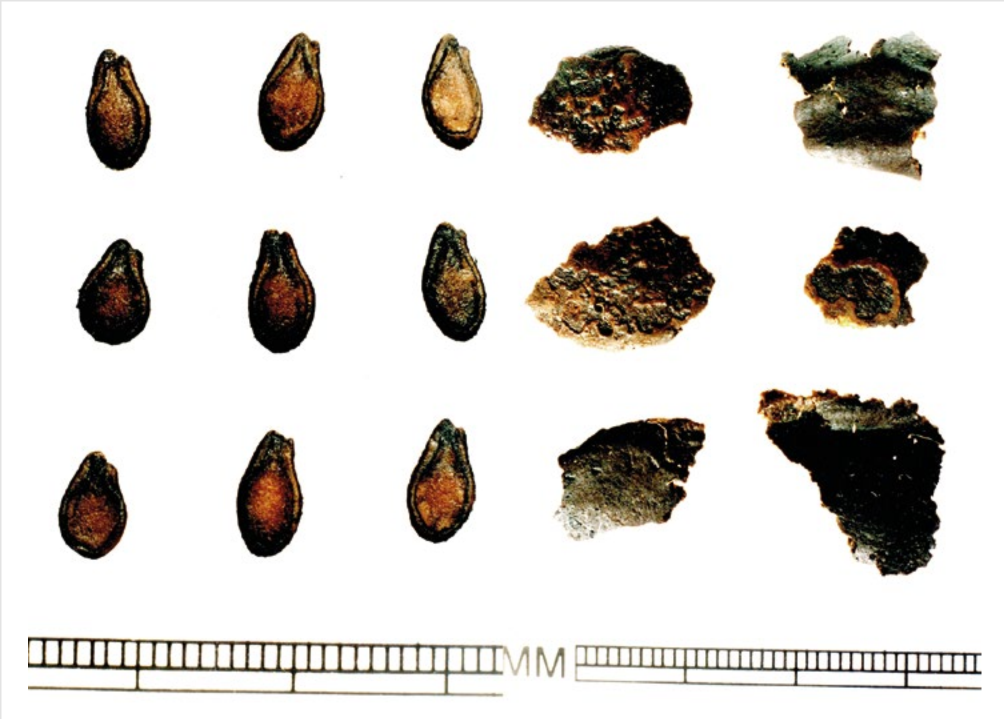


Figure 10.T1.4 Ancient gourd rind fragments (right) and seeds (left) of wax gourd (*Benincasa hispida*) from the Kana site.

Source: Matthews (2003), reproduced with permission. Photograph by Darren Boyd.

Figure 10.T1.5 Electron micrograph of an aroid-like seed from the 10,000-year-old fill of the Phase 1 palaeochannel, Kundil's Baret, at Kuk (average seed dimension 600 x 300 µm).

Modern taro seeds are typically larger (seed dimension 1000 x 500 µm). The ancient seed illustrated was identified in a sediment sample collected in the field by Tim Denham in 1998.

Source: Image taken on a Cambridge S360 SEM (ANU Microscopy Unit) and is reproduced courtesy of Simon Haberle and Tim Denham.

Table 10.1 Archaeobotanical table listing potential food plants documented from Pleistocene and Holocene contexts at Kuk. Only potential food plants are considered, although other uses may have been as important in the past (cf. Powell 1976a).

Species/Genus[1]	Exploited Form[2]	Edible Part(s)[3]	Archaeobotanical Evidence[4]	Earliest Record[5]
Abelmoschus sp.[6]	c	l, sh	s	pre-P1
Acalypha sp.	w, t	l	s, p	pre-P1
Castanopsis sp.	w, t	n	w, p?	pre-P1
Cerastium sp.	w	p	s	pre-P1
Coleus sp.	w	l	s	pre-P1
Ficus cf. *copiosa*[6]	c, w	f, l	s	pre-P1
Ficus spp.	c, w	l, f	w	pre-P1
Garcinia sp.	w	f, l, b	w	pre-P1
Hydrocotyle sp.	w	l?	s	pre-P1
Lycopodium spp.	w	sh	p	pre-P1
Maesa sp.	w	f	s, w	pre-P1
Musaceae	c, w	f, c	ph, st	pre-P1
Oenanthe javanica	c, w	l, sh	p	pre-P1
Pandanus cf. *antaresensis*	w	d	p	pre-P1
Pandanus cf. *brosimos*	c, w	d	p	pre-P1
Pandanus spp.	c, w	d	s, p	pre-P1
Parsonsia sp.	w	n	p	pre-P1
Phragmites karka	w	l, r, sh	ph	pre-P1
Pouzolzia hirta	w	l, st	s	pre-P1
Rubus moluccanus	w	f	s	pre-P1
Rubus rosifolius	w	f	s	pre-P1
cf. *Setaria palmifolia*	c, w	s	ph	pre-P1
Solanum nigrum	c, w	l, sh	s	pre-P1
Syzygium sp.	w	f	w	pre-P1
Wahlenbergia sp.	w	p	s, p	pre-P1
cf. Zingiberaceae	c, w	r, l, sh	ph	pre-P1
Colocasia esculenta	c	c, l	st	P1
Dioscorea sp.	c	t	st	P1
Elaeocarpaceae	w	n	p	P1
Ipomoea sp.	w	sh	p	P1
Musa section bananas[7]	c, w	f, c	ph	P1
Ingentimusa section[7] bananas	w	f, c?	ph	P1
Phragmites sp.	w	st	ph	P1
Typha sp.	w	st	p	P1
Solanum sp.	c, w	f, l, sh, t	s	pre-P2
Commelina sp.[6]	c, w	l, sh	s	P2
Drymaria cordata[6]	w	l?	s	P2
Floscopa sp.[6]	c, w	l, sh	s	P2
Viola arcuata	w	l	s	P2
Amaranthus sp.	c	l, p	s	P2/P3
Bidens pilosa	w	s	p	P2/P3
Polygonum chinense	w	l	s	P4/P6
Finschia sp.	w	s	s	P5

Species/Genus[1]	Exploited Form[2]	Edible Part(s)[3]	Archaeobotanical Evidence[4]	Earliest Record[5]
Saccharum officinarum	c	st	pa	P5/6
Bambusa sp.	c, w	sh	w	P6
Ipomoea batatas[8]	c	t	t	P6
Elaeocarpus sp.	w	n	w	P6
prob. *Ipomoea batatas*	c	t	pa	P6
Polyscias sp.	w	l	w	P6
Oxalis corniculata	w	l, sh	s	post-P6

Source: Updated version of Denham et al. (2003: Table S3) and Denham, Haberle and Lentfer (2004: Table 2).

Notes:

[1] List of edible species at Kuk based on ethnographically documented use of plants in New Guinea (Powell et al. 1975: 15–39; Powell 1976a: 108–112; Powell with Harrison 1982: 57–86; French 1986; M. Bourke 1989 and pers. comm., 2002; Haberle 1995; G. Hope, pers. comm., 2002). Edible species have been reported from other early and mid Holocene archaeological sites in the highlands.

[2] Exploited form: c = cultivated, w = wild (used as supplementary food), t = transplanted.

[3] Edible part(s): b = bark, c = corm, d = drupe, f = fruit, g = gourd, l = leaf, n = nut, p = plant, r = rhizome, s = seed, sh = shoot, st = stem, t = tuber.

[4] Evidence: p = pollen (by Simon Haberle), pa = parenchyma (by Tara Lewis), ph = phytolith (by Carol Lentfer), s = seed (by Jocelyn Powell and Laurie Lucking), st = starch (by Richard Fullagar, Judith Field and Michael Therin), t = tuber (by Jon Hather), w = wood (by Jocelyn Powell and Laurie Lucking). Only those cases relevant for the earliest recorded occurrence are listed.

[5] Earliest record are given for Pleistocene contexts (pre-P1), Phase 1 contexts (P1), contexts postdating Phase 1 and predating Phase 2 (pre-P2), Phase 2, 3, 4, 5 and 6 contexts (P2-6), and postdating Phase 6 (post-P6).

[6] Identification to genus or species level should be considered provisional because it is based on a single seed.

[7] A review of the sections within the genus *Musa* (Wong et al. 2002), which is not universally accepted (De Langhe et al. 2009), has reclassified the five former sections into three: section Musa contains the former Eumusa and Rhodochlamys; section Callimusa contains the former Callimusa and Australimusa; and section Ingentimusa remains the same. Previous identifications of Callimusa (formerly Australimusa) phytoliths from Phase 2 and 4 contexts at Kuk (Wilson 1985: Table 3) are excluded because they were based on a single phytolith each and no such phytolith morphotypes were documented from Phase 1–3 contexts at Kuk targeted during recent research (Denham et al. 2003: 192).

[8] Provisionally identified as *Dioscorea esculenta* by Jon Hather (pers. comm. to Jack Golson), although reanalysis suggests probably *Ipomoea batatas* (Lewis, Denham and Golson 2016).

Interdisciplinary study at Kuk since the early 1970s has made several significant contributions to archaeobotanical research in Melanesia. A combination of techniques has obtained evidence for the presence of a suite of food plants at Kuk from the Pleistocene to the present (Table 10.1). The focus here is on food plants, although plants were used for a variety of different purposes including medicines, ornamentation, rituals, construction, tools and so on (Powell 1976a).

Archaeobotanical investigations were undertaken on samples collected from archaeological and stratigraphic contexts, with subsequent identification of micro- and macrobotanical remains to genus and species level, where possible. The results of macrobotanical work undertaken in the 1970s were complemented during the 1990s by employing microfossil techniques, primarily phytolith analysis of stratigraphic samples (Textbox 10.2) and starch granule analysis of tool residues (Textbox 10.3) to yield evidence of plants that do not regularly produce pollen or seeds under cultivation, specifically bananas (*Musa* spp.), taro (*Colocasia esculenta*) and yams (*Dioscorea* spp.). The 1970s investigations targeted all archaeological phases and major stratigraphic units at the site, whereas the 1990s investigations targeted early and mid Holocene contexts only.

Textbox 10.2 Analysis of opaline phytoliths at Kuk

Carol Lentfer

Introduction

Opaline silica phytoliths are produced in plants as biogenic silica derived from monosilicic acid deposited in cells and cellular spaces. Similar to other plant microfossils such as pollen, spores, raphides, druses and starch granules, they are deposited as discrete or articulated units in sediments following decomposition of plant tissues. Consequently, they can be used for reconstruction of vegetation at a localised level, providing the means for the reconstruction of on-site vegetation and change according to natural or anthropogenic processes. However, as with all particulate sedimentary inclusions, phytoliths can be subject to translocation through water and wind movement, which results in them ending up in different sedimentary locations such as swamps, lakebeds, seabeds, dunes or glacial deposits. This gives the opportunity for analysis of vegetation at a more regional level, the scale of which is determined by the types of taphonomic processes operative in specific geographical settings.

Phytolith production in plants can be influenced by soil characteristics and other environmental factors, but primarily it is genetically determined. Some plant families such as grasses and sedges have very high phytolith production and others such as aroids (e.g. taro), yams and *Pandanus* spp. are characterised by having very low or nil phytolith production. Furthermore, unlike pollen and spore production, where only one morphotype is produced, a single plant species can produce multiple types of phytoliths, referred to as 'multiplicity'. In some instances, different plant parts such as leaves, stems, flower bracts and fruit produce different diagnostic morphotypes, which can sometimes be useful for determining how plants may have changed or been exploited in the past. However, many plants produce morphotypes that are the same or very similar and difficult to differentiate, especially when phytoliths become disarticulated and occur as discrete particles in phytolith residues. This is referred to as 'redundancy'. Many trees and shrubs in New Guinea are characterised by this feature, sometimes making it very difficult to identify plants to species, genus or family level from the analysis of phytoliths alone (Lentfer 2003b). Nevertheless, given the overall capacity to discriminate between particular plant groups and identify patterns of vegetation change and other important environmental processes, phytolith analysis has proven to be an extremely useful tool for palaeoenvironmental reconstruction in New Guinea (e.g. Lentfer and Green 2004; Lentfer and Torrence 2007).

Phytolith analysis at Kuk

Phytolith analysis was undertaken for various Late Pleistocene and early to mid Holocene contexts at Kuk, including through major stratigraphic units and the fills of palaeochannels, ditches and features associated with Phases 1, 2 and 3. It was thought that phytolith analysis would offer an effective means for palaeoenvironmental reconstruction: identifying past vegetation growing in the swamp and on the surrounding hillsides; tracking environmental change and helping to estimate its extent and identify its cause, whether induced by shifts in climate or by human activity. It would also have the potential to build on previous phytolith studies undertaken at Kuk documenting the presence and introduction of economically important plants (Wilson 1985; Bowdery 1999).

Methodology

Phytoliths were extracted from 40 sediment samples (see Table 10.T2.1), using heavy liquid extraction (Lentfer and Boyd 1998). Phytoliths were mounted in benzyl benzoate and examined using optical microscopy at 400x and 600x magnification. At least 400 phytoliths were recorded per sample. Following initial counts, slides were quick-scanned to record presence of previously unrecorded morphotypes. Morphotypes were assigned to categories representing either plant groups or phytolith groups dependent on diagnostic potential.

Table 10.T2.1 Percentage composition of diagnostic *Musa* and *Ensete* seed phytoliths in phytolith assemblages.

Archaeostratigraphy	Sediment sample no.	Musaceae phytoliths % of total	Diagnostic seed phytoliths/ total Musaceae		
			M	E	I
Black silty clay	1	1.42	12.5	0	0
Black clay	2	0.71	+	+	0
	3	0.83	+	+	0
Phase 3	28	0.51	0	0	0
palaeochannel fills (103)	30	n/c(+)	0	0	0
	32	1.90	0	0	0
Phase 3	58	1.34	0	0	0
palaeochannel fills (107)	59	n/c(+)	0	0	0
	60	3.09	0	0	0
Early Phase 3	52	2.78	0	0	0
ditch fill (353)	53	3.16	0	0	0
Late Phase 2	55	11.49(+)	0	0	0
curvilinear feature fill (504)	56	15.77(+)	9	0	0
Early Phase 2	35	9.38(+)	12.5	0	0
palaeosurface feature fill (3004)	36	4.37(+)	0	0	0
Early Phase 2	37	3.24	0	0	0
palaeosurface feature fill (3009)	38	0.95	20	0	0
'R+W'	4	1.53(+)	0	44.4	0
Grey clay	5	1.12	+	0	0
	6	1.82	16.6	0	0
	7	1.26	0	0	0
	8	0.76	+	0	0
	9	1.53	0	0	0
	10	3.18(+)	10.5	0	0
	11	2.42	0	0	0
	12	9.05(+)	0	0	0
	13	1.57(+)	+	0	0
	14	4.39(+)	0	0	0
	15	0.75	0	0	0
	16	2.11(+)	+	0	0
	17	6.61	4.7	0	0
Phase 1	18	1.80	+	0	0
palaeochannel fill (101b)	19	0.49(+)	66.6	0	+
	20	3.16(+)	0	0	0
Phase 1	25	3.57	0	0	0
palaeosurface feature fill (1401)	26	0.83	0	0	0
Phase 1	21	0.22	0	0	0
palaeochannel fill (101a)	22	3.37(+)	0	0	0
Late Pleistocene peat	23	1.60	0	0	0
	24	0.80	0	0	0

Source: Data collated by Lentfer and Denham.

Notes:

(+) after the Musaceae phytolith percentage (as a percentage of total phytoliths) = presence of articulated Musaceae phytoliths; n/c = no count of disturbed phytolith assemblage/context; M = Musa (formerly Eumusa) section bananas; E = *Ensete*, I = *Musa ingens*.

+ = values below 0.5%.

Palaeoenvironmental reconstruction

The summary diagram (Fig. 10.T2.1) shows evidence of distinct changes in vegetation, which is linked to periods of burning and erosion in the catchment. In particular, there is a broad pattern of change showing a shift from forest vegetation in the Late Pleistocene to vegetation dominated by grasses (Gramineae) in the mid to late Holocene. Microcharcoal levels (see Denham et al. 2003; Denham, Haberle and Lentfer 2004; and cf. Chapter 9 here) are indicative of forest burning in the Late Pleistocene. The negative correlation between frequencies of platy morphotypes, representing broken epidermal phytoliths derived from non-grass and arboreal vegetation, and Gramineae phytoliths shows that each of these burning episodes was instrumental in opening up the forests sufficiently to promote grass growth.

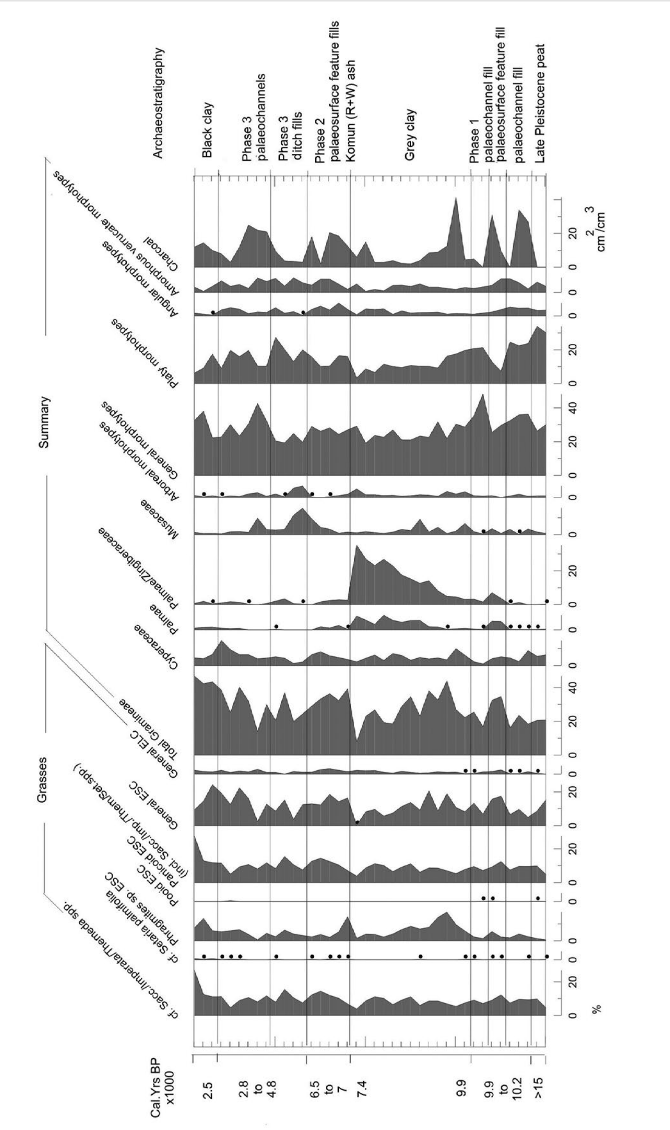


Figure 10.T2.1 Composite phytolith diagram for samples at Kuk. Percentage values < 1% are marked by black dots.

Sacc. = *Saccharum*, ESC = epidermal short cell, Pooid grasses are C3 grasses, Imp. = *Imperata*, Them. = *Themeda*, Set. = *Setaria*, ELC = epidermal long cell. Note the sudden peak in Musaceae phytoliths starting in Phase 2 palaeosurface feature fills after a period of intensive burning. The presence of Musa (formerly Eumusa) section bananas was confirmed during this period. Chronology and stratigraphy after Denham et al. (2003: Fig. 3) and Haberle et al. (2012).

Source: Drawing by Carol Lentfer.

At the beginning of the Holocene, within the period of grey clay deposition, this becomes more obvious, with a major peak in microcharcoal directly followed by an increase in grass phytolith frequencies. This is indicative of burning within the swamp catchment causing forest clearance, erosion and the deposition of grey clay in the swamp. Following clearance, there is a sharp increase in palms and gingers, signalling a period of regrowth, possibly associated with garden fallow. Towards the end of grey clay deposition, a slight increase in burning prompted a sharp decline in palms and gingers and another sharp rise in grasses.

At the beginning of Phase 2, grass phytoliths continued to dominate. The low frequencies of early regrowth elements such as gingers and palms in the phytolith assemblage indicates a shift in land management practice leading to higher and more sustained levels of disturbance of natural forest vegetation in the swamp and its catchment.

Evidence for plant cultivation

Phytolith morphotypes from a number of cultivated plant groups were recorded in the assemblages. Included are morphotypes that occur in palms, gingers and edible grasses such as *Setaria palmifolia* and two *Saccharum* species, *S. officinarum* (sugarcane) (Fig. 10.T2.2), and *S. edule* (edible *pitpit*). The high frequencies of palms and gingers in the grey clay deposit signal periods of regrowth possibly associated with garden fallow. The distribution of grass morphotypes in the phytolith record, however, offers no clear evidence for cultivation of either *Saccharum* or *Setaria*. As pointed out in the second paragraph of this textbox, *Pandanus* spp., *Colocasia* taro and yam have low phytolith production and no diagnostic phytoliths, so their presence is not reflected in the phytolith record.

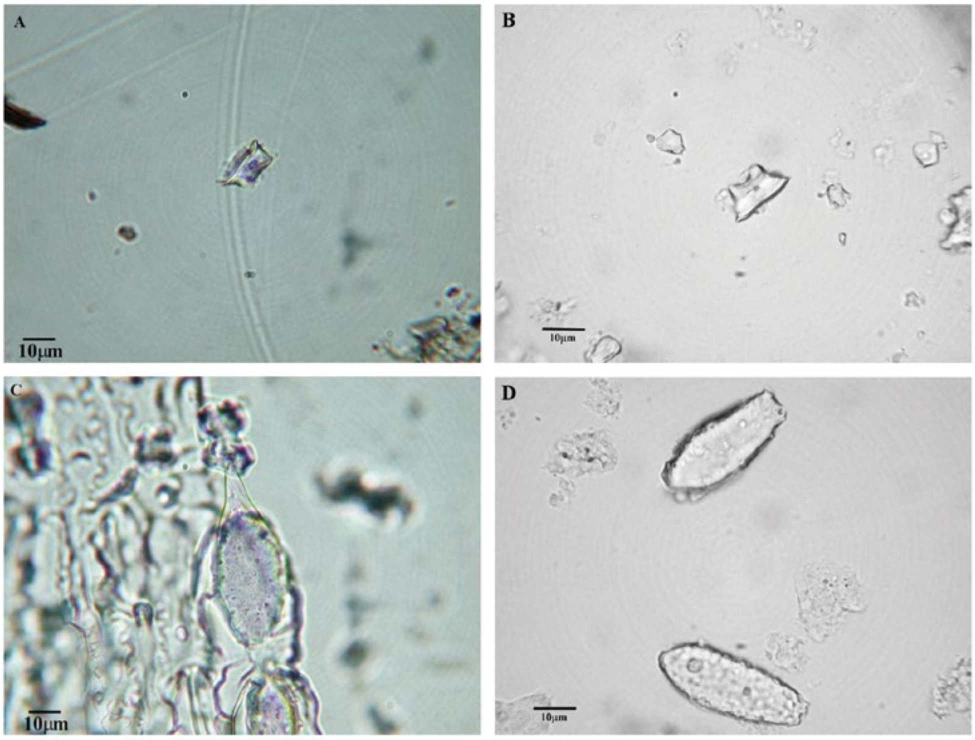


Figure 10.T2.2 Leaf phytoliths from *Saccharum officinarum* (sugarcane, modern reference: WNB1020) and fossil phytoliths found in the fill of the late Phase 2 curvilinear feature 504 (sample 55).

A. Epidermal short cell from WNB1020. B. Epidermal short cell recovered from microfossil assemblage. C. Articulated trichomes of *S. officinarum*. D. Disarticulated trichomes from microfossil assemblage.

Source: Photograph by Carol Lentfer.

The most significant evidence for plants being cultivated at Kuk prior to the mid Holocene comes from the presence of Musaceae phytoliths in the palaeosurface feature fills of Phase 2 and the ditch fills and palaeochannels of Phase 3 (see Fig. 10.T2.1). Notably, *Musa* and *Ensete* phytoliths were identified in these assemblages from diagnostic seed phytoliths (Table 10.T2.1; Fig. 10.T2.3), though there were no diagnostic seed phytoliths of bananas of the Callimusa section, which includes the former Australimusa section (see Table 10.1, note 7). Morphotypes derived from leaves were more abundant in the assemblages than seed morphotypes (Fig. 10.T2.3 H and I), but work on reliably differentiating banana species and cultivars using leaf morphotypes is still in progress (Ball et al. 2006; Lentfer 2009).

Rather than being cultivated, it is possible that bananas and *Ensete* were regrowth elements. However, substantial increases in Musaceae phytoliths first occur in association with a major burning episode and reductions in frequencies of panicoid grasses and reeds (*Phragmites* sp.). Furthermore, it is interesting that the morphotypes of ginger/palm phytoliths, which we should expect to find in association with those of wild bananas in regrowth vegetation following disturbance, are virtually absent from the assemblages where the Musaceae phytoliths peak. This is suggestive of deliberate clearance, possibly linked to the preparation of land for gardening. Furthermore, the relatively high frequencies of Musaceae phytoliths in the fossil assemblages of Phases 2 and 3 especially, in comparison with low frequencies of other regrowth elements such as palms and gingers, point more towards bananas being cultivated than merely a component of wild regrowth vegetation. It is also significant that spikes in banana phytolith frequencies occur in stratigraphic units with posthole, ditch and mound features.

Additionally, as discussed in the main text, wild Musa (formerly Eumusa) section bananas and *Ensete* are predominantly lowland species. Therefore, their appearance at Kuk indicates either a warmer than at present period in the early to mid Holocene or their introduction by humans perhaps as cultivars. If the latter was the case, the presence of Musa section bananas in the assemblage in Phase 1 would imply that they were introduced to the region by about 10,000 years ago and prior to this it is likely that the only banana species growing there was the giant wild species, *Musa ingens*. The presence of Musa section bananas in the grey clay layer shows that they were quite common in the region during the early Holocene and possibly cultivated on the slopes surrounding the swamp. If this was so, the sustained presence of seeded bananas above the Phase 3 horizon (see Table 10.T2.1), dated roughly to around 2500 years ago (see Chapter 14, section 'Soil tillage as an innovation'), would provide tangible evidence that the domestication of edible bananas, leading to sterility and loss of viable seeds, has been a long, drawn-out complex of processes, involving interbreeding of wild and partly domesticated populations over several thousands of years. As indicated by the occasional presence of seeded cultivated diploid bananas in some regions of Papua New Guinea today (Lentfer 2009), similar processes are ongoing and would have been crucial in the development of the diverse range of diploid, triploid and polyploid cultivars that are now grown throughout the world (see Perrier et al. 2011).

Conclusion

Samples at Kuk yielded rich and well preserved phytolith assemblages from the Late Pleistocene to mid Holocene that provides us with a better understanding of past vegetation and the forces driving palaeoenvironmental change at Kuk. The assemblage, together with the microcharcoal record, shows forest clearance and cycles of regrowth signifying land management by the use of fire since the beginning of the Holocene. Phytolith morphotypes found in a number of economically important plants are present in the assemblage. Musaceae morphotypes, in particular, provide strong support for the early cultivation of bananas. This has been a major contributing factor in the Kuk site playing a key role in the recognition of agricultural origins and developments in the New Guinea region.

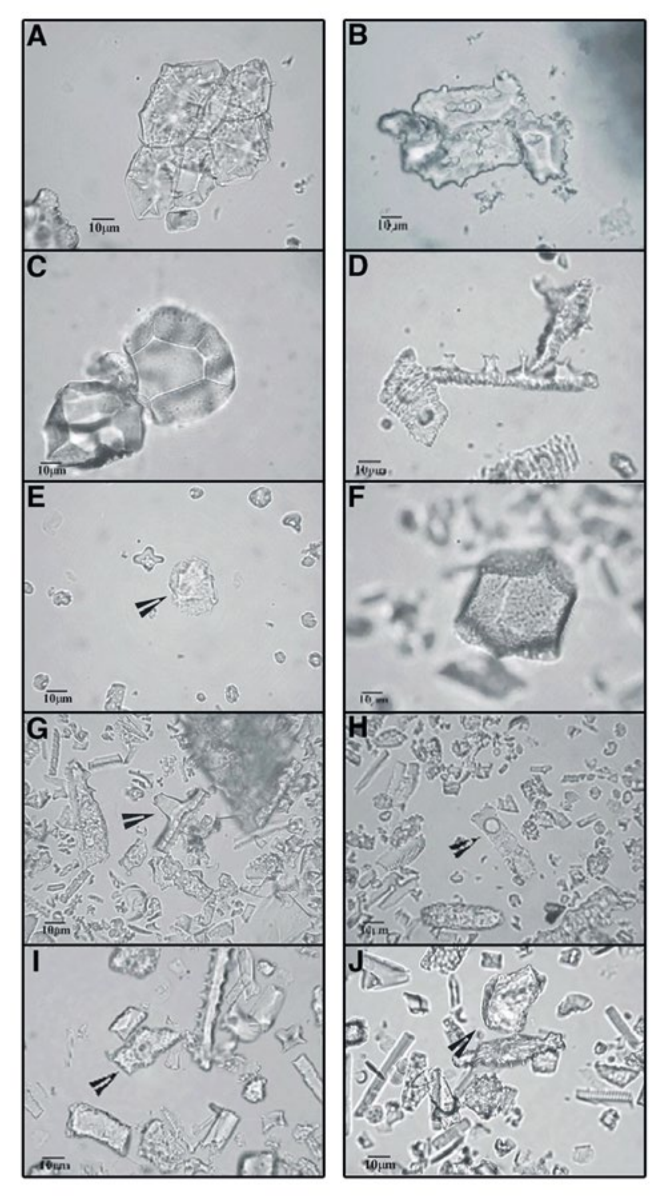


Figure 10.T2.3 Photographs illustrating discrimination of contemporary and prehistoric *Musa* spp. phytoliths.

A. Articulated phytoliths from seed of *Musa acuminata* ssp. *banksii*, showing the distinct dorsal ridging of Musa (formerly Eumusa) section seed phytoliths (modern reference: QH067962). B. Articulated phytoliths from seed of *Musa peekelii*, with the distinctive tabular dorsal surfaces found in Callimusa section seed phytoliths, which were not present in the Kuk assemblages (modern reference: LH82751). C. Seed phytolith from *Musa ingens* (modern reference sample). D. Dorsal and lateral views of *Ensete glaucum* seed phytoliths (modern reference: QH356652). E. Fossil Musa section seed phytolith with distinct dorsal ridging, found in the phytolith assemblage from near the top of grey clay (sample 5). F. Faceted phytolith morphotype found in the phytolith assemblage from the upper fill (101b) of the Phase 1 palaeochannel (sample 19), which is similar to the seed morphotype of *Musa ingens*, although its surface is more heavily textured. G. Lateral view of *Ensete* seed morphotype found in a Phase 2 feature fill and the black clay sediment above (samples 3 and 4). H. Articulated chain of *Musa* leaf phytoliths from within the grey clay formation between Phase 1 and Phase 2 (sample 10). I. Fossil leaf phytolith of *Musa* sp. from the upper fill of the Phase 1 palaeochannel (sample 19). J. Fossil Musa section seed phytolith from the upper fill of the Phase 1 palaeochannel (sample 19).

Source: Photographs by Carol Lentfer.

Textbox 10.3 Tool usewear and residues

Richard Fullagar

The study of how ancient tools were used is as old as archaeology. Over the last 50 years, new techniques have been developed to identify diagnostic wear patterns and organic/inorganic traces that can be related to how stone artefacts were used in the past. The concept of function refers to a range of specific aspects of implement use that usually requires an understanding of design, motion or mode of use (e.g. sawing, scraping), holding, hafting, properties of worked materials (e.g. wood, bone, grass), stages of manufacture and edge reduction and the type of stone (such as obsidian, chert and basalt). The techniques of usewear and residue studies are thus grounded in material sciences like biology. Some wear patterns are highly distinctive, like the polished surface on stone sago pounders (Fig. 10.T3.1). However, experiments are vital to evaluate variables like edge angle and scarring type and to test interpretations of residue forms (cf. Barton 2007).

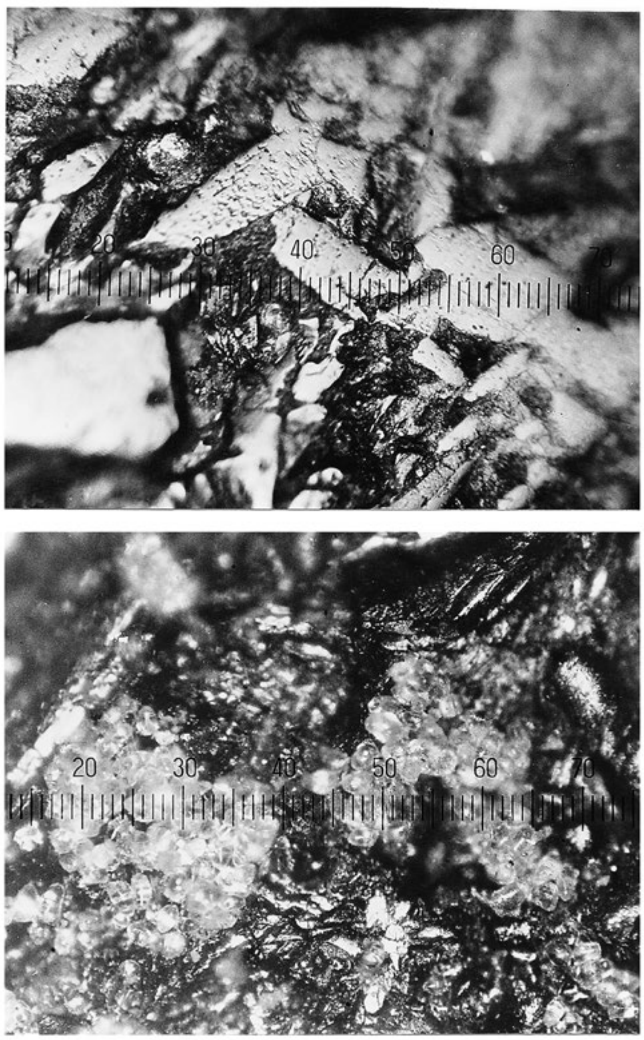


Figure 10.T3.1 Above: Use-polish on an ethnographic sago pounder from PNG collected by Ross Bowden, La Trobe University, Melbourne (Fullagar 1989: Plate 10.10). Below: Sago starch grains from the same artefact. Metallographic microscope, scale divisions are 0.0068mm (Fullagar 1989: Plate 10.11).

Source: Photographs by Richard Fullagar, reproduced with permission.

Tool-use experiments are particularly important for usewear studies because different kinds of stone, like obsidian and basalt, will sustain usewear according to differences in hardness and mineralogical composition. Tool-use experiments are particularly important in the study of residues on tool edges because tiny traces, like feather particles or plant fibres, might not be part of processing or manufacturing particular things, but instead be related to hafting, decoration or storage (e.g. as in a knife sheath). It is vital to integrate the results of usewear and residue analyses with broader information regarding stone tool technology and other data from the archaeological site.

Residue studies require specific comparative reference collections for identifying the diagnostic particle shapes of pollen grains, starch granules and phytoliths. Starch from stone tool surfaces has shown the presence and use of *Colocasia* taro and a yam in the highlands during the early Holocene (Figs 10.T3.2 and 10.T3.3 here; Denham et al. 2003; Fullagar et al. 2006). Earlier use of tubers in Island Melanesia is indicated by starch grains on stone artefacts dating to over 28,000 years ago from Buka (Loy, Spriggs and Wickler 1992).

Microscopy and lighting conditions are critical for observing particular forms of usewear. In the usewear studies reported (see Chapter 20), metallographic microscopes, with vertical incident light, and stereomicroscopes, with a point source of oblique incident light, were used to observe stone tool surfaces and edges. The former provides high magnification (well over 200x) but has a flat image, with little depth of focus, which is useful for examining smooth or polished surfaces. The latter provides images of surface features like striations and scarred or beveled edges in clear relief.

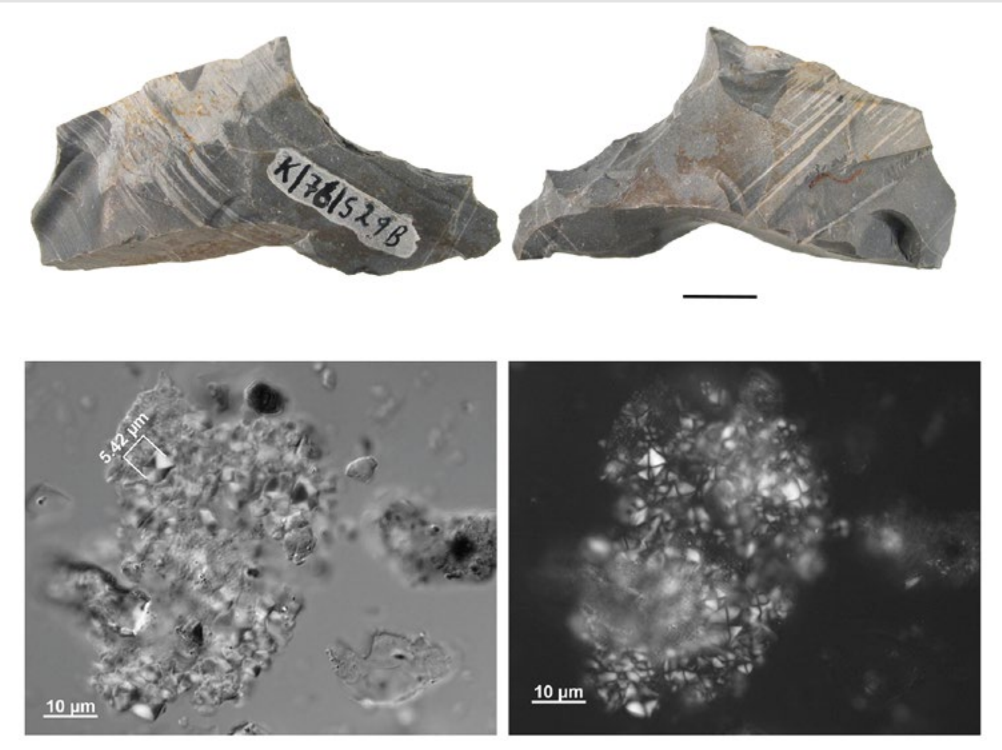


Figure 10.T3.2 Above: Retouched flake (K/76/29B) collected from beneath the grey clay fill of a basin-like Phase 1 feature (c. 10,000 cal. BP) at Kuk (Chapter 20). Scale bar is 10 mm. Below: Starch grains of taro (*Colocasia esculenta*) from the working edge of the retouched flake (left: transmitted light; right: cross-polarised light).

Source: Photographs by Richard Fullagar.

Residues are observed under reflected light microscopes, but tiny particles, organic structures and fibres are best viewed on mounted glass slides through transmitted light. Diagnostic shapes of phytoliths and starch grains found on artefacts and in sediments provide some of the earliest definitive evidence of plant food exploitation and cultivation of tropical crop plants, such as banana and yam (Lentfer, Therin and Torrence 2002; see Textbox 10.2).

In Melanesia, microscopic studies have identified the use of flaked stone tools for a range of distinct tasks other than plant food processing. For example, woodworking in the Jimi River Valley is indicated by a distinctive polish on retouched blade-like flakes (Fullagar 1989), while the usewear on stone drill bits indicates the drilling of shell for making fishhooks at Motupore Island, near Port Moresby (Allen, Holdaway and Fullagar 1997). Evidence for butchering, bone working and skin working is less commonly found (but see Kononenko 2008).

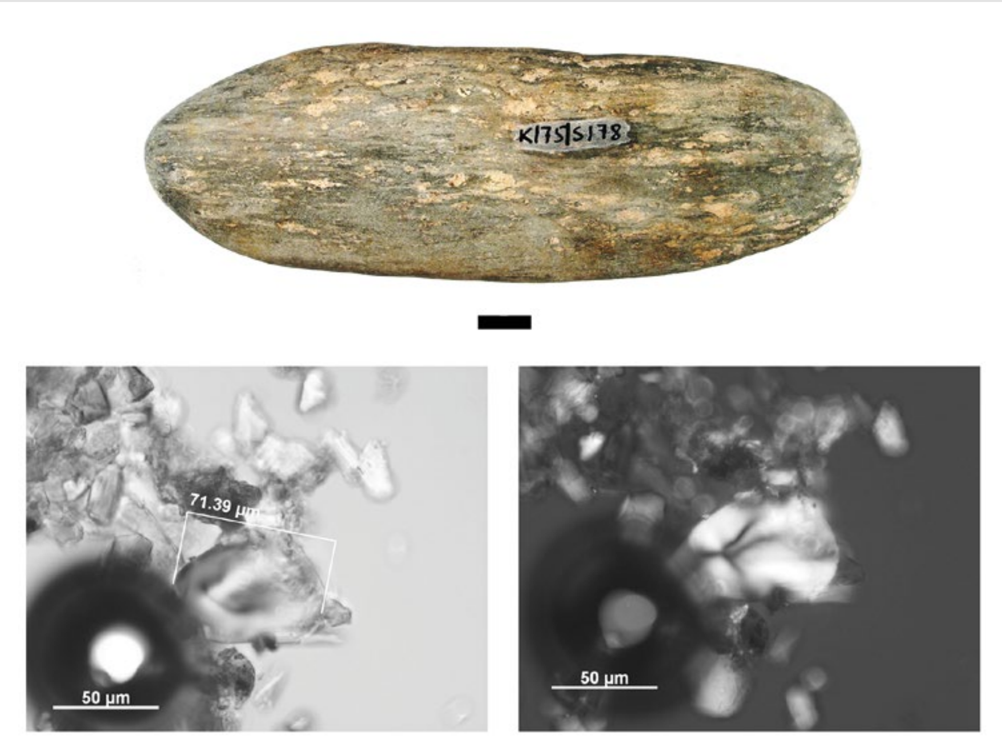


Figure 10.T3.3 Above: Grinding stone (pestle, K/75/S178) recovered from the Phase 1 palaeochannel base of channel 101 (Kundil's Baret) dating to about 10,000 cal. BP. Below: Large starch grain of a yam (*Dioscorea* sp.) from the residue extraction (left: transmitted light; right: cross-polarised light).

Source: Photographs by Richard Fullagar.

Food plants are presumed to have been continuously present in the upper Wahgi region after their earliest record at Kuk. Table 10.2 lists archaeobotanical finds at other sites in the upper Wahgi: gourds at Warrawau (the Manton site), as well as the middle Wahgi site of Kana; and pandanus at four Manim Valley sites (Donoghue 1988). Of the three other sites listed Yuku (bamboo and, problematically, sugarcane) is just north of the upper Wahgi in the upper Yuat; Aibura (bamboo) is at the upper reaches of the Lamari River in Eastern Highlands Province near Kainantu; and the Ivane Valley (pandanus) is in the Papuan highlands to the southeast.

Table 10.2 Macrobotanical remains of food plants reported at other archaeological sites in the highlands.

Plant	Site	Approx. antiquity (years ago)[4]	Laboratory code	References
Bamboo				
Bambusa sp.	Yuku	11,600–10,600	ANU-358	Bulmer 1975: 31
Bambusa sp.	Aibura	after 4450–3900	GaK-623	White 1972: 57, 61
Gourds				
Lagenaria siceraria or *Benincasa hispida*	Warrawau (Manton)	5900–5050	ANU-288 and 2086	Powell 1970b: 144–145; Golson 2002: 70–71; Denham 2003b: 170; 2007a: 88
Benincasa hispida	Kana	2950–2000	ANU-9487	Matthews 2003; Muke and Mandui 2003: 184
Pandanus[1,2]				
Pandanus spp.	Ivane Valley	36,300–34,600	Wk-17261	Fairbairn et al. 2006: 379; Summerhayes et al. 2010: Table S1
Pandanus spp. (wild)	Etpiti	after 2350–2000	ANU-1323	Christensen 1975: Table 1; Donoghue 1988: 85–88
	Kamapuk	from 2750–2350	ANU-1326	Donoghue 1988: 78–80
	Tugeri	after 2700–2350	ANU-1321	Donoghue 1988: 88–90
Pandanus antaresensis	Kamapuk	after 2750–2350	ANU-1326	Donoghue 1988: 81
	Manim 2	from before 11,800–10,300 to just after 7000–6350	ANU-1375 ANU-1373	Christensen 1975: 31; Donoghue 1988: 71–73
Pandanus brosimos	Tugeri	after 1700–1400	ANU-1322	Donoghue 1988: 88–90
Pandanus iwen	Etpiti	after 2350–2000	ANU-1323	Donoghue 1988: 85
	Kamapuk	after 2750–2350	ANU-1326	Donoghue 1988: 78
Pandanus julianettii	Etpiti	after 1350–1050	ANU-1324	Donoghue 1988: 85
	Kamapuk	modern?	stratigraphic inference	Donoghue 1988: 81
	Tugeri	after 1700–1400	ANU-1322	Donoghue 1988: 88
Sugarcane				
Saccharum officinarum[3]	Yuku	5650–4550	GX-3111B	Bulmer 1975: 31

Source: Data collated by Lentfer and Denham.

Notes:

[1] Abundant archaeobotanical material besides pandanus was collected from the Manim Valley sites and is subject to ongoing investigation. Seeds collected as part of palaeoecological studies at wetlands in the highlands are excluded here because of their uncertain associations with humans.

[2] *Pandanus conoideus*, identified at Yuku and formerly referred to as *Pandanus* spp. (Bulmer 1975: 31), was subsequently claimed as approximately 14,000 years old (Bulmer 2005: 392–393). Recent redating by Denham (2016) of pandanus material recovered during the original Yuku excavations has yielded modern radiocarbon dates and it should be considered likely that all *P. conoideus* at Yuku is modern. Consequently, these finds are excluded from consideration here.

[3] The identification of *Saccharum officinarum* at Yuku is uncertain (Yen 1998: 168) and given problems of dating at the site, both botanical identification and age are problematic (Denham 2016).

[4] The radiocarbon calibrations are derived as follows: for Yuku and Aibura from Sutton et al. (2009: Table S1, supplementary information); for Warrawau inferred from chrono-stratigraphic interpretations of the site (references in table); for Kana and the Ivane Valley derived from the listed publications; and for the Manim Valley sites using Calib 6.0.0 (Stuiver and Reimer 1993) and IntCal04 calibration curve (Reimer et al. 2004). Only the highest probability distributions at two standard deviations are given. Calibrated date ranges below 10,000 years are rounded to the nearest 50 years and those above 10,000 years are rounded to the nearest 100 years.

Suite of techniques: Suite of food plants

Through the combined application of a suite of macrobotanical and microbotanical techniques, it was possible to identify in the archaeological and stratigraphic records a suite of plants that could have been used for food during various periods in the past (Table 10.1). The suite of food plants recovered from the archaeological record at Kuk, comprising starch-rich staples and supplements, vegetables and food-bearing trees, is similar to that harvested wild and cultivated in gardens across the Wahgi Valley today (Powell et al. 1975; Powell 1976a; Denham 2016). Many food plants were present from the Pleistocene, although several highly significant examples first appear in the early, mid and late Holocene. Analyses have provided evidence for the use and cultivation of some plants, but most techniques indicate no more than the presence of specific plants. The availability of a wide range of edible plants opens up the possibility for broad-spectrum subsistence systems persisting up to the early Holocene (Powell 1982a: 211).

Starch-rich staples and supplements

The most significant new archaeobotanical evidence is for the use of taro (*Colocasia esculenta*) and a yam (*Dioscorea* sp.) and the presence of *Musa* spp. from the early Holocene (Phase 1). These plants provide energy-rich sources of food and could have functioned as staples in the Wahgi Valley because they provide aseasonal, high-caloric resources in parts of New Guinea today (e.g. Powell 1976a; Gagné 1982a: 236; Dwyer and Minnegal 1991; Yen 1991a, 1995).

Starch granules of taro and yam were recovered from the used edges of stone tools dating from the early and mid Holocene (Fullagar et al. 2006, 2008; see Chapter 20 here). These finds, together with the appearance of other plant residues on stone tools, are indicative of plant processing, most probably prior to consumption. The presence of these two starch-rich plants is significant, because taro and some yam species are indigenous to and were domesticated in the New Guinea region (Lebot 1999; see Chapter 3 here). There is earlier evidence that starch-rich tuberous plants were being exploited in lowland sites of Island Melanesia (Loy, Spriggs and Wickler 1992; Barton and White 1993).

High frequencies of Musaceae phytoliths, including types of seed morphotypes specific to the Musa (formerly Eumusa) section, recur throughout the Holocene (Denham et al. 2003; Lentfer 2003a). Importantly, the high frequencies of banana phytoliths in some Phase 2 contexts (dating from 7000–6400 years ago) are suggestive of deliberate planting in multi-cropped plots within a grassed landscape managed by fire (Textbox 10.2). In New Guinea generally, bananas and possibly *Ensete* could have been exploited for their fruit, flowers, leaves and/or for their seeds and the edible corm at the base of the pseudostem during the early Holocene or earlier (Michael Bourke, pers. comm., 2002; Lentfer 2003b).

Banana, yam and taro starch sources could have been supplemented by edible *pitpit* (*Setaria palmifolia*), which may have been present in the vicinity during the Pleistocene (see Table 10.1), and potentially sugarcane (*Saccharum officinarum*), although mid Holocene claims for the latter at Yuku are unlikely (Bulmer 1975: 31; cf. Yen 1998: 168). Both these grasses have starch-rich pith. *Saccharum officinarum* could also have been a staple as reported ethnohistorically for the highlands (Daniels and Daniels 1993). Gingers (cf. Zingiberaceae) could have been exploited for their starch from the early Holocene, even though they are only minor contributors to diet in the highlands today.

In addition to these known starch sources, wild tubers are eaten in the highlands today, particularly during famine conditions (Watson 1964b; Waddell 1973; Powell et al. 1975: 15–32). Wild forms of *Colocasia* taro (swamp), *Dioscorea* yams (forest), *Pueraria* sp. (forest) and yam-like tubers (possibly *Dioscorea* but unknown species of the forest) grow in highland valleys today and are used for food (Michael Bourke, pers. comm., 2002; Powell et al. 1975: 21, 24–25, 36; Yen 1991b: 77, 81). Other wild varieties of the same species are known but never eaten or have poorly developed tubers or corms (Powell et al. 1975: 21, 24–25). Although many of these plants are generally associated with dryland forests, they may have grown, or been grown, at Kuk during drier periods and could have been significant sources of starch in the past. At present, the taxonomy, ecology, nutritional value and human exploitation of these wild plants are poorly understood and consequently they may have limited archaeobotanical visibility.

In conclusion, several starch-rich plants were potential food sources for people in the highlands at various times from the beginning of the Holocene. Most significantly, the remains of three starch-rich plants, *Musa* bananas, *Colocasia* taro and a *Dioscorea* yam, which have featured prominently in the development of Melanesian and Pacific agriculture, were first present at Kuk in the early Holocene and were associated with the earliest evidence of plant manipulation along the wetland margin.

Vegetables

At an early stage of the Kuk Project, Jocelyn Powell began a programme of macrofossil analysis, using seeds recovered by flotation from sediment samples taken from stratigraphic columns and ditch fills (Powell 1982b). The aim was to obtain more information on the presence of food plants and gardening systems at the site than was provided by pollen analysis. The field and laboratory work was conducted by Powell and Laurie Lucking in 1974–76.

The results showed that many indigenous vegetables were present at Kuk in the early to mid Holocene or earlier (Table 10.1). Many of these plants are highly nutritious, although not major sources of calories. Several are cultivated in gardens today, including *Amaranthus* sp., *Commelina* sp., *Floscopa scandens*, *Oenanthe javanica* and *Solanum* spp. (Powell 1970a: 200; 1981: 296; 1982b: 31–32; Powell et al. 1975: 15–32), whereas others are harvested from wild sources or as garden weeds, e.g. *Cerastium* sp., *Drymaria cordata*, *Hydrocotyle javanica*, *Oxalis corniculata*, *Rubus rosifolius* and *Viola* sp. Although it is possible that these resources were all natural colonisers of the wetland margin at Kuk and other wetlands in the upper Wahgi Valley (Powell 1970b), their distributions may have been enhanced by clearance using fire and by the cultivation of plots. The similarity of the suite of vegetables and starchy staples available in the past at Kuk to contemporary garden assemblages in the area suggest intentional behaviour, i.e. management or deliberate planting in gardens (after Powell 1982b: 31).

Nut- and fruit-bearing trees

Two of the most important nut-bearing trees in the highlands, *Pandanus* spp. and *Castanopsis* sp., were present in the Kuk catchment from the Pleistocene (Table 10.1). Wood from an additional nut-bearing tree, *Elaeocarpus*, was present in Phase 6 contexts at Kuk, and was probably there at an earlier date. *Castanopsis* sp. pollen decreased markedly in the Holocene from Pleistocene levels, largely as a result of forest disturbance (Denham, Haberle and Lentfer 2004: 848).

Pollen records from Kuk (Denham et al. 2003; Denham, Haberle and Lentfer 2004: 845–848) show that *Pandanus* spp. were present in low frequencies in the Pleistocene and at the beginning of the Holocene (Phase 1). During grey clay deposition (approximately between 10,000 and 7000 years ago) the frequency of pandanus pollen increased dramatically. Two kinds of wild nut *Pandanus* were present at Kuk in the Late Pleistocene, *P.* cf. *antaresensis* and *P.* cf. *brosimos*, belonging to two distinct groupings in terms of pollen morphology, the *antaresensis*-type being spiky (echinate) and the *brosimos*-type being smooth (psilate) (Haberle 1995: 200–206).

Pandanus brosimos has a mean usual altitudinal range of 2400–3100 m and *P. julianettii*, referred to as the cultivated form of *P. brosimos* (cf. Haberle 1995: 207), has a mean altitudinal range of 1800–2600 m. *Pandanus antaresensis* has a mean altitudinal range of 1000–2350 m (Table 4.4).

Pandans of the *brosimos/julianettii* complex have been previously characterised as a highly seasonal resource. Indeed, some authors have claimed that human presence in the highlands during the Pleistocene was based on hunting and the seasonal harvesting of nuts (White, Crook and Ruxton 1970: 168–169; Bulmer 1977: 69; Golson 1991b: 86–88; Fairbairn, Hope and Summerhayes 2006: 379). However, seasonality and hence reliability of production in these species have been shown to vary geographically with climate across the highlands (Bourke et al. 2004: 39–40, 154, 191; cf. Donoghue 1988: 50). Consequently, people must have relied upon a much more broad-based diet in those parts of the highlands where nut pandanus produced aseasonally (Denham 2007c).

According to Hyndman (1984: 296), writing of the Wopkaimin of the Star Mountains, *Pandanus antaresensis* produces continuously throughout the year, which would compensate for the difficulty of getting at the nuts inside the hard fused drupes (Haberle 1995: 197). The species is unimportant as a food source throughout the highlands today (Haberle 1995: 197), although a range of other uses has been documented (Hyndman 1984: 296–298; Majnep and Bulmer 2007: 313–314, 330–332, 362). The abundance of carbonised drupe fragments of *P. antaresensis* in Late Pleistocene and early Holocene contexts at Manim 2, a rockshelter off the upper Wahgi Valley (Christensen 1975; Donoghue 1988), suggests that the species may have been a more important food source in the past. The period of relatively intensive exploitation of *P. antaresensis* at Manim 2, from before 11,800–10,300 BP to just after 7000–6350 BP, broadly corresponds to the deposition of grey clay at Kuk (see Fig. 6.10, note C and D) and a peak in the frequency of pandanus pollen (see Chapter 9, section 'The early Holocene' and Fig. 9.4). Haberle (pers. comm., 2008) states that the pandanus pollen at Kuk is overwhelmingly of *antaresensis*-type, which is also the case for a *Syzygium* swamp forest dating to about 8000 years ago at Kelela Swamp in the Baliem Valley (Haberle 1995: 207).

Pandanus of the *brosimos/julianettii* complex and *Castanopsis* are producers of abundant highly nutritious nuts that are still, or were until recently, targeted by highlands populations (Bourke 1996: 49–50 and Bulmer 1964, respectively). For *P. antaresensis*, which is not an important food source, there is no comparable information regarding productivity and food value (Robin Hide, pers. comm., 2008). Bulmer has remarked that the kernels of *antaresensis* nuts 'require considerable effort to extract, for a rather small return' (Majnep and Bulmer 2007: 314; cf. Hyndman 1984: 296). Several other fruit- and nut-bearing species were present at Kuk during the Pleistocene and Holocene (Table 10.1). Although of minor importance in contemporary diets, these fruit- and nut-bearing trees, together with edible forbs, ferns, shrubs, vines and fungi in the understorey, could have been highly significant contributors to diet in the past (after Powell 1982a: 210–211).

Archaeological associations

The presence in prehistoric contexts of plants that are today exploited for food does not mean they were necessarily used for food in the past. The presence of food plants in prehistoric contexts that are today associated with agriculture is not necessarily a sign of agriculture in the past. Even today, in simple numerical terms, most kinds of food plant are wild varieties (Powell 1976: Table 3.1). There is currently insufficient archaeobotanical resolution to determine whether most prehistoric plants were wild or domesticated varieties, although there is evidence for the use of plants that were subsequently domesticated. More detailed corroboratory information on the use of plants is needed from occupation sites in the highlands, such as the archaeobotanical collection from Manim 2 (Christensen 1975).

Most food plants in archaeobotanical assemblages at Kuk occur in low frequencies and are not correlated to archaeological phases. The low frequencies suggest low numbers, wild plants and possibly adventitious colonisation of disturbed habitats. However, given the phenology, reproductive habits, infrequent flowering at altitude and harvesting prior to flowering of these plants under cultivation, their limited archaeobotanical signal is not entirely surprising (after Powell 1970a: 199). Overall, food plants have similarly low frequencies in seed assemblages from samples collected in undoubtedly agricultural contexts, i.e. Phase 4, 5 and 6 ditch fills and stratigraphy, which also had better preservation and generally larger assemblages of most taxa. The lack of correlation between food plant frequencies and archaeological phases in general suggests that the archaeological evidence reflects only a part of broader, continuous land-management practices. The wetland archaeological evidence has been buried and preserved, whereas that on dryland slopes within the catchment has been eroded.

Importantly, high frequencies of *Musa* spp., *Pandanus* spp. and Zingiberaceae phytoliths in early to mid Holocene contexts are suggestive of deliberate management. The presence of Musa section phytoliths, in particular, is significant, because two species of that section, *Musa acuminata* and *Musa balbisiana*, are central to the early domestication of *Musa* bananas and the subsequent development of hybrids and sterile triploids (Yen 1998; De Langhe and de Maret 1999; Lebot 1999).

Previous to the Kuk studies in the 1990s, it was thought that bananas of Musa (formerly Eumusa) section, as distinct from those of the former Australimusa section, were an Austronesian introduction to the region (Simmonds 1962; cf. Wilson 1985; see Table 10.1 note 7). However, recent biomolecular and genetic studies have shown that the wild subspecies of *M. acuminata* indigenous to New Guinea, *M. acuminata* ssp. *banksii*, is an early and significant contributor to the A genome of Musa section banana cultivars (De Langhe and de Maret 1999; Lebot 1999; Careel et al. 2002; Perrier et al. 2009, 2011). The genetic and biogeographic evidence, together with the high numbers of diploid *Musa* spp. still cultivated there, indicate the New Guinea region as a centre for the early domestication of Musa section bananas (Lebot 1999; Perrier et al. 2009, 2011; see Chapter 3 here). The presence of *Musa* spp. at Kuk in the early Holocene is therefore not necessarily a product of human agency, although wild populations of *M. acuminata* ssp. *banksii* and its close relative, *M. schizocarpa,* presently occur at much lower altitudes. In view of the current biogeographical and archaeobotanical evidence, the presence of *Musa acuminata* morphotypes at Kuk suggests natural dispersal into the highlands and/or intentional translocation of bananas from the lowlands by humans following climatic amelioration at the beginning of the Holocene. Irrespective of how they got there, cultivation of bananas at about 7000–6400 years ago at Kuk, including those of Musa section, corroborates and provides a minimum time depth for the domestication of bananas in New Guinea.

Given the estimated timing of the introduction of *Musa* bananas (with New Guinea-type A genome) into Africa by 2500 years ago (Mindzie et al. 2001) and perhaps as early as 5200 years ago (Lejju, Robertshaw and Taylor 2006), it is likely that banana domestication processes were underway before they were introduced there. Such processes would have involved the deliberate selection of desirable traits, ultimately leading to the development of parthenocarpy, hybridisation and seed sterility as seen in the fully domesticated banana varieties grown throughout the world today. Domestication of starch-rich food crops, including bananas, may have been initiated in the New Guinea region during the early Holocene or even earlier. *Colocasia* taro and a *Dioscorea* yam were present in the highlands and were being exploited by at least 10,000 years ago (see Textbox 10.3). Like *Musa* bananas, both taro and yam are generally considered to be lowland plants (Yen 1995: 835) and introduced to the highlands. Their presence in the early Holocene at Kuk therefore gives additional support for human translocation, deliberate planting and incipient domestication of starch-rich food crops.

Conclusion

The archaeobotanical records at Kuk and other sites, taken together with the chronology of agriculture in the highlands, enable some general trends in plant exploitation to be elicited. Some minor starch-rich staples, most vegetables and some nut-bearing trees in Pleistocene contexts are still cultivated and gathered from wild resources in the Kuk vicinity today. The Pleistocene antiquity of these plants at Kuk suggests that they were exploited, gradually brought under cultivation and in some cases domesticated from wild sources in the highlands.

For some of the major starch staples, particularly *Colocasia* taro, *Musa* bananas and *Dioscorea* yams, the history of plant use may be more complex. The earliest records of these three plants at Kuk coincide during the early Holocene, following post–Last Glacial Maximum climatic amelioration. These three plant groups are thought by some to be native to the lowlands of New Guinea, to have been domesticated there first and to have been brought into the highlands by agricultural populations who moved upward as climates ameliorated at the beginning of the Holocene (Hope and Golson 1995; Yen 1995; Golson 2007: 115–117). The archaeobotanical evidence appears to support this scenario. Detailed microfossil research has not been undertaken on sufficient Pleistocene samples to determine if any of the plants in question occurred in the highlands before the Holocene, although Bourke (Table 4.1) would argue the opposite on grounds of their altitudinal limits at the present time.[1] Even if these plants did diffuse to the highlands during the early Holocene, it is still not clear if people brought them as part of agricultural practices or as part of another form of plant exploitation (Denham and Barton 2006). Furthermore, it is quite possible that these three plants all dispersed naturally to the highlands from the lowlands as climates ameliorated.

In summary, from the early Holocene, most of the important plants of traditional highlands agriculture, including several starch-rich staples, were present in the upper Wahgi Valley. By taking the archaeobotanical finds in conjunction with other lines of evidence—primarily archaeological, palaeoecological and stratigraphic—specific landuses can be inferred during periods of wetland manipulation. During archaeological Phase 1 at Kuk, it is unclear whether people were engaged in agriculture (see Chapter 11, section 'Agriculture at 10,000 years ago?'), although they were certainly practising a form of plant exploitation that included, among other things, digging, the likely tending of plants and the processing of tuberous plants. However, by at least 7000–6400 years ago (early Phase 2; see Chapter 12), people had begun to undertake mounded cultivation on the wetland margin, which is likely to have consisted of the intercropping of plants with different edaphic requirements. Subsequent periods of wetland cultivation (Phases 3–6; see Chapters 13–16) required the digging of ditches for drainage and to delimit plots, with cultivation on the intervening drained surfaces.

1 Horrocks, Bulmer and Gardner (2008: 300, cf. 293–294) say that starch evidence from Yuku rockshelter at 1280 m on the northern fall of the Sepik-Wahgi Divide suggests processing of the lesser yam, *Dioscorea esculenta*, possibly from before 14,000 years ago. The starch grain identifications were made on the basis of Horrocks, Grant-Mackie and Matisoo-Smith (2007). However, whatever the status of the identifications, the dating at Yuku is problematical and much of the stratigraphy is likely disturbed: see Table 10.1, notes 2 and 3 here; Denham (2016).

Part Three: People in the Swamp and on its Margins

11

Phase 1: The Case for 10,000-Year-Old Agriculture at Kuk

Tim Denham, Jack Golson and Philip Hughes

Evidence of past human activities sealed by grey clay was first discovered during stratigraphic recording of plantation drains at Kuk in 1974. Excavations occurred at the site in subsequent years (1975–77 and 1998) to determine more fully the character of the finds (Fig. 11.1). The archaeological remains, which date to 10,000 years ago, are unique to Kuk and have two major components: a palaeochannel (a prehistoric channel) and a palaeosurface (an old buried land surface). These components are discussed below and interpreted with respect to associated land usage and whether they represent prehistoric agricultural practices.

Palaeochannel

The palaeochannel, referred to in the field as Kundil's Baret and by Denham (2003a) in his analytical work as channel 101, was recorded in the walls of Station drains and excavated in several trenches (Fig. 11.1). Based on these investigations, the course of the palaeochannel across the edge of the present-day wetland has been reconstructed. Channel 101 has some relatively straight and other slightly sinuous reaches.

The cross-section of the channel is slightly variable along its length, although generally it has a relatively broad bed with moderately sloping concave sides (Figs 11.2 and 11.3). The edges of the channel have slumped and been eroded while it was in use or before it filled in. The basal fill consists of an admixture of soil and subsoil granules and organic matter. The organic matter, which includes insects, leaves, seeds and wood, is well preserved, indicating that waterlogged conditions have persisted since deposition about 10,000 years ago (Fig. 11.4). Examination of these materials has enabled the local environment within and adjacent to the palaeochannel to be reconstructed (Denham et al. 2003; Denham, Haberle and Lentfer 2004; Denham, Sniderman et al. 2009; Haberle et al. 2012).

Figure 11.1 Plan of the SE corner of Kuk Station showing the location of excavations beneath grey clay, the course of channel 101 (Kundil's Baret) and some isolated features.

The course of channel 101 is reconstructed from bank widths recorded in the walls of Station drains and excavation trenches that cross it.

Source: Denham, Golson and Hughes (2004: Fig. 4). Drawing by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU. The inset plan depicts a previously published course for the channel. Source: Golson (1977a: Fig. 2). Reproduced with permission.

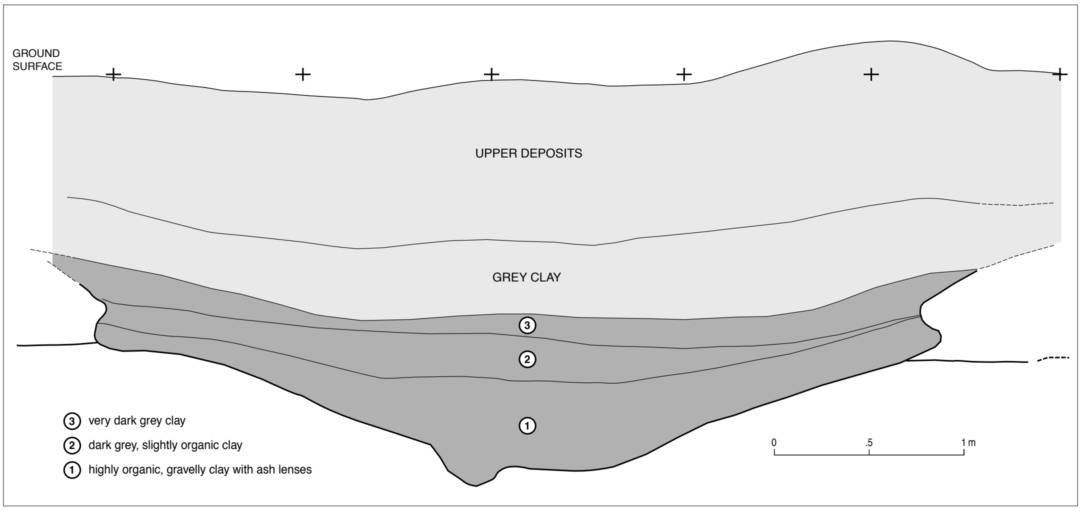


Figure 11.2 A typical cross-section of channel 101 showing its shallow depth, gently concave base and slightly undercut banks.

Source: Denham (2004: Fig. 5), reproduced with permission.

Figure 11.3 Looking south along the bed and east bank of channel 101 after excavation at the north end of block A12d in 1975 (see Fig. 11.1).

Note one ranging pole to the south, at the E–W cross-section through channel fill, and another to the west at the N–S longitudinal section. Both are graduated at 200 mm intervals.

Source: Photograph by Klim Gollan, Kuk archive, 1975.

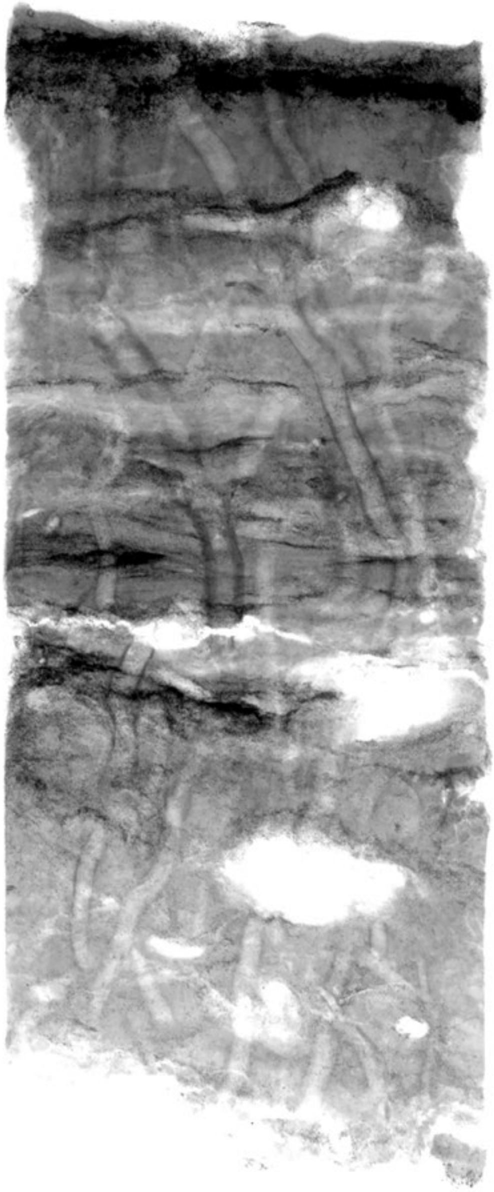


Figure 11.4 X-radiographic image showing the preservation of original sedimentary stratification, or banding, within the basal fill of channel 101.

The lighter vertically inclined lines that cut across the horizontal banding are root channels and faunal burrows (i.e. made by worms and beetles), which formed post-depositionally during a short drier period after the period of initial sedimentation.

Source: Denham, Haberle and Pierret (2009: Fig. 2b), reproduced with permission.

Archaeologists and geomorphologists who have worked at Kuk disagree about whether channel 101 was made by people (proposed by Philip Hughes) or is a natural watercourse (proposed by Tim Denham). Different lines of evidence have been marshalled to support different interpretations. For example, there is some debate about whether the palaeochannel cut a course through low rises on the wetland edge; a natural watercourse would not be expected to cut a course through a low hillock, but would ordinarily pass around its base. Although present-day topography suggests the channel passed through higher ground, there is debate among the authors as to whether this low rise existed 10,000 years ago and whether channel 101 followed a preexisting depression through it (respectively Golson 1991b: 485 and Denham 2003a: 126–146, 2004: 49–53; see Denham, Golson and Hughes 2004: 269–274 for a review). Similarly, features exposed by excavation on the banks could have resulted from human activity or been a product of stream flow around woody debris in the channel, tree-throw or slumping.

Whether the channel was directly dug or modified by people is debatable. Irrespective of its mode of formation, the channel appears to have been short-lived and rapidly filled with materials eroded from the catchment and at the wetland edge following human-induced forest clearance (as discussed below). The open channel would have lowered water tables along the wetland edge, thereby making adjacent palaeosurfaces suitable for plant exploitation practices. A stone pestle recovered from the basal fill of the channel indicates that 10,000 years ago people at Kuk were processing starch-rich food plants, perhaps grown adjacent to the channel. This pestle (K/75/S178) was used to prepare a yam tuber (*Dioscorea* sp.) for consumption (Fullagar et al. 2006: 601–602, Fig. 10; see Chapter 20, section 'Phase 1' and Textbox 10.3).

Palaeosurface

On the land surface adjacent to the palaeochannel are pits, runnels, stakeholes and postholes, with associated artefacts and evidence of limited soil formation (Figs 11.5–11.8). The features are cut into black organic clay, which probably provided the topsoil at the time, and are filled by grey clay. They do not have a regular pattern or design, although some pits are associated with postholes and stakeholes. The human origin of the features is interpreted from their morphology, inferred function, nature of fills and other associations. Taking multiple lines of evidence together, the palaeosurface is considered representative of a former plot used for the cultivation of edible plants.

Figure 11.5 Left image shows the base of a 1976 excavation trench in block A12b after the removal of grey clay, revealing Phase 1 features dug into the surface beneath. The image shows the view SW, with some archaeological features fully excavated and others with their fills of grey clay still to be removed. Right image shows the view to the south, with all features fully excavated, revealing pits, basins, stakeholes and the like thought to represent the planting, staking and harvesting of plants. The area in the lower half of this photograph appears in Figure 11.7 as an elevated location between two areas of elongated depressions, B and C, at the northern end of the excavation. The ranging pole is graduated at 200 mm intervals.

Source: Photographs by Alistair Marshall, Kuk archive, 1976.

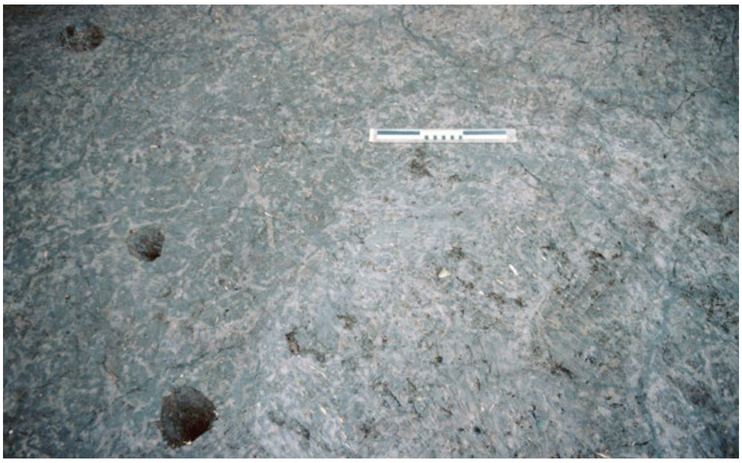


Figure 11.6 A close-up of the saucer-like feature immediately north of the two easterly stake holes in the line of three across the middle of Figure 11.5b.

In it is shown a chert flake (K/76/S28) found during excavation underneath the grey clay fill and discussed in Chapter 20. The scale is graduated at 100 mm intervals.

Source: Photograph by Alistair Marshall, Kuk archive, 1976.

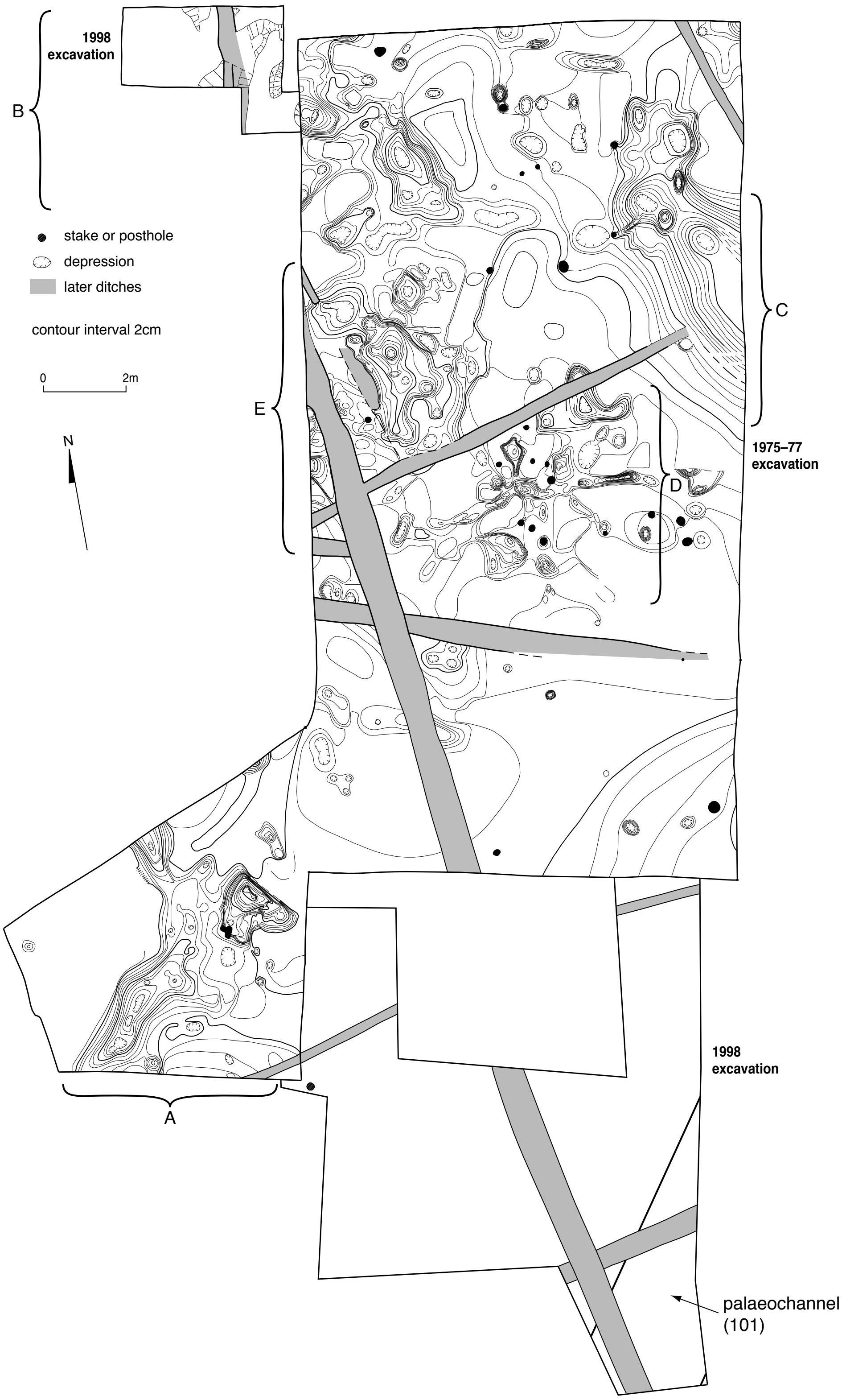


Figure 11.7 Composite base plan of the Phase 1 palaeosurface exposed in excavations in block A12b undertaken in 1975–77 and in 1998.

The features have been grouped into five complexes: three composite curvilinear or sinuous runnels (A, B and C) and two locations comprising upraised areas formed by surrounding intersecting depressions (D and E).

Source: Denham, Golson and Hughes (2004: Fig. 9) modified from Denham (2004: Fig. 7). Reproduced with permission.

Figure 11.8 A view NE over complex A (of Figure 11.7) after its excavation in 1977, showing the character of the archaeological remains.

Source: Photograph by Ed Harris, Kuk archive, 1977.

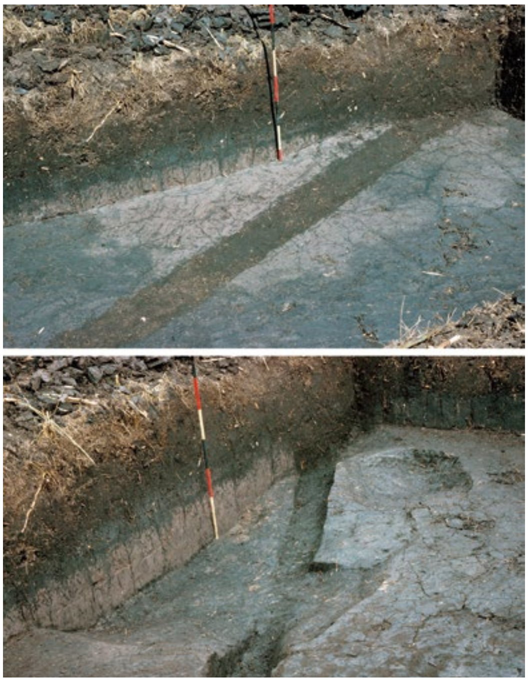


Figure 11.9 Top image is a view of the base of an excavation trench of 1975 at the northern end of block A12c: a grey clay-filled feature with a Phase 5 garden ditch crossing it from WSW to ENE. Bottom image taken after excavation of the feature, which appears as a complex of intersecting basins.

Source: Photographs by Klim Gollan, Kuk archive, 1975.

First, the edges of many features are smooth and clearly defined against underlying strata (Figs 11.9a and 11.9b), particularly Ep and Rom ashes (Fig. 11.10). Consequently, these often shallow features are not products of clay deformation or peat shrinkage. Edge definition and smoothness are suggestive of dug features rather than of tree bowls, root moulds and tree-throw depressions, which would be anticipated to have more irregular edges. In the context of the limited Papua New Guinea archaeological database at the time of the Kuk investigations, it was initially suggested that such basins might have been pig wallows, given their similarity to depressions in Phase 2 accompanied by stakeholes, although this interpretation has long since been discounted (Denham, Golson and Hughes 2004: 277; and cf. Fig. 12.10).

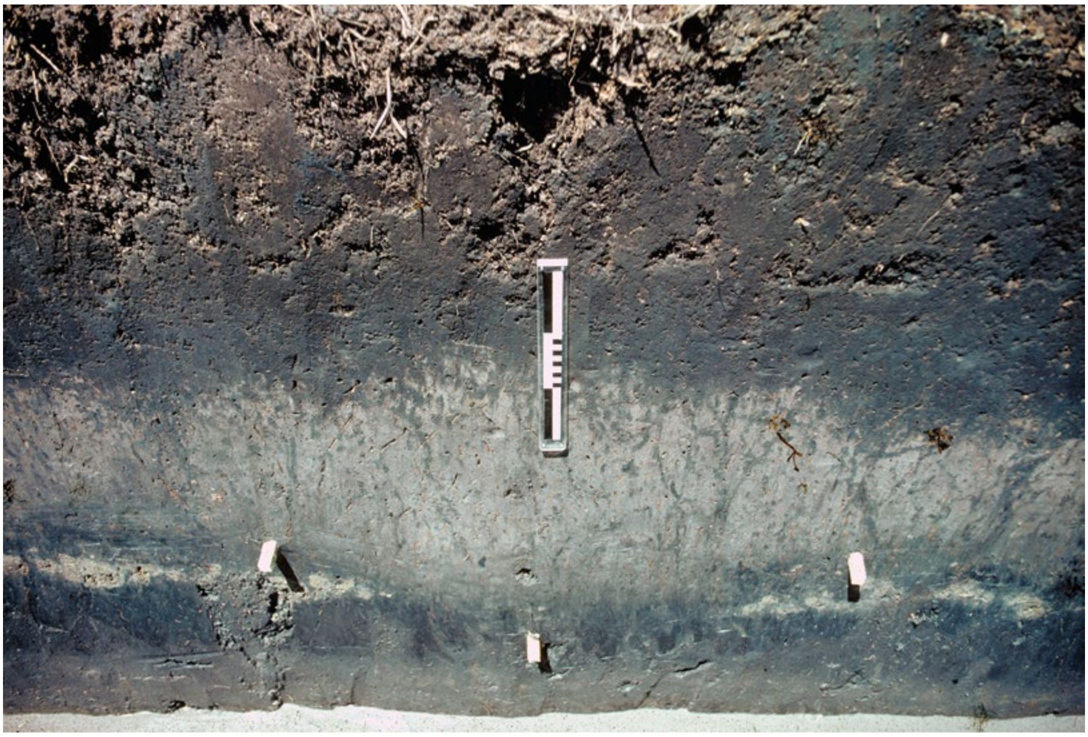


Figure 11.10 A basin-shaped feature buried under grey clay in the west wall of Station drain A12a/b, which was dug in 1976.

Note how the feature cuts across and is clearly defined against an underlying exposure of Ep ash that is preserved as a lens of indurated nodules.

Source: Photograph by Alistair Marshall, Kuk archive, 1976.

Second, runnels and pits are interpreted to represent the wet cultivation and harvesting of taro (*Colocasia esculenta*), respectively. These features did not form an integrated drainage network as described for areas of the Phase 2 palaeosurface in Chapter 12. Pits and runnels would have been wetter than adjacent areas and such conditions are favourable to the growth of *Colocasia* taro (cf. Fig. 11.11). Smaller pits within larger features and irregularly shaped pits may represent the digging of taro corms (after Powell et al. 1975: 11–12 and Tim Bayliss-Smith, pers. comm., 2006).

Third, *Colocasia* taro is known to have been in the vicinity and used by people during Phase 1 because aroid seeds have been collected from the fills of channel 101 (see Textbox 10.1) and starch grains have been identified on the used edge of a stone flake (K/76/S29B) collected from the palaeosurface (Fullagar et al. 2006: 605; see also Table 10.T3.1 and Chapter 18). Processing of taro is necessary to remove bitter-tasting oxalates, to enhance taste and to liberate nutrients for digestion. The few stone artefacts present on this palaeosurface are of the kind to be expected within a subsistence plot and represent the use of stone tools to process plants prior to cooking. At this time, most artefacts used for gardening and food processing were probably wooden and have not been preserved in palaeosurface features.

Fourth, numerous postholes and stakeholes occur on the palaeosurface and seem to be associated with pits (Figure 11.12). In gardens in the Kuk vicinity today, posts and stakes are used to support crops such as species of cane grass (e.g. *Setaria palmifolia*) and *Musa* bananas (after Powell et al. 1975: 4–12; Gorecki 1982: 203–210; see Figs 12.12–12.13), some of which were present in the Kuk vicinity at least 10,000 years ago (see Table 10.1).

Fifth, the basal fills of features on the palaeosurface are more heterogeneous than underlying (black organic clay) and overlying (grey clay) strata (Fig. 11.13). Although only a coarse guide, this heterogeneity is interpreted as representing limited soil formation on black organic clay when it was exposed at the surface during Phase 1. The soil profile is characteristic of immature soils in alluvial and wetland settings that do not generally have long periods to form before being buried or waterlogged. Limited mechanical admixture plausibly reflects minimal tillage techniques, such as dibbling during planting and/or digging during harvesting.

Sixth, elevated charcoal densities in the fill of one palaeosurface feature could indicate localised burning within the plot. Burning occurs prior to planting in plots across New Guinea today, although the case in question may have been associated with other activities, e.g. hunting or a temporary rest site.

Figure 11.11 Taro growing in wet conditions along an in-filled drain at a garden near Mt Ambra.

Source: Photograph by Alistair Marshall, Kuk archive, 1976.

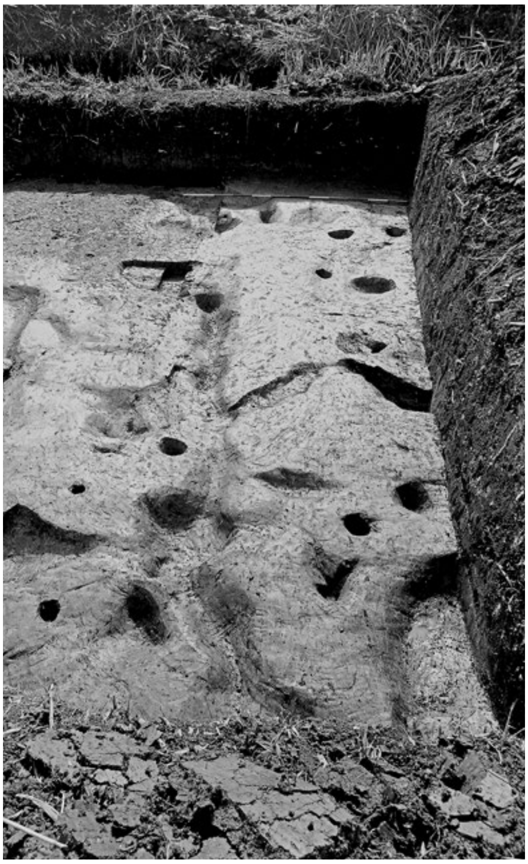


Figure 11.12 Looking east over part of the Phase 1 palaeosurface excavated in 1976, showing the juxtaposition of various feature types, particularly microtopographic drainage features and stakeholes.

The area in the photograph is part of complex D in Figure 11.7. It can be identified in Figure 11.7 by the group of four features, two stakeholes to the right of the lower bracket of D, one stakehole and one small pit to the left of the bracket. Note that the triangular depression to the right of the upper case D on Figure 11.7 is a later disturbance. The ranging pole is graduated at 200 mm intervals.

Source: Photograph by Alistair Marshall, Kuk archive, 1976.

Figure 11.13 X-radiographic image showing soil formation at the base of a Phase 1 feature.

Soil formation is evident from the slightly less dense aggregates (lighter patches in the lower third of the image), which are clearly discernible against the overlying darker and denser grey clay fill.

Source: Denham, Haberle and Pierret (2009: Fig. 2a), reproduced with permission.

In summary, the multidisciplinary evidence for the Phase 1 palaeosurface is consistent with clearance, cultivation, digging and staking within a plot. The plot was probably inter-cropped, i.e. different plants were grown together within the plot. *Colocasia* taro was used and a range of other edible and starch-rich plants were present in the vicinity, including edible cane grass (e.g. *Setaria palmifolia),* Musa bananas, gingers (*Zingiberaceae*) and a yam (*Dioscorea* sp.). A range of vegetables (*Coleus* sp., *Oenanthe javanica* and *Solanum* sp.), berries (*Rubus* spp.) and nut-bearing trees (*Castanopsis* sp., *Pandanus* spp.) were also present and potentially used.

Palaeosurface features appear to be restricted in distribution to an area of higher ground adjacent to the palaeochannel. The use of this area of higher ground seems to have been short-lived, occurring during the period when channel 101 was open. Following the abandonment of the channel, which filled in rapidly with debris and sediment eroding from the catchment, a reversion to wetter conditions and burial under grey clay prevented further human modification of the palaeosurface, retarded subsequent soil formation and aided preservation of the archaeological remains. Occasional reuse within the plot probably occurred to harvest wild plants or cultivated ones surviving within the abandoned plot, e.g. *Colocasia* taro and *Musa* bananas. Similar practices of harvesting *Musa* bananas and other crops in abandoned gardens are common throughout New Guinea today.

Landuse

Several lines of on-site and off-site evidence indicate that people were manipulating their environment in the Kuk catchment and on the wetland edge 10,000 years ago. Materials deposited within channel 101 reflect human alteration of the environment at both local and regional scales. The presence of delicate materials such as soil aggregates and leaves, as well as coarse organic materials such as branches, are suggestive of a local origin. Delicate aggregates and organic materials would not be expected to survive extended periods of transportation in a small stream. The presence of these materials together with large blocks of wood is consistent with the clearing of vegetation and resultant soil erosion on land immediately adjacent to channel 101. Such an interpretation is supported by high charcoal frequencies in these fills as well as in that of one adjacent palaeosurface feature (Denham et al. 2003; Denham, Sniderman et al. 2009; Haberle et al. 2012).

The fills of channel 101 are suggestive of extensive human activities in the stream's catchment. Deposition of grey clay in the palaeochannel and on the palaeosurface over the period 10,000 to 7000 years ago has been interpreted to be a result of erosion following forest clearance for dryland cultivation under a swiddening regime (Golson and Hughes 1980; Hughes, Sullivan and Yok 1991). Recent palaeoecological research has shown the role of fire in that clearance (Denham et al. 2003; Denham, Haberle and Lentfer 2004; Denham and Haberle 2008; Denham, Sniderman et al. 2009). Sediments, pollen, macrobotanical remains and charcoal in channel 101 reflect increased local disturbance using fire. High pulses of charcoal represent an increased intensity of fires within the catchment in contrast to Late Pleistocene records (see Chapter 9). Increasing frequency of fires (measured from microscopic charcoal) is accompanied by decreasing frequencies of primary forest taxa and increasing frequencies of disturbed, secondary and grassland taxa (measured from pollen). Disturbance of the primary forest occurred at a time when there is no clear evidence that forests were under climatic stress (cf. Brookfield 1989), which would have sensitised them to disturbance. Sustained and cumulative disturbance accompanied by fire indicates human as opposed to climatic causes (after Haberle 1994). In the highlands context, these signatures are interpreted as representing extensive swidden cultivation of slash-and-burn or slash-and-mulch types (cf. Haberle 2003). Smaller-scale house-garden horticulture is less likely to result in a cumulative and prolonged signal of forest disturbance (cf. Harris 1995: 853; 1996b: 568). Similarly, the palaeoecological signals under discussion are not consistent with anthropogenic exploitation of patches within the forest caused by landslides, lightning, tree-throw and other natural phenomena.

While the antiquity of the archaeological and palaeoecological records is unique to Kuk, they are not likely to have been restricted to the site or its catchment. Evidence for the extent of regional forest clearance by the mid Holocene is provided by three sites in the upper Wahgi Valley in addition to Kuk: Draepi-Minjigina, Lake Ambra and the Manton site on Warrawau Tea Estate (Powell 1982a: 218–221, 223; see Fig. 9.1 Inset here). Although the timing of initial forest clearance at these sites is unknown, the Kuk evidence suggests that it occurred in the early rather than the mid Holocene (Denham, Haberle and Lentfer 2004; Denham and Haberle 2008). Similar forest disturbance was initiated in the Baliem Valley of Indonesian New Guinea before 7800 years ago (Haberle, Hope and de Fretes 1991).

Although dryland practices continued in the catchment at Kuk after 10,000 years ago, there is no archaeological evidence for continued use of the wetland margin during the next 3000 years. There was a gradual succession from wetter (typha reed and pandanus swamp forest) to drier (Compositae, ferns and forest regrowth) conditions locally on the swamp margin, with an increasingly deforested dryland landscape in the catchments. Intact chains of phytoliths within the grey clay indicate that Musa bananas were growing in the vicinity. Diagnostic seed phytoliths of *Musa* (formerly Eumusa) section bananas are present with the onset of grey clay deposition (see Textbox 10.2). A stone mortar fragment (K/77/S34) collected from within grey clay (Golson 2000, Fig. 11.14 here; see also Chapter 18) is suggestive of people processing plants, like nuts of *Castanopsis* and *Elaeocarpus*, seeds of Job's tears (*Coix lachryma-jobi*) (Bulmer and Bulmer 1964: 70; R. Bulmer 1964), or *Colocasia* taro, as Swadling has argued (1983: 74–75; cf. Swadling and Hide 2005: 295–296). This item belongs to the well known but less well understood stone mortar complex of New Guinea, few examples of which have been found in datable contexts. The find spot at Kuk is conservatively dated to around 7500–7000 years ago, which makes it the oldest specimen on record from New Guinea (Golson 2000: 236).

Figure 11.14 The rim fragment of a stone mortar found in the grey clay fill of a Phase 1 basin, above its base, during excavation in 1977.

The Phase 1 basin in question is the one protruding east from beneath the west wall of the 1976 excavation, which is in the foreground of Figure 11.5b. It was fully exposed in 1977 when the trench wall was moved back and forms part of complex B, which Denham defined after his 1998 excavation (see Fig. 11.7). Figure 11.14 (top) looking down at the outside of the vessel, with the lip at the top and the shoulder below. Figure 11.14 (bottom) looking at the inside of the rim with the lip at the top.

Source: Photographs by Bob Cooper and Darren Boyd; cf. Golson (2000: Plate 1a and 1b).

Agriculture at 10,000 years ago?

In the context of continuing dryland cultivation, Phase 1 is a short-lived period of activity in the Kuk Swamp around 10,000 years ago. The spatial extent and chronology of plant exploitation practices elsewhere in New Guinea during the early Holocene remain to be determined. Before this can be undertaken, better resolution is needed in translating generalised palaeoecological signals into specific prehistoric practices (cf. Haberle 2003; Powell 1970a; Denham 2007a; Denham and Haberle 2008). Even with high-resolution palaeoecological indicators, prehistoric subsistence is best inferred following the excavation of the physical evidence of former practices, which are best preserved along wetland margins.

Both on-site and off-site records at Kuk indicate localised and patchwork forest clearance within the catchment using fire, which led to increased erosion rates. Archaeological traces of prehistoric dryland practices are prone to destruction by subsequent erosion, gardening and soil formation, whereas the morphology of the constituent features on the wetland edge has been preserved by burial and waterlogging.

The authors differ about the interpretation of the Phase 1 evidence (Denham, Golson and Hughes 2004: 278, 293). For Hughes and Golson (drawing on Golson and Hughes 1980), channel 101 is artificial, dug to allow the cultivation of the wetland margin, as represented by the features on the Phase 1 palaeosurface. For them, Phase 1 was similar to Phases 2–6 at Kuk, that is, 'wetland management for cultivation' (Hope and Golson 1995: 824) associated with dryland gardening in the swamp catchments. In their view, the appearance of these practices at Kuk 10,000 years ago represents new developments in both the dryland and wetland spheres, shifting cultivation in the former and drained cultivation in the latter. These developments are 'new' in the wider context of highlands prehistory because they contrast with Late Pleistocene evidence for forest disturbance (Golson 1991a: 84–88).

On the basis of archaeological, palaeoecological and sedimentological evidence produced by his more recent research (Denham et al. 2003; Denham 2003a, 2004), Denham questions these interpretations. He sees channel 101 as a natural channel that was not modified to any great extent by people. In his view, the Phase 1 palaeosurface at Kuk represents some form of plant exploitation on a wetland margin, not as a separate sphere, but rather as consistent with the spatial extension of dryland practices onto the swamp margin, perhaps during short-lived, locally drier conditions. Dryland practices may have been modified for the wetland edge, for example for the cultivation or exploitation of *Colocasia* taro.

Even though specific interpretations vary, all three authors agree that the multidisciplinary evidence for Phase 1 at Kuk represents prehistoric plant exploitation. The archaeological remains, archaeobotanical finds and palaeoecological signals can all be interpreted with reference to contemporary forms of plant exploitation in New Guinea. For Golson and Hughes, the drainage and modification of the wetland margin signify the emergence of wetland agriculture, potentially focused on *Colocasia* taro. This interpretation is based on the nature of the archaeological remains at Kuk and was proposed before macrobotanical and microfossil evidence of *Colocasia* taro had been found. For Denham, the evidence indicates practices similar in nature (on-site archaeological evidence) and environmental impact (off-site palaeoecological evidence) to extensive forms of plant exploitation, or potentially swidden cultivation. At this time, there may have been no great differences in the way people exploited drylands and wetlands, although different plants may have been present and targeted in each environment. People may have begun to focus on starch-rich edible plants, such as *Musa* bananas on drier slopes and *Colocasia* taro in wetter environments, which is characteristic of present-day agriculture across New Guinea.

The absence of archaeological remains at Kuk and other wetland sites in the highlands over the subsequent 3000 years prevents a greater understanding of the diversity and development of subsistence practices in dryland and wetland environments. Palaeoecological signals indicating forest disturbance using fire, similar to those documented during Phase 1 at Kuk, continue from the early to mid Holocene and are accompanied by increased deposition of grey clay on the wetland margin suggestive of increased erosion in the catchment. It is not until the advent of mounded cultivation on the wetland margin at 7000–6500 years ago that clearly intensive forms of cultivation are present.

12

Phase 2: Mounded Cultivation During the Mid Holocene

Tim Denham, Jack Golson and Philip Hughes

Introduction

For Golson and Hughes, the evidence of landuse 10,000 years ago at Kuk qualifies as agriculture, but for Denham it is insufficient to support this claim. In contrast, the appearance of mounded cultivation dating within the period 6950–6440 years ago at Kuk Swamp represents the earliest unequivocal evidence of agriculture in the highlands of New Guinea (Hope and Golson 1995: 823). Directly comparable, but later, mid Holocene remains have been documented at two other sites in the upper Wahgi Valley, Mugumamp and Warrawau, while more uncertain evidence has been documented at the more distant sites, Kana and Ruti (see Fig. 12.1). Evidence for early Phase 2 at Kuk and other sites in the highlands is central to arguments for the early and independent origins of agriculture in New Guinea (Hope and Golson 1995; Denham et al. 2003; Denham, Golson and Hughes 2004). In this chapter, archaeological remains at Kuk are considered in greater depth, because they have been investigated in greater detail and have guided the interpretation of finds at other highland sites.

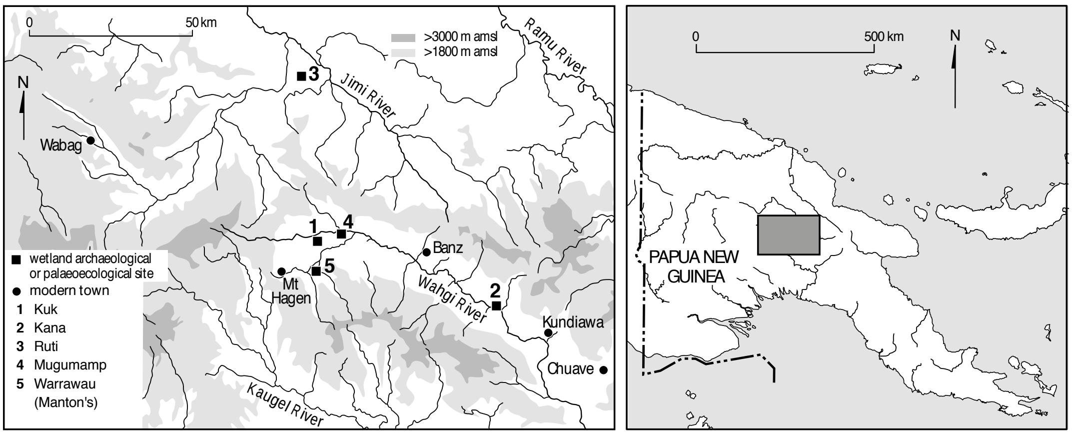


Figure 12.1 The location of sites said to have evidence comparable to Phase 2 at Kuk.

Source: Drawing by Kara Rasmanis.

Kuk

In stratigraphic terms, Phase 2 features at Kuk postdate grey clay and predate Kim tephra (R) deposition (see Fig. 6.10). During the first years of investigation (1972–74), these features, appearing in plantation drain walls as shallow depressions in the upper surface of grey clay, were thought to be natural. Excavations undertaken in 1975 indicated they were of human origin. At least two distinct periods, or subphases, are present at Kuk: an early subphase within the period 6950–6440 years ago and a late subphase falling before 3980–3630 years ago. Both identifiable subphases are associated with distinctive and well-dated stratigraphic markers. Many early subphase features contain basal lenses of a deposit now called Red and White (R+W), which was initially thought to be a tephra and given the name Komun, but which micromorphological research has shown to be comprised predominantly of phytoliths (Denham 2003a: E4.8 and Fig. E4.8; see Table 7.1 here). R+W dates to 6440–5990 years ago (Table 7.2) and features that contain this deposit must predate its formation. Samples of charcoal from the basal fills of several early subphase features date to 6950–6440 years ago (Denham et al. 2003). Late subphase features contain and predate lenses of Kim (R) ash, a tephra that fell 3980–3630 years ago (Denham et al. 2003; Coulter et al. 2009; see Table 7.2 here). Some features in both subphases have neither R+W nor R lenses preserved in their fill, which suggests erosion or reworking by later human activities and by soil formation.

The early subphase is better defined than the later one and is discussed in detail, whereas the late subphase is only briefly summarised because it has been poorly characterised in excavations to date. More localised subphases may be present, but have not been identified because they lack distinctive stratigraphic markers. These subphases could potentially represent spatially variable use of the wetland margin at different times in the past.

Early subphase: Mounded cultivation at 6950–6440 years ago

The archaeological and palaeoecological evidence for early Phase 2 at Kuk demonstrates prehistoric cultivation using mounds and the creation of anthropogenic grasslands at Kuk at some stage between 6950 and 6440 years ago. The early subphase has two main archaeological components: at least three palaeochannels and a palaeosurface of variable form.

Palaeochannels

Based on radiocarbon dates and diagnostic stratigraphy, three palaeochannels—William's Baret (104), Kupalg's Baret (105) and Mek's Baret (109)—are potentially contemporary with the early Phase 2 palaeosurface (Fig. 12.2). Like all but one of the palaeochannels associated with Phases 1–6, channels 104 and 105 drained the southern catchment of Kuk Swamp, whereas the exception, channel 109, located in an area of hillocks at the western end of E–W Road 3, appeared to have a very small catchment of a few hectares on the margin of the swamp.

These palaeochannels have previously been interpreted to be artificial (Golson 1977a: 615–616; Golson and Hughes 1980: 298), although a recent reassessment of the archaeological evidence questions this interpretation (Denham 2003a: 160–176; 2003b: 163–164). The slightly sinuous plans, cross-sectional morphologies and course gradients provide information that can be used to support both positions. Debate continues on this matter and the key points of dispute are summarised below.

a. Several reaches of channels 104 and 105 are relatively straight and this observation is taken by Hughes and Golson to indicate artificial construction (Figs 12.2 and 12.3). Although unusual, natural watercourses do occasionally have straight sections (Ferguson 1981: 119). Other reaches of palaeochannel course are slightly sinuous, and these are more consistent with natural watercourses. The surface traces of originally straight channels, once abandoned and largely filled in, can become slightly sinuous with continued flow, as happened to the undoubtedly artificial Phase 5 and 6 palaeochannels, as depicted in Winifred Mumford's 1972 map of the course of Wai's Baret (Golson 1976: Fig. 3; see Fig. 15.3 here).

b. Channels 104 and 109 have wide and shallow cross-sections, whereas that for channel 105 is deeper and U- to V-shaped (Fig. 12.4a–c). The cross-sections of the first two channels may indicate low energy flow with banks subject to subaerial erosion, whereas the cross-section of channel 105 suggests bank profiles dominated by fluvial processes and down-cutting as a result of channel rejuvenation (see Fig. 12.4c). Channel cross-sections are within the range of natural watercourses such as brooks and streams (Knighton 1998: Table 5.1).

c. Field observations made by Golson and Hughes suggested that channels 104 and 105 traversed undulating topography without deviation. In particular, channel 105 was interpreted to traverse slightly higher ground comprised of Pleistocene tephra-mantled lahar deposits, which were over 1 m high in the present-day landscape. As had been the case with Kundil's Baret (channel 101) of Phase 1, the straight course and passage through higher ground was interpreted as inconsistent with a natural watercourse and suggestive of artificial construction (Fig. 12.5). Despite the massive and spectacular section of channel 105 cutting through Pleistocene deposits (Fig. 12.6), it is unclear whether the higher ground existed at the time of palaeochannel formation or whether it was a product of differential shrinkage of the stratigraphy (Denham, Golson and Hughes 2004: 269–274). Unfortunately, there are no sufficiently detailed survey records for the potentially significant straight reach of channel 105 (indicated in Fig. 12.3). Channel 109 is in a different setting and its course has not been surveyed across the landscape.

Figure 12.2 The courses of Phase 2 palaeochannels in the eastern part of Kuk Station.

Channel 105 disappears northwestwards off the map from its SW corner, while the channel at complex 109, which was the subject of only limited investigation at the northern end of block C2, is off the map altogether. Only the most relevant of the low hillocks that form prominent features of the relatively flat wetland margin are shown.

Source: Denham, Golson and Hughes (2004: Fig. 11), reproduced with permission. Drawing by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

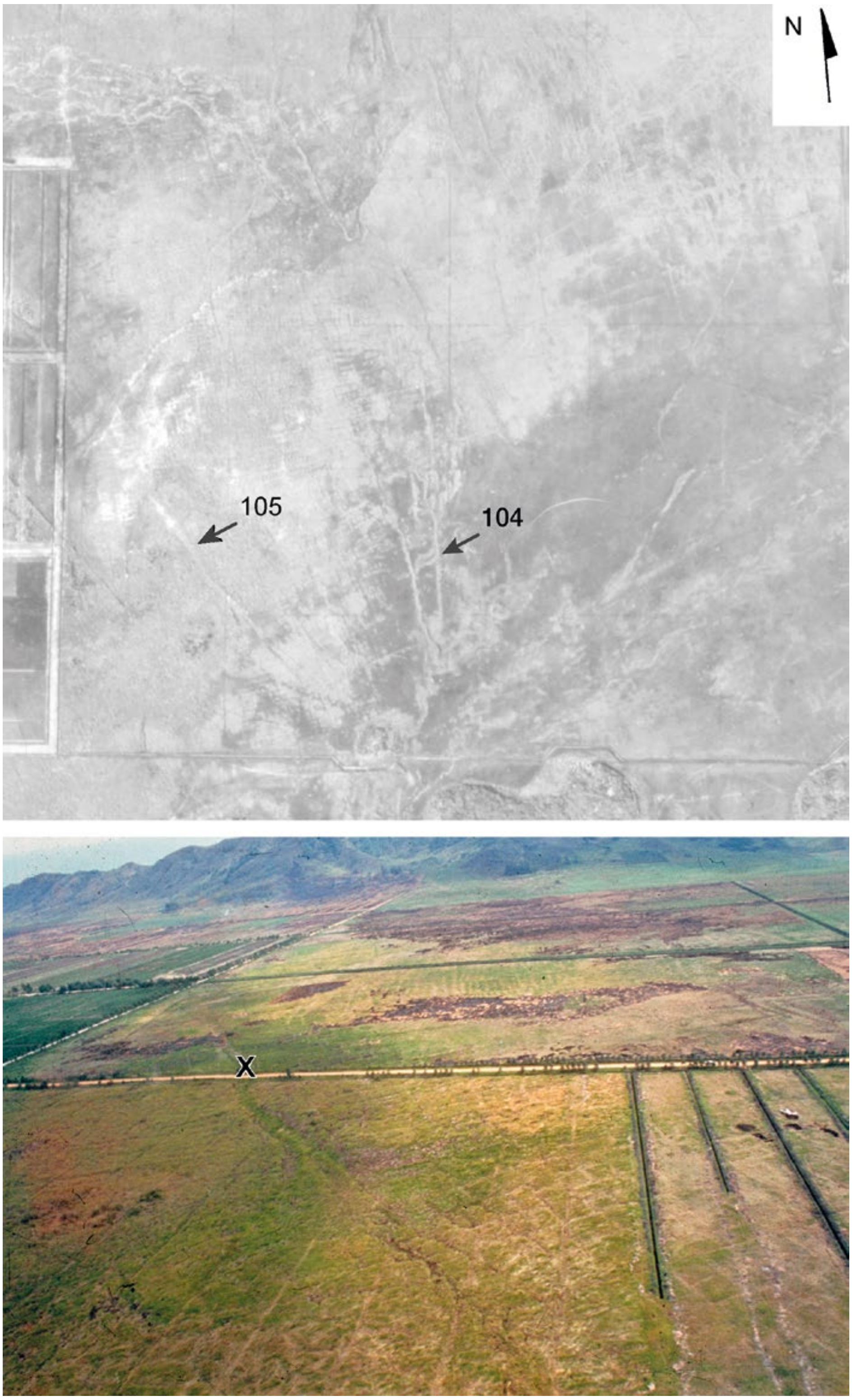


Figure 12.3 Early Phase 2 palaeochannel courses at Kuk from the air.

The vertical photograph (top) depicts the courses of channels 104 (William's Baret) and 105 (Kupalg's Baret); and the oblique photograph (bottom) shows the NNW course of channel 105 crossing E–W Rd 1 from block A8 to block B7, 'x' marks the location of Figure 12.6.

Source: Upper photograph by Mapmakers January 1970, Run 24, reproduced with permission; lower photograph by Wal Ambrose, Kuk archive, 1972.

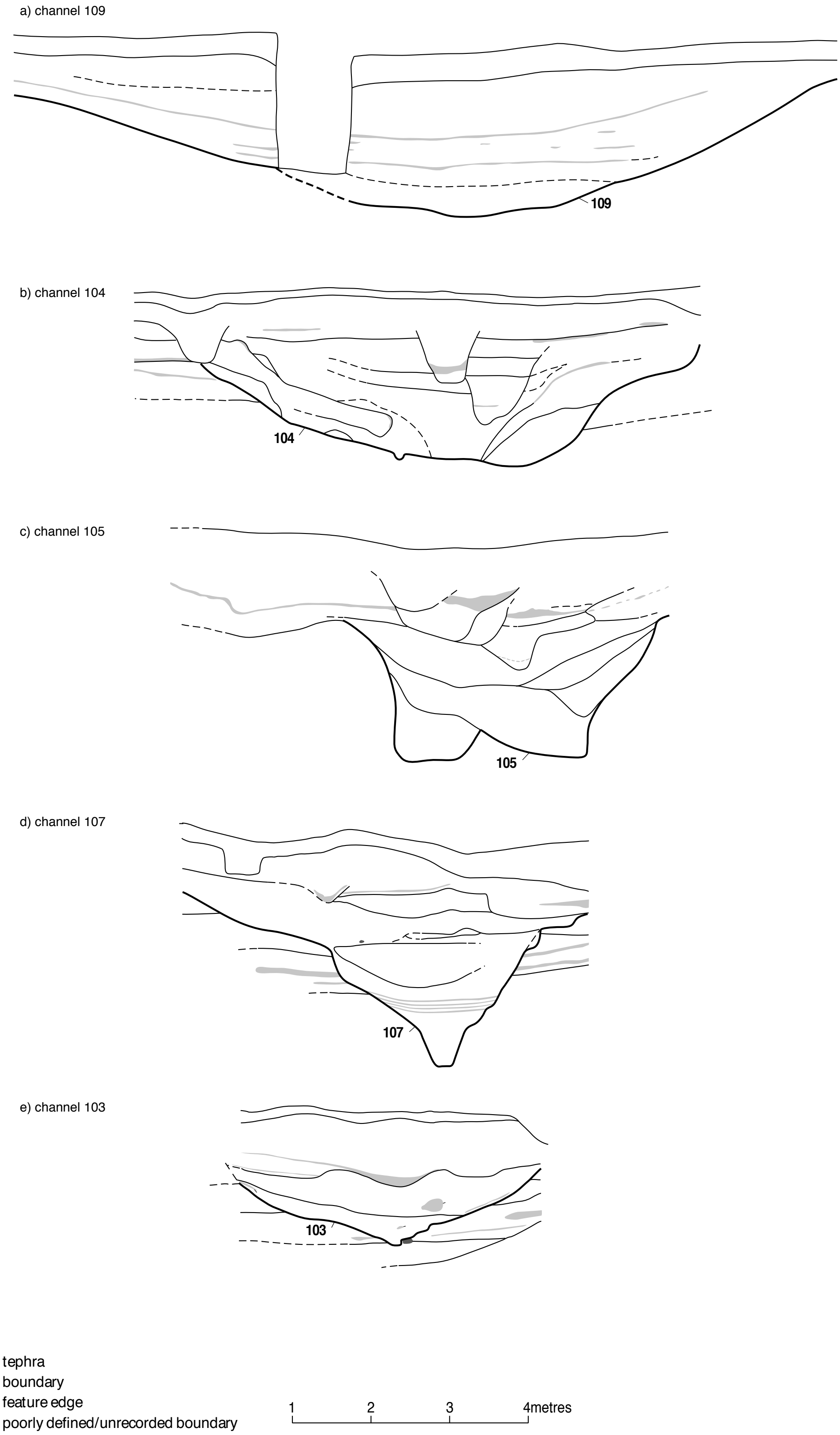


Figure 12.4 Typical cross-sections of Phase 2 palaeochannels.

Source: Drawing reconstructed by Tim Denham from the fieldnotes of Philip Hughes and Jack Golson. Reproduced with permission from Denham, Golson and Hughes (2004: Fig. 5).

Figure 12.5 Looking south from E–W Rd 3 to a surface dip that marks channel 105 (Kupalg's Baret) crossing a hillock in block C6.

Source: Photograph by Jack Golson, Kuk archive, 1975.

Figure 12.6 Kupalg's Baret (channel 105) exposed in profile in the north wall of the north drain of E–W Rd 1.

Korowa of Kuk village stands on the bottom of the road drain, part of which he has dug out to expose the section across the channel and its fill. The location is indicated by an 'x' on Figure 12.3 (lower).

Source: Photograph by Philip Hughes, Kuk archive, 1975.

In summary, it remains a matter of debate whether the palaeochannels associated with early Phase 2 are artificial. Irrespective of their mode of formation, there is no direct association between the palaeochannels and palaeosurface. In contrast to Phase 1, in which the investigated palaeosurface was immediately adjacent to the palaeochannel, early Phase 2 palaeochannels are located over 300 m west of areas where the contemporary palaeosurface has been excavated (Denham, Golson and Hughes 2004: 287). Any association between palaeochannels and palaeosurface during early Phase 2 is indirect; that is, palaeochannels allowed human use of the southern portion of the wetland margin because they limited flooding by incident water from the southern catchment and aided local drainage.

Palaeosurfaces

Early use of the palaeosurface at the top of grey clay was restricted to the southern portion of the wetland margin, being largely limited to the A blocks and the southern portion of the B blocks. It is assumed that areas to the north were lower and too wet to use at this time. Excavations targeted on the early palaeosurface revealed two distinct types: 'integrated' and 'discrete'. The integrated palaeosurface consists of regular to semi-regular networks of features dug into grey clay, which defined upraised 'islands' at the surface of grey clay (Figs 12.7 and 12.8). The discrete type is in some places suggestive of denudation and truncation of more integrated forms, whereas in other areas scattered features suggest different and less intensive practices taking place between integrated plots (Figs 12.9 and 12.10). Many of the features are shallow and fills are not clearly differentiated from the main black clay stratigraphic unit (Fig. 12.11), except where basal R+W lenses are present. Multiple lines of evidence indicate early palaeosurface types to be associated with human activities and, more specifically, with cultivation.

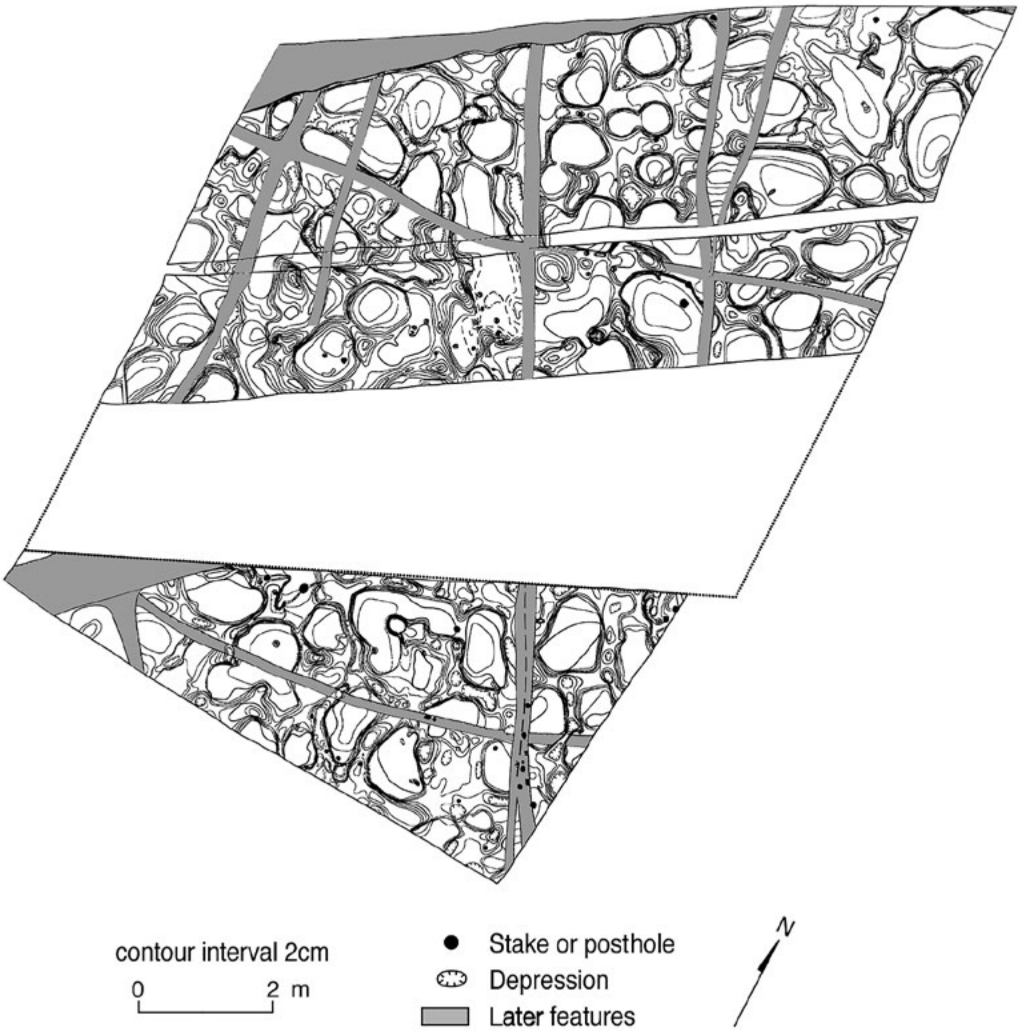


Figure 12.7 Base plan of two excavation trenches at the north end of block A11f showing the 'integrated' type of early Phase 2 palaeosurface.

Originally, the more northerly of the two excavation trenches was dug as two separate trenches, one in 1976 (see Fig. 12.8), the other in 1977, parallel to the first but initially separated from it by a narrow baulk. The triangular cutting to the south was excavated in 1977. Note the use of different datums for the northerly and southerly trenches.

Source: GIS image prepared by Uri Gilad from a contour plan of 1977 by Art and Cherie Rohn.

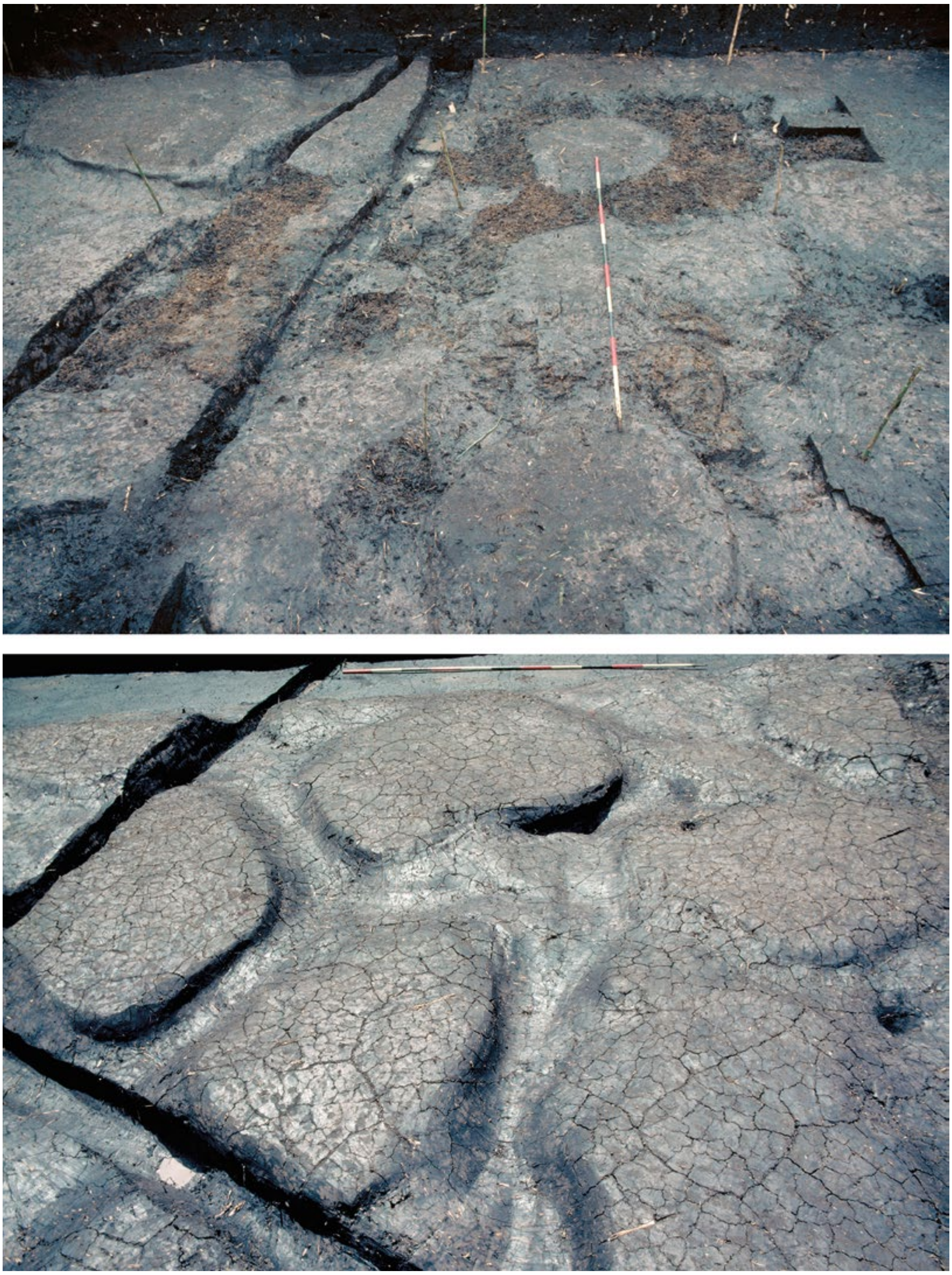


Figure 12.8 The first trench of the Phase 2 excavations shown in Figure 12.7: (upper) grey clay 'islands' contrast with surrounding fills with their lenses of R+W (Komun), looking S; and (lower) grey clay 'islands' are clearly defined following removal of the surrounding fills, looking N. The linear features crossing the palaeosurface are garden ditches of a later date. Ranging poles are calibrated at 200 mm intervals.

Source: Photographs by Alistair Marshall, Kuk archive, 1976.

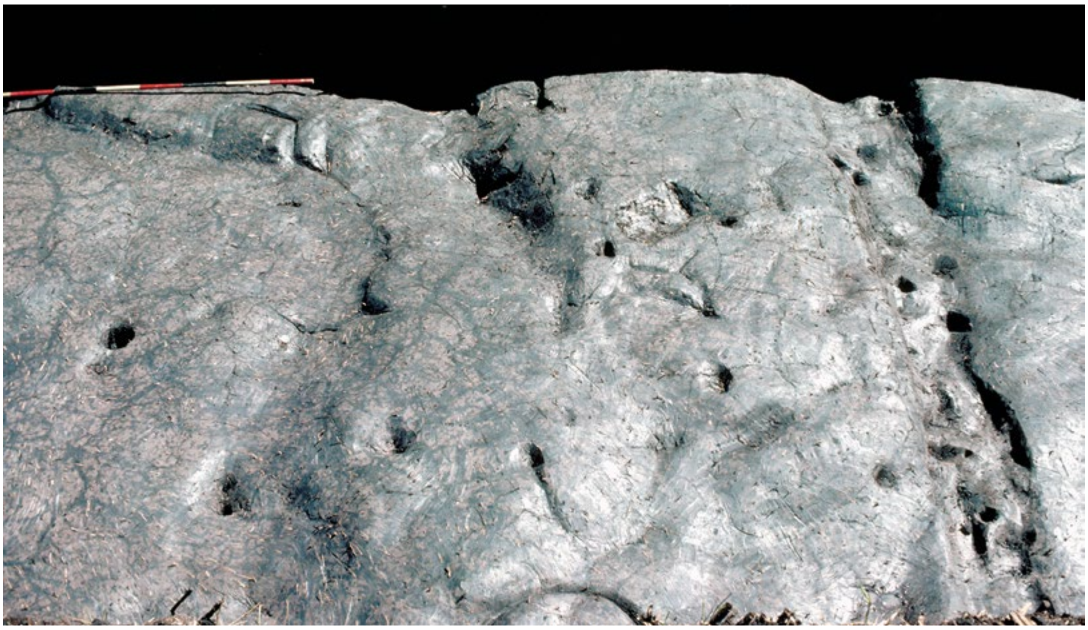


Figure 12.9 An excavation at the northern end of block A11h provides an example of the 'discrete' type of early Phase 2 palaeosurface.

The juxtaposition of various feature types, like shallow saucers and deeper pits, and the association of post and stakeholes are reminiscent of the Phase 1 palaeosurface shown in Figure 11.12.

Source: Photographs by Alistair Marshall, Kuk archive, 1976.

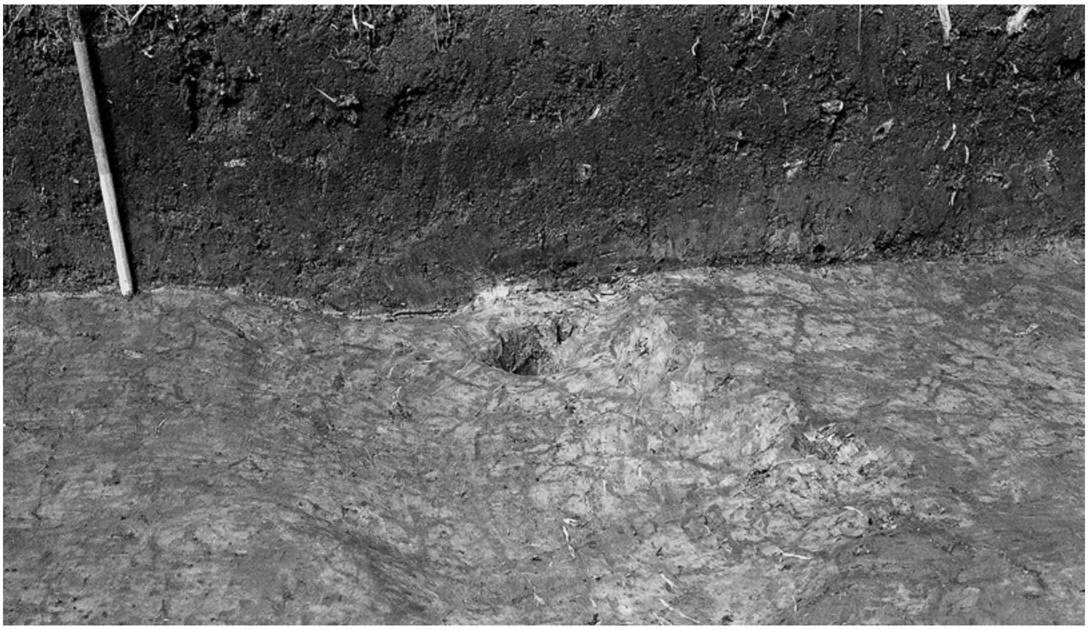


Figure 12.10 Looking west over a shallow pit with stakehole in the NW corner of an excavation at the northern end of block A12d (see Fig. 15.10).

At the time, the presence of a stakehole with a shallow pit was seen as providing strong support for the presence of pigs, because the contemporary tethering of pigs produced the same combination of features in the ground (cf. Denham, Golson and Hughes 2004: 284). Ru Kundil of Kuk village, who witnessed the excavation, thought so too, exclaiming (in pidgin) 'They staked a pig here!'. This interpretation is no longer current, given that pigs were probably introduced to New Guinea within the last 3000 years (see Chapter 15).

Source: Photograph by Klim Gollan, Kuk archive, 1975.

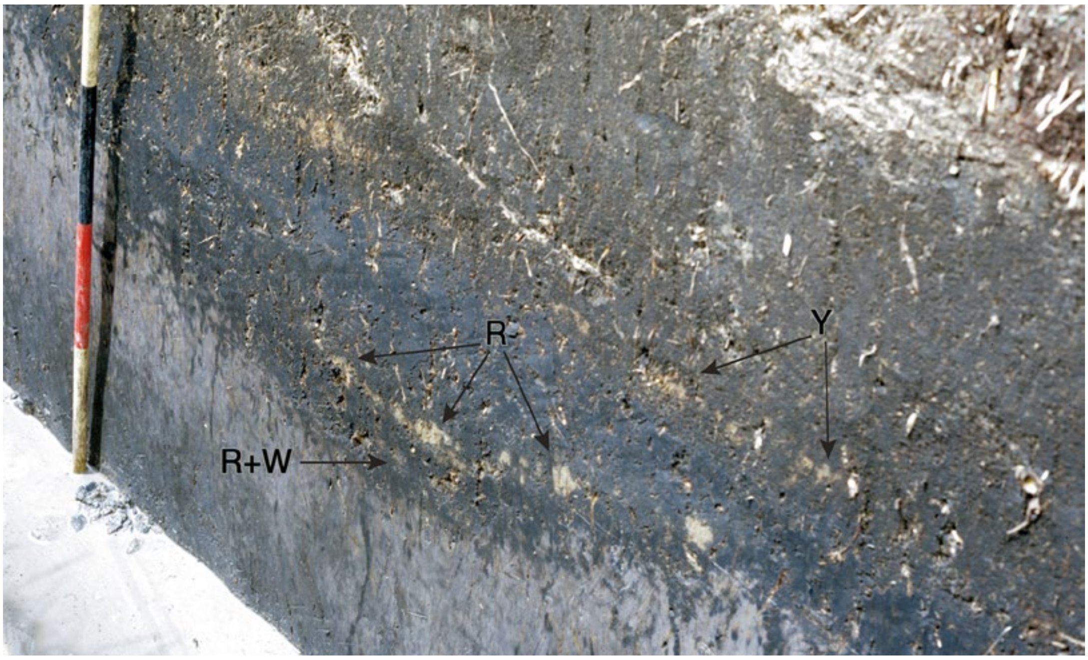


Figure 12.11 This basin-like depression in the top of grey clay is typical of how Phase 2 features appear in the walls of modern drains that cut across them, in this case the west wall of drain A11d/e.

In the stratigraphy, there is a discontinuous lens of Kim (R) ash dipping to 100 mm above the base of the basin and a similarly discontinuous but level-lying stretch of Baglaga (Y) ash above the northern rim of the basin at the transition from clay to soil. There are a few traces of R+W (Komun) below Kim. The ranging pole is graduated at 200 m intervals, although here the white segment above the metal point of the pole is partially obscured by mud.

Source: Photograph by Jim Rhoads, Kuk archive, 1974.

The highly regular form of the 'island beds' are more suggestive of artificial than natural formation and appear to be of human origin (see Figs 12.7 and 12.8). Non-human modes of formation were considered, particularly given the morphological resemblance of feature types to known microtopographic forms. For example, integrated and discrete palaeosurface types are morphologically comparable to network and 'melon-hole' gilgai, respectively (Hallsworth, Robertson and Gibbons 1955: 3 and 9). However, neither the geochemical and physical properties of the deposits nor prehistoric environmental conditions at Kuk are consistent with those required for gilgai formation or vertisol development (Denham 2003a: Appendix C6). The 'islands' formed the surface on which soil from the digging of adjacent subsoil features was heaped at the time of use, making mounds that have subsequently disappeared.

Repeated associations of vertical or slanting postholes and stakeholes with the deeper of the basins on the palaeosurface are considered to represent the staking of plants such as edible cane grass (e.g. *Setaria palmifolia*), *Saccharum* sugarcanes and *Musa* bananas and the use of branches as ladders to help with the wrapping or harvesting of bunches of bananas (Figs 12.12 and 12.13; Gorecki 1982: 206–208). The planting of other crops and the staking of yams and beans are unlikely to leave archaeological traces (Gorecki 1982: 206 and 209 respectively).

Figure 12.12 Stakes propping up banana plants at the Highlands Agricultural College, Korn Farm, Mount Hagen.

Source: Photographer unknown, the Kuk archive, 1977.

Figure 12.13 William Thomas on a tree ladder attending to the wrapping of bananas in his garden near Mt Ambra.

Source: Photographer unknown, the Kuk archive, 1977.

Artefacts and manuports, although sparse, were collected from contexts associated with the early palaeosurface (see Chapter 20, section 'Phase 2'; cf. Fullagar et al. 2006: 607–609, where the artefact catalogued K/76/S19 is wrongly attributed to Phase 3). Stone tools exhibit evidence for the processing of *Colocasia* taro and of palms (and, less likely, gingers), as well as for the presence of unidentified plant residues. These artefacts show that people were exploiting plants, including starch-rich root crops, when the mounded palaeosurface was used.

Evidence for the cultivation of bananas has been recovered from the fills of palaeosurface features (see Textbox 10.2). Locally elevated Musaceae phytolith levels (see samples 35, 36 and 37 of Table 10.1 and Fig. 10.T2.1) are interpreted to represent the deliberate planting of *Musa* bananas within mounded plots. Lower values in other feature fills represent spatial variability in cultivated plant densities within intercropped plots, i.e. high Musaceae phytolith densities were derived from the *in situ* death and decomposition of banana plants and plant parts. Analyses of plant seeds in general suggest that gardens and garden fallow were located in the vicinity at this time (Powell et al. 1975: 42).

Elevated charcoal levels and heterogeneous fills are interpreted as local burning and mechanical admixture. Burning may have accompanied initial clearing or reuse of the plot prior to mound construction and planting. Burning of vegetation enables organic nutrients to be rapidly released into the soil and provides fertiliser for the next planting. Heterogeneous feature fills are interpreted as reflecting a physical admixture of materials falling and being washed into features between mounds during construction and use. As well as intermixing, feature fills preserve characteristics associated with prehistoric soil formation that are missing from the overlying black clay.

The early integrated palaeosurface was previously interpreted as representing small-scale microtopographical manipulation of the wetland to enable the multicropping of plants with different edaphic requirements (Golson 1977a: 617). Water-tolerant plants, such as *Colocasia* taro, were potentially planted along the edges and in the bases of the palaeosurface drainage network, while water-intolerant plants such as *Saccharum* sugarcanes, *Musa* bananas, yams (*Dioscorea* spp.), edible *pitpit* (*Setaria palmifolia*) and mixed vegetables were planted and staked on the 'island beds' (after Powell et al. 1975: 42; Golson 1977a: 616, 1981: 57–58). Archaeobotanical finds confirm the presence of several important food plant species in the highlands by the mid Holocene (Denham et al. 2003; Denham 2003a: 311–328).

Recent research shows that although edaphic requirements were almost certainly a consideration in mound construction, the network of cut features did not contain permanent standing water. Diatom assemblages within the fills of palaeosurface features indicate damp conditions (Denham, Sniderman et al. 2009: 730–731). Based on this finding, mounds provided raised areas for the cultivation of moisture-intolerant plants and facilitated drainage during periods with standing surface water, which would have periodically collected above the massively structured clays in this flood-prone location (Denham, Sniderman et al. 2009: 737).

Landuse

The palaeoecology of the Kuk vicinity underwent a dramatic transformation at the beginning of Phase 2 (Denham, Haberle and Lentfer 2004; Haberle et al. 2012; and see Chapter 9 here). The forest signal drops significantly and is accompanied by dramatic increases in grass taxa frequencies. Associated charcoal frequencies suggest the formation and management of grasslands on the valley floor using fire, with only isolated stands of forest surviving on higher valley slopes (Denham and Haberle 2008). Thus, the formation and maintenance of extensive grasslands was a product of human activities and such degraded environments are characteristic of presently and recently cultivated areas across the highlands today. Mounded cultivation on the wetland margin occurred within such an open grassed landscape and was maintained by periodic burning. The maintenance of an anthropic landscape, for both the dryland and wetland environments, is suggestive of cultivation in the highlands context, but the dryland agricultural practices occurring at this time remain uncertain.

Late subphase: Cultivation before Kim ashfall, predating 3980–3630 years ago

The late subphase has three main components: palaeochannels, palaeosurface features and at least three composite features with linear and sinuous plans. Limited investigation of the late subphase hinders detailed interpretation, but the constituent features are analogous to those of the early palaeosurface and are interpreted in a similar way.

Palaeochannels

Two artificial palaeochannels, Kum's Baret (103) and Joseph's Baret (107), are definitely associated with the late subphase because both contain lenses of Kim tephra (R) low down in their fill (Fig. 12.4d and 12.4e), although channel 107 continues in operation beyond into early Phase 3.

A possible third palaeochannel is Kui's Baret (102), which could equally be early or mid Phase 3, under which it is discussed (see Chapter 13). The stratigraphic evidence to indicate the age of channel 102 was removed when channel 106 (a later cut of Kui's Baret) was dug.

Channels 103 and 107 differ in plan and cross-section from those of the early subphase. In plan, they follow extremely straight courses adjacent to each other across the southern wetland margin (see Fig. 12.2). In cross-section, they exhibit steeper U- to V-shaped cross-sections than those associated with the early subphase (compare Figs 12.4a, 12.4b, 12.4d, 12.4e). Both palaeochannels cut through low rises on the present-day landscape. It is uncertain whether people deliberately dug through these low rises in order to align the course of the channel, an interpretation proposed by Golson and Hughes, or whether the rises result from differential lowering of the ground surface due to sediment drying, shrinkage and erosion following recent drainage; namely, the rises did not exist at the time the palaeochannels were dug, the interpretation proposed by Denham (see Denham, Golson and Hughes 2004: 282, cf. 269–274). Irrespective of these differing interpretations, both palaeochannels were dug to enhance and regulate water flow and to prevent inundation of the wetland margin.

Late subphase palaeochannels do not appear to have articulated directly with the palaeosurface. Few Kim (R) ash-marked features of the late subphase were encountered in excavations adjacent to channels 103 and 107. As with the early subphase, the late subphase palaeochannels would have modified the hydrology of the wetland margin sufficiently to enable cultivation of the palaeosurface.

Palaeosurface

The late palaeosurface was preserved north of its early subphase equivalent; the greatest density of features occurred in B and C blocks. The palaeosurface has been recorded mainly in plantation drains with few occurrences in excavation trenches. It is unclear whether late subphase features form discrete or integrated palaeosurface types. Late subphase features appear to be more subangular in cross-section and more linear in plan than the rounded and sinuous features of the early subphase. Based on morphology, the features probably functioned in similar ways to those of the early palaeosurface and were dug to enable cultivation of plants with different edaphic requirements.

Two relatively straight linear features (328 and 355) and a sinuous curvilinear feature (504) were documented during excavations near palaeochannels 103 and 107 in blocks A12a and A12b (Fig. 12.2), though none of them was shown to articulate with either channel. The two linear features were extremely shallow, contained lenses of Kim tephra (R) and cut early subphase features marked by lenses of R+W ash. Both linear features were poorly documented during the original excavations in 1975 and not clearly defined during reexcavation in 1999.

The sinuous curvilinear feature 504 was well defined by excavations undertaken by Golson in 1976, 1977 and Denham in 1999. It was a composite feature consisting of a string of basins connected by short channel sections with rounded (concave) bases and sides (Figs 12.14 and 12.15). It is interpreted to be a prehistoric garden feature that contained an admixture of dense macrocharcoal, soil and subsoil aggregates and extremely high Musaceae phytolith frequencies (see samples 55 and 56, Table 10.2). All this suggests that cultivation occurred in the immediate vicinity and included clearance of grasslands using fire, physical disturbance of the ground surface, potentially to break up dense grass root mats, and planting of bananas with other crops in the same plot. As for the garden feature itself, Golson thinks it has a structural resemblance to the basins and interfluves of the integrated Phase 2 palaeosurface, though on a linear rather than an areal plan, and may have been used for the cultivation of moisture-tolerant crops like taro.

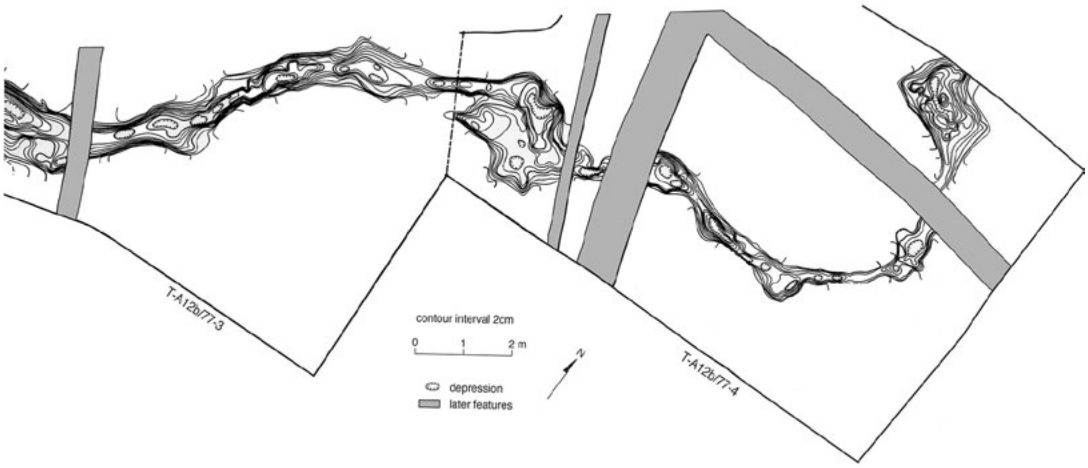


Figure 12.14 Plan of the sinuous curvilinear feature 504 of late Phase 2 age in the northern part of block A12b.

Source: Digitised by Uri Gilad, based on the original field plan drawn by Art and Cherie Rohn, 1977.

Figure 12.15 Looking SW along the line of sinuous curvilinear feature 504. The ranging pole is graduated at 200 mm intervals.

Source: Photograph by Ed Harris, Kuk archive, 1977.

Landuse

The palaeoecology at Kuk during the late subphase was similar to that of early Phase 2, namely the valley floor in the vicinity of Kuk was carpeted with grassland maintained by periodic burning (Denham, Haberle and Lentfer 2004; Haberle et al. 2012; Chapter 9 here). There is considerable continuity between the two subphases in terms of feature morphologies. Most features in both subphases are rounded in plan and section; they form complexes with curvilinear or sinuous plan forms. There are two palaeochannels, in the late subphase, which are the earliest to be unarguably considered artificial by Denham, Golson and Hughes, as well as three straight or curvilinear alignments of human construction. These palaeochannels and alignments are potentially of great significance for understanding the emergence of rectilinear ditch networks in Phase 3. At present, more research is needed to clarify the transition between Phases 2 and 3 at Kuk and other wetland sites.

Regional processes in the upper Wahgi Valley and beyond

Palaeosurfaces similar in form to the early integrated type at Kuk have been documented in excavations at two other wetland sites in the upper Wahgi Valley (Golson 1982: 121; Denham 2003b: 170–173). More equivocal evidence has been claimed to represent former agricultural activities of similar type and age at Kana near Minj (Muke and Mandui 2003) and on the Ruti Flats (Gillieson, Gorecki and Hope 1985).

As mentioned in Chapter 1, the 1966 excavations by Golson, Lampert and Ambrose at the Manton site on Warrawau Tea Estate on the floor of the upper Wahgi Valley, some 6 km across the Wahgi River from Kuk, provided the first direct evidence of the age of New Guinea agriculture (Golson et al. 1967; Lampert 1967; see Figs 12.16 and 12.17 here). A woman's digging stick yielded a radiocarbon date that calibrates to between 2000 and 2500 years ago, well before the entry into New Guinea of the tropical American sweet potato that is the present staple of highlands agriculture.

Figure 12.16 Aerial view of Warrawau Tea Estate in the upper Wahgi Valley looking SE from the river to the foothills of the Kubor Range.

Source: Photograph by Philip Hughes, Kuk archive, 1975.

In 1977, Golson and Hughes redug four of the original 1966 trenches at the Manton site in order to reexamine the ditch sequence in relation to that established at Kuk (Fig. 12.17; Golson 2002). A palaeosurface of similar form to the early Phase 2 palaeosurface at Kuk was present in one excavation trench (Trench M). Although of similar form, the 'islands' of grey sandy clay at Manton were much steeper and higher than those unearthed at Kuk (Fig. 12.18). In two other reexcavated trenches (Trenches C and D), a feature formerly interpreted to be a pond was investigated and found to be a palaeochannel. Fragments of gourd exocarp, originally interpreted to be bottle gourd (*Lagenaria siceraria*; Powell 1970a: 144–145), but now thought more likely to be wax gourd (*Benincasa hispida*; Golson 2002: 74), were collected from near the base of this palaeochannel. Radiocarbon dates and tephrochronology indicate that the palaeosurface and palaeochannel at Manton predate Kim tephra (R ash) and probably date to approximately 5500–5000 years ago (Golson 2002). Although of similar age, it is not known if the palaeochannel and palaeosurface were in use at the same time.

Also in 1977, Ed Harris and Philip Hughes (1978) conducted open area excavation and test pitting at Mugumamp Ridge in the North Wahgi swamp some 8 km east-northeast of Kuk. They uncovered a palaeosurface comparable to that of early Phase 2 at Kuk, comprising basins, 'islands' and postholes (Figs 12.19 and 12.20). Based on site stratigraphy and specifically the location of Kim (R) ash in the fills of features, the palaeosurface at Mugumamp is at least 4000 years old and may postdate late Phase 2 at Kuk (see Table 12.1). The association between the palaeosurface and a ditch encountered in the main excavation trench at Mugumamp is uncertain. Harris and Hughes (1978: 440–442) consider them to be functionally and chronologically associated, i.e. the ditch was dug to drain water, thereby enabling cultivation of the palaeosurface. In a review of the published evidence Denham (2003b: 170–171) concluded that the ditch postdated the palaeosurface.

The three morphologically comparable palaeosurfaces at Kuk, Mugumamp and Warrawau were not contemporaneous (Table 12.1). These sites show continuity of mounded cultivation practices in the upper Wahgi Valley over millennia. Mounded cultivation on the wetland margins at all three sites occurred within a highly degraded environment in the valley, to whose formation it probably contributed.

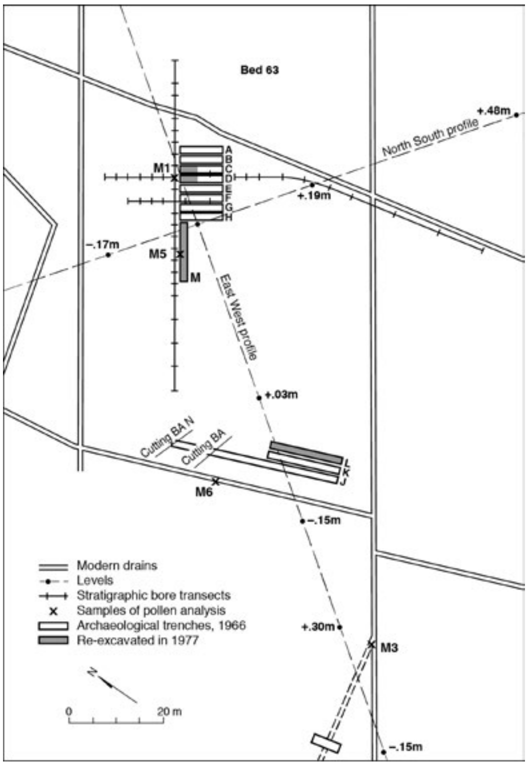


Figure 12.17 Plan of the 1966 and 1977 excavations at the Manton site on Warrawau Tea Estate.

Source: Denham (2003b: Fig. 8), amended from Powell (1970a: Fig.8.2) and reproduced with permission from Denham (2003b).

Figure 12.18 Emptying Trench M at the Manton site. The excavator, Jack Golson, is exposing 'islands' of grey clay that represent the base of former mounds used for cultivation.

Source: Photograph by Ed Harris, Kuk archive, 1977.

Table 12.1 Relative inter-site chronology for Phase 2.

Date (cal. BP)	Deposit	Kuk[1]	Warrawau[2]	Mugumamp[3]	Kana[4]	Ruti[4]
3980–3630	Kim (R) ash					
				X		X?
c. 4840–4440		Late			X?	
			X			
6440–5990	'R+W'					
6950–6440		Early				

An 'X' denotes the presence of archaeological evidence for mound cultivation at a site and 'X?' denotes less clear, yet claimed evidence.

Source: Data collated by Denham and Golson.

Notes:

[1] Early and late subphase dates at Kuk are based on tephrochronology and radiocarbon dates. The late subphase date of c. 4840–4440 cal. BP given here for Kuk is based on the most recent radiocarbon date from feature 504 (ANU-11183; see Denham 2003a: Table F2.4). However, in this chapter and throughout this volume, this subphase is reported as pre-3980–3630 cal. BP, namely predating Kim (R) ash deposition, which is considered a more robust and secure basis than the single radiocarbon date (see Table 7.2).

[2] The relative date at Warrawau is based on tephrochonology, i.e. the lie of Kim (R) ash in palaeosurface features, and on radiocarbon dates for a palaeochannel (ANU-288 and 2086; see Denham 2003a: Table 2.4).

[3] The relative date for Mugumamp is based on tephrochronology, i.e. the lie of Kim (R) ash at the base of palaeosurface features.

[4] The relative dates for Kana and Ruti are based on tephrochronology, i.e. the lie of Kim (R) ash, although the presence of Phase 2 at both sites is considered provisional (Denham 2003b: 169 and 171–172, respectively).

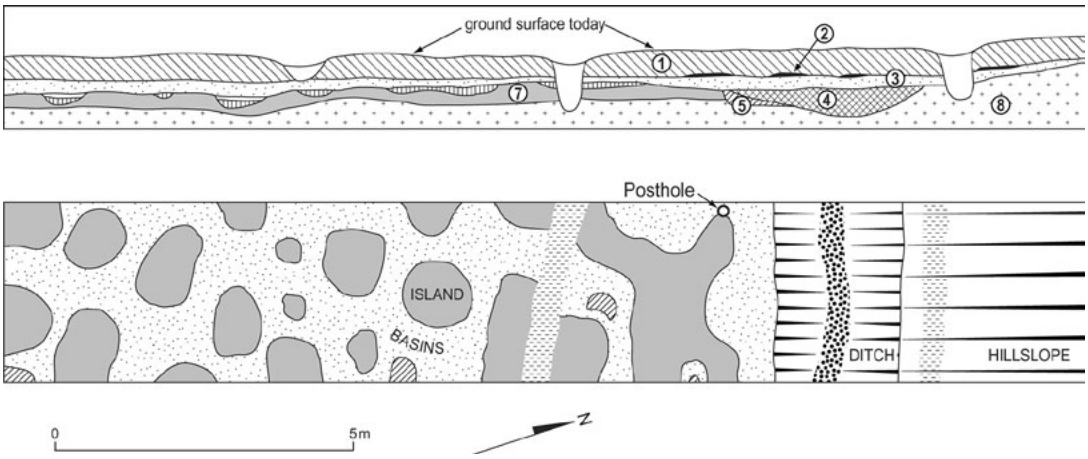


Figure 12.19 Records from the 1977 excavations at Mugumamp Ridge in the North Wahgi Swamp: (upper) the west wall section of the main trench, Trench II; and (lower) the plan of its base.

Source: Drawings from Harris and Hughes (1978: Figs 3A and 3D), reproduced with permission.

Archaeological remains of palaeosurfaces at Kuk, Mugumamp and Warrawau can be correlated with palaeoecological records for dryland activities at several sites in the upper Wahgi Valley. Palaeoecological records at Draepi-Minjigina, Ambra Crater, Lake Ambra and Warrawau, as well as Kuk, indicate significant disturbance to primary forest using fire by the mid Holocene (see Chapter 9, sections 'The early Holocene' and 'Mid to late Holocene'). At this time, the humanly created grasslands documented at Kuk were regional phenomena in the upper Wahgi Valley, although they were not ubiquitous because disturbance and regrowth communities were present at Warrawau (Denham 2003b: 173). The development of extensive grasslands maintained by burning across large tracts of the upper Wahgi Valley and the presence of disturbed communities in some locales are inferred from palaeoecology to be the result of spatially variable shifting cultivation on valley slopes above the wetlands (Powell 1982a: 218). In contrast to the wetland agricultural practices, no dryland agricultural sites of similar age have yet been documented archaeologically in New Guinea. The absence of archaeological sites of dryland cultivation is not surprising, however, because the valley slopes upon which these practices occurred have been denuded by a combination of erosion, mass wasting and cultivation, which are likely to have removed traces of earlier practices.

Beyond the upper Wahgi Valley, Paul Gorecki and Dave Gillieson conducted archaeological excavations on the Ruti flats of the lower Jimi Valley in the 1980s (Gillieson, Gorecki and Hope 1985; Gillieson et al. 1987; Gorecki 1989; Fig. 12.21 here). Mounds and hollows were reported for two open area excavations, MSB and MTG, and these were interpreted to be of similar age and function to the remains of past cultivation reported for Kuk and Mugumamp (see Fig. 12.22 for site MTG).

John Muke directed archaeological investigations on a community coffee plantation at Kana in the middle Wahgi Valley in 1993 and 1994, with additional investigations in 1996 and 1997 (Muke and Mandui 2003). Archaeological investigations were restricted to excavating, recording and sampling within two plantation drains. Two drain sections (WD3 and WD5) were investigated in detail. Several features of possible mid Holocene age were identified, including at least two basins and a ditch (Figs 12.23 and 12.24). The form and function of these features were interpreted to be similar to the basin-like features of similar age at Kuk, Mugumamp and the Manton site at Warrawau.

Figure 12.20 Photograph looking SW over the mid Holocene palaeosurface exposed in Trench II at Mugumamp.

Source: Photograph by Ed Harris, Kuk archive 1977.

A recent review of the Ruti and Kana evidence casts doubt on whether these remains represent mid Holocene cultivation (Denham 2003b: 171–172 and 169–170 respectively). Problems arise at both sites in determining the precise age of the remains, how they formed and what they were used for. Until additional archaeological excavations are undertaken, claims of mid Holocene cultivation at both sites should be considered provisional.

Palaeoecological records from other highland valleys show discontinuous and highly variable disturbance of forests using fire from the mid Holocene onwards (Haberle 1994). Palaeoecology suggests that similar landuses to those documented in the upper Wahgi Valley were widespread across the highlands (Powell 1982a: 224), but most of these areas have not been investigated by archaeological excavation to uncover evidence of past cultivation practices.

Figure 12.21 Looking NE to the Bismarck Range across Yeni Swamp at the Ruti Flats in the lower Jimi Valley, more than 1000 m lower in altitude and over 50 km north of Kuk.

Across the foreground runs a drainage ditch that produced the first artefacts (site MSC), with an excavation thought to contain evidence of gardening (site MSB) some 200 m away (back and to the left in the image). A second site of suggested gardening, MTG (see Figure 12.22), is nearer the forest edge but off the photograph to the left.

Source: Photograph by Dave Gillieson, 1984, reproduced with permission.

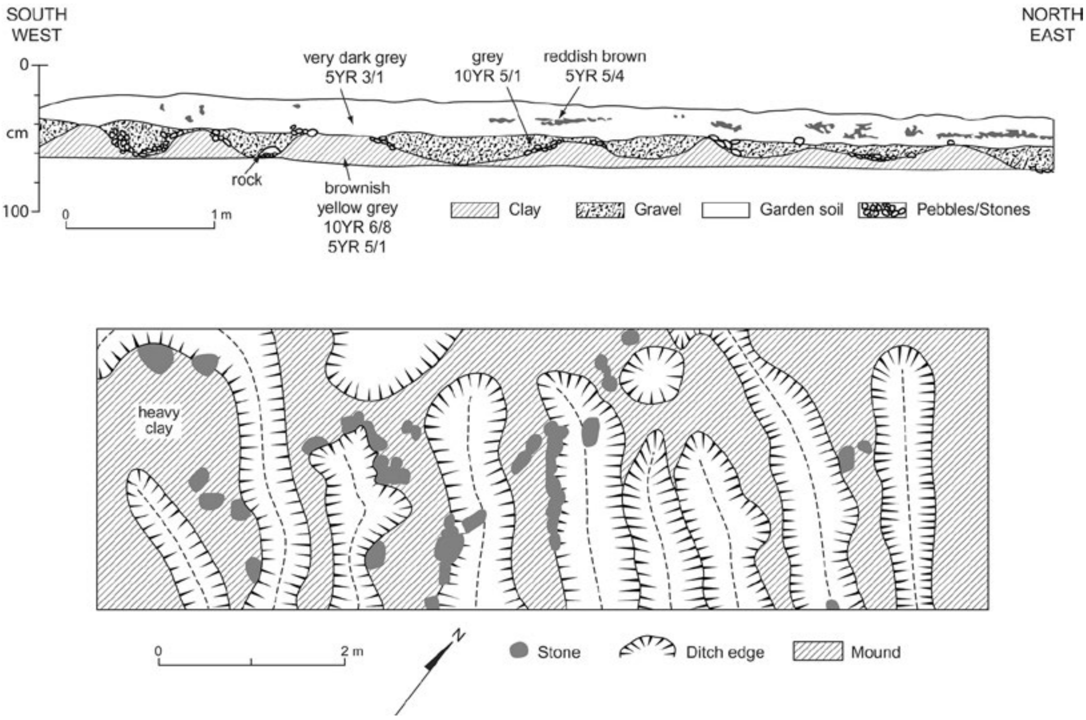


Figure 12.22 Archaeological records of the excavations at site MTG at Yeni Swamp: (upper) NW wall section; and (lower) plan of the base of the trench (note the difference in scales).

Source: Gillieson, Gorecki and Hope (1985: Fig. 5), reproduced with permission.

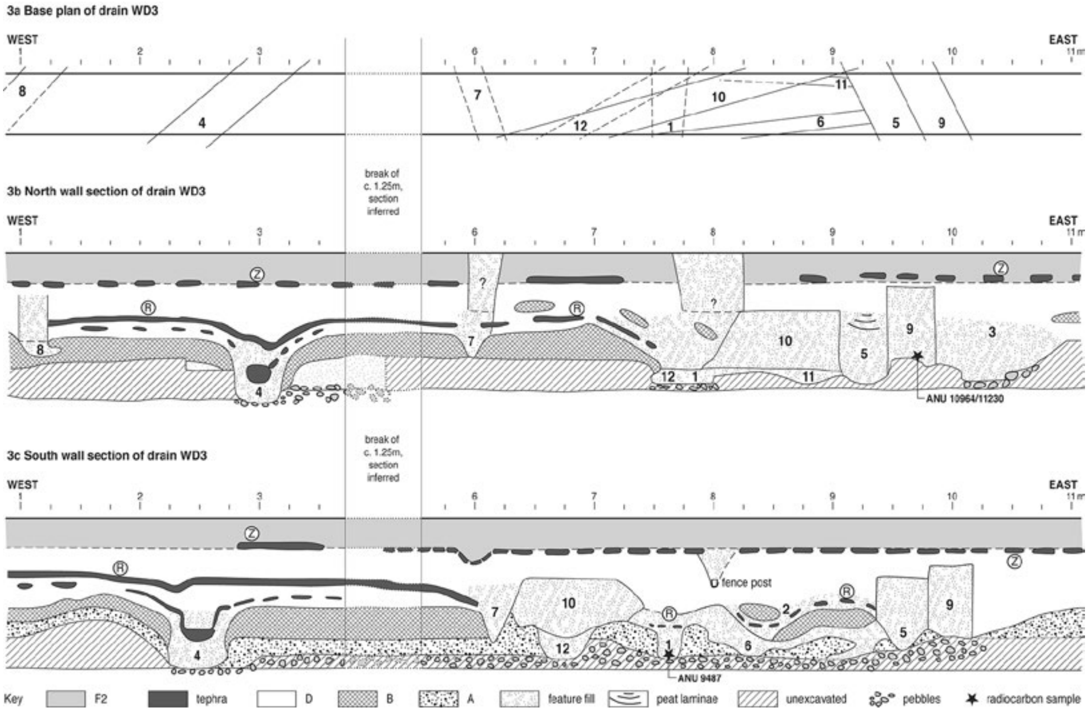


Figure 12.23 Records of excavations in 1994 at drain WD3 at Kana near Minj in the middle Wahgi Valley: (upper) plan of drain base; (middle) section at north wall; and (lower) section at south wall.

Feature 4 was considered by the excavators definitely, and features 2, 3 and 12 possibly, to correlate with Kuk Phase 2 (Muke and Mandui 2003: Table 2). Two additional features of similar suggested age were recorded in drain WD5.

Source: Muke and Mandui (2003: Fig. 3), reproduced with permission.

Figure 12.24 Looking at feature 4 at the west end of the north wall of drain WD3 at Kana (see Fig. 12.23 middle).

Feature 4, a ditch with a rounded base, is accepted as being of Kuk Phase 2 age because it is sealed by a continuous stretch of Kim (R) ash dipping over the top of its fill (Muke and Mandui 2003: Table 2).

Source: Photograph by John Muke, 1994.

13

Phase 3: The Emergence of Ditches

Tim Denham, Jack Golson and Philip Hughes

Ditches and associated artefacts ranging in age from roughly 4000–2000 years old have been documented at Kuk and several other wetlands in the highland interior of New Guinea (Fig. 13.1 and Table 13.1). Ditches and ditch networks have been mapped and investigated in greatest detail at Kuk, while more limited excavation, recording and dating have occurred elsewhere: in the upper Wahgi Valley at the Manton site on Warrawau Plantation; in the middle Wahgi Valley at Kana; at Tambul in the upper Kaugel Valley; and at Haeapugua in the Tari Basin (see Table 13.1). The archaeological remains at Kuk have guided the interpretation of finds at other sites.

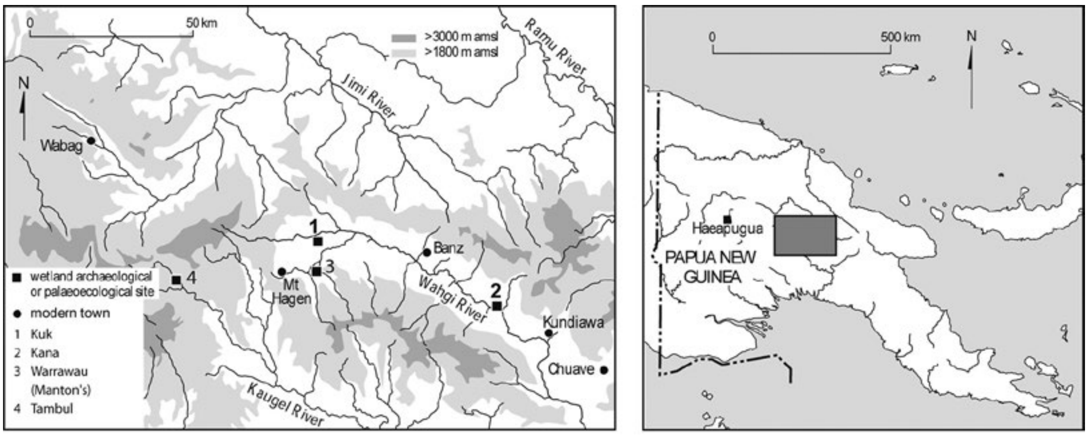


Figure 13.1 The location of archaeological sites with evidence of drainage networks contemporary with Phase 3 at Kuk.

Source: Denham (2005: Fig. 1), reproduced with permission.

The earliest ditch networks at Kuk

Ditch networks at Kuk were traced in numerous excavation trenches dug across the wetland in 1974–77 and 1998–99 (Fig. 13.2). Phase 3 at Kuk consists of at least three palaeochannels associated with networks of linear ditches, with few artefacts recovered during the limited excavation of ditch fills. Only in 1998 and 1999 were ditches systematically excavated to investigate fills, to collect associated artefacts and to undertake sampling for palaeoenvironmental reconstruction.

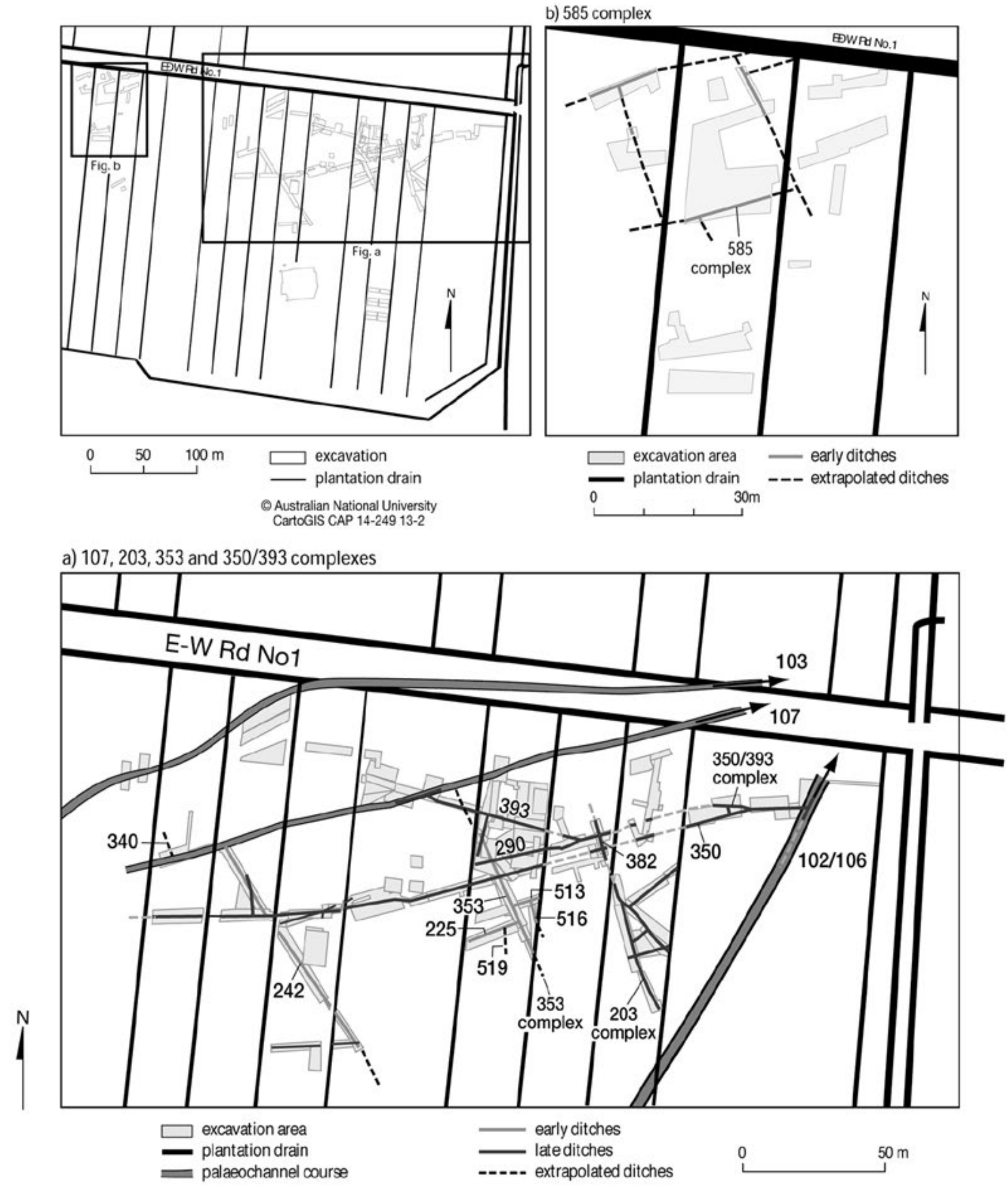


Figure 13.2 Plans showing the nature and extent of early and late Phase 3 networks.

The networks are reconstructed from exposures in excavation trenches and station drains in two areas at Kuk: a) blocks A11 and A12; and b) block A10.

Source: Denham, Golson and Hughes (2004: Fig. 16), reproduced with permission.

Phase 3 ditches are not visible as surface depressions or vegetation marks on aerial photographs because any trace is masked by more recent deposition of sediment in the swamp. Very few of the shallower features, potentially associated with former cultivation on surfaces between ditches, were found and any that existed have been reworked by later gardening and soil formation.

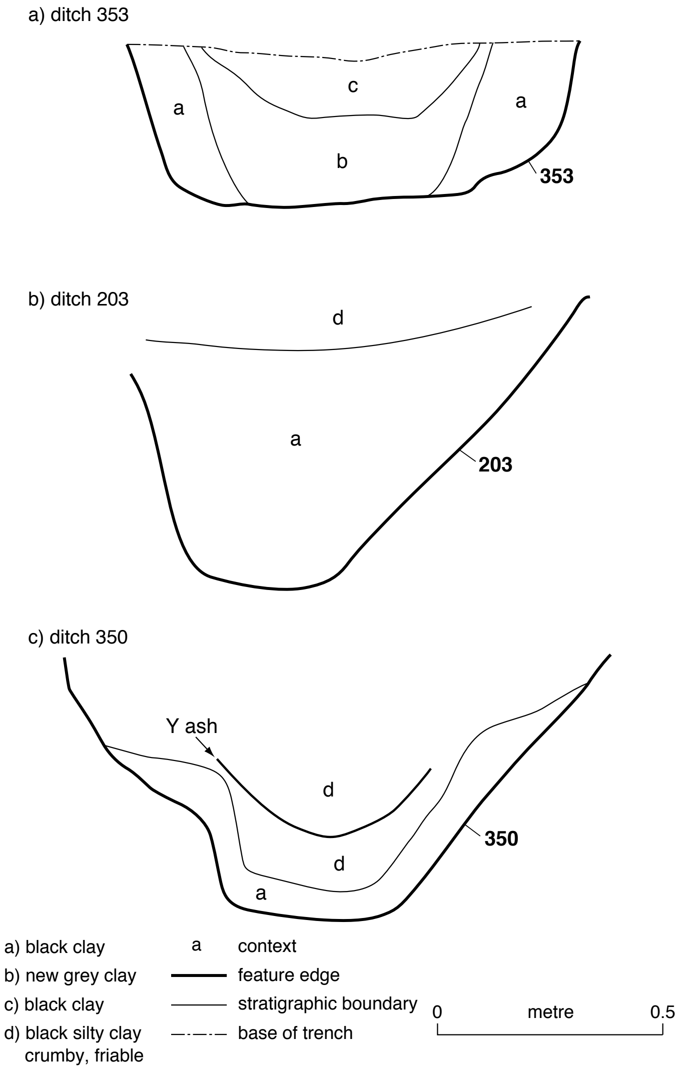


Figure 13.3 Schematic representation of stratigraphic criteria used to group Phase 3 ditches into subphases.

a) early, b) mid to late and c) late.

Source: Denham, Golson and Hughes (2004: Fig. 17), reproduced with permission.

In stratigraphic terms, Phase 3 postdates deposition of Kim (R) tephra and predates deposition of Mun (Niupela or NP) and Baglaga (Y) tephras (see Fig. 6.10). Phase 3 ditches contain a basal fill of massive black clay that is indistinguishable from the main black clay stratigraphic unit. Most ditches lack archaeological associations with features or deposits of known age. Consequently, fill stratigraphy has been used to group Phase 3 ditches into the following subphases (Fig. 13.3a–c):

a. Early subphase ditches contained a three-part fill sequence of basal black clay, middle grey clay (referred to in the field as ‘new grey clay’, probably derived from erosion of the small tephra-covered hills of the southern catchment) and upper black clay;
b. Mid to late subphase ditches contained a basal black clay fill with a level or slightly dipping lens of Baglaga (Y) ash above; and
c. Late subphase ditches contained a basal black clay fill with a slight to moderately dipping lens of Baglaga (Y) ash above.

These stratigraphic criteria evolved during the course of the project and served as guides to the age of an individual ditch.

Phase 3 ditch networks lack the extensive grid-like patterns of the more recent drainage systems of Phases 4–6 (see Chapters 14–16) and some present-day ditch networks in the highlands (see Chapter 5). They display some rectilinear components (i.e. ditches form rectangular patterns in plan, Fig. 13.4a), whereas other components are dendritic (i.e. ditches branch at acute angles, Fig. 13.4b) and triangular (i.e. form 'A-frame' junctions, Fig. 13.4c). Several of these components are clearly artificial.

Figure 13.4 Different types of ditch articulation in Phase 3 networks at Kuk.

a) rectilinear, formed by right-angled junctions, like ditch 516 with ditch 513 at the lower right of the 353 complex; b) dendritic, like ditch 290 with ditch 393 at the north end of block A12c; c) triangular, like the small cross ditch in the middle of the picture between ditches 350 and 393, on the line of the undug drain A12e/f. The ranging pole is graduated at 200 mm intervals.

Sources: Photograph a) Alistair Marshall; photographs b) and c) Klim Gollan, Kuk archive, 1975–76.

Phase 3 ditches are limited to the southern wetland margin at Kuk, with very few occurring in C and D blocks. These more northerly areas are presumed to have been too wet to make drainage viable and were left as swampland. Phase 3 subphases at Kuk probably represent relatively continuous but spatially variable drainage and cultivation of the wetland edge, but there is currently insufficient archaeological precision to clarify each period of use for a given locale.

Palaeochannels

Based on radiocarbon dates and stratigraphic relationships, at least two palaeochannels (106, 107) and possibly three more (102, 103, 108) are associated with Phase 3 ditch networks (Fig. 13.5a–d; Denham 2003a: 219–225). Kui's Baret (channel 102) is probably associated with Phase 3, but could also be of late Phase 2 age, based on the available dating and stratigraphic evidence. The majority of channel 102 was destroyed by the digging of a later channel, 106, on the same alignment. Kum's Baret (channel 103) was potentially open during early Phase 3 as it is broadly contemporaneous with Joseph's Baret (channel 107), which articulates with early Phase 3 ditches. Most Phase 3 palaeochannels are clearly artificial, but the mode of formation of Nema's Baret (channel 108) is uncertain and open to debate (Denham 2003a: 222–224).

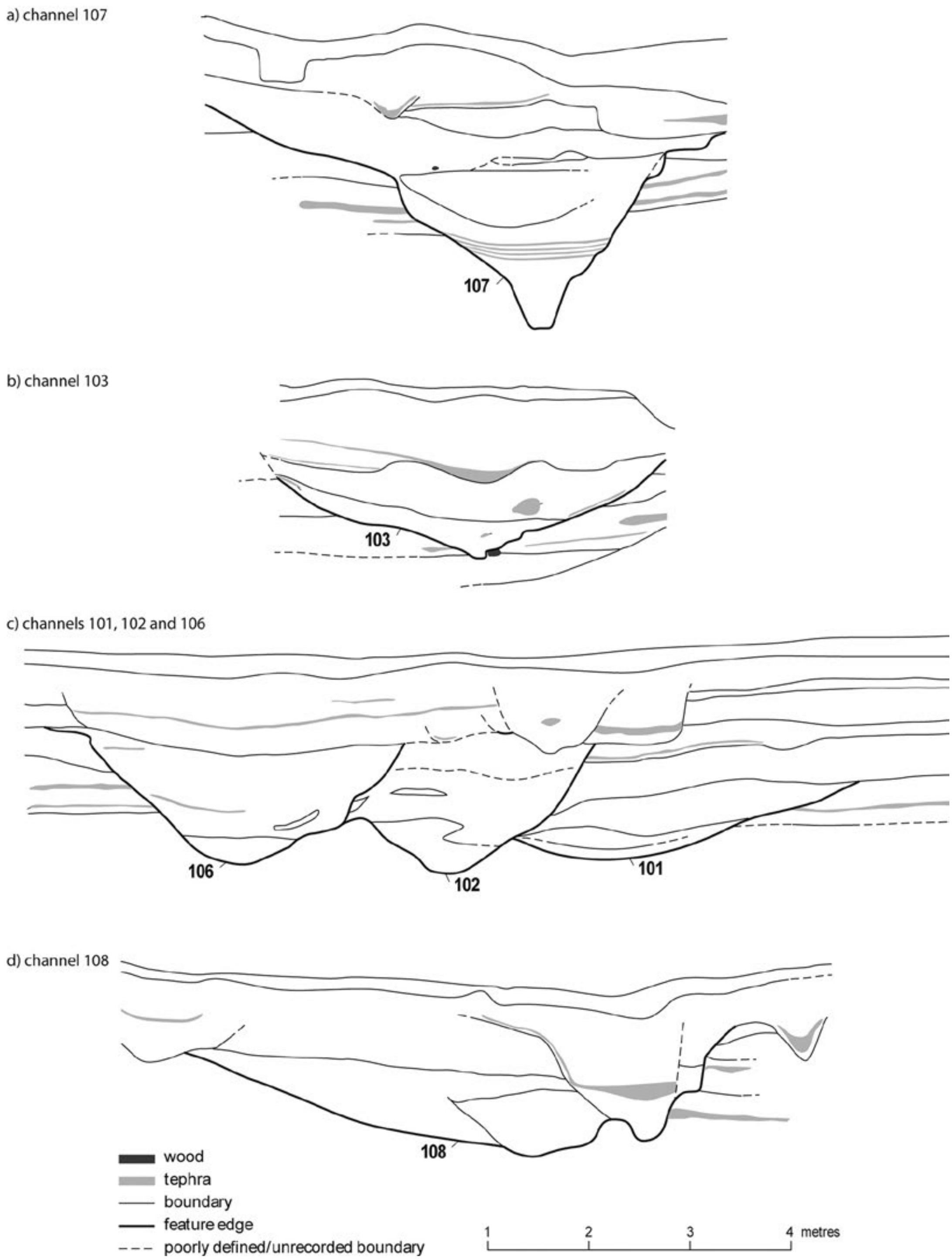


Figure 13.5 Typical cross-sections of palaeochannels of certain and possible Phase 3 age plotted on Figure 13.7.

a) channel 107 (cf. Fig. 13.6); b) possibly channel 103; c) channel 106 and possibly 102); and d) channel 108.

Source: Denham, Golson and Hughes (2004: Fig. 5), reproduced with permission.

Figure 13.6 Jack Golson recording the profile of channel 107 at the west wall of drain A11e/f towards its north end.

Source: Photograph by Klim Gollan, Kuk archive, 1975.

Channels 102 (where not destroyed by the later digging of channel 106 along the same course), 103, 106 and 107 all have U- to V-shaped cross-sectional morphologies (Figs 13.5a–d and 13.6), which are more angular than those of early Phase 2. These palaeochannels follow extremely straight courses that are visible on aerial photographs and have been independently reconstructed from plantation drain wall records and excavation trenches (cf. Fig. 13.7). They cut across low rises on the present-day landscape, although, as discussed for earlier palaeochannels, this may be a product of more recent differential shrinkage of the stratigraphy (Denham, Golson and Hughes 2004: 269–274). Additionally, channel 106 was recut along the course of channel 102 for much of its length. Taken together, these characteristics suggest all four palaeochannels were humanly made.

By contrast, the course and cross-sectional morphology of channel 108 are more suggestive to Denham of a natural watercourse. In plan it lacks the straighter reaches of other Phase 3 palaeochannels and follows a meandering course (see Fig. 13.7). In cross-section it is wider and shallower, much like channels 104 and 109 of early Phase 2 (see Fig. 12.4), and exhibits several episodes of within-bank migration, although these might be interpreted as redigging (cf. Fig. 13.5d). The age of channel 108 is uncertain because radiocarbon dates on organic materials within basal fills do not produce a robust sequence and its stratigraphic relationships are unclear.

Excavations showed the direct articulation of two palaeochannels, 106 and 107, with ditch networks (Fig. 13.2a); channel 106 articulates with a late subphase ditch network (350/393) and channel 107 articulates with two early subphase ditches (242 and 340). One of the ditches of the late 350/393 complex was cut along the course of channel 107 after it had filled and been abandoned. No ditches were found to articulate with channel 108 in the limited excavations undertaken.

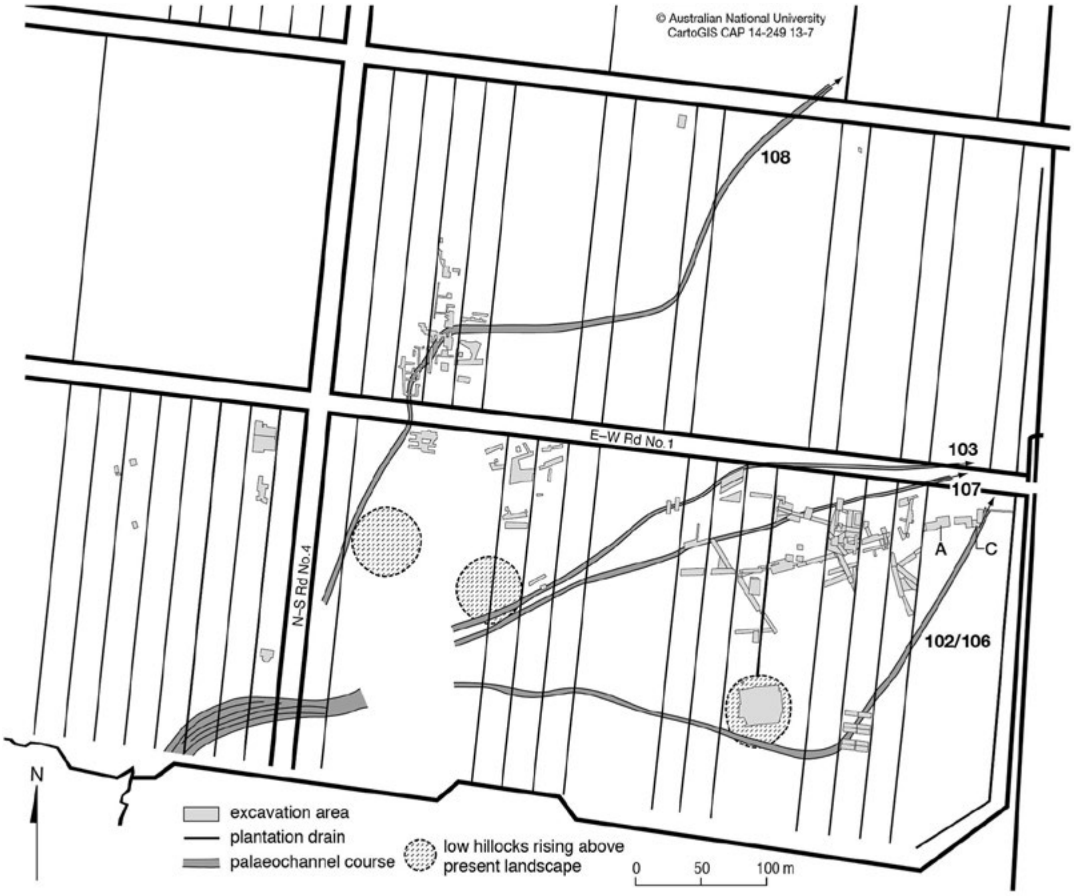


Figure 13.7 Plan showing the course of two certain Phase 3 channels (106 and 107) and three possible channels (102, 103 and 108) across the SE corner of Kuk Station.

The letters A and C, at the eastern end of the plan, just south of E–W Rd 1, mark the findspots of objects discussed in Chapter 20. A is the location of a possible axe and B marks a collection of stones from a cooking pit dug into a Phase 3 ditch.

Source: Denham, Golson and Hughes (2004: Fig. 5), reproduced with permission. Drawing by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

In summary, most Phase 3 palaeochannels are clearly artificial and were dug to articulate with ditch networks. The construction of these large-scale drainage features marks a technological innovation from previous practices; they unequivocally represent deliberate and planned attempts to drain the wetland margin for cultivation. Large-scale palaeochannels were dug to divert incident water from the southern catchment and to receive discharge from artificial ditch networks that were dug to lower the watertable on the wetland margin. At present, the age and archaeological associations of channels 102 and 108 are unclear and require further investigation.

Early ditch networks around 4400–4000 years ago

A conservative interpretation of radiometric age determinations on a ditch fill (ditch 353, dates OZF239 and OZF240) indicates that early subphase ditch networks date to around 4400–4000 years ago (Denham et al. 2003: Table S1; Denham 2005a: 345). Three early subphase ditch networks are associated with the deposition of a distinctive three-part fill sequence comprising alternating black, grey and black clays (Fig. 13.8). All three early ditch networks exhibit rectilinear alignments with dominant orientations of north-northwest and east-northeast (Fig. 13.2): the 107 complex consists of two ditches that articulate directly with channel 107 (Fig. 13.2a);

the 353 complex consists of an integrated drainage hierarchy of ditches (Fig. 13.2a); and the 585 complex delimits a possible enclosure (Fig. 13.2b). Each ditch complex is numbered after a major constituent feature.

The 353 and 585 complexes have different network designs, hierarchies and patterns. The 353 complex in block A12b (Fig. 13.2a) has three levels within a drainage hierarchy, each of which is interpreted to have corresponding functions (Denham 2003a: Fig. 6.10):

1. a major water conduit (ditch 353) to a palaeochannel (presumed to be channel 107);
2. two tributaries joining 353 at right angles (ditches 225 and 513); and
3. two plot-dividing ditches joining the tributaries almost at right angles (ditch 516 joining 513 and ditch 519 joining 225).

In contrast, the 585 complex in blocks A10f and A10g (Fig. 13.2b) has no defined drainage hierarchy and ditches of different sizes articulate to define an enclosed area measuring 29 m by 24 m. This ditched enclosure is the earliest excavated in New Guinea.

Mid to late ditches

Numerous ditches of uncertain age and association have been put into a mid to late category based on the stratigraphic characteristics of their infilling. The spatial extent of individual ditches, as well as the drainage networks of which they are part, are poorly defined and can only be partially extrapolated. In the southern portion of the B blocks, these limited extrapolations exhibit regular right-angled patterns that can be extended to form rectilinear drainage networks. These ditch networks define rectangular enclosures, similar to that of the early subphase (585 complex of Fig. 13.2b), and are suggestive of field systems.

Late ditch networks predating the age range 2700–2400 years ago

The age range for this subphase is based on a stratigraphic position predating Baglaga (Y) ash, which is poorly dated between 2650 and 1950 calibrated years BP (Denham et al. 2003: Table S2), and the secondary fill of a Phase 3 ditch that was radiocarbon dated to between 2730 and 2360 calibrated years BP (ANU-8056, 2480±80 BP; Denham 2005a: 344). Consequently, 2700–2500 years ago is a conservative estimate for the antiquity of late Phase 3 ditches at Kuk. However, the late subphase, characterised by the 203 and 350/393 complexes (Fig. 13.2a), did not greatly predate the fall of Baglaga (Y) ash. This is illustrated by the presence of the ash low in the fills of late subphase ditches (Figs 13.3c and 13.9). The spatial design of these ditch networks included offset and oblique (dendritic), right-angled (rectilinear) and A-frame (triangular) junctions (Figs 13.2a and 13.4).

The 350/393 complex (Figure 13.2a) articulated with channel 106. One of the ditches of the complex (393) came in from the west-northwest (Fig. 13.10) after having followed the alignment of channel 107 for a short distance, where it was cut into the post-abandonment fills. An association between the 203 complex (Fig. 13.2a) and a palaeochannel was not established. The form of constituent features varied, with the ditches of the 203 complex being narrower, deeper and more angular than those of the 350/393 complex. Differences in form may reflect the amount of time ditches were in use prior to abandonment or reflect different digging styles and techniques.

Continuities between the two complexes are exhibited in similar network designs and reuse of older ditch lines. The 203 complex slightly predates the 350/393 complex, with the latter including recut and modified elements of the former. The continuity of form suggests that groups with a shared cultural tradition constructed both networks.

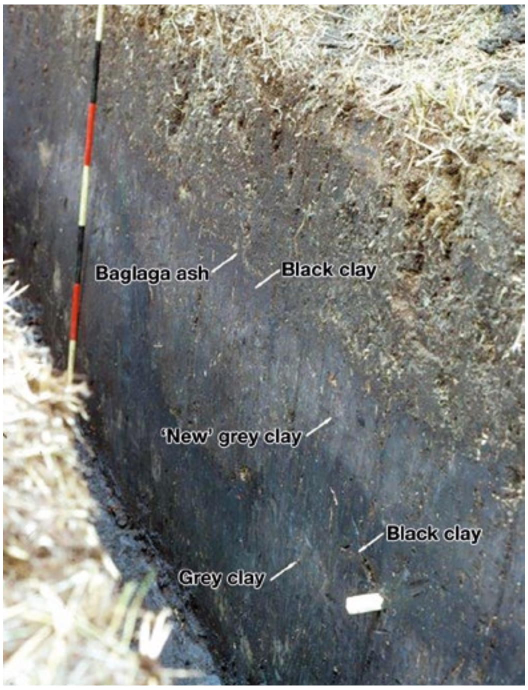


Figure 13.8 A typical early Phase 3 ditch, with steep sides, flat base and characteristic three-part fill sequence.

The fill sequence consists of basal black clay, middle (or 'new') grey clay and upper black clay. Above the fill is a short discontinuous lens of Baglaga (Y) ash. The ranging pole is divided at 200 mm intervals.

Source: Photograph by Philip Hughes, Kuk archive, 1974.

Figure 13.9 A typical late Phase 3 ditch, with steep sides, flat base, a conspicuous dip of Baglaga (Y) ash above a soft black clay fill and an overlying lens of Olgaboli (Q) ash.

The ranging pole is divided at 200 mm intervals.

Source: Photograph by Philip Hughes, Kuk archive, 1974.

Figure 13.10 Looking WNW in block A12b upstream along the course of ditch 393 of the 350/393 complex of Figure 13.2a.

Ditch 393 is exposed at the surface of grey clay, where there are also faint indications of Phase 2 features. The straight-line ditching across the excavation trench belongs to later phases, mainly Phase 5. For a plan of 393 and the later ditches see Denham (2003a: Fig. 5.21 upper).

Source: Photograph by Klim Gollan, Kuk archive, 1975.

Landuse

Only early Phase 3 contexts have been subject to detailed analyses to reconstruct prehistoric environments, because multidisciplinary investigations have focused upon the earliest manifestations of cultivation at Kuk (Denham 2003a; see Chapter 9 here). The environment at that time was similar to, but distinct from that of Phase 2 (Denham, Haberle and Lentfer 2004; Haberle et al. 2012). Grasslands predominated, although there was limited recovery of forest species within the catchment during Phase 3 (Denham, Sniderman et al. 2009).

There were decreased frequencies of Musa section banana phytoliths in samples collected from black clay, i.e. up to 2500 years ago (see Fig. 10.1, Table 10.1 and Textbox 10.2). However, the fills of ditches and palaeochannels associated with early Phase 3 generally exhibited higher Musaceae frequencies, whereas later Phase 3 drainage phases have not been subject to intensive phytolith investigation (Haberle et al. 2012). The contrast between very low Musaceae phytolith frequencies in black clay and higher frequencies in early Phase 3 features is suggestive of an association between bananas and periods of wetland drainage for cultivation.

Regional processes in the upper Wahgi Valley and beyond

There are sites providing archaeological evidence of wetland drainage of similar age to Kuk Phase 3 in the upper and middle Wahgi Valley, as well as further west in the upper Kaugel Valley and in the Haeapugua Basin near Tari (see Fig. 13.1, Table 13.1). These sites are briefly discussed below, as well as finds from the Minjigina archaeological site at around 1900 m altitude at the eastern foot of Mt Hagen.

In 1966, Jack Golson and Wal Ambrose joined Ron Lampert and Jocelyn Powell in archaeological and palynological investigations at the Manton site on the floor of the upper Wahgi Valley at Warrawau Tea Estate (Fig. 13.1; see Chapter 12, Figs 12.16–12.17). Excavation recovered a pointed wooden digging stick from the basal fill of a small linear ditch at 115 cm below ground surface. The report that announced the find of the stick and its date of 2300±120 BP (Table 13.1 here, ANU-43; Golson et al. 1967; cf. Lampert 1967) interpreted the artefact and ditch, together with undated finds of wooden digging implements, wooden stakes, ditches and axes, to be consistent with contemporary agricultural practices. When the Kuk investigations began some years later, the date of the stick proved to be contemporary with late Phase 3 at Kuk (Golson 1977a: 621).

Table 13.1 Radiocarbon dates for Phase 3 features at other wetland sites in the highlands.

ANU #	Location	Context	Material	Radiocarbon Age (BP)	Calibrated Date (cal. BP)[1]	%
Minjigina (Powell 1970a: 174)[2]						
255	Cooking pit	fill	Charcoal	2310±90	2710–2630 2620–2560 2540–2110	0.089 0.039 0.873
Haeapugua (Ballard 1995: C40)						
7800	Ditch, LOJ/a	basal fill	Charcoal	2390±230	2950–1880	1.00
Kana (Muke and Mandui 2003)						
9382	Feature I, Drain WD5	basal fill	Bulk sediment	2970±70	3340–2950	1.00
9487	Feature I, Drain WD3	basal fill	Gourd exocarp (Benincasa hispida)	2450±200	2950–2000	1.00

ANU #	Location	Context	Material	Radiocarbon Age (BP)	Calibrated Date (cal. BP)[1]	%
Tambul (Golson 1996: 155)						
2282	Ditch	basal fill	Wood, Hastate-type spade	3930±80	4570–4150 4120–4090	0.985 0.015
Warrawau (Manton's) (Golson et al. 1967: 370)						
43	Ditch, Cutting M	basal fill	Wood, Digging stick	2300±120	2710–2040	1.00

Source: Denham (2005a: Table 5).

Notes:

[1] All calibrations were undertaken to two sigma, Method B, Calib 4.1, IntCal98 atmospheric curve (Stuiver and Reimer 1993).

[2] A date of 2280±90 BP (ANU-277) obtained on the basal fill of a ditch at Minjigina is not considered to be representative of Phase 3, but has been interpreted as deriving from a Phase 4 feature (Golson 1982: 121; Golson and Steensberg 1985: 376).

Figure 13.11 Looking slightly WSW over Draepi Swamp and the Minjigina Tea Estate at an early stage of its development, about 2000 m altitude and some 13 km NNW of Mount Hagen town.

Plantation drains can be seen beyond the ridge in the right foreground, with a line of vegetation beyond that. It was here that Jocelyn Powell did palynological work in 1967 (Powell 1970a: Chapter 9; 1982: 218–224) and, following her discovery of archaeological material in newly dug drain walls, that Ron Lampert undertook exploratory excavations later that year (Powell 1970a: Appendix 5).

Source: Photograph by Ron Lampert, Kuk archive, 1973.

A small excavation by Ron Lampert in 1967 at Minjigina on Mt Hagen's volcanic apron at the head of the Wahgi Valley (Fig. 13.11), together with recording in plantation drains by Jocelyn Powell and others over a longer period, revealed 'digging sticks, ditches and an associated cooking pit' (Powell 1970a: 172–174; 1970b: 199). Radiocarbon dates obtained on charcoal from the cooking pit (ANU-255) and on the basal fill of a ditch (ANU-277) were comparable to each other and to the dated wooden digging stick from the Manton site at Warrawau (Table 13.1). However, the presence of Olgaboli (Q) tephra dipping into the Minjigina ditch above a digging stick suggested that both the ditch and stick were contemporary with Kuk Phase 4 and not Phase 3 (Golson and Steensberg 1985: 376; see Chapter 14 here). Charcoal from the cooking pit provided a more secure date than the bulk sediment sample from the ditch and suggests that this wetland margin was sufficiently dry to enable cooking in an earth oven during Kuk Phase 3.

At Kana, in the middle Wahgi Valley (Fig. 13.1), John Muke and Herman Mandui recorded several features of Kuk Phase 3 or Phase 4 age (Muke and Mandui 2003). Of most significance for an inter-site characterisation of Phase 3 are two radiocarbon dates from two different features, one on a sediment sample from a feature fill and another on exocarp fragments of wax gourd (*Benincasa hispida*; Matthews 2003; Table 13.1 here; cf. Textbox 10.1). While the dates on both samples correspond to Kuk Phase 3, Muke and Mandui (2003: 184) interpret the first of the two features as belonging to Phase 2 because of the claimed presence of Kim (R) tephra above the fill. Irrespective of debates over their precise age, Muke and Mandui report several linear features that are at least of Phase 3 age.

In 1976, Jack Golson and Philip Hughes conducted limited archaeological recording at the Tambul High Altitude Experiment Station (HAES) of the then Department of Agriculture, Stock and Fisheries, at 2240 m altitude in the upper Kaugel Valley (Fig. 13.1). They investigated the circumstances of an archaeological discovery made earlier in the year by Station personnel digging a new drain (Golson 1996). The discovery was that of a hastate-type spade (Fig. 13.12) lying in the bottom of a prehistoric ditch cut across by the modern drain (Figure 13.13; on hastate spades see Chapter 19, section 'Shorter paddle tools'). Dating between some 4500 and 4000 years ago (Golson 1996: 157), the Tambul spade is the oldest reported wooden digging implement in Papua New Guinea (Table 13.1). Similar types of wooden spade have been documented in use by people in Papua New Guinea in the recent past (Fig. 13.14).

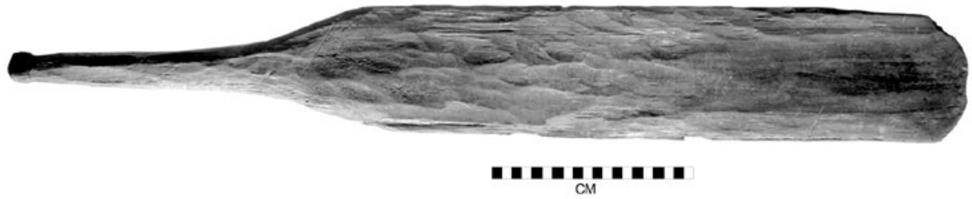


Figure 13.12 The Tambul spade.
Source: Photograph by Bob Cooper and Darren Boyd.

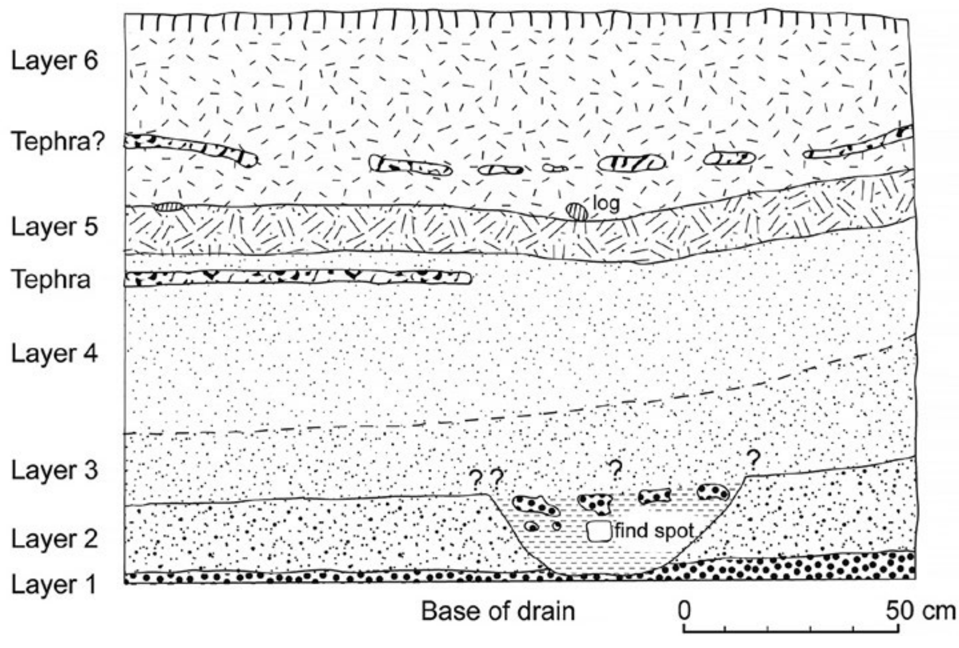


Figure 13.13 West wall section at the findspot of the small wooden paddle-shaped spade in Figure 13.12.
Source: Golson (1996: Fig. 3a), reproduced with permission.

Figure 13.14 A small paddle-shaped spade, comparable to the Tambul spade of Figure 13.12, in use.

The spade is being used to trim the walls of a garden ditch by a young Kapauku man at the Paniai (formerly Wissel) Lakes in the highlands of the Indonesian province of Papua.

Source: 1963 photograph by Naomichi Ishige of the National Museum of Ethnology, Osaka, Japan, reproduced with permission.

The evidence from Tambul complements a record of anthropogenic disturbance at Sirunki (2500 m) in Enga Province (Golson 1996: 164). Walker and Flenley (1979: 339–340) inferred the degradation of primary forest—and its replacement with secondary forest and taxa of disturbance and open land—to be anthropogenic and to roughly date to a period from 4300–3000 years ago. The altitudinal expansion of permanent settlement was interpreted to represent the exploitation of tree crops, hunting and encouragement of useful plants. The evidence from Tambul indicates the altitudinal expansion of agricultural activities into a marginal environment for many of the known cultivars (Bayliss-Smith 1985a, 1988: 155; Golson 1996: 145–146).

Archaeological survey and excavations combined with ethnohistorical research were conducted by Chris Ballard at Haeapugua in the Tari Basin during 1991 and 1992. The earliest evidence of linear ditches in the swamp was found at site LOJ (Fig. 13.15 here; Ballard 1995: C40–46). A radiocarbon date (ANU-7800) obtained on dispersed charcoal collected from the base of a linear feature corresponded to late Phase 3 at Kuk and is comparable to dates at Warrawau and Kana (Tables 13.1 and 13.2). Another date obtained on thin and discontinuous patches of dark grey clay at a second site (LOI) corroborated the LOJ date (Ballard 1995: C10:36). Ballard suggests that these finds represent 'the earliest evidence for agriculture in the region' and 'cultural continuity with the current Huli-speaking populations' (1995: 213). He cross-correlates his archaeological findings to a time of increased vegetation disturbance using fire, evidenced in palaeoecological records for the region (Haberle 1998b: 6–7).

Table 13.2 Inter-site chronology for Phase 3.

Date (cal. BP)	Kuk	Tambul	Kana	Warrawau	Haeapugua
2750–2150	Late[1]		X	X	X
	Mid to late[2]		X?		
c. 4350–3980	Early[3]	X			

Source: Data collated by Denham and Golson.

Notes:

[1] A combined calculation based on ANU-43 (Warrawau), ANU-7800 (Haeapugua) and ANU-9487 (Kana) yields a date range of 2750–2150 cal. BP for this subphase (T=0.5, 5%=6.0, OxCal v3.3, Bronk Ramsey (1999); reported in Denham (2005a: 347 and Table 5)); this date range incorporates that of 2700–2400 years ago for late Phase 3 at Kuk.

[2] The mid to late correlations between Kuk and Kana are weak and approximate. More than one mid to late ditch network has been documented at Kuk, while only one feature at Kana was dated (ANU-9382).

[3] The dating evidence from an early subphase ditch (353) at Kuk, when interpreted conservatively, yields a date range of 4350–3980 cal. BP (3780±50 BP, OZF240; Denham 2005a: Table 4), which overlaps with that of the ditch and spade at Tambul (ANU-2282, see Table 13.1 here).

In summary, ditches have been identified, excavated and dated at several wetland sites in the Wahgi Valley, upper Kaugel Valley and Tari Basin (Fig. 13.1 and Table 13.2). Taken together with the recovery of a spade associated with ditch maintenance at Tambul, these finds indicate prehistoric drainage of the wetland margin. In the absence of suitable domesticated animals, the intervening drained land was almost certainly intended for the cultivation of plants. Cultivation practices were initially considered to comprise swidden cultivation (Walker and Flenley 1979; Bayliss-Smith 1985a), but the Tambul evidence shows they also included more intensive forms of wetland drainage and cultivation, enabling settlement and resulting in forest clearance in relatively high altitude areas by 4000 years ago.

Based on the dates from Haeapugua, Kana and Warrawau, a later expansion of agricultural activities from a more restricted setting, such as Kuk, may have occurred around or before 2700–2400 years ago, the approximate date range for the cessation of Phase 3 ditch digging at Kuk. The archaeological evidence suggests that similar agricultural activities were taking place throughout the Wahgi Valley and in the Tari Basin, as well as, potentially, in other intermontane valleys. People were also using the relatively dry wetland margin at Minjigina at this time. There is insufficient detail in the archaeological records at other sites to determine if wetland cultivation was abandoned at the end of Phase 3, as at Kuk.

Palaeoenvironmental studies in the upper Wahgi Valley and across the highlands reflect the widespread clearance of forest using fire by 4000 years ago. Although forest clearance occurred in several intermontane valleys, the intensity and duration of disturbance varied between sites. These periods of forest disturbance are interpreted as representing clearance for agriculture.

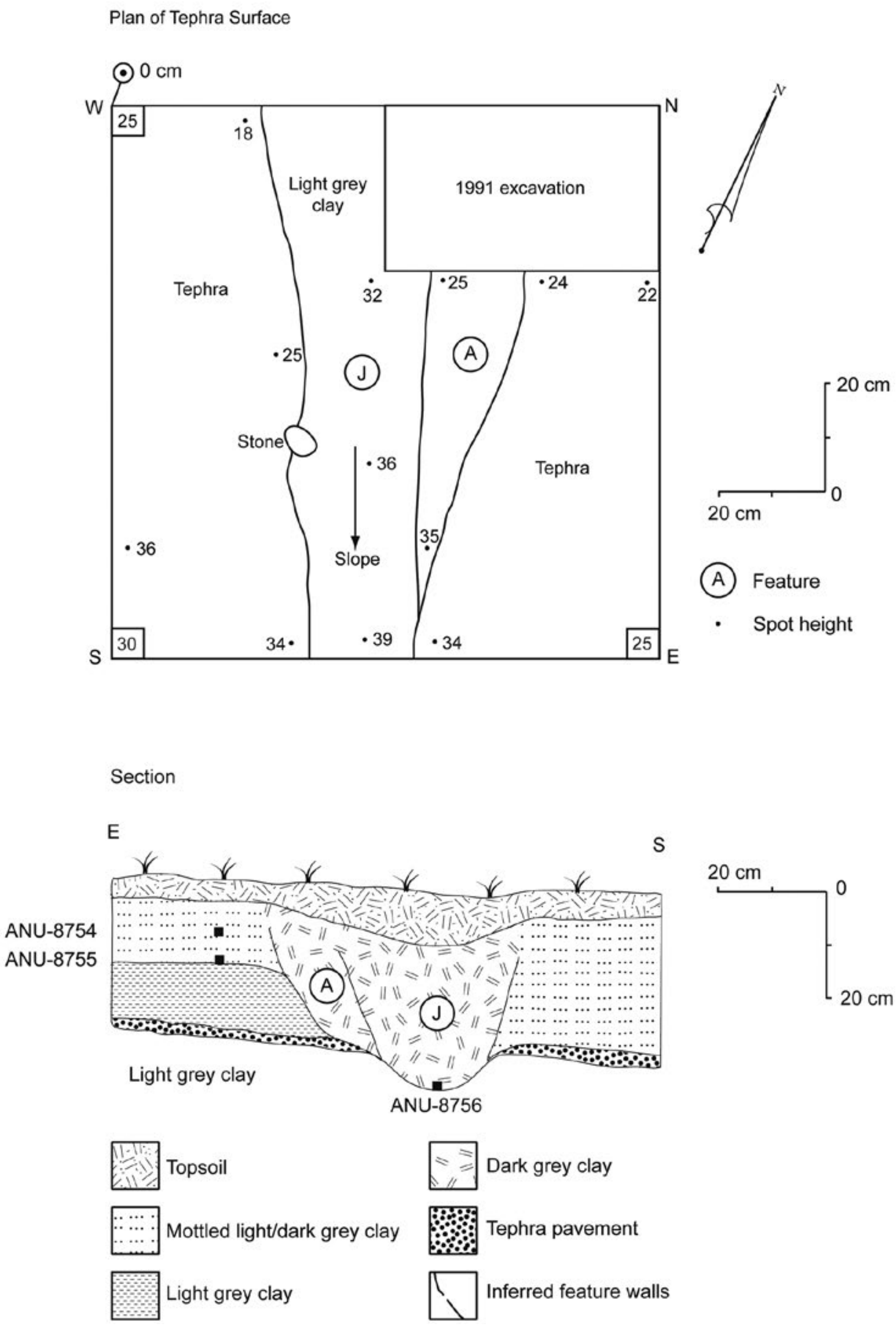


Figure 13.15 Top, base plan; and bottom, cross-section of the 1992 extension of 1991 excavations at site LOJ, Haeapugua Swamp, Tari Basin, Southern Highlands Province.

Source: Ballard (1995: Fig. LOJ/4), reproduced with permission.

As with contemporary agricultural practices in the highlands of New Guinea, people in the past would have utilised a variety of environments for gardening, hunting and gathering. Archaeological excavations and palaeoecological studies indicate that drainage and cultivation of the wetlands occurred in concert with gardening on adjacent valley slopes. People cultivated plots in different locations for several possible ecological and social reasons:

- to enable the cultivation of plants with different edaphic requirements, e.g. *Colocasia* taro, yams (*Dioscorea* spp.), *Musa* bananas and sugarcane (*Saccharum* sp.);
- to limit the effects of drought and other catastrophic events, which usually have less impact in wetlands;
- to maintain an admixture of short-cultivation and long-fallow (dryland), with long-cultivation and short-fallow (wetland) plots;
- to spread risk in the event of warfare and subsequent destruction of, or limited access to, gardens; and
- to maintain tenure and rights over fragmented plots inherited within group territories.

If ecological and social issues are considered together, ditches had functional and cultural values. Ditches enabled wetlands to be drained and cultivated, while simultaneously being boundaries and markers of individual and group tenure of the land.

The emergence of ditches in highland New Guinea

The straighter form of Phase 3 ditches is a break with earlier, more amorphous and curvilinear forms of Phases 1 and 2. This relatively sudden emergence of straight ditches from more curvilinear forms of late Phase 2 is not fully understood (Denham 2005a). There appears to be some continuity between late Phase 2 and early Phase 3 (see Chapter 12), such as the curvilinear feature and two linear features of late Phase 2, which may indicate experimentation with the digging of linear ditch-like features. In addition, there is evidence that channel 107 was dug in late Phase 2 and was maintained and still in use during early Phase 3. These finds point towards a swift on-the-spot transformation of late Phase 2 practices into the digging of drainage ditches during early Phase 3.

The emergence of rectilinear field forms and associated tools in the highlands occurred independently of outside influences. The early subphase ditch complexes at Kuk and the finds at Tambul predate the appearance of Lapita pottery in the Bismarck Archipelago at 3470–3250 cal. BP and its subsequent dispersal to Remote Oceania from 3250–3100 cal. BP (Denham, Bronk Ramsey and Specht 2012; cf. Spriggs 2001). The absence of comparable finds of similar antiquity in Indo-Malaysia, despite limited archaeological investigations, support the interpretation that the construction of ditches and ditch networks in highland New Guinea is likely to have been an indigenous innovation.

The social distinction between wetland and dryland agricultural practices during Phase 3 is uncertain. In part, Phase 3 ditches at Kuk were necessary to enable drainage of increasingly wet land for cultivation. Their innovation could also have been driven by increasing social needs to demarcate and bound plots of land, such as increasing competition or territoriality within and between social groups, or to minimise risk and maintain production with the advent of increased climatic variability associated with the intensification of El Niño–Southern Oscillation (ENSO; Moy et al. 2002). Once created, wetland plots would have maintained fertility for longer and, consequently, would have been replanted for several years before being left abandoned to fallow. In contrast, plots on dryland slopes would have been cleared from grassland or remnant stands of disturbed forest. These dryland plots are likely to have been used for a shorter time, perhaps only a few years, before abandonment due to decreasing soil fertility and crop yields. Furthermore, dryland plots would have been more susceptible to drought.

The transition between Phases 3 and 4 at Kuk is much clearer than that between Phases 2 and 3. First, the patterns of ditch networks differ; those of Phase 3 are variously designed with rectilinear, dendritic and triangular components, whereas those of Phase 4 are organised into more systematic grids (compare Fig. 13.4a–c here to Fig. 14.12). Second, the cross-sectional morphologies of ditches differ: Phase 3 ditches, though variable in form (Fig. 13.3a–c), often have a combination of flat to slightly concave base and steep sides that contrasts with the characteristic slot-like appearance of Phase 4 ditches (see Fig. 14.8). Third, there is a period of some hundreds of years between Phase 3, the later stage of which has been dated to 2700–2500 years ago, and Phase 4, which is thought to have begun around 2000 years ago.

The reasons for the abandonment of wetland cultivation at Kuk, marked by the end of Phase 3, are unknown, but many can be hypothesised. A hydrological cause may include higher watertables along the wetland edge that made continued drainage impractical. Agronomically, the introduction of new crops and techniques of cultivation may have increased or prolonged fertility of horticultural practices on dryland slopes, thereby making wetland cultivation less important (Golson 1977a: 621–623). Social processes leading to wetland abandonment should not be overlooked (see Golson and Gardner 1990). Territorial disputes, warfare and subsequent group displacement could have led to the abandonment of ditch networks, followed by flooding of the wetland; the area could have been recolonised by people who did not know, or did not want to know, how to drain wetlands for cultivation. Although we may never know the precise reason for the abandonment of Phase 3 ditch networks at Kuk, the wetland margin was left uncultivated for some hundreds of years.

14

Phase 4: Major Disposal Channels, Slot-Like Ditches and Grid-Patterned Fields

Tim Bayliss-Smith, Jack Golson and Philip Hughes

Introduction

Phase 4 in its wider context

This chapter focuses on the evidence for a distinctive new phase of swamp drainage at Kuk Phase 4, which took place between about 2000 and 1100 years ago. Elsewhere in the Pacific region at this time, there were changes in landuse that have been seen as symptoms of agricultural intensification, often involving enhanced water control and the formation of island beds or pondfields for the cultivation of taro, *Colocasia esculenta*. The evidence comes from both Polynesia (e.g. Kirch and Lepofsky 1993) and Island Melanesia (e.g. Spriggs 2002). In New Caledonia, for example, which was first colonised by Austronesian-speaking settlers 3000 years ago, extensive pondfield terracing began during the period assigned in New Guinea to Kuk Phase 4, and this intensification process continued into recent times (Sand 2012: 172). Archaeologists have disagreed about whether these changes in the wider region are independent of each other or whether they reflect the movement of crops, techniques and ideas from place to place. The New Guinea highlands have generally been regarded as largely autonomous in their trajectory of change, but by Phase 4 times some external influence becomes a possibility.

Swamp drainage in the highlands was certainly a widespread phenomenon in Phase 4 times, but direct evidence for the plants being cultivated remains sparse. We suggest that in the highlands they included bananas, taro and indigenous yams (*Dioscorea alata*, *D. nummularia* and *D. bulbifera*), all long-established starch staples, plus sugarcane and green vegetables. It is unlikely that by this time highlanders would have been in possession of the lesser yam, *Dioscorea esculenta*, which some scholars believe to be of Southeast Asian origin. There is evidence to suggest that its arrival in the Pacific was later than that of the pottery, pigs and other items of Southeast Asian derivation that appeared in the Bismarck Archipelago with Austronesian colonists around 3300 years ago in the archaeological context of the Lapita culture (Spriggs 1997: 88; Summerhayes 2010: 13, 25–26; cf. Denham, Bronk Ramsey and Specht 2012: 43–44).[1]

1 This is because of the inability of linguists to reconstruct a word for *Dioscorea esculenta* in Proto-Oceanic, the language thought to be associated with the Austronesian-speaking migrants who initiated the Lapita culture. See also Chapter 4, footnote 4 and Chapter 10, footnote 1.

How quickly did these Austronesian innovations spread to the New Guinea mainland? In a comprehensive review, O'Connor et al. (2011) find no support for claims for the presence of pottery and pigs in mainland New Guinea in the early to mid Holocene, nor indeed before 3000 cal. BP, given the sparseness of the evidence for interaction between the mainland and the Bismarck Archipelago during the Lapita phase there (2011: 19–20).

The situation was already changing, however, at least as far as the south coast of Papua was concerned. For Wari Island, off the tip of the tail of Papua some 60 km southeast of Samarai, Negishi and Ono (2009: 46–48) described a ceramic sequence starting between some 2800 and 2600 years ago, with pig present in two middle layers, the upper of them dating between about 2300 and 2000 years ago. This was followed by the appearance of the first results from recent substantial excavations at Caution Bay, 20 km northwest of Port Moresby. Here essentially the first Lapita pottery on the New Guinea mainland was found at sites belonging to a period dated on the calibrated results of a set of radiocarbon dates to between about 2900 and 2500 cal. BP (David et al. 2011; McNiven et al. 2011), the end date now able to be replaced by one of 2600 cal. BP as the result of further dating (Bruno David, pers. comm., 2014). These sites are said to 'contain not only Lapita assemblages, but also rich ceramic sequences variably covering individual horizons and long cultural sequences' (David et al. 2012: 73) extending after 2000 BP, the date when previously settlement of southern Papua by Austronesian-speaking pottery makers was thought roughly to have begun (David et al. 2012: 73–75).

The relevance of this survey for our study of Kuk is that it reopens the possibility of external influences in Phase 4 times. The presence of pig bone at some of these lowland sites provides the earliest possible date for the appearance of pig in interior Papua New Guinea, whether in association with the lesser yam or not. McNiven et al. (2012: 146) suggest that pigs were present in the Caution Bay area by at least 2500 years ago on the basis of finds at the Edubu 1 site, which is consistent with the information from Negishi and Ono (2009) on pig bone finds on Wari Island cited above. We return to this subject in Chapter 15, section 'Artefacts, houses and pigs'.

Soil tillage as an innovation

Between Phases 3 and 4 there is an interval stratigraphically marked by two tephras, Mun (NP) and Baglaga (Y), and a change in the composition of the swamp deposits from black clay to the formation called 'garden soils', as discussed in Chapter 6 (cf. Figs 6.10, 6.11). The very sporadic occurrences of Mun ash are found at the stratigraphic break, with the more common and more continuous Baglaga appearing just a few centimetres above it. At an early stage of the Kuk investigations, Golson (1977a: 621–622) argued that this stratigraphic change was linked with an important development in the practice of dryland agriculture, in the form of soil tillage.

Soil tillage was an important innovation that responded to problems in dryland agriculture following the progressive replacement of local forest by grassland, as discussed in Chapter 9, section 'Mid to late Holocene'. Grassland soils are not only relatively infertile, they are also more difficult to cultivate. Soil tillage would have been a necessary step towards making areas of grassland productive, by removing roots from fallows and by increasing soil aeration. This would have provided an improved dryland system for the cultivation of bananas, yams and sugarcane.

The first unit of the garden soils above the stratigraphic change is a soft, silty clay containing soil aggregates and this is interpreted by Hughes and Golson (Chapter 6, section 'Garden soils') as the result of erosion from local catchments where soils were being disturbed with the introduction of tillage. In the same chapter, however, Denham offers a different explanation for the change in the composition of the swamp deposits, seeing it as due to weak soil formation on slowly accumulating sediments (see Denham 2003a, vol. 2, Appendices E6 and E7).

Figure 6.10 (and the following explanatory text) treats this change as representing a stratigraphic event, not a pedological process. It shows its location and sets out the evidence for its date in calibrated radiocarbon years: after a late stage of black clay formation dating within the age range 2730–2360 BP and before the horizon underlying Baglaga tephra that formed within the age range 2710–2120 BP. We adopt a date of 2500 years ago for the stratigraphic break and look at what happens during the period following this from the viewpoint of both dryland and wetland agriculture.

Taro in the wetlands

In the major highlands valleys where people had little access to forests suitable for swiddens, taro (*Colocasia esculenta*) was probably becoming less important than in Phase 3 times. We interpret the appearance of tillage at Kuk as signalling the cultivation of grassland soils for a range of crops including bananas and yams. Even before the onset of Phase 4, dryland taro would have been restricted to small patches of enriched soils, for example adjacent to houses, in wet gullies and in places made fertile by short woody fallows. Taro is limited to such sites today in the upper Wahgi Valley (Powell et al. 1975: 11–12; Stewart and Strathern 2002: 290) and elsewhere (Bowers 1968: 80–81; Waddell 1972: 57, 63; Clarke 1977; Sillitoe 1996: 341–344; see Fig. 11.11). In the Lamari Valley in the eastern highlands, where the retreat of forests meant that people were obliged to use grassland soils for both taro and yams, taro cultivation is restricted mainly to sites made productive by the irrigation water provided by bamboo piping (Boyd 1981: 78).

Taro's need for fertile soils has been much emphasised. From an extensive review based on his own and others' observations, Clarke (1977: 160) noted that highlanders only select for taro certain places that they are sure will be suitable, such as patches cleared from bush, gullies and old house sites. Even in such places, taro is always planted in newly cleared soil, often after minimal tillage, and is never replanted in the same place for a second crop. For the Wola, who live at around 1700 m in Southern Highlands Province, Sillitoe (1996: 340) noted that 'gardens put down a second time to taro or a varied intercrop will not give worthwhile yields, wherever the site and whatever the soils except for the occasional exceptionally fertile pocket'.

As well as soil problems, taro is also vulnerable to pest attack, particularly in dryland sites where the corms suffer damage from the larvae of *Papuana* beetles that thrive in areas of cane grass (*Miscanthus floridulus*) (Fig. 14.1). Four species have been identified that attack taro corms and shoots in the highlands: *Papuana trinodasa* Prell., *P. tibialis* Arrow, *P. woodlarkiana* Montr. and *P. biroi* Endrodi (Gagné 1982b: 486; French 2006: 93). It is beetle attack that makes taro cultivation difficult and unrewarding today in the deforested regions of the highlands and the problem is only avoided if the crop is planted in forest swiddens or in wetlands (Bayliss-Smith and Golson 1992b: 13–15). In the southern highlands, Sillitoe (1996: 252) notes that in the taro gardens of the Wola *Papuana* beetles cause 'considerable local damage'. In the Bimin Valley of the Telefomin district of Sandaun (formerly West Sepik) Province, cultivators making taro gardens at 1800–2000 m do not generally suffer any *Papuana* beetle damage if they restrict their plantings to forest swiddens (Bayliss-Smith 1985b). Out of a sample of 90 corms grown in swidden gardens within the closed forests of Bimin, only two were found to have holes made by beetle larvae, but more significant damage was reported from lower sites cleared from a fallow vegetation of open bush and *Miscanthus* cane grass (Bayliss-Smith 1985b: 108, 110). Such sites today are not regarded as suitable for taro and are relegated to sweet potato cultivation.

Figure 14.1 Specimens of *Papuana woodlarkiana* and a photograph showing damage by *Papuana* beetles to taro corms harvested at Baisu Corrective Institution.

Baisu is located in the upper Wahgi wetlands 4 km east of Kuk. The drainage and cultivation of taro here represent a useful analogue for Kuk Phase 4. At Baisu repeat harvests of taro from the same ground can be achieved by using Lindane pesticide; we argue that at Kuk in prehistory a swamp fallow would have been needed to eliminate infestations of taro beetles (Bayliss-Smith 1985a; Bayliss-Smith and Golson 1992a).

Source: Upper image, www.lescoleopteres.com/coleoptera-dynastidae-C-21_26.html (with permission); lower image, photograph by Tim Bayliss-Smith.

The same environments that confer protection from beetles generally also provide higher levels of fertility and soil moisture. For example, in the Mount Hagen area near Kuk taro gardens are of two types: *pana me* at the forest margin or within secondary forest regrowth and *pana ui* in swamps that require drainage (Powell et al. 1975: 11). Even in such sites, which are normally less vulnerable to beetle attack, the taro plants require some protection: 'flat stones are laid near the stalk on the surface of the ground in order to prevent beetles from boring holes into the tubers' (Powell et al. 1975: 21). Taro is almost never replanted on the same site, perhaps because the soils become infertile as Clarke (1977) suggested, but also because beetle infestation becomes a threat.

Experimental studies confirm these ethnographic observations. After ditching and tillage, swamp soils cultivated in 1980 at Baisu Corrective Institution 4 km east of Kuk produced good crops of taro. Yields ranged from 14–24 tonnes per hectare per year (average: 21 t/ha/yr), but in all cases the crop was protected from damage by the use of Lindane insecticide, applied at the time of planting and again at mid growth (Bayliss-Smith and Golson 1992a: 13–14). Experimental plots established on the Kuk Station that were also treated initially with Lindane had a comparable yield of 18 t/ha/yr, but adjacent plots without Lindane protection were ravaged by beetles and achieved a yield of only 3 t/ha/yr of corms mostly riddled with the holes of *Papuana* larvae. Indeed, it proved difficult in the untreated plots at Kuk to grow taro at all, despite persistent replanting in the first two months after the initial planting. All too often the taro setts would be attacked before any root system was established and their underground parts eaten away. Of the 140 plants in the control plots only 77 (55 per cent) survived to harvest, whereas the 120 Lindane-treated plants all survived and flourished until harvested 52 weeks later (Bayliss-Smith and Golson 1992a: 14).

The scale of damage to taro in drained soils and grassland sites is confirmed for other highlands regions. In his dryland experimental plots near Mount Hagen, Bill Clarke (1977: 163) planted root crops on a soil cleared from *Miscanthus* grassland and locally regarded as 'good'. Sweet potato plots yielded 18 t/ha/yr but taro plots produced only 4.4 t/ha/yr and 42 per cent of the taro plants were destroyed by beetles. Another site with a 'poor' soil that was previously cultivated for sweet potato produced a minimal 0.8 t/ha/yr of taro with heavy beetle damage and almost half of the plants not surviving to harvest (Clarke 1977: 163). Experiments by Swift (1985) at Wau Ecology Institute produced similar results in six different plots, with taro yields averaging 2.95 t/ha/yr. Five plots experienced beetle damage affecting up to 60 per cent of plants, the larvae boring holes into corms and causing parts to rot, so reducing the edible portion (Swift 1985: 75).

Both the Mount Hagen and the Wau taro trials were located in areas of forest disturbance and widespread grasslands and the soils at each site had previously been cultivated. The same is true of the drained fields at Baisu and the plots at Kuk Station in the trials of 1980. As a result, in all four cases we can invoke a decline in soil fertility as well as a build-up of local *Papuana* beetle populations, making sustained taro production almost impossible without the use of Lindane insecticide.

We believe that these various findings have far-reaching implications for our interpretation of Phase 4 at Kuk. Dryland soils under grassland would have been problematic for taro, although, after soil tillage, more or less suitable for yams and bananas. The wetlands, despite the logistic problems of drainage, offered an attractive alternative. Waterlogged conditions eradicate taro beetles and also produce high soil fertility from alluvial and organic deposits. Drainage makes available these pest-free fertile soils for taro cultivation, but it also permits the invasion of beetles especially where there are nearby grassland habitats for *Papuana* spp., which is the scenario proposed for Kuk as a result of the extensive forest clearances that had taken place by 2500 years ago. After a single taro crop was taken, the increasing insect damage and declining soil fertility would have obliged the cultivators to shift their efforts to another site. Once the drainage system was no longer maintained, a swamp fallow could be quickly reestablished, which would eliminate taro beetle infestation. Some years later, provided the site was recycled before fading memory and the infilling process had eliminated all trace of its drainage network, then the former ditches could be reexcavated with comparatively little effort.

Perhaps the cultivation of Kuk Swamp in Phase 4 was dominated by a cycle of taro followed by swamp fallow, or perhaps Phase 4 landuse may have been not unlike the *pana* type of mixed garden found today in the upper Wahgi Valley (Stewart and Strathern 2002: 290), but without the introduced maize:

> *Pana* gardens are planted with many different kinds of vegetables. They may have *Colocasia* taro and bananas as their main crops. The crops develop at different times, greens and cucumbers first, then maize, New Guinea asparagus [*Setaria palmifolia*], and later taro, then finally bananas and sugarcane. A *pana* garden therefore lasts for quite a long time. It needs fertile soil, and often is cut into tree fallow for this reason.

In the past, wetlands provided an alternative to tree fallows, especially for those communities lacking access to secondary forest, and we can interpret Phase 4 as evidence of the spread of *pana*-type gardens from drylands into the swamps. The attractions of wetlands like Kuk would have been greatly enhanced in times of drought and it is this aspect of the Phase 4 context that we now review.

Responses to drought

Up until the last few years, it has been difficult to investigate the influence of Holocene climatic fluctuations on agricultural change in New Guinea. The indirect indicators of past climates in the highlands, principally pollen and sediments from lake cores and swamp deposits, revealed interesting long-term trends in vegetation cover and erosion rates, but these trends could largely be explained as the outcome of human impacts on the landscape rather than climatic factors. In the analysis of pollen, for example, the methods available are not yet sensitive enough to allow us to detect short-term fluctuations in climate such as those associated with ENSO, the El Niño–Southern Oscillation (Haberle 1998a: 9).

The possibility that swamp drainage in New Guinea was a response to drought was an idea first explored by Brookfield (1989), who suggested that ENSO events seemed to be intensifying in the late Holocene. Following the construction of a proxy El Niño record extending back for 2000 years in equatorial Peru, Simon Haberle (1998a: 9) made a comparison with the pollen and archaeological record from New Guinea and concluded that:

> [s]wamp cultivation occurs during periods of greatest climatic variability. Periods of chronic drought stress may have initiated the need for greater ground-water control leading to the development of grid patterns of field ditches, seen in Phase 4 and onwards at Kuk Swamp.

In contrast to the Phase 4 period, Haberle argued, the period that followed between about 800 and 1000 years ago seems to have been a time of warmer and more stable climate, corresponding to the Mediaeval Warm Period of the northern hemisphere. He pointed out that at Kuk there is no evidence for swamp cultivation at this time (Haberle 1998a: 9, Fig. 11; cf. Haberle and David 2004: 176, Fig. 5).

We can get some idea of the response of highlanders to droughts in the past by considering the impact of ENSO fluctuations during the 20th century. The severe droughts of 1940–41, 1982–83 and 1997–98 all caused crop losses and localised food shortages. Losses were particularly serious during the intense 1997–98 event, especially in the zone above 2000 m where repeated frosts damaged the sweet potato crop. Rebecca Robinson (1999, 2001) monitored the effects of the 1997–98 drought around Lake Kopiago in Southern Highlands Province (altitude 1320 m). Local responses included a widespread burning of fallow vegetation to make new gardens (most of which failed), followed by long-distance mobility to exploit pandanus and famine foods, and also the reclamation of wetlands as an alternative to dryland cultivation. She found (Robinson 1999: 157) that:

> [w]etlands at Kopiago are a highly productive zone, but subject to crop losses from flooding. In dry spells new ditches are excavated. In droughts short term mid- or deep-swamp gardens, sometimes with incomplete ditches, are made to provide human food and pig fodder during the drought. These gardens have to be abandoned when regular rains recommence.

In 1997, very little rain fell after April. After five months of drought, most people in the Kopiago Basin were relying on famine foods to replace their diminishing supplies of sweet potato. The margins of Lake Kopiago receded and in October some people began to establish ditched or partially ditched gardens in the deep swamp. Sweet potato crops were harvested within four months, though some of these gardens, for example at Konapia Kana, were abandoned after being flooded in March 1998 when the rains returned. Elsewhere, for example at Kale Kana where a denser network of deeper drains had been dug, the new gardens remained viable until they were flooded in August 1998 (Robinson 1999: 83, 89–90; 2001: 192).

These observations match those of patrol officer McBride in 1960, who noted that the best crops he had seen were grown in the drained swamplands of the Kopiago Basin and in the upper Tubudu Valley. Ditches to drain the swamps were dug in dry weather and the crops took only four months to mature: 'three crops are grown a year on one site; four if the land does not become flooded' (B. McBride 1960, cited by Robinson 1999: 30).

The response to drought at Kopiago relates to an economy dominated by sweet potato and pig husbandry, whereas at Kuk in the past taro was probably a major staple. Taro takes longer than sweet potato to mature, so that any lowering of the watertable needs to be prolonged if swamp cultivation is to be productive. For example, on drained wetlands at Baisu, 4 km east of Kuk, taro was being harvested in 1980 on average 50 weeks after planting (Bayliss-Smith and Golson 1992a: 14). However, the yields at Baisu were remarkably high, averaging 21 tonnes per hectare, which is two to three times better than rain-fed taro grown on dryland sites in a regime of forest-fallow swiddens (Bayliss-Smith 1985a: 299). It is clear from these data that wetland drainage could offer substantial rewards to farmers at Kuk in prehistory, if there were sufficient labour and skills and an appropriate form of social organisation. Could it be that a period of unusually intense El Niño droughts provided a particular incentive for swamp drainage to be initiated?

El Niño and Phase 4

Ethnographic analogies based on sweet potato and the Kopiago Basin may not be easily transferable to Kuk Swamp in the pre–sweet potato era, but it is worth noting that the initiation of Phase 4 drainage in the period following the stratigraphic break of 2500 years ago did occur at a time of extreme El Niño phenomena. ENSO events can be reconstructed from the record of sea-surface temperatures that is preserved in oxygen isotope ratios in *Porites* corals, including fossil corals on islands offshore from Madang and Wewak on the north coast of New Guinea (Gagan et al. 2004; McGregor and Gagan 2004). All of the coral records available show large and protracted isotope anomalies indicative of severe and frequent El Niño events during the period between about 2500 and 1700 years ago. The record from Madang shows a four-year El Niño 2500 years ago that is almost twice the amplitude of the 1997–98 event (Tudhope et al. 2001). The record from Muschu Island near Wewak dated to about 2040 years ago is even more remarkable. It shows a severe seven-year El Niño 'longer than any recorded Holocene or modern event' (McGregor and Gagan 2004: 14). There is confirmation from work in southern China that suggests there was a high incidence of regional droughts during the period around 2100 years ago (Yancheva et al. 2007). An oxygen isotope record of a coral from Christmas Island also reveals an extreme El Niño, at least double the severity of the 1997–98 event and dated to 1700 years ago (Woodroffe, Beech and Gagan 2003).

If a prolonged drought in 1997–98 dried up Lake Kopiago and encouraged a phase of ditch digging in the former wetlands, it is worth speculating in what way communities living beside the upper Wahgi swamps might have responded to a seven-year drought 2000 years ago. The spread of grasslands in the highlands was already well advanced by that time, as we have seen. Golson (1977a: 624) originally proposed that Phase 4 at Kuk represented an 'experiment' in wetland cultivation made necessary by the degraded character of vegetation and soils in the Wahgi, a problem only somewhat mitigated by the innovation of dryland tillage. In later publications, the incentives for wealth and status enhancement through wetland drainage have been emphasised (e.g. Golson 1982; Golson and Gardner 1990; Bayliss-Smith and Golson 1992a), but the new evidence for severe droughts during the period under review may mean that the case for subsistence crisis needs to be reopened. At the very least, we can envisage frequent and severe droughts as providing a strong incentive for large-scale drainage, so providing a context for renewed drainage activity.

Forest foraging and high-altitude cultivation

Drought might also have increased the search for food from higher altitudes. One important tree crop is nut pandanus, *karuka* (*Pandanus* spp.), especially *P. julianettii*, which is cultivated in open forests between 1800 and 2600 m, but also wild *karuka* like *P. brosimos*, with an altitudinal range from 2400 to 3100 m (see mean altitudinal ranges in Table 4.4). Flowering and fruiting of *P. julianettii* is irregular and is stimulated by periods of dry weather (Bourke et al. 2004: 39–41). As noted above, Robinson (1999: 25) observed during the 1997–98 drought that many people in the Lake Kopiago region migrated to higher altitudes to take advantage of the pandanus nut harvest. Ole Christensen recorded in his 1972 fieldnotes that during periods of food shortage in the Wurup Valley of the upper Wahgi, men would move up to the forests in search of *karuka*; they would live in rockshelters close to the pandanus groves or in bush huts, eat *karuka* nuts and carry the remainder back to lower altitudes for their families (cited by Donoghue 1988: 49–50, who says, however, that it is unclear whether the latter activity concerns the harvesting of wild or high-elevation cultivated varieties).

If El Niño started to intensify 2500 years ago, then we might expect to see also an increased exploitation of resources like *karuka* from nearby montane forests. Direct evidence for such use is available from sites in the Manim Valley, a side valley off the Wurup Valley 12–15 km south-southwest of Kuk, where Christensen (1975) studied the deposits in four rockshelters. Our survey of the four sites is mainly based on Donoghue's (1988) analysis of Christensen's archaeobotanical data. However, we draw attention to the discussion in Chapter 10, section 'Nut- and fruit-bearing trees' and to Table 10.2, which is the source of the radiocarbon chronology used here.

We start with the Manim 2 site at 1770 m, where the wild nut pandanus *Pandanus antaresensis*, with a wide altitudinal range of 1000 to 2350 m, was dominant among the organic remains from first occupation, before the radiocarbon date ANU-1375, with a calibrated age range of 11,800–10,300 BP, late in the Pleistocene. Its disappearance just after the radiocarbon date ANU-1373, with a calibrated age range of 7000–6350 BP, is seen as indicating a shift of site-based activities to ones related to an agricultural zone. There was a sudden massive but short-lived increase in the sedimentation rate at the Manim shelter around 2750–2150 BP (the calibrated range of ANU-1370), attributed by Hughes (1985: 400) to the tillage of grassland then adjacent to the site.[2] Around the same time (ANU-1326, with a calibration range of 2750–2350 BP), the gardening zone reached the Kamapuk shelter (2050 m altitude) and species of wild pandanus, notably *P. iwen* from *Nothofagus* forest above the site, appeared in the deposits. At higher levels Etpiti (2200 m) and Tugeri (2450 m) came into use, the former after the calibrated date range of ANU-1323, 2350–2000 BP, the latter after that of ANU-1321, 2700–2350 BP. We can conclude that, at this time of intensified El Niño, cultivation was extending upslope into former montane forest and the high-level rockshelters started to be used for overnight stays by people seeking access to resources beyond the limits of cultivation, though nut pandanus was not involved in the first activities there (Donoghue 1988: 85 for Etpiti, 88 for Tugeri).

These changes in resource use after 2500 years ago at Wurup may be matched elsewhere in the highlands, although they are not easy to detect in pollen diagrams. However, the record for Sirunki and Inim (2500 m) shows renewed forest disturbance probably for gardens, starting at an inferred date about 2000 years ago (Walker and Flenley 1979: 339–340; cf. Golson 1996: 164). At other sites in the Wahgi Valley, there are similar indications of renewed deforestation starting 1900 years ago (Haberle 2003: 155). Movements of population to intensify the use of resources at higher altitudes would be one likely response to prolonged drought in the upper Wahgi, just as the cultivation of wetlands would be another.

2 ANU-1370, 2380±110 (Christensen 1975: Table 1), is not included in Table 10.2, but is calibrated in the same way as the radiocarbon dates in that table; see Table 10.2, note 4.

Agricultural use of the high-altitude zone is suggested by the evidence from Tambul in the upper Kaugel Valley, some 45 km southwest of Kuk, where Phase 4 ditches have been recorded in the valley floor at about 2200 m altitude, on land belonging to the High Altitude Experiment Station (Golson, fieldnotes, 1976). This site is too high for yams and bananas, but taro and sugarcane can be grown today, although their yields are low (Bayliss-Smith 1988). In experimental plots that Bayliss-Smith established adjacent to the Phase 4 site at Tambul, taro averaged 3.6–5.2 tonnes per hectare (Bayliss-Smith 1985a: Table 5), less than 25 per cent of the yield obtainable in the Wahgi swamps. We can conclude that in the zone above 2000 m lower yields and fewer crop species were clear disadvantages, but were compensated by ready access to pandanus nuts, hunting and other forest resources (Bayliss-Smith 1985a: 311).

To summarise, the occasionally drought-prone Wahgi landscape was dominated by grasslands made productive through soil tillage. Its peoples were strongly dependent on bananas and yams, while intermittently they engaged in high-altitude foraging. This was the wider context for the initiation of a new phase of drainage at Kuk, known as Phase 4.

Evidence

Dating Phase 4

Phase 4 represents the onset of a new and distinctive system of wetland management, marked by the digging of new disposal channels along new lines, whose subsequent cleaning out removed potential evidence of their initial construction. As we shall see, however, indications were preserved at some places of at least two subphases of use, the earlier phase beginning between the fall of Baglaga (Y) and Kuning (Sandy 2) tephras. The chronology of these events is not very tight (Table 7.2). There are radiocarbon dates with calibrated age ranges Before Present (BP = AD 1950) on samples from above Baglaga tephra of 2110–1820 (at Ambra crater near Kuk, Sniderman, Finn and Denham 2009: Table 2, OZF144) and of 2340–1925 (at Tambul, Denham et al. 2003: Table S1, Y ash, ANU-3213) and from below Kuning tephra of 1690–1420 (Ambra crater, Sniderman, Finn and Denham 2009: Table 2, Sandy 2 OZF143). Here we adopt 2000 years ago as an approximate date for the beginning of the phase.

The close of Phase 4 is much more precisely defined in that there is no trace of this drainage phase after Olgaboli (Q) Tephra was erupted from the Long Island volcanic centre. Radiocarbon samples from Kuk and elsewhere date this event between 1230 and 970 cal. BP or AD 720 and 980 (see Table 7.2). Olgaboli ash occurs widely across the central highlands. At Kuk it is sometimes found deep in the fill of Phase 4 ditches that had only recently been abandoned, or perhaps were still functioning when it fell but were never used again. Here we use 1100 years ago as an approximate date for both the fall of Olgaboli ash and the end of Phase 4.

The geography of Phase 4

Like Phase 3, Phase 4 was not just a local event. Ditches from this period and of the same type as those at Kuk described below have been found at some other sites in the upper Wahgi, such as Kana near Minj on the valley floor (Muke and Mandui 2003: 182–183) and Draepi-Minjigina 20 km northwest of Kuk at 1885 m (Powell et al. 1975: 46; see Chapter 13, section 'Regional processes in the upper Wahgi Valley and beyond' and Fig. 13.11). The evidence from Tambul, at 2280 m altitude, has been noted earlier in this chapter. Phase 4 was not detected at the Manton site on Warrawau Tea Estate, admittedly in a very limited investigation.

In Southern Highlands Province, at Haeapugua near Tari, ditches were dug in marginal wetlands in the period 2500 to 2000 years ago, but the deeper-lying central swamps remained unutilised until sweet potato times (Ballard 2001: 296). The earliest linear ditch feature at Haeapugua was dated to about 2400 years and it represents the first evidence for systematic agriculture in the Tari Basin (Ballard 1995: Appendix C10, 40). Tim Denham (2003a: 343; 2005a: 347–348) suggests that the Haeapugua ditch and also some features of similar age at Kana and Warrawau correspond to late Phase 3 features at Kuk.

It would appear from this evidence that by about 2000 years ago there was widespread agricultural activity in Western Highlands and Southern Highlands Provinces, certainly at wetland sites. Pollen diagrams for the Wahgi Valley show a major expansion of grasslands at the expense of forest and forest regrowth after 1900 years ago (Haberle 2003: 155). While direct evidence is not yet forthcoming, everywhere the likely crop in wetlands was taro. In an exploratory investigation of phytoliths at Kuk, Sam Wilson (1985: 93–95) identified banana phytoliths in sediment samples from Phases 1–4, but had less success in distinguishing between sections of the genus (see Table 10.1 note 7).

The archaeological evidence from Kuk

Phase 4 ditches have been investigated in some detail using the original field records for three areas of the site (Fig. 14.2): block A9 near the southern margins of Kuk Swamp (Bayliss-Smith and Golson 1992a, 1992b); blocks A10 and A11, which are lower-lying (Bayliss-Smith and Golson 1999); and blocks C9 and D7, D8 and D9 located in the deeper swamp.

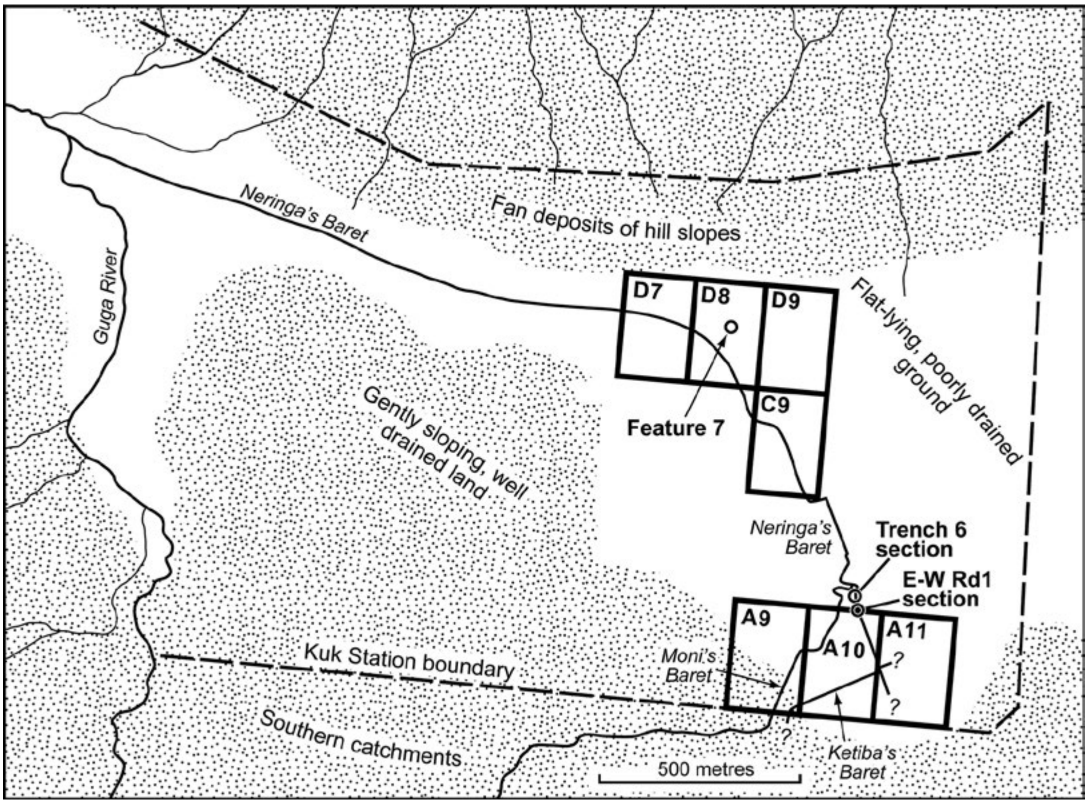


Figure 14.2 Map of Kuk Station showing the major disposal channels of Phase 4, Neringa's Baret and Moni's Baret, a possible minor disposal channel, feature 7 (cf. Fig. 14.7), and the Kuk Station blocks referred to in this chapter.

Block A9, blocks A10 and A11 and blocks C9, D7, D8 and D9 constitute three sample areas where an analysis of field ditch size and shape was carried out.

Source: Drawing by Philip Stickler based on field data in the Kuk archive, 1972–76.

The record from the swamp margins (A9) is the most difficult to interpret, as some Phase 4 ditches there were recut, and not always along the same line (Golson 1976: Fig. 8; Bayliss-Smith and Golson 1992a: Fig. 10; see Fig. 14.3 here). Moreover, the margins of Kuk Swamp were also subject to heavy use in Phases 5 and 6, obliterating some of the earlier evidence. A much clearer record survives in the low-lying parts of blocks A10 and A11, which have well-preserved networks of ditches with Olgaboli Tephra in their fill, indicating use of this area right up to the end of the phase. The records from the deepest swamp blocks C and D are patchier.

In the three areas where they were investigated, the Phase 4 ditches and fields are remarkably uniform in their size and shape. The field ditches are linear and meet each other at right angles, generating a distinctive grid-like pattern. Altogether this phase gives the appearance of a systematic and perhaps more specialised use of wetlands based on a well-tried technology. As discussed above, it is possible to argue for an indirect influence from incoming Austronesians, given the chronology for broadly similar forms of wetland agriculture elsewhere in the Pacific.

Whether in low-lying or more elevated sites, ditch depths and field sizes show no consistent variation, implying that hydrology and agronomy are only part of the explanation for the layout of these systems. The digging of the field ditches and their spacing seem to have been more a repetition of habit than a response to local drainage needs. Each planting area ('plot', 'garden' or 'field') that is defined by the grid network of ditches is of such standard design that it may reflect social norms more than functional considerations. Before discussing such interpretations, we first present the evidence, starting with the major disposal channels, followed by the minor ditches and the fields or gardens that they define.

Figure 14.3 A slot-type field ditch of Phase 4 partly recut on a different line.

The ditch runs south beneath the raised floor of House F of Phase 6, the southern part of which is intact at the top of the picture. The area in front of this has been excavated to the top of grey clay, at which level the outlines of various earlier features were clearly visible and investigated. These included the bottom half of a Phase 3 ditch in the foreground, where the Phase 4 slot ditch was subsequently dug across it. The scale across the slot ditch just in front of the unexcavated house floor is graduated at 100 mm intervals.

Source: Photograph by Murray Woods, Kuk archive, 1972.

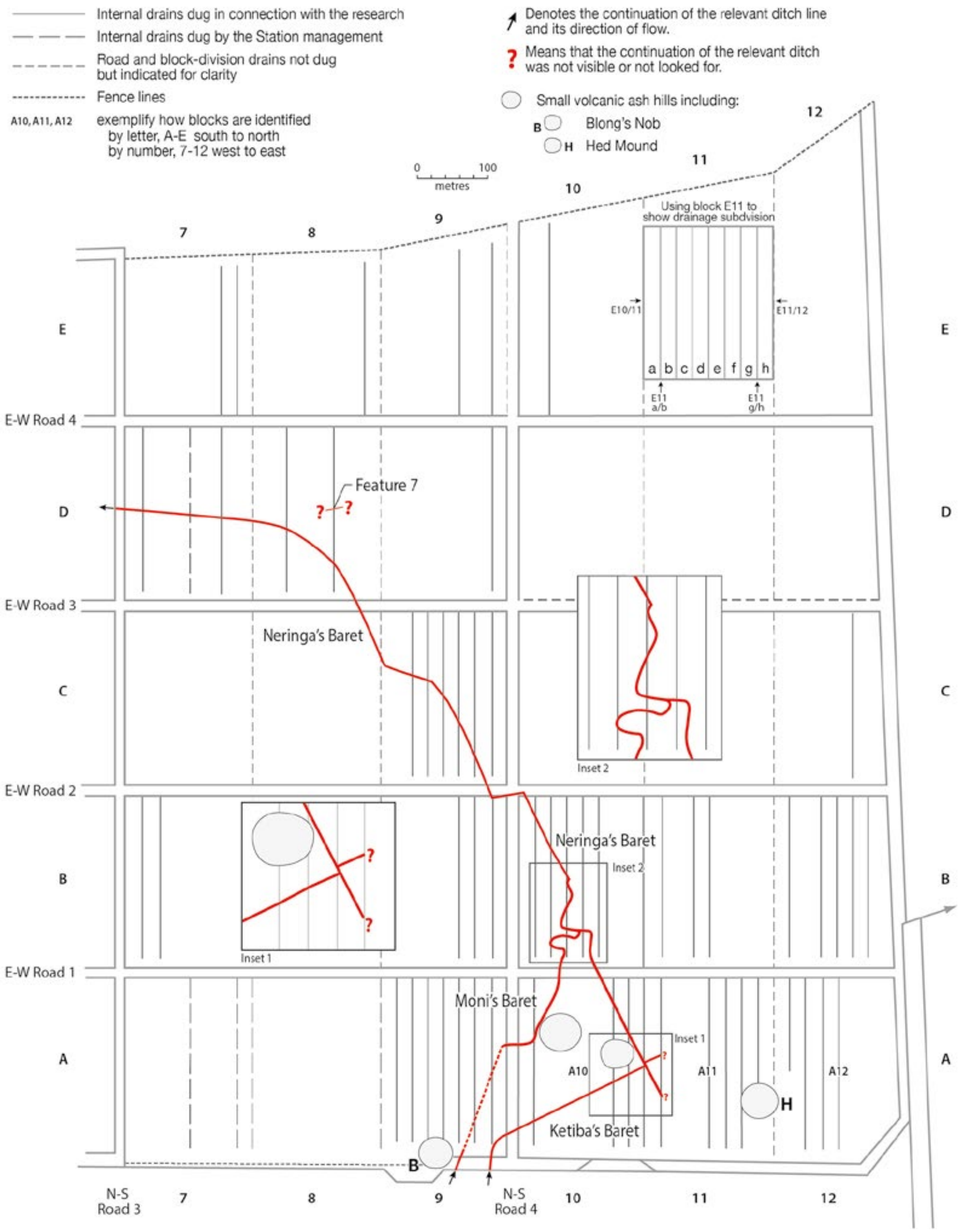


Figure 14.4 Map of the eastern half of Kuk Station showing details of the course of Neringa's Baret and Moni's Baret.

The course of Neringa's through the two right-angled turns at the junction of N–S Rd 4 and E–W Rd 2 is inferred, not demonstrated, because it appears that all traces of the Phase 4 fill along this alignment were removed when it was recut as Wai's Baret in Phase 5 and Phase 6 times (see Fig. 15.4 and Fig. 16.3). There is no other channel in this area that could be an alternative course of Neringa's. Inset 1 highlights the right-angled change of direction in the line of Neringa's Baret, whose SW–NE segment we had called Ketiba's Baret. Inset 2 does the same for the juncture of the two major Phase 4 channels into a single course, in which, a little to the north, there is a slight kink that is perpetuated in Simon's Baret of Phases 5 and 6 (Fig. 15.4 and Fig. 16.3). Feature 7 is a possible forerunner of Korowa's Baret, the minor disposal channel of Phases 5 and 6 that collected the waters entering the swamp from the slopes of Ep Ridge to the north (Fig. 15.4 and Fig. 16.3).

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Major disposal channels

As in previous phases, a precondition for agricultural use of Kuk in Phase 4 was the successful evacuation of water away from the swamp, and on this occasion two major channels, the one called Neringa's Baret and the other Moni's Baret, were dug to take the water towards an outfall at the Guga River (Figs 14.2 and 14.4).

Neringa's Baret

The alignment and fills of this major channel have been studied in detail. Initially (e.g. Bayliss-Smith and Golson 1999: 221), Neringa's Baret was interpreted as having two tributary channels joining it at right angles in block A10 and feeding in water from the southern swamp—Ketiba's Baret from the west and an unnamed channel from the east. We now suggest that Ketiba's Baret was part of the main channel, which was provided with a right-angled bend and became Neringa's. This is because it is appreciably longer than the other two ditches associated with it.

Ketiba's was identified in the walls of the Station's southern boundary drain emerging from the major southern catchment of Kuk Swamp, 300 m from its right-angled transformation into Neringa's. The unnamed tributary channel that joins Neringa's from the east was not found 100 m away in the walls of drain A11d/e (Fig. 14.4 Inset 1), close to the eastern boundary of Phase 4 activity at Kuk (see below). Finally, a proposed continuation of the line of Neringa's Baret south beyond the right-angled bend of Ketipa's/Neringa's, indicated on Figures 14.2 and 14.4, was not certainly identified in the southern boundary drain, suggesting that it might have run less than 125 m beyond the Ketiba/Neringa corner (Fig. 14.4).

From the right-angled bend, Neringa's moves northwest in a straight line across the northern end of the A blocks and into the B blocks. In the southern part of block B10, it follows a winding course then makes a short kink to the northeast (Fig. 14.4 Inset 2) before resuming a straight northwest course. From the middle of the B blocks, it is inferred that the course of Neringa's Baret was recut in Phases 5 and 6 to form the northerly continuation of Wai's Baret, the major disposal channel of those phases (Fig. 15.4). From the northern end of the B blocks to just into the southern end of the C blocks no traces of channel fill of Phase 4 age have been identified and it is presumed that this is because the Phase 4 fill was removed by the recuttings of Phase 5 and 6 times. Crucially, detailed inspection of the stratigraphy along drain B10a/b revealed that the two crossings of Wai's (Fig. 15.4) were the only major channels present, i.e. there is no other channel that could be an alternative course for Neringa's. At the junction of N–S Rd 4 and E–W Rd 2, the inferred course of Neringa's makes two right-angled turns (Fig. 14.4; see also Fig. 15.4 Inset 2) before continuing northwest across the C blocks and northwest, then west, across the D blocks.

From the right-angled bend at Ketiba's to its outfall at the Guga, Neringa's Baret extends for a distance of 2.4 km. Over this distance it has a fall in level of 5.5 m, suggesting an average hydraulic gradient of just 1: 440 (Bayliss-Smith and Golson 1999: 222). This rather gentle slope implies the need for a careful grading of the base for the channel to maintain its hydraulic efficiency.

The straightness of its course and the presence of several sharp right-angled corners show that Neringa's Baret was indisputably artificial. Its highly distinctive character may mean that it served as a land boundary of some sort as well as leading water from the southern catchment to the Guga River outfall. The right-angled corner in block A10 appears to have been aligned to avoid a low tephra-mantled hillock immediately to the northwest of it. During Phase 4 times, this hillock, although only 1–2 m high, would have been a prominent feature in an otherwise flat landscape and could have been used for purposes of orientation.

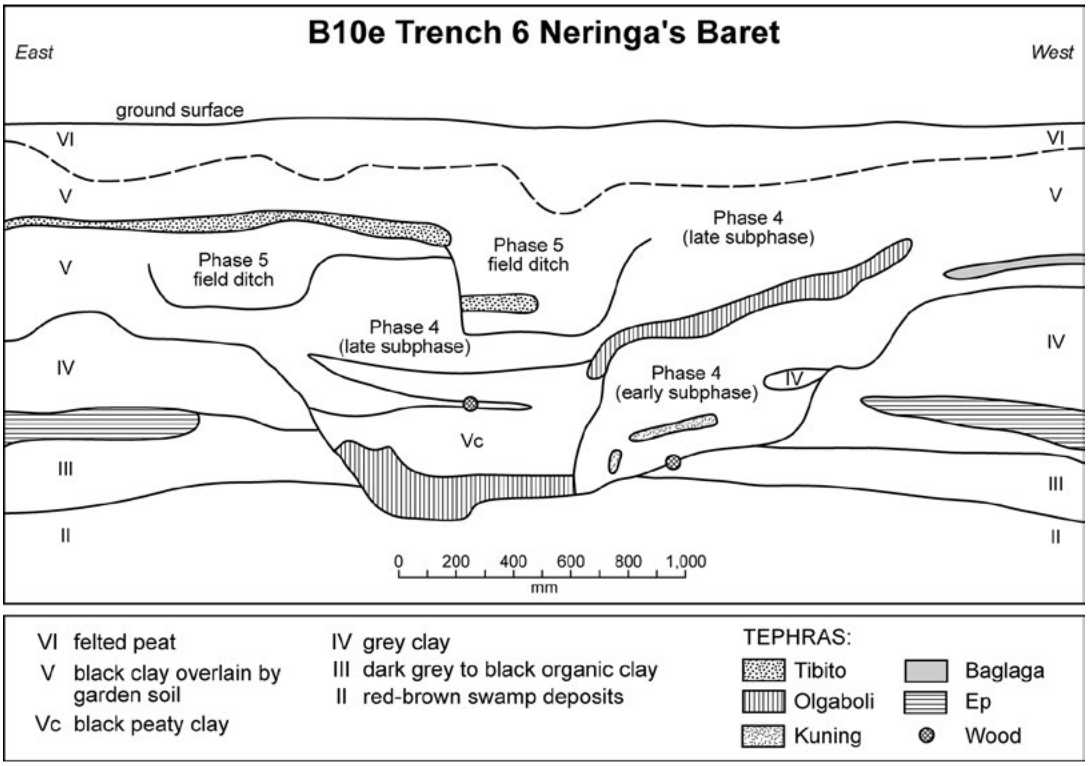


Figure 14.5 Section across Neringa's Baret at the south wall of trench 6 in block B10e (see Fig. 14.2 for location).

The section shows two subphases of Neringa's Baret, the earlier channel with a lens of Kuning tephra in the fill just above its base, the later and somewhat narrower channel having Olgaboli Tephra preserved at the base and the edge of its fill. Note the presence of an early and a late Phase 5 ditch in Neringa's Baret fill as shown by the lie of Tibito ash in relation to the two bases.

Source: Drawing by Ian Agnew from a draft based on a 1974 scale drawing by Jim Rhoads in the Kuk archive.

We have evidence about Neringa's Baret from various parts of the Kuk site. An excavation by Jim Rhoads in block A10h along the northern flank of the above-mentioned hillock revealed a minimum of two subphases of use. The earlier channel was at least 2.5 m wide and just over 1.0 m deep below the estimated level of the contemporary ground surface, while the later one was narrower, but originally almost as deep. However, by the time Olgaboli Tephra fell it had partially infilled and was only 0.6 m deep.

Evidence that Neringa's Baret was a channel with at least two subphases was also provided by a further excavation by Rhoads in B10e (Fig. 14.5). In this case, a lens of Kuning (Sandy 2) tephra lay 0.18 m above the bottom of the earlier channel. Based on the calibrated age range, 1690–1420 BP, of the only dated surface on which this ash fell, at Ambra crater, it would be possible to argue that Neringa's Baret was initially excavated not long before the fall of Kuning tephra. Alternatively, Neringa's Baret may have originated earlier, with evidence of an initial cut removed when, not long before the Kuning ashfall, the channel was cleaned out and deepened. In either case, the initial excavation of Neringa's Baret—which ushered in Phase 4—would have occurred towards the end of the period of extreme El Niño drought events between 2500 and 1700 years ago. In its later subphase, the channel looks to have been slightly narrower than the initial one. Olgaboli ash is preserved at the edge of the channel fill at a depth of 0.5 m below the estimated level of the contemporary ground surface.

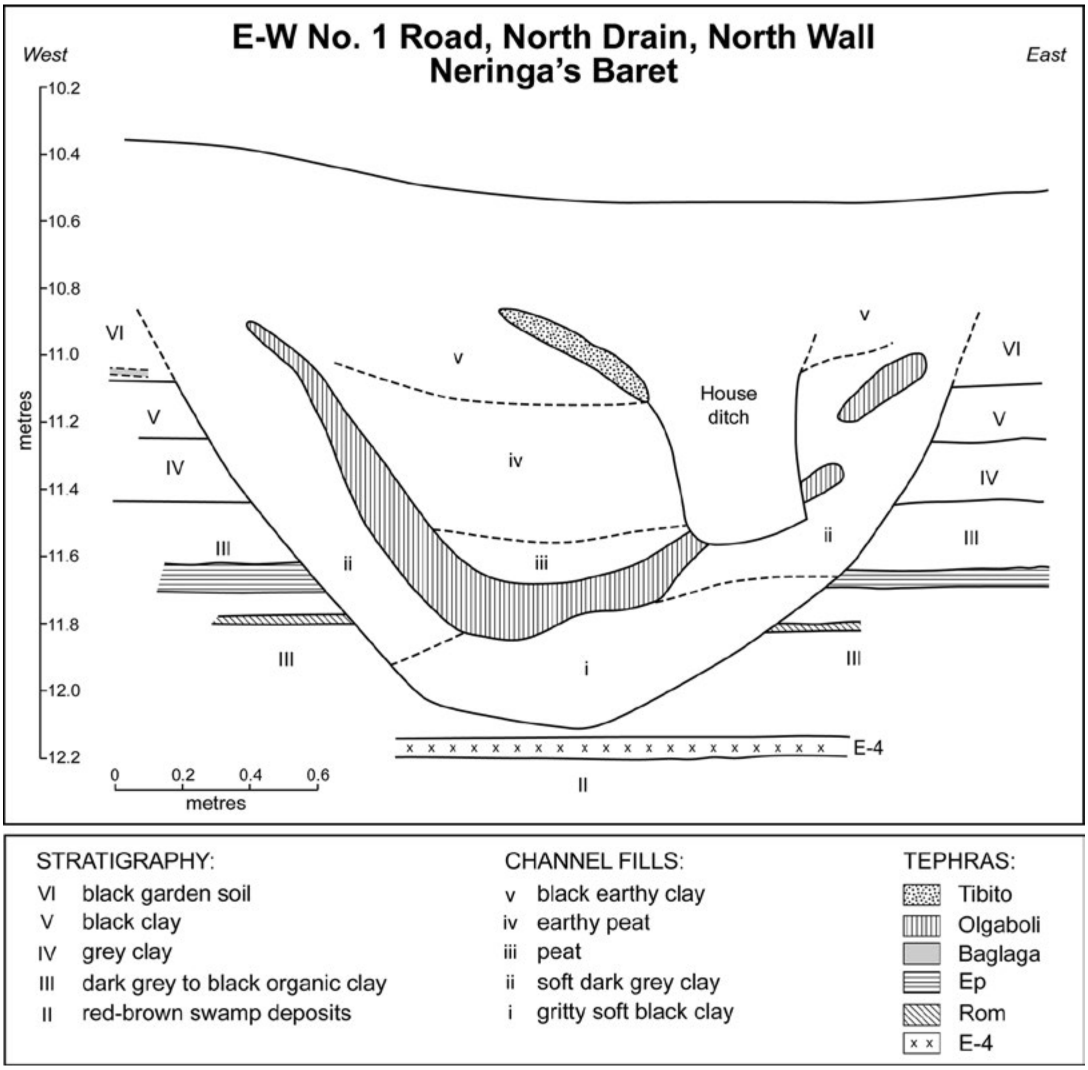


Figure 14.6 Section across Neringa's Baret at the north wall of the north drain of E–W Rd 1, showing a smooth U-shaped perimeter (see Fig. 14.2 for location).

In relation to its contemporary land surface, the channel at this point is 2.1 m wide and 1.2 m deep and has a cross-sectional area of about 2 m². It shows no evidence of different subphases of Phase 4, presumably because the latest cleaning of the channel, which occurred not long before the fall of Olgaboli Tephra, removed any trace of them. A lens of Tibito Tephra sits on the shoulder of an intrusive ditch. When first recorded in mid-1973, the wall of the ditch was clearly drawn as cutting the ash layer. That is, the ditch was seen as a Phase 6 structure, possibly a house ditch. This date fits well with the description of the ditch fill as loose and root-penetrated, though its status as a house ditch was not confirmed.

Source: Drawing by Philip Stickler based on a draft prepared by the authors from 1973 field recordings in the Kuk archive.

The most complete cross-section of Neringa's Baret recorded was at the point where it was crossed by the north drain of the modern E–W Rd 1 (Fig. 14.6). Here the channel has a smooth U-shaped perimeter 2.1 m wide and 1.2 m deep below the presumed contemporary surface. We estimate the channel's cross-sectional area to be 2 m^2 at this point. There is no evidence in this cross-section for different subphases of Phase 4, presumably because the latest cleaning of the channel, which occurred not long before Olgaboli Tephra fell, had removed any trace of them. In this profile Olgaboli Tephra lies up to 0.3 m above the base.

About 600 m downstream to the northwest, where traces of several major disposal channels intersect the modern E–W Rd 3, there is the remnant of an earlier channel that could have been Neringa's Baret, most of which was subsequently reused for the digging of Wai's Baret in Phases 5 and 6 (see cross-section E of Figs 15.2 and 15.7). Extrapolating the channel's bank form from this remnant, a cross-sectional area of about 4.0 m^2 can be estimated. On the basis of this evidence it would appear that Neringa's Baret became a more substantial channel downstream towards the outlet.

Moni's Baret

In contrast to Neringa's Baret, we have very little information about this disposal channel. It is inferred to follow the alignment of Nema's Baret (see channel 108 of Fig. 13.7) through blocks A9 and A10 to the southern end of B10 (Fig. 14.4). It is well preserved as it crosses the southern boundary drain of the station, with Olgaboli Tephra capping its fill. In the swamp to the north, however, much of the original fill has been replaced by younger material accompanied by Tibito Tephra. This may have resulted from natural scour along the line of the channel after it was abandoned, or from its reuse in Phase 5, or both. On entering block B10, Moni's deviates from the line of Nema's and follows a highly sinuous course to join Neringa's at a right angle (Fig. 14.4 Inset 2). This sinuosity is hard to explain, but there is no doubt that much of the channel was artificially cut into the grey clay rather than being incised by a naturally meandering stream.

We cannot say whether Neringa's and Moni's Barets operated simultaneously or whether one lay abandoned while the other was in operation. The fact that Moni's and Neringa's Barets focus on the removal of water coming in from the south into the same segment of swamp favours the second of the two alternatives. This is particularly so in the light of the fact that only limited land was drained to the east of Neringa's Baret in Phase 4.

Minor disposal channels

In addition to the major disposal channels, there are others of slightly smaller size. They are tributaries of the major channels but are not so deep. On the other hand, they are clearly more substantial than the widespread network of very small channels that we term field ditches. These minor disposal channels seem to occupy an intermediate position in a hierarchy that runs from the major disposal channels, Neringa's and Moni's Barets, to field ditches that may again have larger and smaller examples. This hierarchy of ditches has ethnographic parallels in modern drainage practices found in, for example, the Tari Basin of Southern Highlands Province (Ballard 1995: 96; cf. Chapter 5, section 'Wetland drains').

An example of a presumed minor disposal channel thought to be joining Neringa's Baret from the east was recorded in block D8 in the northern part of the site (Figs 14.2 and 14.4). Called Feature 7, it was exposed in cross-section in drain D8e/f (Fig. 14.7). Its location and direction are similar to those of Korowa's Baret of Phase 5 (Figs 15.2 and 15.4) and Phase 6 (Fig. 16.3). This runs westwards towards Wai's Baret along the bottomlands of the swamp between the gentle upward slope of the surface to the south and its more pronounced rise to the north (see Fig. 6.8), intercepting runoff from the northeast of the swamp and from the streams that flow southwards from Ep Ridge. The presumed role of Feature 7 in the hydrology of Phase 4 would have been to remove water from the field ditches that defined gardens established along the northern margins of Kuk Swamp. It can be roughly reconstructed from a discontinuous lens of Olgaboli Tephra, 30 mm in thickness, which outlines some of the channel base as it existed at the end of Phase 4 (Fig. 14.7).

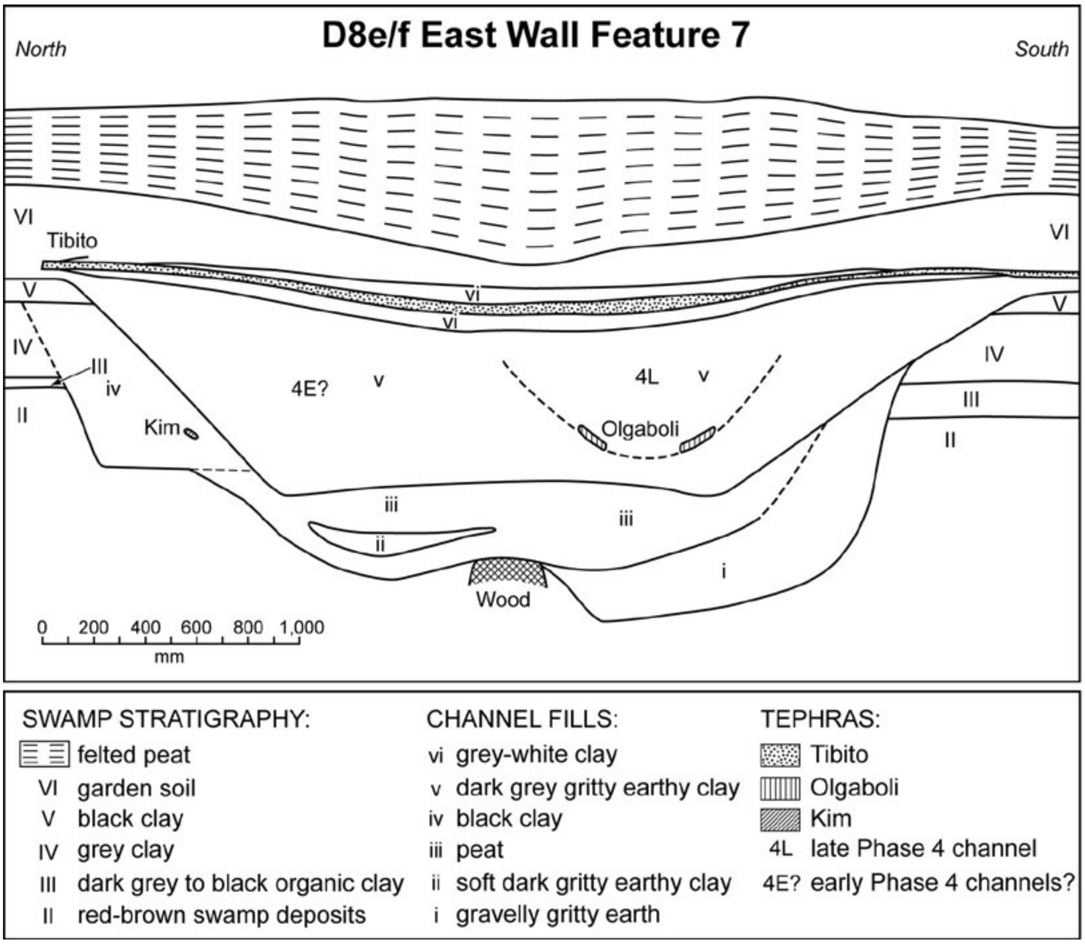


Figure 14.7 Section across a wide channel complex in the east wall of drain D8e/f, showing the outline of Feature 7 (4L), interpreted as a late Phase 4 minor disposal channel cut into the fill of the latest channel of the complex, its base marked by Olgaboli Tephra.

Traces of Olgaboli ash were also visible in the west wall partner of the feature, which is thought to have flowed westwards as a tributary of Neringa's Baret in the northern part of Kuk Swamp (see Figs 14.2 and 14.4), in much the same way as the better known Korowa's Baret of Phase 5 (Figs 15.2 and 15.4) and Phase 6 (Fig. 16.3). The channel complex is difficult to interpret, but the presence of Kim (R) tephra suggests that it goes back to Phase 2, unless the ash occurs in a secondary context.

Source: Drawing by Philip Stickler based on a draft prepared by the authors from 1975 field recordings in the Kuk archive.

Extrapolating from somewhat incomplete evidence, we can estimate that Feature 7 was originally about 3 m wide and 1 m deep, with about 0.1 m of infill in the final minor disposal channel at the time of the tephra fall. At this time, the disposal channel's cross-sectional area was about 0.7 m^2, which is considerably smaller than Neringa's Baret, the major disposal channel that it joins, but an order of magnitude larger than most of the field ditches.

Field ditches: Shape and size

There is a striking difference between the size and shape of Phase 4 field ditches compared to those of the preceding Phase 3. We were able to generate a large sample of Phase 4 ditches from the systematic record of those that were positively identified in the walls of station drains, especially those with lenses of Olgaboli Tephra in their fill. Some particular examples of ditch cross-sections are shown in Figure 14.8.

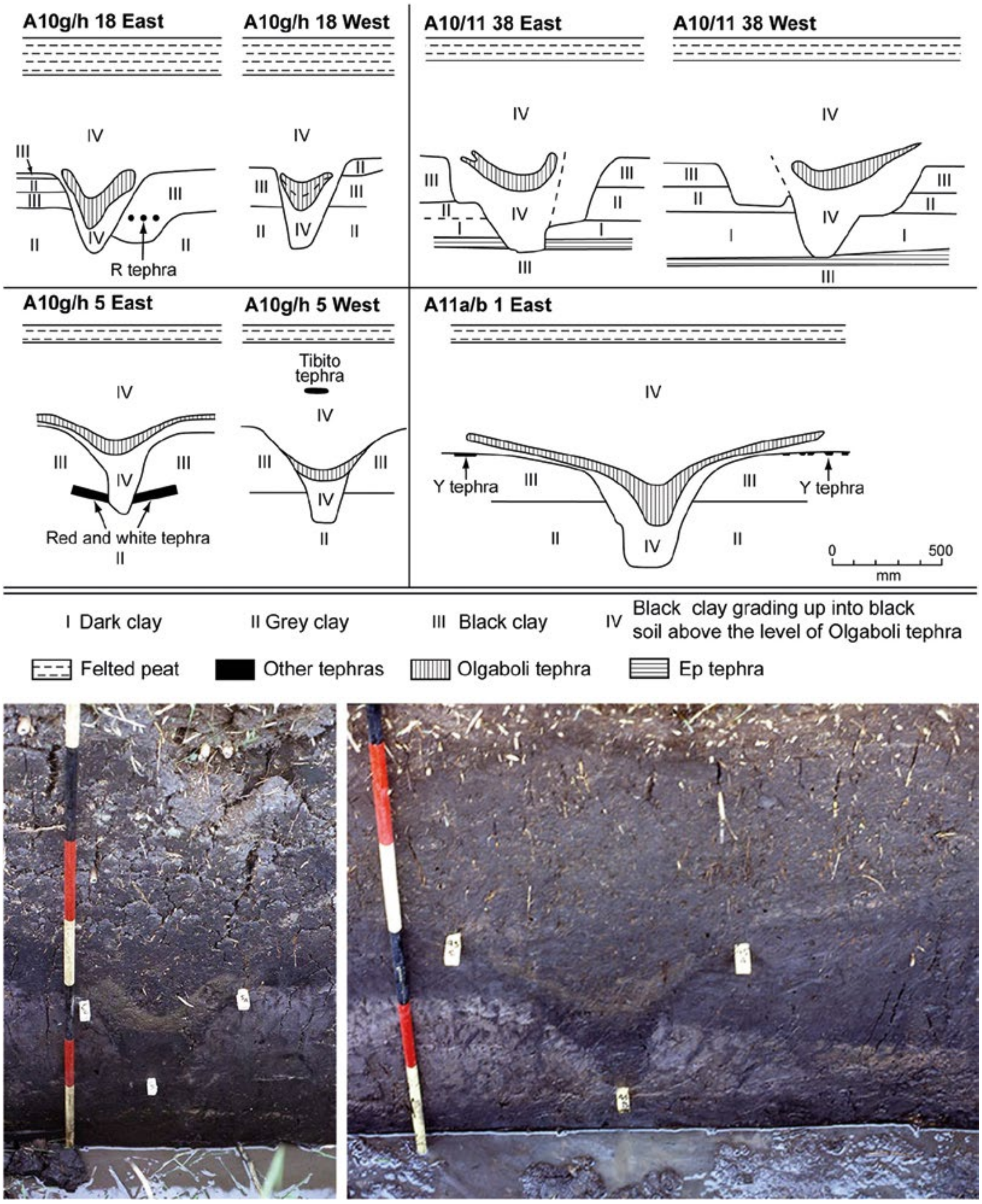


Figure 14.8 Examples of Phase 4 minor field ditches in blocks A10 and A11 in cross-section.

The drawn ditches (top) range from early to late Phase 4 in age by the evidence of the lie of Olgaboli Tephra in their fills. The two ditch photographs (bottom) repeat the features of shape shown in the line drawings and reveal the character of the ash dipping over the ditch fill. The one at the left shows the west wall of drain A10f/g at its north end, the one at right shows the west wall of drain A11a/b about 80 m from the north end. The pegs were part of the process of ditch and stratigraphic record, the upper two pegs here marking the level from which the ditches could clearly be seen to have been dug and the third peg at the base. In the picture to the right, the falling level of grey clay to the north of the ditch indicates the presence of one of the runnels defining the island beds of Phase 2 (see Fig. 12.8b). The ranging poles are graduated at 200 mm intervals.

Source: Drawing by Michael Young after Bayliss-Smith and Golson (1999: Fig. 11.5) (reproduced with permission) and photographs by Jim Rhoads 1974 (left), Ron Lampert 1973 (right) from the Kuk archive.

All of the field data were corrected for width distortion using the following methods. For each field ditch an accurate cross-section was drawn using the field sketch, the field measurements (made in centimetres), data from the levelling survey and knowledge of each ditch's direction of flow. Direction could be estimated because in most cases the same ditch could be traced in both west and east walls of the north–south Station drains, enabling the degree of obliqueness of its intersection with the drain to be assessed. Unlike in earlier phases, in Phase 4 the field ditches articulate to form grid networks, most of the ditches running either WSW–ENE or NNW–SSE. In the latter case, the intersection with Station drains was too oblique for an accurate cross-section to be attempted, but in the former case, the field measurements of width could be adjusted to produce an accurate cross-section drawn perpendicular to direction of flow. From the plans of these cross-sections, widths and depths were estimated to the nearest centimetre by direct measurement. By counting squares on the graph paper that was used for drawing the plans of the ditches, an accurate measurement could be made of their cross-sectional area (in metres squared).

This work was carried out for three sample areas of Kuk Swamp (Fig. 14.2)—block A9 near the southern margin, blocks A10 and A11, which are somewhat lower-lying, and blocks C9, D7, D8 and D9 in the deep swamp, where people might have encountered more severe drainage problems. In fact, to a remarkable degree, the differences between field ditches measured in the three sample areas were small and probably not significant. It would seem that Phase 4 ditches were dug in very much the same way in all parts of the swamp, and in the descriptions that follow we refer only to the aggregate sample.

From these data it is clear that in Phase 4, the field ditches were significantly narrower features than they had been in the previous phase. To describe 'the typical Phase 4 ditch', we use modal rather than mean widths because, for all measures of width, the sample does not have a normal distribution around its mean. Statistics for 'the average Phase 4 ditch' are distorted by the presence in the sample of some ditches that are much wider than more typical ones. Their larger size appears to be sometimes by design, because they were more important or had been recut along a slightly different line and thereby widened, but sometimes their greater width is merely because the cross-section happens to be located close to a junction where widths flare out as two ditches approach each other at right angles.

The width of ditches was measured at three points in their cross-section. Maximum width (Wmax) was measured at the top of black clay and gives a mode of 410 mm and a mean of 473 mm (Fig. 14.9). In either case, this statistic is less than half the equivalent measure for late Phase 3 ditches where Wmax averaged 905 mm. For each Phase 4 ditch, its width was also measured 10 mm above the lowest point of the base (Wbase) and 100 mm above this same point (W100mm). The mode for Wbase is 70 mm (mean 94 mm), while the mode for W100mm is 160 mm (mean 215 mm). These ditches are indeed the 'slot-type barets' that Golson (1976: 212) originally described, narrow gutter-like features with steep sides and rounded bases (see Fig. 14.8).

The narrower shape of Phase 4 ditches may partly result from better preservation of the original form. If taro were the principal crop of Phase 4, then the ditches would be exposed to subaerial erosion for only one crop, lasting perhaps for one year before fallowing. This short cycle of cultivation may contrast with Phase 3, when longer-term crops like bananas may have been cultivated for several years. The longer that drained fields are subject to erosion and human activities, the more likely that their edges will become blurred, perhaps contributing to the wider forms that we see both in Phase 3 and, subsequently, in Phase 5 (see Fig. 15.14).

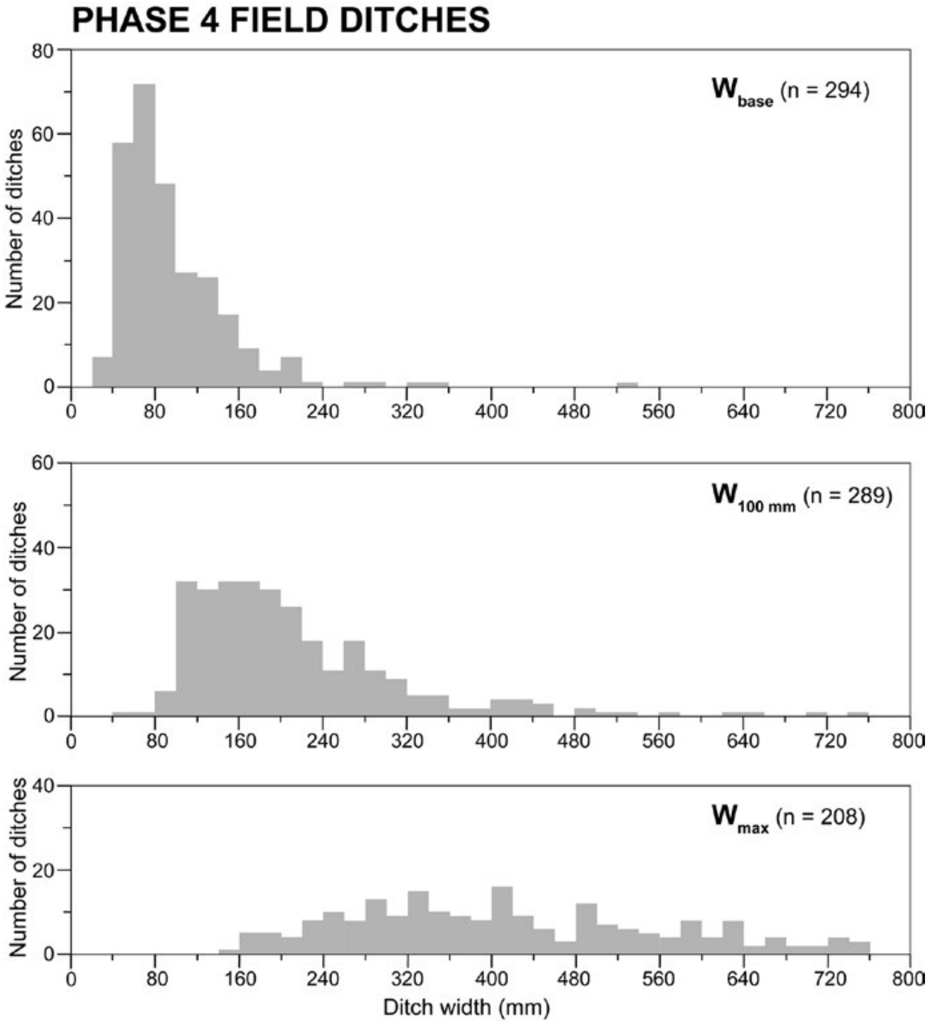


Figure 14.9 Bar charts showing the widths of Phase 4 field ditches.

Wbase is measured 10 mm above the lowest point of the base; W100mm is measured 100 mm above the base; and Wmax is measured at the top of the black clay level.

Source: Drawing by David Williams based on measurements and calculations by Tim Bayliss-Smith.

Ditches in Phase 4 were also shallower than they had been in late Phase 3 (Fig. 14.10). Maximum depth (Dmax) was defined as depth below the top of black clay and the modal depth is 350 mm (mean 351 mm) compared to a mean of 528 mm in the previous phase. The shallowness suggests a limited capacity to lower the water tables in adjacent fields, but also a limited need to do so if taro was the crop (see Fig. 11.11).

For ditches where all dimensions were preserved and recorded, we can also estimate the cross-sectional area of the channel from the top of the black clay level down to the base. As a result of the variations in width discussed above, cross-sectional area differs somewhat, but the great majority of ditches are less than 0.2 m² and the modal size category is 0.08–0.10 m² (see Fig. 14.10).

We can summarise by saying that the small field ditches that define the Phase 4 planting beds are remarkably uniform in size and shape. They are mostly linear, gutter-like features, deeper than they are wide and crossing each other at right angles (Fig. 14.11). Most have steeply sloping sides and rounded bases and their shape would suggest that a heavy digging stick was used to produce them (Figs 14.3 and 14.8). As we discuss below, these ditches form grid-like networks defining rectangular planting surfaces that we could call beds, gardens or fields.

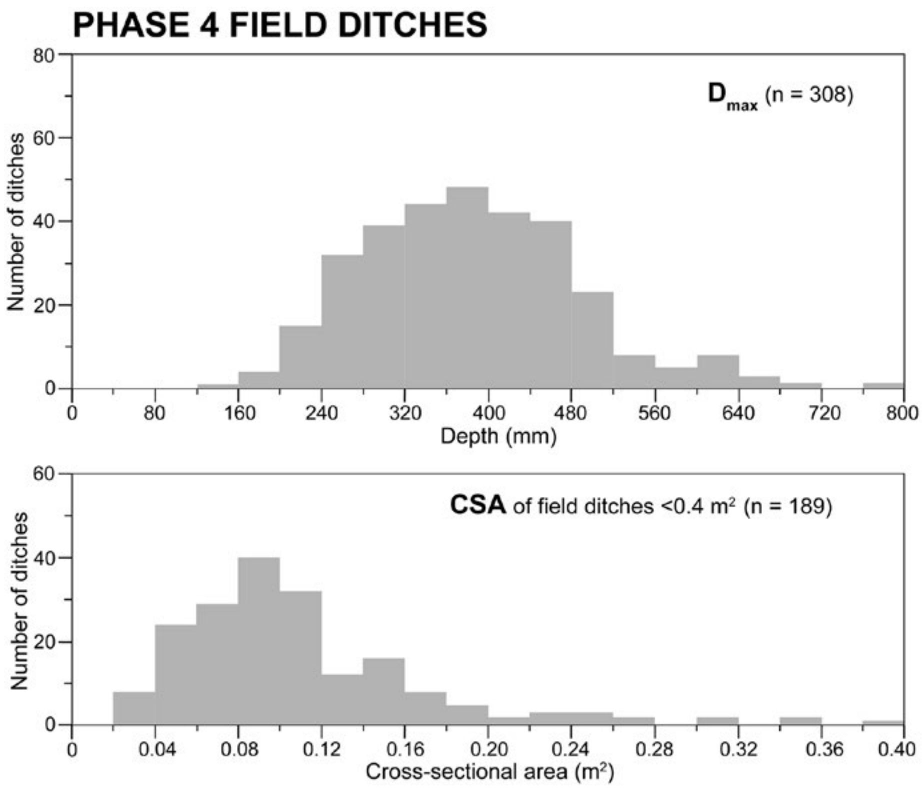


Figure 14.10 Bar charts showing the maximum depth (Dmax) and cross-sectional area (CSA) of Phase 4 field ditches.

Dmax is measured as depth below the top of black clay. CSA is the channel's cross-sectional area below the same level.

Source: Drawing by David Williams based on measurements and calculations by Tim Bayliss-Smith.

Figure 14.11 Two views of the same slot ditches exposed beneath Phase 6 houses and cut through by the deep perimeter ditches of these: left, looking west and right, looking south.

The houses are B and C of the cluster at the north end of blocks A9g and A9h (see Fig. 16.3 Inset and Figs 17. 1 and 17.5) and the raised floor of House C has been partly removed to show the southerly continuation of the ditches first seen on the strip of ground between it and House B. Even so, it is difficult to interpret the pattern that emerges, though we presume that we are dealing primarily with Phase 4 field ditches by their shape and the presence of Olgaboli Tephra, though possibly not all of the same age within Phase 4. The ranging pole in both pictures is graduated at 200 mm intervals.

Source: Photographs by Ron Lampert, Kuk archive, 1972.

The field ditches articulate with larger disposal channels. We can establish the relationship between the disposal channels and the field ditches by looking at levels in block A10. Here Neringa's Baret, the major disposal channel, was excavated to a depth of 300 mm below the bases of the field ditches and at least 700 mm below the surfaces that were being cultivated at the time of Olgaboli Tephra. These differences in level suggest that Phase 4 was organised around a hierarchy of ditch sizes, varying in depth and importance according to their functional roles.

The depth of field ditches is not related to the local ground elevation. For example, in blocks A10 and A11, the depths of individual ditches range from 200 to 650 mm below the level of black clay, while the level of the ground surface into which they are dug varies by more than a metre across these two blocks. For a sample of 104 ditches that were measured, there was no statistical relationship between ditch depth and the elevation of the ground surface into which they were dug (Bayliss-Smith and Golson 1999: Fig.11.7). This lack of correlation is true also when we compare ditches at the swamp margins (A blocks) with those in deeper areas of the swamp (C and D blocks). These findings seem to indicate that in Phase 4, ditch depth was not affected by local swamp elevation, perhaps because the whole of Kuk Swamp was relatively dry when the ditches were dug so that low-lying areas were not in any need of deeper drainage. Perhaps the large investment in digging deep disposal channels was so effective that all parts of the swamp, high and low, were equally well drained. An alternative possibility is that field ditches were more important as markers of field boundaries than as drainage features. Perhaps their rationale was more social than hydraulic.

Fields and fallows

These minor ditches define small gardens or fields that can be reconstructed from their exposures in the walls of the north–south drains of the Station (Fig. 14.12). The fields average about 13.5 m by 9 m and are highly standardised in size and shape. As with ditch depths, we do not find that fields in low-lying areas are any different in their dimensions from those around the swamp margins, which suggests that the 'design' of the system was in relation to social norms rather than hydraulic requirements.

Not all of Kuk Swamp was used during Phase 4. We estimate that about 75 hectares of the 125 ha total area of archaeological investigation show at least one episode of Phase 4 drainage. The area that was never used in Phase 4 is in the eastern part of the site, on land remote from the northwest-flowing Neringa's Baret (Figs 14.2 and 14.4). Although the intensity of our drain digging and the detail of its archaeological record decreased eastwards and especially northeastwards across the site, we established through inspection of drain walls that there was no Phase 4 ditching in block A12, little in the eastern half of block A11 and none in at least the eastern three-quarters of block B12, whereas, closer to the line of Neringa's Baret, there was good Phase 4 evidence in the western half of block B11. While, with a single exception, we dug no drains in blocks C and D10–12, drains in blocks C9 and D7–9 to the west did show evidence of Phase 4 ditching.

The single exception referred to above, drain C12e/f, towards the eastern boundary of the Station (Fig. 14.4), deserves individual comment. Roughly halfway south along the drain from E–W Rd 3 we found what the fieldbook describes as 'a most surprising appearance' of a Phase 4 field ditch, oriented WSW–ENE, with substantial Olgaboli Tephra in its fill. It is slightly larger than the average for Phase 4 field ditches found in other parts of Kuk Swamp. Whether it signals the start of a new area of drainage activity to the east is unknown for lack of any other evidence.

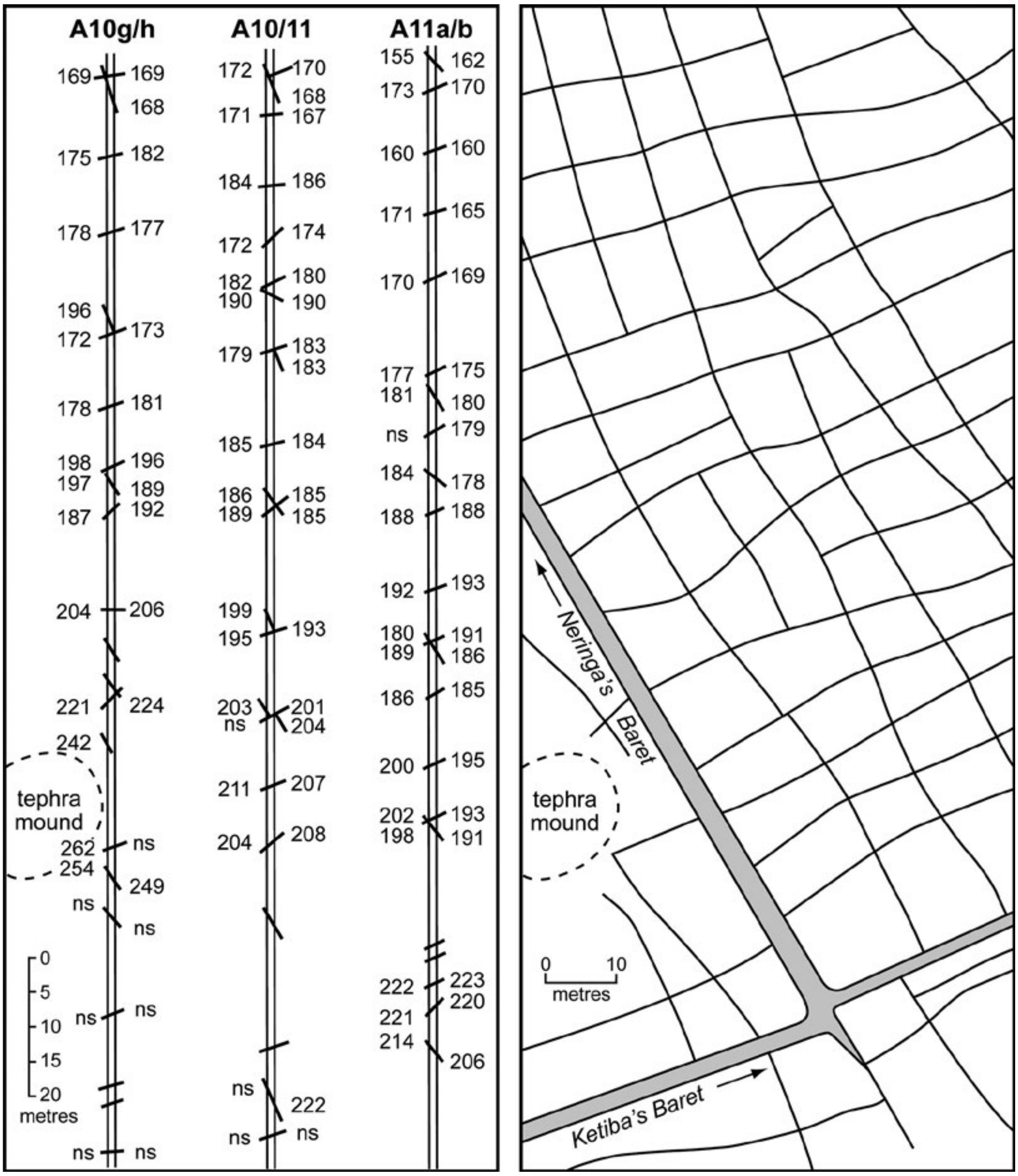


Figure 14.12 Evidence (left panel) for the intersection of Phase 4 field ditches with the Station drains in blocks A10h and A11a; and reconstruction (right panel) of the layout of these field ditches in the same area. The reconstruction also shows the major disposal channel, Neringa's Baret, with its SW–NE segment, Ketiba's Baret.

Source: Drawing by Michael Young after Bayliss-Smith and Golson (1999: Fig. 11.4), reproduced with permission.

It would also seem that not all Phase 4 field systems were in simultaneous use, as demonstrated by the position of Olgaboli Tephra in the infill of many of the field ditches. Tephra occurs in some places near to the base of the features, but in others it lies close to the contemporary land surface (for examples see Fig. 14.8). This disparity suggests we should envisage Phase 4 as a kind of shifting cultivation system, with the land made usable by the major disposal channels being in reality a mosaic of productive gardens and fallow plots.

Figure 14.13 A grid of taro gardens at 2125 m altitude on swampy land by the Kaugel River at Kiripia near Tambul, some 45 km SW of Kuk.
Source: Photograph by Tim Bayliss-Smith, 1980.

More important than fertility loss, drained soils under taro cultivation quickly become infested with *Papuana* beetles, which severely damage the crops and can only effectively be dealt with by allowing gardens to go into swamp fallow, as discussed above. This cycle of drained garden followed by swamp fallow represents modern practice in the upper Kaugel wetlands near Tambul, 40–50 km southwest of Kuk and 2100–2200 m above sea level (see Fig. 14.13). In the Kaugel Valley, only if a period of reuse occurs within about 20 years of abandonment is it possible for the cultivator to relocate the former ditches because of their soft fill and so exhume the former drainage network. A cycle of wetland drainage and fallow is also suggested by Robinson (1999: 55), who found at Bitsamu in the Kopiago Basin (1320 m) that disused ditches faintly visible on 1967 air photographs could no longer be seen in 1995 at ground level. In this case, completely new ditches had to be dug. Reuse of former lines of drainage makes the task of reclaiming land for a new garden easier than if a completely new network has to be made.

Artefacts

None of the wooden tool types associated with agriculture in the ethnographic record of the upper Wahgi (see Chapter 19) were found preserved in the swamp gardens of Phase 4 at Kuk. This is likely to have been because the subsequent drainage works of Phases 5 and 6 disrupted the waterlogging that would have ensured their survival. However, an example of a woman's light digging stick was found at Draepi-Minjigina in a Phase 4 ditch sealed in by Olgaboli ash (Golson and Steensberg 1985: 376) and we have already said that the gutter-like character of the Phase 4 field ditches suggests that they were made with the men's heavy digging stick. The so-called hastate spade of Phase 3 age found at Tambul (see Fig. 13.12) shows that paddle-bladed implements were likely to have been in use for trenching and ditching in Phase 4 at Kuk, as they definitely were in Phases 5 and 6 (see Chapter 19, sections 'Long-handled paddle implements' and 'Shorter paddle tools').

Stone axes would have been used for clearing trees, if trees were present, and for chopping grass stems. Axel Steensberg (1980: 53–59) has reviewed the tools and practices employed by highlanders to deal with the grassland sod when establishing gardens on dryland or drained swamp, including demonstrations of swamp grass clearance that were organised at Kuk (see Chapter 19, section 'Digging sticks and tools of clearance').

Interpretation

Labour and yields in Phase 4

Phase 4 in the wetlands appears to be a specialised and relatively intensive production system and it presumably had a dryland counterpart, although evidence for landuse outside the wetlands is always difficult to find. Our guess is that wetland taro production was a supplement to dryland yams and bananas, cultivated by means of tillage of grassland soils, and with some limited hunting and foraging.

A possible ethnographic parallel to the Phase 4 system at Kuk was provided in 1980 by the taro fields at Baisu Corrective Institution, 4 km east of Kuk, discussed above. Measurements by Bayliss-Smith (1985a: 310, Table 5) of the yield of harvested taro and the input of labour required showed that about 3300 hours of work were needed per hectare of cultivated wetland. This work was rewarded by an annual yield ranging from 14 to 25 tonnes per hectare of taro corms, the average being 21 tonnes. This yield is comparable to that recorded at Kuk Station for taro grown in 1980–81 in plots protected from *Papuana* beetle damage, which averaged 18 t/ha/yr. Both yield figures are much higher than that recorded for unprotected plots at Kuk, and also higher than the yield reported by Clarke (1977: 160, 163, Table 1) for taro grown in dryland sites near Mount Hagen. Here soil deficiencies and beetle damage reduced yields to 4.4–5.3 tonnes per hectare on 'good' sites under tall grass and, unsurprisingly, less on poorer ones.

Adjusting the Baisu figures to take account of the differences in efficiency between steel and wooden spades, a total of 4000 hours per hectare for the Phase 4 system can be estimated. These figures can be compared with modern taro swiddens elsewhere in the highlands. The comparison indicates that between three and four times more labour is needed for drained cultivation of grassy swamps than for shifting cultivation in forests, but in return the food yields are about doubled (Bayliss-Smith and Golson 1992b: 19–20).

All these findings suggest an intensive use of labour in Phase 4 that was compensated by high returns. Unfortunately, we cannot compare wetland taro with any reconstructed landuse system for dryland sites centred on the cultivation of yams and bananas. Today, unlike the sweet potato, these crops are little grown in deforested valleys like the Wahgi, so that data on their productivity are lacking. Nor can we be certain about the gendered division of labour. Ethnographic analogies would suggest that the major disposal channels would have been men's work, while other tasks might have been shared. In the Kaugel Valley today, making small field ditches with digging sticks is women's work, but larger ditches are dug by men. In the Wahgi, the ethnographic evidence suggests that ditching was always men's work. Everywhere, highlands ethnography emphasises the primary role of women in planting, weeding and harvesting.

Digging the major disposal channels

In addition to the labour costs of field ditching and cultivation, we must consider also the major disposal channels. Calculations show that initiating these channels would have required quite a substantial investment of labour (see Chapter 5, section 'Social contexts for wetland drainage').

As we have noted, Neringa's Baret covered 2.4 km from its right-angled bend in the A blocks northwest to its Guga outfall. If we assume its cross-sectional area averaged 2 m^2, then each kilometre of length would have required the digging out of about 2000 m^3 of saturated peat and clay.

We estimate, using ethnographic and experimental data from a range of sites and adjusting for the use of wooden spades and digging sticks, that productivity levels for men would have been about 0.5 m^3 per hour, over a working day of perhaps five hours. Each kilometre of major disposal channel therefore required about 800 man-days of digging, which represents about 2 months of work for a gang of 16 men. To dig the whole of Neringa's Baret working six days per week would thus have required an investment of about five months' work by these 16 men (correcting the original estimates of Bayliss-Smith and Golson 1999: 222).

These figures have implications both for leadership and social organisation. As John Burton (1984: 88) has remarked in relation to stone-axe quarrying at nearby Tuman, 'non-ranked, non-hierarchical societies can organise themselves for large-scale productive ventures when a range of conditions are met'. These conditions include peaceful relations with neighbouring groups; ideologies of male solidarity and female support; and enough men who can remember the skills previously acquired so as to ensure technical success. Like the equivalent disposal channels of Phase 3 and perhaps earlier phases, we conclude that the scale of Neringa's Baret signals that it was an important community project in Phase 4. It should therefore be seen as a form of 'landesque capital' and it was through this capital formation that Kuk Swamp became an enhanced landscape for future agricultural production.

Implications for surplus production

It also becomes possible to estimate, using the Baisu data, the potential for surplus production from the Phase 4 wetlands (Bayliss-Smith and Golson 1992a: 13–17). An average annual taro yield of 21 tonnes per hectare gross would generate enough food energy to support a total population at Kuk of either 162, 240 or 480 people, depending on the assumed level of dependence on the production from wetlands (75 per cent, 50 per cent and 25 per cent respectively). These calculations use a conservative estimate of the proportion of wetland area in use at any one time, based on a 1: 19 ratio of years of cultivation to years of swamp fallow. The model also assumes that 75 ha of swamp was under this cycle of intermittent use at Kuk, based on the portion of the archaeological site of 125 ha that shows evidence of use in Phase 4 (see Bayliss-Smith and Golson 1992a: 13–17 for the detail of the calculations).

The above population estimates relate to a situation with no pigs (see Chapter 15, section 'Artefacts, houses and pigs'). If, however, the pig had arrived in the highlands by this time and the Kuk community of Phase 4 fed a portion of its taro surplus to maintain domestic pigs, then the human carrying capacity is somewhat diminished. However, in such a case the incentives for wetland drainage would become clearer, because pigs can be used as valuable exchange items to generate wealth and prestige, as exemplifed in the sweet potato economy of recent times. In the deforested landscapes of the Wahgi Valley floor, hunting and foraging would have become unrewarding, giving added value to any domesticated sources of fat and protein in the diet.

Whatever the scenario, it is clear that Phase 4 had a significant potential to support a larger population than the preexisting dryland system within the degraded grassland landscape of the Wahgi Valley floor (although our lack of precise knowledge of the dryland sphere must always be remembered). Phase 4 also had potential for wealth generation and hence to be an engine for social change, with or without the presence of pigs as a medium of exchange.

The social organisation of Phase 4

Direct evidence for Phase 4 societies is lacking, but we can make some progress by considering the societal implications of the Phase 4 system. There was, firstly, the intensification of labour use that wetland landuse demanded and, secondly, the boost to food energy production that it had the potential to provide. In relation to labour intensity, we have already indicated the heavy work inputs needed for cultivating wetland taro. At the beginning there would be need for a group of workers, probably men, organised to plan and dig the major disposal channels. This initial investment would be followed by more individual and incremental efforts by both men and women, digging the field ditches, tilling the soil, planting crops, weeding and harvesting. In the upper Kaugel Valley today, the sod is broken and turned by the men with heavy digging sticks and the resultant clods are pulverised by the women. Perhaps the field ditches would have been men's work, again with the use of heavy digging sticks, while some of the lighter tasks were women's responsibility.

Early interpretations focused on the likely role of population pressure in persuading people to intensify their agriculture through wetland drainage (Golson 1977a), but subsequently the positive role of incentives was emphasised (Golson 1982: 135). It was Modjeska (1977) who first pointed out that the surplus of root crops (we assume taro) that was gained by cultivating drained soils must have constituted a resource that could be used for status enhancement through exchange, whether or not pig husbandry was implicated in this process.

Kuk as a Phase 4 'hotspot'?

Arguments like these persuaded Modjeska (1977: 85–89) to suggest the Wahgi wetlands were what we might call a 'hotspot' of social change in the highlands, with privileged access to sites suitable for the intensification of food supplies. Modjeska envisaged the emergence of sedentary communities of up to 600 people living adjacent to their wetland cultivations, with the potential for both conflict and exchange with neighbouring groups, including the swidden cultivators of the valley slopes. Applying this model to the Kuk situation, we might see Phase 4 as allowing the early development of a distinctive social structure, including the systems of big-man leadership and the gendered division of labour that were so characteristic of the sedentary agrarian societies of the highlands in the 20th century.

Intensive cultivation today in the highlands is also driven by aspirations for wealth and enhanced status. For example, the high cash price that consumers will pay for root crops is frequently a motive for valley floor drainage projects. One example is the drainage system at Kiripia (2125 m altitude) in the upper Kaugel Valley, designed for taro production and mapped in 1980 (Bayliss-Smith 1985a: 295; Fig. 14.13). The landscape of drainage for taro at Kiripia certainly resembles closely the field systems that we can reconstruct for Phase 4 at Kuk (Fig. 14.12), apart from the tighter grid of field ditches at Kiripia, an adjustment perhaps to the cooler and damper environment of the upper Kaugel Valley. In addition, however, the underlying motives of the people who drain the wetlands at Kiripia may also constitute a parallel case to Kuk.

For an archaeological test of the 'hotspot' model, we need to look for evidence of regional exchange. We need to demonstrate that there was an expansion of exchange systems centred on the Wahgi. We also need to show that this expansion was occurring at the same time as the landuse intensification signalled by Phase 4 drainage because it was fuelled by the surplus taro production that drainage generated. Unfortunately, most 'trade' items of that period would have been perishable and so unlikely to survive as evidence: meat, plumes, furs, artefacts of wood or fibre, salt. However, the lithic evidence—polished stone or the raw materials for stone axe production—is a rare exception and it provides us with an opportunity to test the 'hotspot' hypothesis (Golson and Gardner 1990: 405–407).

At European contact in the 1930s, the Tuman quarries of the middle Wahgi and others in the Jimi Valley north of the Sepik-Wahgi Divide were prime sources of high-grade stone in the central highlands. The full story is told in Chapter 21, section 'The age of the axe trade in the upper Wahgi', but the implications of the issues of Phase 4, in the upper Wahgi, are set out here. John Burton has graphed the occurrence of polished axe stone at two of Christensen's Manim Valley rockshelters, Kamapuk and Etpiti, to show the entry of material from these modern quarries, in their case predominantly the Tuman source, into the archaeological record and its steady rise to almost complete dominance in the two assemblages (Burton 1984: 227–228, Table 10.8, Fig. 10.15; cf. Burton 1989: 256). Unfortunately, chronology is provided by only two radiocarbon dates, one at each site, and is thus not as tight as could be wished.

Quarried axestone made an appearance in level 8 at Kamapuk, the level below that with the first pandanus nuts at the site and a radiocarbon date (ANU-1326) calibrating to an age range of 2750–2350 BP. At Etpiti the first quarried stone was also found immediately below a radiocarbon-dated level, level 7, with a calibrated age range of 1350–1050 BP (ANU-1324; for both sets of calibrations consult Table 10.2 and see note 4 below it). At both sites the quarry stone joined other stone types sporadically present from the beginnings of site utilisation. Also at both sites fragments of quarry stone were found that were large enough to be recognisable as belonging to planilateral axes (Burton 1984: 228) of the sort well known in the upper Wahgi at the time of European contact. The earliest of these at Etpiti was in the radiocarbon-dated level 7 and at Kamapuk in level 4.

As Burton admits (1984: 228), the trend he has identified, signalling the development of large-scale axe-stone quarrying to serve regional exchange systems and not just local demand, needs confirmation at other stratified sites. However, despite its chronological looseness, the evidence suggests a beginning for this development that matches quite well the dates for Phase 4. This intriguing observation supports the idea that wetland drainage at Kuk needs to be viewed in the context of wealth generation, not subsistence crisis.

A role for big-man leaders

Social structure in prehistory is notoriously difficult to reconstruct, and in the Phase 4 case we have not much basis for speculation beyond the organisational requirements of the drainage itself and ethnographic analogy. As already discussed, the Phase 4 major disposal channels are quite substantial investments. Digging Neringa's Baret, we estimate, would have required the sustained efforts of a gang of 16 men over a period of about five months. Had it been a part-time project, it would of course have taken longer. To maintain the enthusiasm and solidarity of such a group, and to release so many men from other tasks, it seems likely that some form of authority and charisma would need to be exerted, by the kind of leader we might compare to the big-man of modern times.

Ethnographic accounts of the initiation of major channels are lacking, but in the Baliem Valley in the 1960s the cleaning out of an already existing channel was done by a cooperative work party (Heider 1970: 40).

> Some men stand in the ditches, up to their waist in water and mud, cutting into the mud with the broad-bladed digging sticks and heaving it onto the banks with their hands; other men or women on the banks then spread this mud out evenly with their feet.

Heider goes on to talk about the reopening of old gardens in no-man's-land on the swampy valley floor after peace was restored by the government in 1961 (1970: 42). Just as warfare in the Wahgi today can lead to the abandonment of agriculture in disputed areas, so in the Baliem the breakdown of political alliances can have the same effect. Episodes of swamp drainage can therefore reflect the vicissitudes of local politics rather than being a response to regional economic or ecological problems.

In the relatively egalitarian societies that today characterise the New Guinea highlands, organising a cooperative project is a delicate and sometimes fragile enterprise. The exhortations of big-men are easily ignored and opportunities for genuine coercion are few. Both men and women can withhold their labour unless convinced of the collective benefits of what might otherwise be construed as a boost to the status of just one individual, the big-man himself. Perhaps wetland drainage was also subject to these various vicissitudes, dependent as it was on collective labour for the initiation and then the maintenance of the major disposal channels. Moreover, success in large-scale drainage may depend on peace and the maintenance of regional alliances, which may break down.

The vulnerability of the cooperative enterprise to breakdown, because of warfare and the relatively weak position of big-man leaders, is a factor that might help to explain the complete abandonment of Phase 4 after the fall of Olgaboli Tephra from the sky about 1100 years ago. We can only speculate about the effect of such an extraordinary event on local alliances, exchange networks and the bonds between leaders and followers, but one obvious effect—the short-term fertility boost of tephra to soils and agriculture in the dryland sphere—may have been enough in itself to inhibit wetland cooperation for a generation or more.

Dryland agriculture after Phase 4

The initial effects of a tephra fall are damaging to crops and food shortages or famine are likely to ensue (see Chapter 8 for a review of the effects of a tephra fall on plants, animals, buildings and health). However, the longer-term effects are more positive. In several oral histories that recount the Time of Darkness, in other words the fall of Tibito Tephra, possibly in the AD 1660s, informants indicated the beneficial effects. In Enga, for example, '[t]o everyone's surprise the plants grew at a great rate and gave unheard-of yields of food' (Blong 1982: 119). This effect of a boost to soil fertility has been noted in various volcanic eruptions around the world (Blong 1982: 169). At Kuk, the improved productivity of dryland agriculture may have mitigated the damage to wetland gardens caused by the fall of Olgaboli Tephra (but see Chapter 8, sections 'Longer-term impacts' and 'Soil replenishment').

The sustainability of dryland agriculture may have been boosted further by the innovation of tree fallowing, specifically the planting of *Casuarina*, for which Golson (1977a: 624–625) noted a marked rise in importance in the pollen record after the fall of Olgaboli Tephra and the end of Phase 4 drainage at Kuk. In a later detailed review of the evidence, Haberle (1998a: 8) shows this change to be synchronous in all sites in the upper Wahgi Valley and some 300–400 years later in the Kainantu region of Eastern Highlands Province.

The deliberate planting of *Casuarina oligodon* and the protection of seedlings of this and other fast-growing trees like *Trema* and *Dodonaea* are widely reported in the highlands (Golson and Gardner 1990: 399). The practice may have started because of the need to provide handy supplies of timber for firewood, fencing and building in circumstances of deforestation. However, the ability of these trees, particularly *Casuarina* as a nitrogen-fixing legume, to restore fertility in otherwise treeless landscapes would have recommended their use in fallowing. Citing Bourke (1997) on the danger of emphasising fallowing rather than timber production as the reason for tree planting, Haberle (1998a: 10) admits that it is impossible to discriminate between the two motives in the pollen record. In a subsequent publication, Bourke and Allen (2009: 246) report that planting *Casuarina oligodon* in fallows is most important in central Simbu Province, in adjacent parts of Eastern Highlands Province, in the Simbai and Kaironk areas of Madang Province and in the Oksapmin district of Sandaun Province, but is not a practice in the three other highlands provinces, Western Highlands, Southern Highlands and Enga, where it is found around the edges of fields, around houses and in small plantations. Whatever the reasons behind it, *Casuarina*'s increased presence in the pollen diagrams after around 1100 years ago is good evidence for advanced deforestation.

We can therefore envisage various alternative scenarios for the end of Phase 4 at Kuk. One model would emphasise the fragility of intragroup social structures in the Wahgi Valley, with group cooperation successfully mobilised for drainage projects under big-man leadership, but with these arrangements easily undermined by individualism reasserting itself. A second model would emphasise fragile intergroup politics, with drainage outfalls easily disrupted by warfare or the breakdown of alliances, especially after a traumatic event such as the fall of Olgaboli Tephra. A third model would emphasise, instead, new projects within the dryland sphere, projects that eventually proved more attractive to both individuals and leaders after the boost to dryland agriculture provided by the fall of Olgaboli Tephra, especially if followed by the initiation of *Casuarina* woody fallows. For whatever combination of reasons, after the ashfall 1100 years ago, the Wahgi wetlands were not brought back into use and drainage efforts lapsed for more than three centuries.

Conclusion

Draining the Wahgi swamps was a daunting task in Phase 4, not so much because of the heavy labour demands of wetland cultivation (the dryland sphere may also have been problematic in its low yields and heavy requirements for soil tillage), but more because of the difficult initial investments required in planning and digging the disposal channels. To enable collective enterprises of this kind to go ahead, political arrangements at the regional scale needed to be favourable, in particular secure alliances with neighbours to protect vulnerable drainage outfalls. At a local level, too, however strong a big-man might have been, his leadership was short-term and individualism was easily reasserted.

We can therefore see the drained wetlands of Phase 4 as a rather fragile social landscape, vulnerable to the breakdown of the necessary political conditions. In our view, drainage is more an expression of cooperation and male solidarity under big-man leadership than the result of separate households responding in isolation to a subsistence crisis. We should also stress the positive advantages that wetlands offered, as insurance against the uncertain yields from dryland agriculture vulnerable to El Niño drought and to declining soil fertility, as well as a means towards surplus production, intensified exchange between groups and status enhancement for embryo big-men. The archaeological evidence currently available could support any or all of these scenarios and a more certain explanation for Phase 4 at Kuk will need more data from further fieldwork and laboratory studies.

15

Phase 5: Retreating Forests, Flat-Bottomed Ditches and Raised Fields

Tim Bayliss-Smith, Jack Golson and Philip Hughes

Introduction

Before Phase 5

The reasons for abandonment of Kuk Swamp and other Wahgi wetlands around the time that Olgaboli (Q) Tephra fell were discussed in the previous chapter. In the short term, the effects of the tephra fall were no doubt damaging to crops, and in indirect ways the event may have caused some disruption to the political stability and social bonds that underpinned the wetland drainage efforts of Phase 4. It is also likely that Olgaboli Tephra provided a temporary fertility boost to dryland agriculture. However, we cannot be sure about the extent to which the marked and sustained increase in *Casuarina* in the pollen record after the fall of Olgaboli registers the initiation of tree fallows for soil regeneration, as once proposed, rather than tree planting for timber production in circumstances of deforestation (see Chapter 14, section 'Dryland agriculture after Phase 4'). For whatever combination of reasons, the fall of Olgaboli Tephra saw the beginning of a long period of disuse of Kuk Swamp for gardening.

Dryland cultivation at this time probably involved almost all of today's crops with the obvious and major exception of the sweet potato. In the Wahgi grasslands, we can reconstruct an agricultural system based on soil tillage for bananas and yams, together almost certainly with sugarcane and possibly winged bean (*Psophocarpus tetragonolobus*). It seems likely that some taro was still being cultivated on small patches of enriched soils, but we believe that taro's importance had declined because in the largely deforested landscapes of the upper Wahgi Valley, all dryland sites and drained wetlands would have experienced major damage to taro corms from *Papuana* beetles (see Chapter 14, sections 'Taro in the wetlands' and 'Fields and fallows').

Pigs were certainly present in late Phase 5 (as discussed below), though possibly only in small numbers. Exchange systems would have involved a range of valued commodities other than pigs, but of these the stone-axe trade is almost the only form of exchange with some potential for being registered in the archaeological record. The distribution of high-grade stone from quarries in the Wahgi and Jimi Valleys is a useful indicator of the growth and spread of regional exchange systems (Burton 1984, 1989; see Chapter 21, section 'Ground axes and axe quarries'). The indications are that such growth and spread had already begun in Phase 4 times, though the proposition is in need of support at additional stratified sites in the region (see Chapter 14, section 'Kuk as a Phase 4 "hotspot"?').

Dating the onset of Phase 5

Phase 5 of drainage started at some point after the fall of Olgaboli (Q) Tephra between AD 720 and 980 (Table 7.2, citing Haberle 1998a) and before that of Kenta (Sandy 1) tephra, an ash that is not often preserved at Kuk and has not been dated there. The phase ends with another tephra fall, that of Tibito (Z), and there are two radiocarbon dates from below this ash that relate to the operation of the Phase 5 system. Charcoal low in the fill of a Phase 5 ditch and wood from the older phase of a recut Phase 5 ditch are highly likely to date between AD 1310 and 1620 in the first case and AD 1430 and 1650 in the second.[1] The second age range applies also to a wooden paddle-shaped spade found close to the dated wood in the older phase of the ditch, as discussed below.

Dates for Phase 5 were subsequently obtained for another Wahgi Valley swamp site, Kana, near Minj, where Tibito Tephra and Olgaboli Tephra were both present, but not Kenta tephra. The dates caused some difficulties. Bark from the base of a ditch typologically and stratigraphically equivalent to Kuk Phase 5 gave a date within the range AD 980–1410. On the other hand, a digging stick from a similar ditch at the site at first gave an unacceptably old age. Then, after treatment for possible contamination, a result within a date range from AD 1430–1660,[2] almost identical with that for Phase 5 wood from Kuk discussed above.

In order to judge whether Phase 5 is likely to have begun as early as between AD 980 and 1410, as suggested by the bark result at Kana, we look at evidence relevant to the date of the fall of Kenta tephra, by which time Phase 5 was underway at Kuk. The evidence in question comes from site MSI at Yeni Swamp on the Ruti Flats some 50 km north of Kuk at about 500 m altitude (Gillieson, Gorecki and Hope 1985: Fig. 4; Gillieson, Hope and Luly 1989: 108–116, Fig. 6.3). There are two bands of tephra in sedge peat above a carbonised wood layer 1 m below the swamp surface. The age of this wood layer lies between AD 1020 and 1260, somewhat younger than Olgaboli (Q) Tephra, so indicating that the upper ash is Tibito (Z) Tephra and the lower one Kenta (Sandy 1) tephra. A radiocarbon date for peat lying on top of Kenta tephra at the site gives a terminal date for the ashfall within a calibrated age range between AD 1270 and 1640 (Table 7.2, ANU-3909). Assuming an even rate of peat growth over the roughly 0.6 m separating the layer of carbonised wood dated between AD 1020 and 1260 and Tibito Tephra dated possibly to the AD 1660s (Table 7.2, and discussed below), Kenta tephra, about halfway between the two, would have a date within an approximate range from AD 1340 to 1460.

Comparing the calculated estimate for Kenta tephra's deposition of between AD 1340 and 1460 with the date ranges for the four Phase 5 garden ditches that we have discussed, we can say with some confidence that two of these, one at Kuk (AD 1430–1650) and one at Kana (AD 1430–1660), cannot belong to the pre-Kenta stage of Phase 5 because they are too young. The same is likely to be true for the second Kuk ditch (AD 1310–1620). On the other hand, the date range of the bark from the second Kana ditch, AD 980–1410, starts appreciably earlier than those of the three other ditch features and also that of Kenta tephra. We propose that, as represented by the bark date of the second Kana ditch, Phase 5 began at some point within the age range AD 980–1410. For reasons that are set out in the next section, we favour a starting date for Phase 5 of around AD 1250, in other words within the third quartile (about AD 1200–1300) of the date range for the Kana ditch. This date would give Phase 5 a total duration of about 400 years before a terminal date possibly in the AD 1660s. This duration for the phase would be consistent with the archaeological evidence from Kuk that at least three subphases occurred within it.

1 Calibration of the charcoal date, ANU-1055, 480±60 BP, and of the wood date (Golson and Steensberg 1985: 375–376), K-2643, 370±70 BP, both at two standard deviations, BP = Before Present, which is AD 1950 by radiocarbon convention.

2 Muke and Mandui 2003: bark sample, ANU-9381, 820±130 BP (181, 184, Fig. 2a feature 8, Table 4); untreated digging stick, ANU-10964, 1520±150 BP (184, Table 4); digging stick after treatment, (184, Table 4). All dates calibrated at two standard deviations.

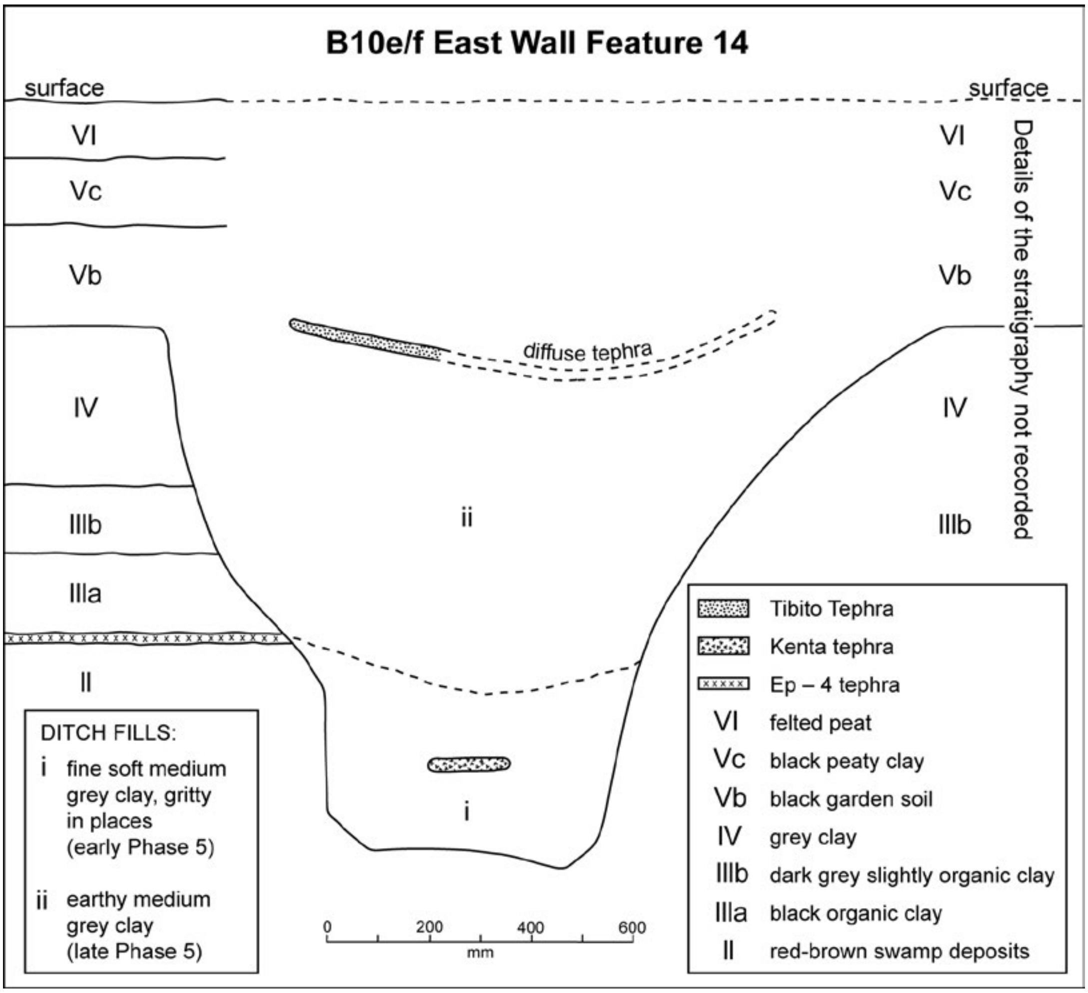


Figure 15.1 Cross-section of a composite ditch exposed in the east wall of drain B10e/f.

Kenta tephra marks an early stage of ditching, followed by recutting to a wider and shallower ditch form whose fill is sealed by Tibito Tephra. The ash signals the end of Phase 5.

Source: Drawing by Philip Stickler, after a field drawing of 1974 in the Kuk archive.

Kenta tephra is of rare occurrence at Kuk and cannot often be found in ditch cross-sections, in contrast to the later Tibito Tephra. Nevertheless, the circumstances of its appearance lend support to the case we are arguing for a beginning of Phase 5 around AD 1250. As an example, we reproduce the cross-section of a ditch in the east wall of drain B10e/f about 70 m from its northern end (Fig. 15.1). Kenta tephra belongs to a very early subphase of the structure, whereas Tibito Tephra seals in its final subphase. The cross-section of the ditch in the west wall of the drain shows a profile that suggests a more complex history than that revealed by its partner in the east wall (cf. the profile of Korowa's Baret in Fig. 16.6).

The wider context of mediaeval warming

Even though there is only one reliable radiocarbon date for the onset of Phase 5 (ANU-9381, from Kana) and this converts to a wide age range, AD 980–1410, we think that there are good arguments to support a likely date around AD 1250 for the beginning of this phase. We argued in Chapter 14 that Phase 4 began in the context of severe El Niño–Southern Oscillation (ENSO) droughts that were experienced in New Guinea during the period between 2500 and 1700 years ago (Gagan et al. 2004; McGregor and Gagan 2004). It was this crisis, we suggested, that provided the incentive and the opportunity for large-scale wetland drainage. Simon Haberle (1998a: 9) has proposed that this disturbed period of intensified ENSO was followed in New Guinea by warmer and more stable conditions that correspond to the northern hemisphere's Mediaeval Warm Period (MWP) or Little Climate Optimum (LCO). The MWP/LCO (called MWP from here on) is now interpreted by many climatologists as a global phenomenon with regional variations that affected climates during the period from about AD 950 to 1250 (Mann et al. 2009: 1257), reaching peaks at about AD 1000 and again at AD 1100 (Moberg et al. 2005: 616). It may be no coincidence that at Kuk these MWP peak temperatures fall within the interval between Phase 4 and Phase 5, when no swamp agriculture took place at Kuk (Chapter 14, section 'Responses to drought', citing Haberle 1998a and Haberle and David 2004).

It is generally agreed that the MWP was followed by a global change towards cooler and more unstable climates, culminating in the Little Ice Age (LIA) of AD 1400–1700 (Wanner et al. 2008; Mann et al. 2009). In New Guinea the effects of these changes were too subtle to be reflected in lake sediments or the pollen record, where the anthropogenic signal is dominant. However, we can find evidence in changing sea-surface temperatures as reconstructed from marine sediments in the Makassar Strait between Kalimantan and Sulawesi in Indonesia (Oppo, Rosenthal and Linsley 2009). Between AD 1000 and 1250, during a period corresponding to the MWP, sea-surface temperatures were close to modern values, but they fell rapidly after that date and from AD 1550 to 1850 were up to 1°C cooler than today. The change is linked to a weakening in the summer monsoon after AD 1250, signalling the end of a period of stable, warm and wet conditions in eastern Indonesia and a shift towards more frequent droughts.

Providing a date for this climatic shift in the New Guinea highlands, therefore, requires that we extrapolate from reconstructed events elsewhere in the region. The validity of this extrapolation depends on the assumption that strong regional and global teleconnections make climatic events more or less synchronous in different regions. If we adopt these assumptions, then we may estimate a date for the end of the MWP in New Guinea and the onset of less stable conditions, a transition that elsewhere took place in the period AD 1250–1300. For example, a warmer period ended in the South Island of New Zealand about AD 1280, in Patagonia around AD 1250 and in central Chile around AD 1260; the South American summer monsoon intensified dramatically about AD 1300 in northern Peru, about AD 1250 in southern Ecuador and about AD 1290 in Panama; and there was a shift towards more El Niños in the Galapagos Islands around AD 1250 (Cook, Palmer and D'Arrigo 2002; Villalba 1994; Moy et al. 2002; Lachniet et al. 2004; Conroy et al. 2008; Bird et al. 2011). Patrick Nunn chose the year AD 1300 as marking the climatic shift that generated big changes in the Pacific islands, mainly through increased storminess and sea level fall as the Little Ice Age approached (Nunn 2000, 2007; Nunn and Britton 2001), but he now regards this 'event' as spanning the period AD 1250–1300 (Nunn and Hunter-Anderson 2011: 95). One of the largest volcanic eruptions of the entire Holocene took place in AD 1257 from Samalas volcano on Lombok Island, Indonesia, and is thought to have triggered a moderate to strong El Niño event and to have had global effects including famines in Europe in 1258 (Oppenheimer 2003; Emile-Geay et al. 2008; Miller et al. 2012; Lavigne et al. 2013; Sigl et al. 2014).

While direct evidence from New Guinea cannot at present confirm the nature and timing of the MWP-LIA shift, from our knowledge of the wider picture it seems highly probable that there was a transition around AD 1250 or soon afterwards towards less stable and somewhat cooler conditions with more frequent droughts. As in the case of the extreme ENSO events that, we believe, initiated Phase 4 around 2000 years ago, we suggest that Phase 5 at Kuk began at this time of climatic transition.

The end of Phase 5

As with Phase 4, a tephra fall provides a convenient chronological marker for the end of Phase 5 drainage activity, although in this case the hiatus between Phase 5 and Phase 6 was of brief duration. The volcanic ash, known as Tibito Tephra, was found so close to the base of some ditches as to make it clear that they were open and in principle operational at the time of its fall. This tephra has been the subject of discussion in two earlier chapters of this volume as to its age, extent, effects and source (Chapters 7 and 8). It derived from a cataclysmic eruption of Long Island off the northern coast of New Guinea and was deposited across a conservatively estimated 84,000 km^2 of mainland New Guinea (Fig. 8.2), being sporadically preserved in accretionary environments like Kuk Swamp where it can be present in bands up to 50 mm thick.

The fall of Tibito Tephra is remembered in highlands legends as the Time of Darkness (Blong 1982). In Chapter 8 of this volume, Blong summarises more recent evidence bearing on its age, including radiocarbon dates and their calibrations. He confirms that Tibito Tephra originated from a Long Island eruption, one ranked by Briffa et al. (1998) as within the top 10 most extreme volcanic events occurring worldwide in the past 600 years. All 10 eruptions produced sulphuric aerosols affecting the stratosphere, and in most cases global temperatures were reduced for one or two years. The evidence for this effect comes from the coniferous forests of the northern hemisphere where a narrowing in the tree rings of pines, firs and spruces suggests that the growth of trees was affected by lower temperatures (Briffa et al. 1998).

There are drops in temperature shown in northern hemisphere tree rings dated to AD 1666/67 and 1675 that cannot be clearly assigned to any particular volcano. Can either event be the result of Long Island's eruption? Briffa et al. (1998: 453) suggested that one or other of these tree-ring anomalies might provide 'possible evidence of this eruption'. In a previous publication, we have favoured AD 1665 or 1666 as the likely date for Tibito Tephra (Bayliss-Smith et al. 2005: 110), but in the context of continuing uncertainty have chosen to talk about it as an event of the AD 1660s. Whatever its precise date, this tephra deposit brought Phase 5 at Kuk to an end by disrupting drainage and gardening, though at the same time dryland agriculture probably benefited from the fertilising effects of the ashfall.

Evidence

The regional geography of Phase 5

Besides being widespread across Kuk Swamp, Phase 5 has been identified at scattered localities through the upper Wahgi Valley: at Kana near Minj (as discussed above); at Kotna north of the river closer to Kuk; and at the Manton site on Warrawau Tea Estate across the Wahgi river south of Kuk (Golson 1982: 121; Muke and Mandui 2003). Further afield its equivalent is present at Mogoropugua and Haeapugua Swamps in Southern Highlands Province (Ballard 1995: 191–195; 2001).

Because Phase 6—the phase that is contemporary with the sweet potato—involved a retreat of cultivation from the deeper swamp to its margins at Kuk and was not explicitly noted at the upper Wahgi sites mentioned in connection with Phase 5, it may well be that the widespread systems of former drainage that are visible from the air largely represent Phase 5 cultivation. If this were the case, it would explain the lack of tradition regarding large-scale drainage among the older inhabitants of the upper Wahgi, who were systematically canvassed on the matter during the 1972 and 1973 fieldwork seasons (Ian Hughes, pers. comm., cited by Golson 1977a: 628).[3]

3 Nine maps used by Ian Hughes when interviewing in the upper Wahgi have been copied by the Pacific Manuscripts Bureau so that they can be accessed by other researchers.

This supports the evidence of early European explorers like Mick Leahy and Jim Taylor, who did not report seeing signs of such drainage in 1933, when Leahy first visited the North Wahgi and Kuk Swamps, and Taylor the swamp at the future Warrawau Tea Estate (Golson 1976: 216; see Chapter 23, section 'The prelude'). On the other hand, the missionary Vicedom, based in the 1930s at Ogelbeng on what Blong (1986a: 288) calls the southeastern apron of the Mt Hagen volcano, makes reference to cultivation in the swampy upper Wahgi Valley below it, with the use of deep ditching around gardens (Vicedom and Tischner 1943–48: 185; 1983: 209). We discuss this question specifically for Kuk later in the chapter.

The pollen evidence for vegetation changes suggests strongly that dryland sites were also impacted by agriculture before and during Phase 5 (cf. Chapter 9, section 'Mid to late Holocene'). Simon Haberle (1998a: 8) identifies two periods of what he calls 'intensified agricultural activity' in the upper Waghi Valley and its catchments. The first is accompanied by an increase in *Casuarina* pollen beginning in the period between AD 760 and 980, after the end of Phase 4. There is archaeological evidence from the Etpiti rockshelter (2200 m) in the Manim Valley (Christensen 1975: 31, 34; Donoghue 1988: 93), which we believe can be read as confirming this trend. The change in cultural material and sedimentation rate about 1100 years ago suggests either horticultural activities on the mountain slopes near the site or possibly an increased use of bush shelters by people seeking greater access to montane forest resources. According to Haberle, the second period of intensified dryland activity begins up to 300 years before the fall of Tibito Tephra, when there was 'a further reduction in forest cover, an increase in *Casuarina* planting, and an increase in soil erosion' between AD 1300 and 1550 (Haberle 1998a: 8).

In Southern Highlands Province, Chris Ballard's (2001: 296) investigations resulted in dates that broadly match this chronology, but here the archaeological evidence for intensification relates to the use of wetlands. There was gardening along the wetland margins at Haeapugua Swamp between about 1300 and 1000 years ago and again from 600 to 200 years ago.

The archaeological evidence from Kuk

Following on earlier overviews of Phase 5 (Golson 1976, 1977a), the evidence from Kuk has now been analysed in detail in three areas (Fig. 15.2). They represent the swamp margins (most of block A9), areas of intermediate drainage difficulty (most of blocks A10 and A11) and the more problematic low-lying centre of the swamp (block C9). In these sample blocks, a detailed analysis of the ditch networks and morphology has been carried out, as well as an analysis of the major disposal channels (Bayliss-Smith et al. 2005). The following account is primarily based on this work.

As with Phase 4, the evidence points to a highly organised system of drainage constructed around a hierarchy of ditches consisting of a major disposal channel, called Wai's Baret, minor disposal channels that were tributaries to Wai's Baret, and numerous field ditches joining each other at right angles to define garden areas. In terms of hydrology it is a system very similar to Phase 4, but the field ditches in particular have a shape and depth that immediately differentiate them from their Phase 4 predecessors. Phase 5 is therefore distinctive on the basis of ditch morphology and ditch fill, compacted earth as against silty clay, as well as the common presence of Tibito Tephra at late Phase 5 ditches.

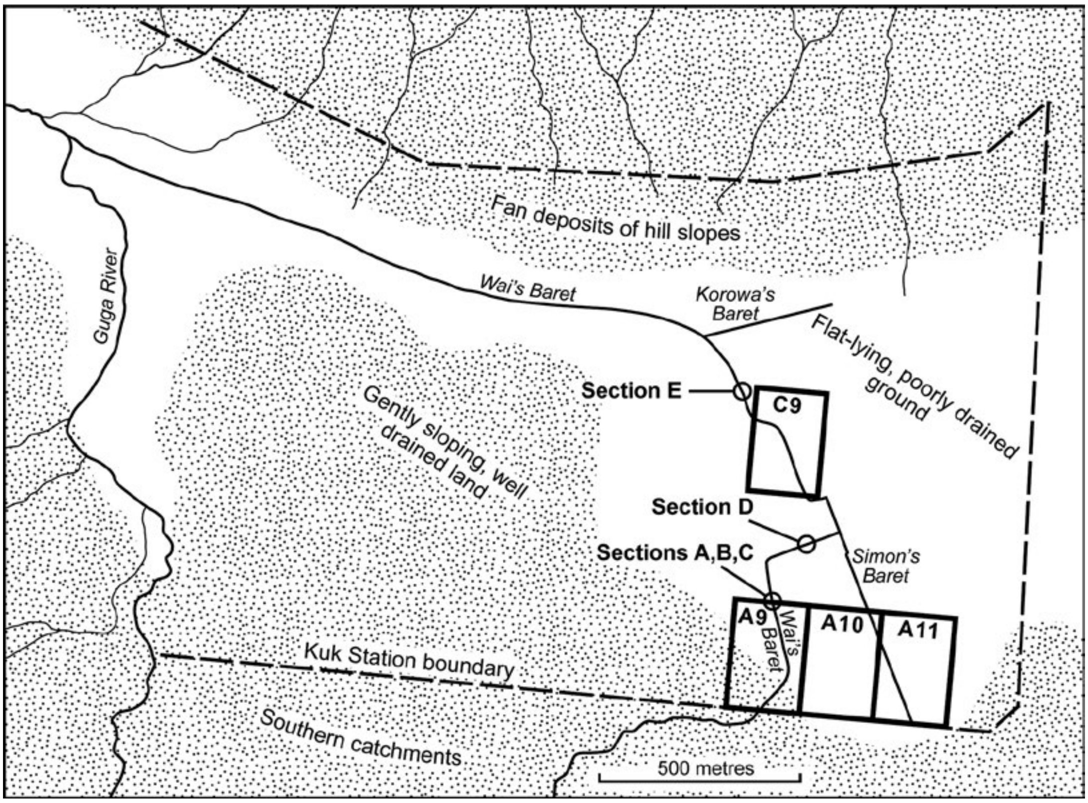


Figure 15.2 The framework of Phase 5 drainage at Kuk Swamp, showing the location of the profiles across the major disposal channel, Wai's Baret, which are displayed in Figure 15.7.

Block A9, blocks A10 and A11 and block C9 are three sample areas where detailed analysis of ditch morphology and networks was carried out.

Source: Drawing by Philip Stickler after Bayliss-Smith et al. (2005: Fig. 1), reproduced with permission.

The major disposal channel: Wai's Baret

As in previous phases, the problem facing those wishing to establish gardens in Kuk Swamp at the start of Phase 5 was finding a way to remove the stream waters that enter the swamp from its southern catchments, as well as to get rid of locally generated runoff. The annual water surplus (precipitation minus evapotranspiration) is about 1700 mm (McAlpine, Keig with Falls 1983: Fig. 8.11; cf. Hughes, Sullivan and Yok 1991: 229). All of this water needed to escape across the surface of Kuk Swamp, which has shallow gradients of between 1:130 and 1:430. The scale of the problem facing the former inhabitants of Kuk can be gauged from the situation in the 1930s, after perhaps a generation of total abandonment of drainage effort (see Chapter 16, section 'Dating Phase 6 at Kuk'). In April 1933, Kuk Swamp was covered in thick cane grass and largely under water. The first patrol of Mick Leahy and Jim Taylor struggled to cross the area, carrying their dogs over the deeper pools (Gorecki 1979b: 26; cf. Chapter 23, section 'The prelude').

The former channels of prehistoric drainage visible on the ground surface after the establishment of the Research Station in 1969 were at first mistaken for natural streams by the archaeologists beginning work there in 1972. The channel initially called Creek 2 (Golson 1976: Fig. 3; see Fig. 15.3 here) was later shown to be artificial by its straightness and right-angled changes of direction as it flowed across the A and B blocks, so it was called Wai's Baret, the first disposal channel to be named for one of the workmen (see Figs 15.2 and 15.4).

Figure 15.3 Looking SSE over the sinuous channel that developed along the course of Wai's Baret in block A9f after the abandonment of swamp drainage for cultivation at Kuk, perhaps around AD 1900.
Source: Photograph by Wal Ambrose, Kuk archive, 1972.

A crucial factor in this interpretation was the short stretch of ditching at the intersection of E–W Rd 2 and N–S Rd 4, which links the northern end of the channel crossing the A and B blocks from the southeast with the southern end of that crossing the C and D blocks to the northwest (Fig. 15.4 Inset 2). Because this short stretch was present in the walls of drain B9g/h, but not in those of the next drain to the west, B9f/g, we can be certain that the right-angled bend that Wai's Baret makes at this point is an original and deliberate feature. As described in Chapter 14, section 'Major disposal channels', our later investigations implied that the northerly continuation of Wai's Baret from the middle of the B blocks was cut along the course of the previous Neringa's Baret.

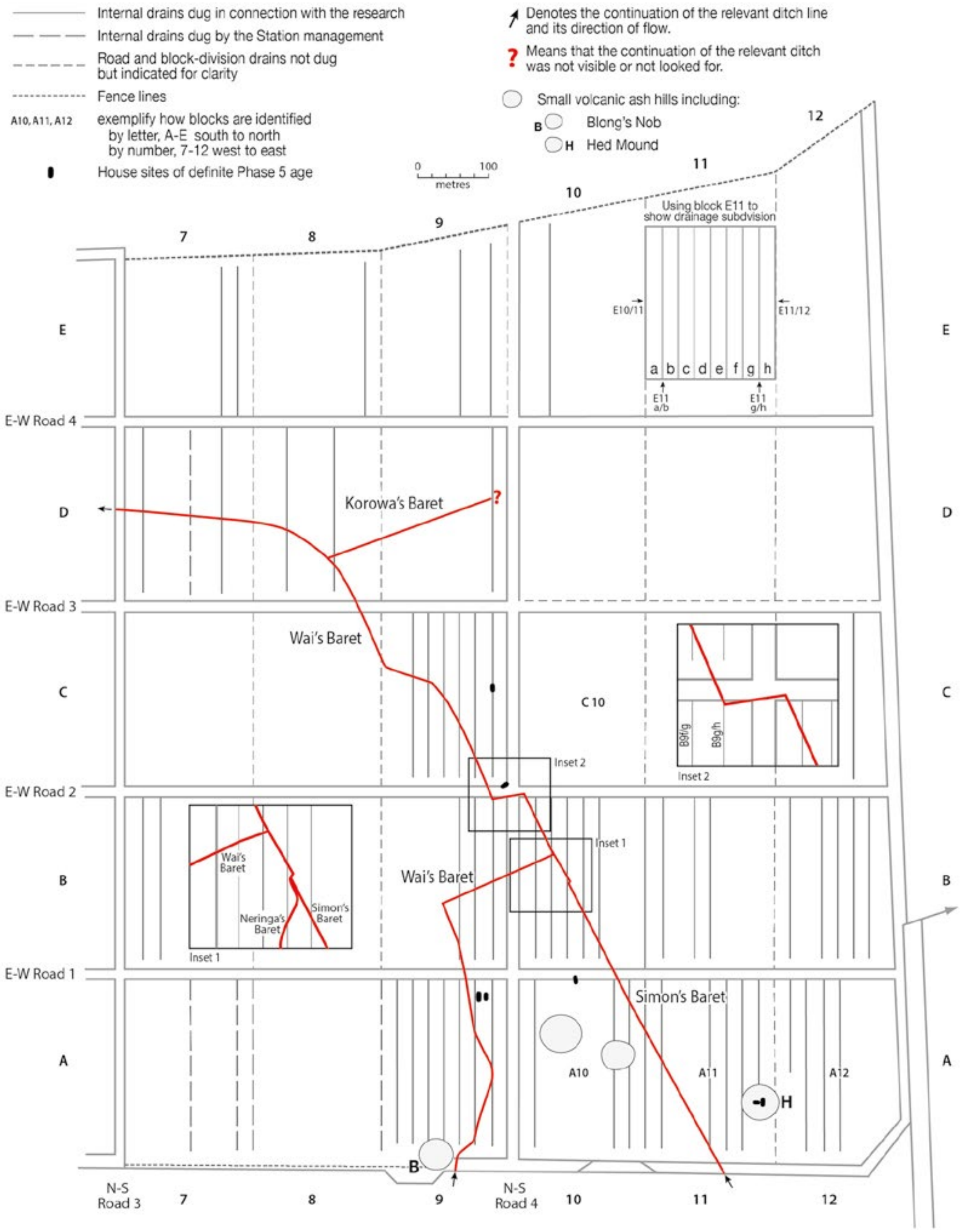


Figure 15.4 Baret draining the SE margins of Kuk Swamp and Korowa's Baret performing a similar role in the NE.

Inset 1 shows how, whether digging proceeded from the north or south, Simon's Baret reused some of the existing channel of Neringa's Baret, including the kink (see Fig. 14.4 Inset 2), which continued in existence into Phase 6 (see Fig. 16.3). Inset 2 shows the short stretch of ditching that was crucial in the development of the argument for the artificial nature of swamp drainage during Kuk Phases 4–6. On present evidence houses made their first appearance in the swamp at a late stage of Phase 5.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

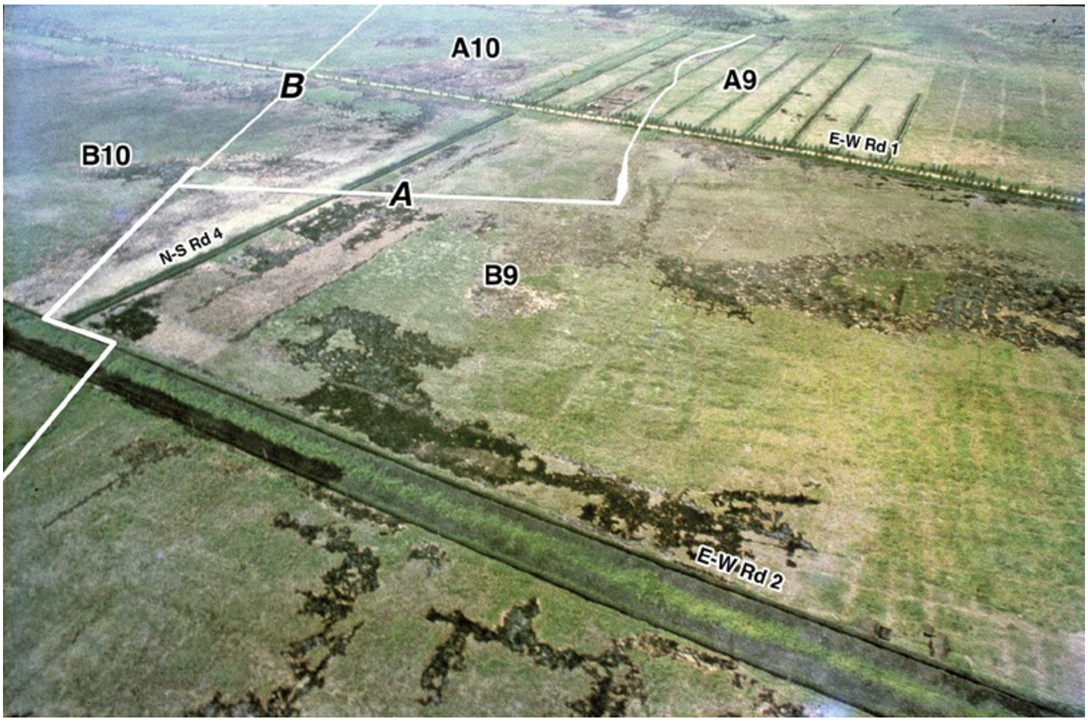


Figure 15.5 View SSE showing Wai's (A) and Simon's (B) Barets, the courses of which have been digitally enhanced.

Wai's Baret moves from the southern catchment through block A9, the one almost fully provided with its complement of modern drains, and crosses E–W Rd 1 into block B9, where it makes a right-angled bend from NNW to ENE. It crosses the future line of N–S Rd 4, whose western road drain has been dug, into block B10. Here it makes another right-angled bend, from ENE back to NNW. At this bend it is joined by Simon's Baret, which comes in on a direct SSE–NNW line from the southern catchment (see Fig. 15.6). From its junction with Simon's, Wai's Baret continues NNW to the line of E–W Rd 2, whose north and south road drains have been dug, and makes a right-angled bend WSW. The situation here is best understood by comparing it with Inset 2 of Figure 15.4.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

The distinctive nature of the channel's course here and elsewhere suggests that its purpose was to mark some kind of land boundary as well as to lead water from the southern catchment to the Guga River outfall. Together with Simon's Baret, one of its tributaries, Wai's Baret was the primary means whereby the southern part of Kuk Swamp was brought into agricultural use at the start of Phase 5 (see Figs 15.5 and 15.6).

The earliest channel in the Wai's Baret complex, which can be termed early Phase 5, was the deepest of four channels dug on the same line (Fig. 15.7; see Fig. 15.2 for location of profiles). It had a cross-sectional area of about 3.0 m^2, which means it was appreciably larger than its Phase 4 equivalent, Neringa's Baret (about 2.0 m^2, see Chapter 14, section 'Major disposal channels'). The mid-Phase 5 channel in Wai's Baret is poorly represented, but it appears to have had a cross-sectional area of about 2.5 m^2. The late Phase 5 channel was wider and shallower than those of the two previous subphases and its basal fill commonly contained lenses of Tibito Tephra. The cross-sectional area of the late Phase 5 channel was about 2.0 m^2, which implies approximately a 33 per cent decline in hydraulic capacity since the beginning of Phase 5. The last and smallest channel postdates Tibito Tephra and can therefore confidently be assigned to Phase 6.

Figure 15.6 View slightly west of north from the Kuk southern boundary drain showing the course of Simon's Baret (A) NNW from here and across E–W Rd 1 towards the junction of the drains of the future E–W Rd 2 and N–S Rd 4.

In the background are the slopes of Ep Ridge and in the foreground the grid of sweet potato gardens on rising ground above the swamp.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

Increased land clearance, burning and soil tillage in the Kuk Swamp catchment, as well as increasingly intense activity within the swamp itself, must all have contributed to a higher sediment load in the disposal channels. As a result, we might expect the clogging of drainage and a need for more frequent cleaning out of channels. Yet the data for Wai's Baret suggest a progressive decline, from early Phase 5 to late Phase 5 and into Phase 6 times, in the amount of labour invested in the maintenance of the major disposal channel. As the discharge carried by Wai's Baret cannot have declined at all between early Phase 5 and Phase 6, the inference must be that Wai's Baret became less and less efficient and was progressively more prone to overbank flow during high discharge events.

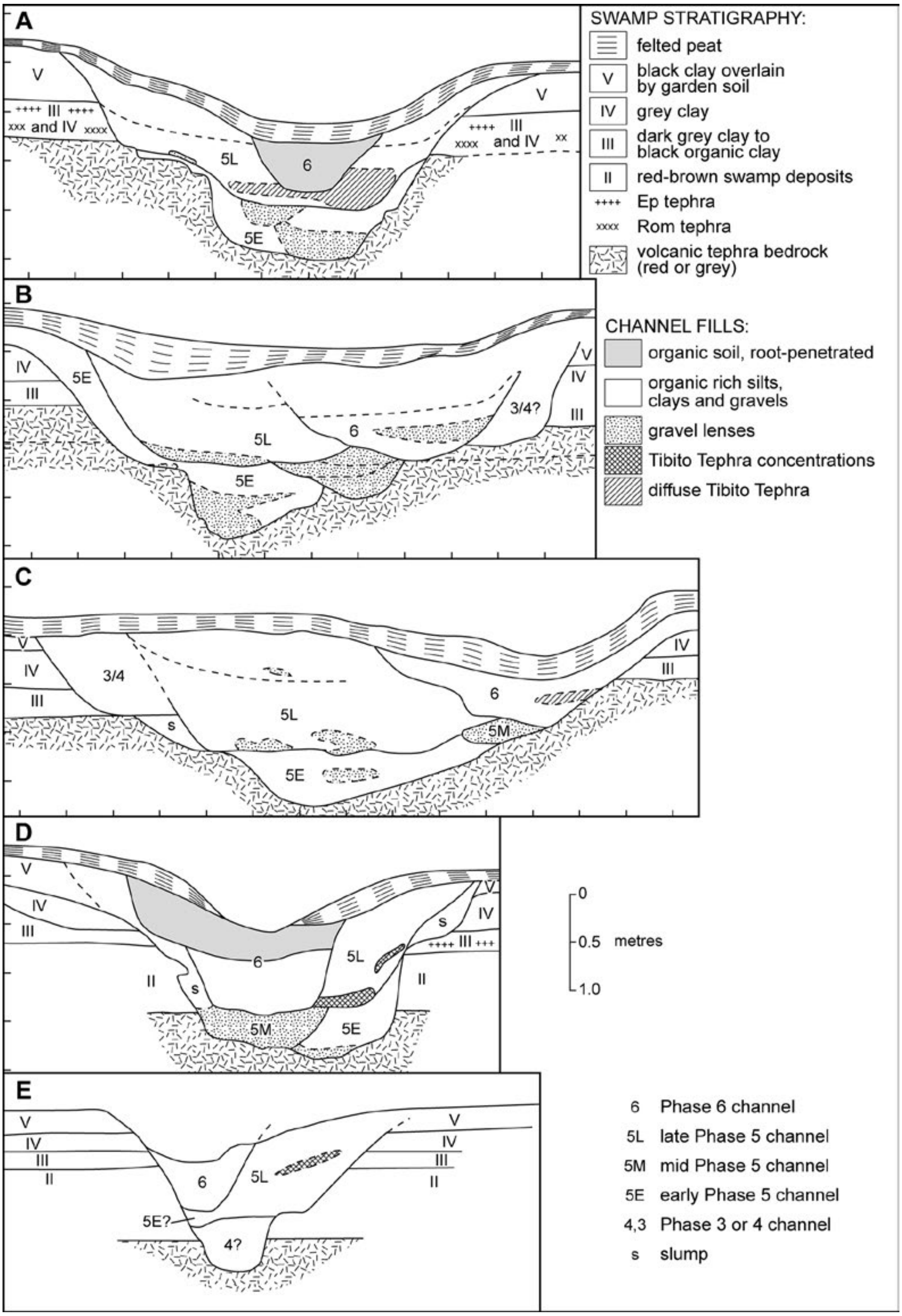


Figure 15.7 Five cross-sections through Wai's Baret.

The profiles cover the history of the channel from early Phase 5 through mid and late Phase 5 into Phase 6. Section A is at the north wall of the south drain of E–W Rd 1 and B and C at the south and north wall of the north drain, respectively. Note that C is a mirror image of the actual section. Section D is at the east wall of drain B10W and E at the south wall of the south drain of E–W Rd 3.

Source: Drawing by Ian Agnew after Bayliss-Smith et al. (2005: Fig. 2), reproduced with permission.

We can compare Wai's Baret in Phase 5 with the main modern drain along Kuk's southern boundary, first dug in 1969. At the point where runoff from the southern catchment enters Kuk Swamp (see Figs 15.2 and 15.4), its cross-sectional area is 3.9 m^2. Measurements of discharge at this point carried out by Philip Hughes and Marjorie Sullivan over a 20-month period in 1986 and 1987, combined with their longer-term observations in the mid to late 1970s, indicated that overbank flooding occurs on average a little more than once a year. The population and landuse intensity in the catchment today is higher than in prehistoric times and it is likely that flood peaks are larger today than in the past because there is more bare ground, especially in gardens and coffee plantations (Hughes, Sullivan and Yok 1991: 234–235). Hence the major disposal drain dug for the modern Station needed to be larger than its prehistoric equivalents to cope with all but the largest flood events.

We can conclude that the early Phase 5 cross-section of Wai's Baret, which was about 3.0 m^2 in area, was probably effective in preventing flooding of garden lands adjacent to the channel except for the 'once in a year' large flood. Unless we invoke a drier climate, we must conclude that successive phases of Wai's Baret would have been progressively less efficient at preventing flooding. Possible reasons for this disintensification are discussed below.

Tributary channels

Simon's Baret

Occupying an intermediate place in the drainage hierarchy between the major disposal channel and the minor field ditches were tributary channels such as Simon's Baret, which serviced the field drains principally in blocks A10, A11 and B10. A section through this channel (Fig. 15.8) shows the same progressive decline in drainage capacity that characterises Wai's Baret. The deepest and narrowest channel is the earlier of the two that date from Phase 5. If the cross-sectional area is calculated below the level of the upcast grey and black clay (a proxy measure for the Phase 5 land surface), then its channel capacity is about 1.8 m^2, some 60 per cent of the size of Wai's Baret, into which it flowed. The upcast clay on the ditch's northern bank would be consistent with the digging efforts of a man working his way upstream with his paddle spade and throwing the spoil upwards to his left (assuming he was right-handed).

The later Phase 5 channel is 250 mm shallower than its predecessor, but is slightly wider, so that its capacity was only slightly less, about 1.7 m^2. Tibito Tephra is present in the fill about 200 mm above the base, suggesting that by the mid-AD 1660s the channel's cross-sectional area had fallen to about 1.5 m^2. The change since the onset of Phase 5 amounts to a 14 per cent decline in channel capacity, a less drastic change than the 33 per cent decline in the capacity of Wai's Baret.

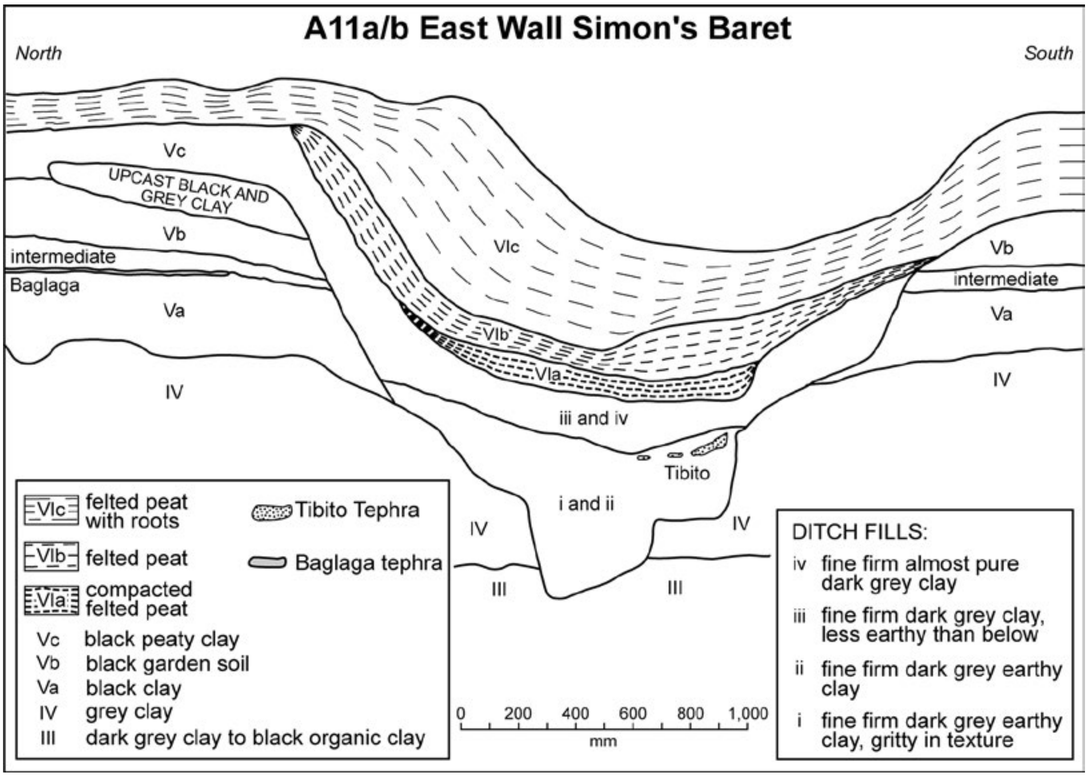


Figure 15.8 Cross-section through the tributary channel, Simon's Baret, in the east wall of drain A11a/b.

The profile shows evidence of two subphases of use in Phase 5, followed by the fall of Tibito Tephra after which the Phase 6 channel was dug considerably shallower and wider.

Source: Drawing by Philip Stickler based on a field recording, Kuk archive, 1973.

Korowa's Baret

Further evidence for minor disposal channels is available from the northern part of Kuk Swamp, in block D9 (see Figs 15.2 and 15.4), paralleling the Phase 4 channel called Feature 7 (Figs 14.2, 14.4 and 14.7) and interpreted as a minor disposal channel serving the drainage of the northeast margin of the site. In Phase 5 there is a second tributary of Wai's Baret, known as Korowa's Baret, which shows evidence of four subphases of use in Phase 5, the last of which is marked by traces of Tibito Tephra (Fig. 16.6). All of these subphases show the same tendency to shallow and widen during Phase 5, as evident in Wai's and Simon's Barets. The deepest ditch is interpreted as an early Phase 5 channel. When it came to be cleaned out, the next channel to be dug was 100 mm shallower and about 500 mm wider than its predecessor, and this trend was repeated in the next, mid-Phase 5 channel. These three early to mid-Phase 5 channels all have similar cross-sectional areas below the level of grey clay, estimated to be about 1.7 m^2.

The late Phase 5 channel, which has traces of Tibito Tephra in the top of its fill, was dug to be even wider, but its flat base is also about 200 mm shallower, so it has a smaller cross-sectional area (about 1.5 m^2). If we take the average of the estimated cross-sectional areas of the early and mid-Phase 5 channels (1.74 m^2), then the change from early/mid to late Phase 5 represents a 14 per cent decline in channel capacity, exactly the same proportional decline as we have estimated for Simon's Baret.

Minor field ditches

The field ditches of Phase 5, in contrast to the narrow slot-type ditches of the preceding phase, are generally trapezoidal in shape, flat-bottomed and steep-sided (Fig. 15.9a, 15.9c and Fig. 15.10). When measured from field data using the methods already described (see Chapter 14, section 'Field ditches: Shape and size'), most of these ditches have a depth of 300–600 mm below the top of black clay (mean depth 430 mm). In terms of width, typically they are 600–800 mm wide at this same level (mean width 679 mm). Figures 15.11 and 15.12 summarise some statistics relating to the depths and widths of Phase 5 field ditches compared to their equivalents in previous phases. The Phase 5 sample includes field ditches both from block C9 in the lower-lying part of Kuk Swamp and from A9 at the swamp margins, 250–500 m further to the south, but we have analysed them as an aggregate sample because there is little or no difference in ditch morphology between the two areas.

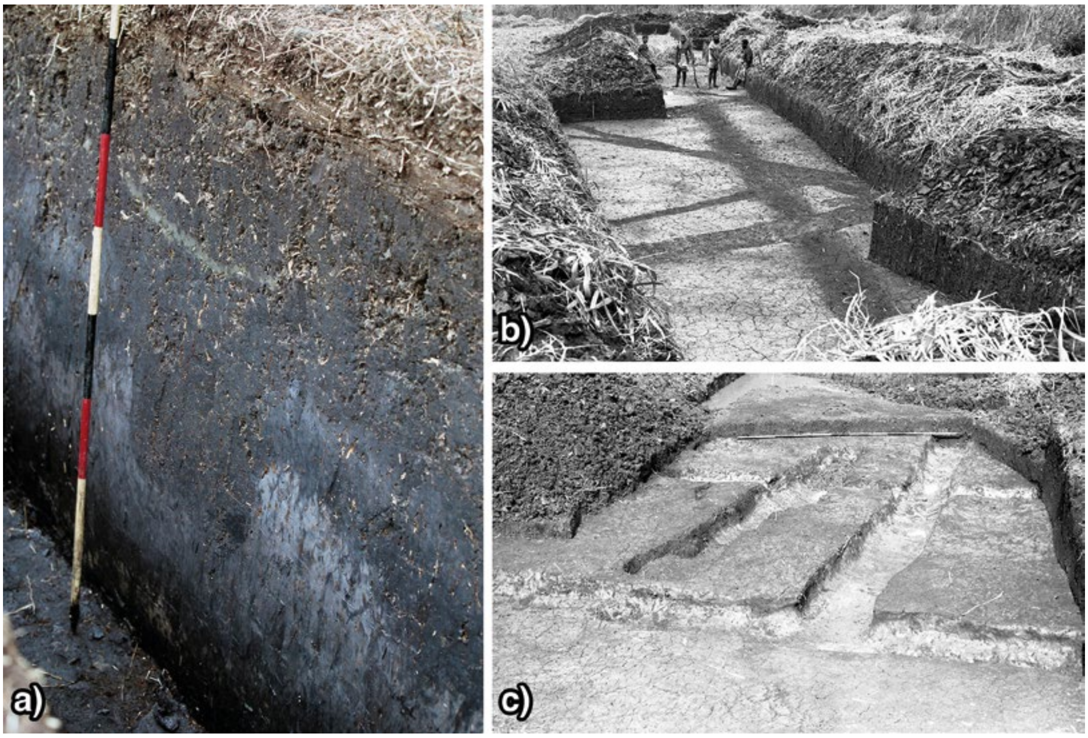


Figure 15.9 Three views showing the shape and size of Phase 5 ditches.

a) A view of the west wall of drain A10g/h, a 1 m wide and 1.5 m deep structure that cuts fairly acutely across a flat-bottomed, steep-sided ditch dug from above black clay through new grey clay and black clay into the main grey clay layer. The ditch was well filled when a barely dipping layer of Tibito Tephra was deposited across it, showing it to be an early Phase 5 feature. b) is a companion picture to Figure 13.10, where the focus is on a major arterial ditch of Phase 3, Denham's feature 393. Note the younger ditches that cut across it. The nearest and widest of these is definitely Phase 5 because there is Tibito Tephra clearly exposed in and limited to its fill. The narrower ditches are likely to belong to different stages of the same phase. c) A view west over the right-angled junction of two Phase 5 ditches excavated at the northern end of block A12d. The ditches of Figure 15.9b and 15.9c are shown at the level of grey clay, as are other features, like the Phase 3 'trough' that runs parallel to the tributary ditch. The ranging pole is graduated at 200 mm intervals.

Source: Photographs by Klim Gollan, Kuk archive, 1975.

A profile drawing of the south wall of the excavation accompanying a prior publication of this plan (Denham, Golson and Hughes 2004: Fig. 12) shows the full depth of the north–south ditch (390) to have been at least 400 mm, half of this above the level of grey clay. Figure 15.9c shows the ditches and other features at the top of grey clay, which was the level from which they were excavated.

Because their widths are quite variable (see Fig. 15.12), the cross-sectional areas of Phase 5 ditches also vary, but usually within the range 0.1–0.4 m^2. For a sample of 16 field ditches in block A9, the cross-sectional area of the channel below the level of black clay averaged 0.295 m^2, which represents three times more volume excavated per ditch than in Phase 4, but achieving a similar depth of land drainage. In both phases, the modal depth of field ditches below black clay was 300–400 mm, but their shapes are radically different. It would appear that the Phase 5 cultivators were actively seeking to generate more soil in the context of a regime of soil tillage that was in operation (see below, 'Phases 3, 4 and 5 compared').

All Phase 5 ditches give the appearance of having been dug and smoothed with wooden spades rather than the digging sticks that are inferred for Phase 4. The main difference is in shape, as represented by basal width, maximum width and cross-sectional area, rather than depth. The evidence does not allow us to measure changes in capacity between early and late Phase 5 ditches, but in many cases shallowing can be detected.

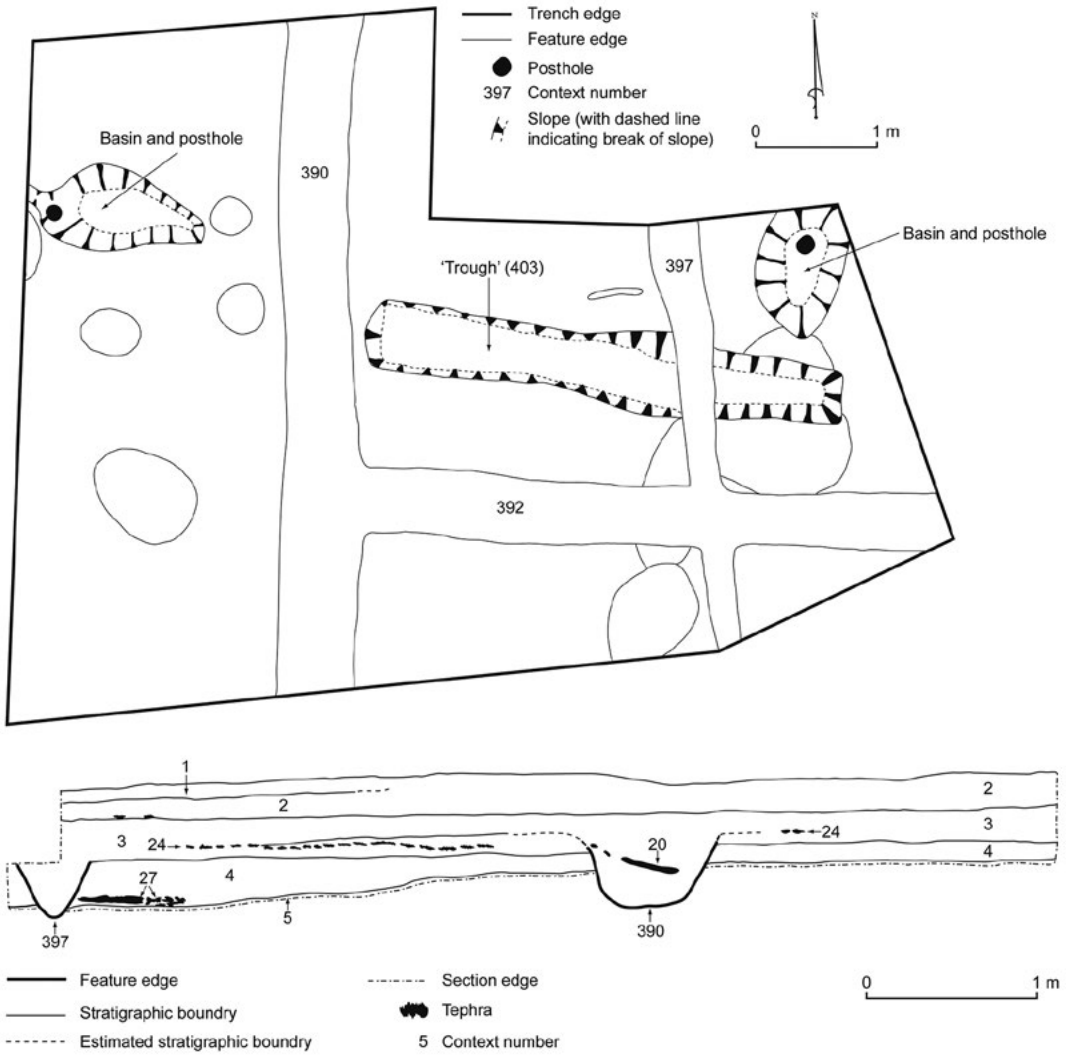


Figure 15.10 A plan of the excavation in Figure 15.9c, showing the right-angled junction of two Phase 5 field ditches, 392 with 390. Other features include an unusual 'trough' (403) of Phase 3 age and, in the NW corner of the excavation, a Phase 2 basin with posthole (see Fig. 12.10).

Source: Drawing by Tim Denham from a field plan by Jack Golson of 1975, Kuk archive.

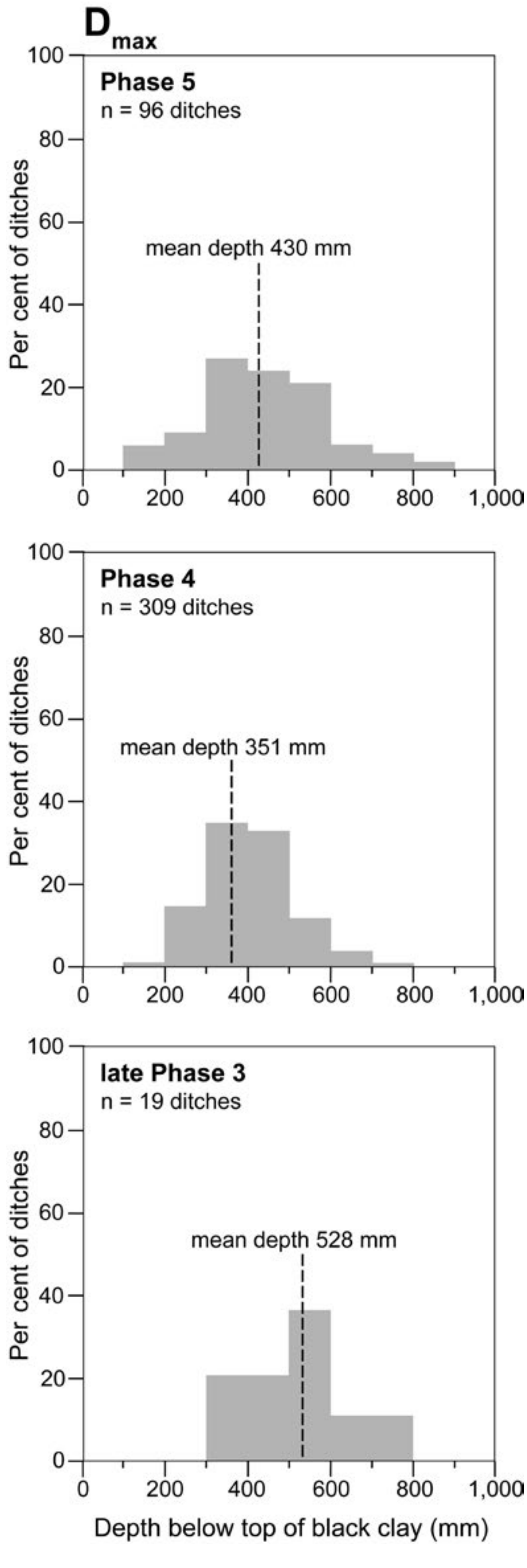


Figure 15.11 The depths of a sample of field ditches from late Phase 5 compared to those from the two previous phases, Phase 4 and Phase 3.

In each case, depths are measured from the top of black clay (Dmax). Field ditches in Phase 5 have the same modal depth as those in Phase 4 (300–400 mm), whereas many Phase 3 ditches are somewhat deeper, although the sample size for Phase 3 is too small for statistical significance. These aggregate statistics were derived from measurements taken in the field from ditches recorded in the north–south Station drains and positively identified according to phase in either the west wall, the east wall or both. For late Phase 3, there were 34 identified field ditches in blocks A11, A12 and B11 where measurements were available; for Phase 4, there were 240 different field ditches available in A9, A10, A11, C9, D7, D8 and D9; and for Phase 5, 126 different ditches were available in A9, A10, A11 and C9. In many cases the availability of measurements from both east and west wall partners enabled us to enlarge the sample, but on the other hand, the flooding of some drains obscured the base of ditches and so prevented any Dmax measurement from being made.

Source: Drawing by Philip Stickler based on measurements and calculations by Tim Bayliss-Smith on field data from the Kuk archive, 1972–76.

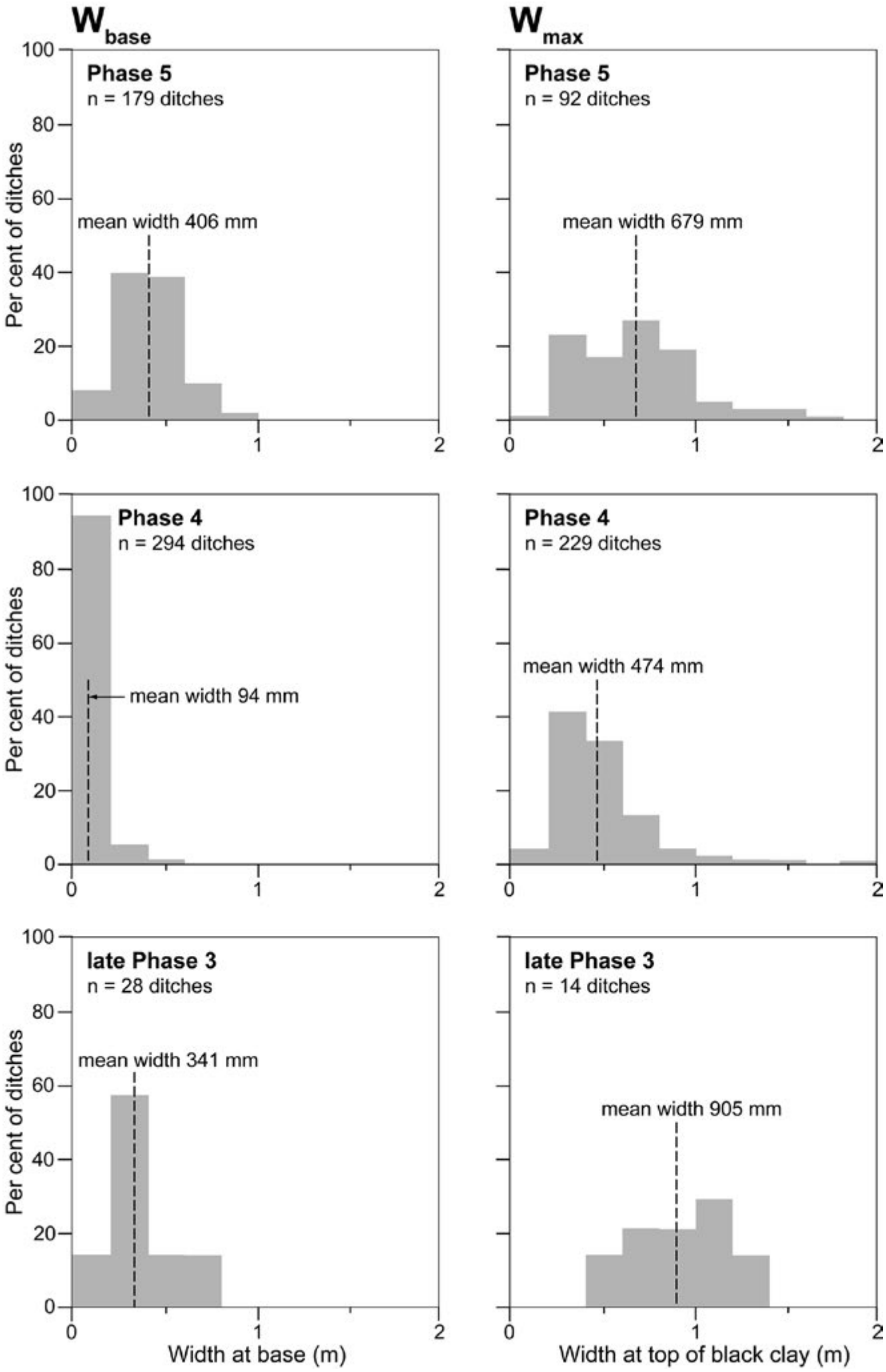


Figure 15.12 The widths of a sample of field ditches from late Phase 5 compared to examples from Phase 4 and Phase 3.

To obtain these width statistics we used the same sample that was measured for depths, but with widths adjusted to remove the distortion that results from cross-sections that are not at right angles to the course of a ditch. When ditch sections were redrawn perpendicular to the direction of flow, true lateral measurements could be made. Because some features of some ditches in the Phase 5 sample had been obliterated by later ditch digging, not all width measurements could be recorded for every field ditch, so that sample sizes vary somewhat between the different types of measurement. The maximum width measure is taken from where the ditch profile starts to level out at the top of black clay (Wmax). Basal width is measured 10 mm above the lowest point of the ditch (Wbase). Both measures show that the Phase 5 field ditches resemble those of Phase 3, whereas Phase 4 ditches have a radically different shape, being considerably narrower especially towards their base.

Source: Drawing by Philip Stickler based on measurements and calculations by Tim Bayliss-Smith on field data from the Kuk archive, 1972–76.

Ditch networks and field systems

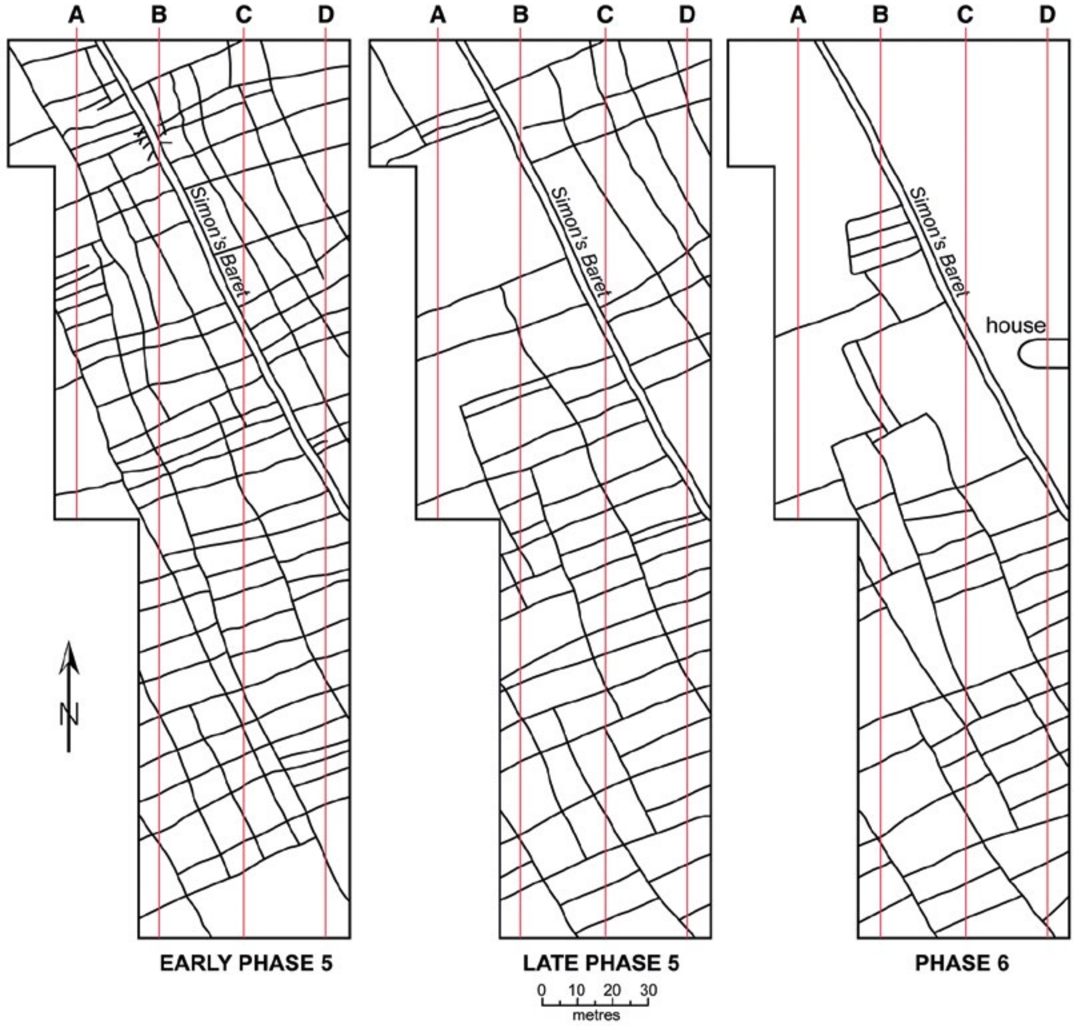


Figure 15.13 Ditch networks of early and late Phase 5 and Phase 6 in blocks A10 and A11.

The reconstructions are based on the intersection of ditches with Station drains A10f/g (A), A10g/h (B), A10/11 (C) and A11a/b (D), as well as limited excavation (cf. Fig. 14.12 and Fig. 16.12 for similar exercises for Phase 4 and Phase 6 respectively). Note the house site east of Simon's Baret in the Phase 6 panel.

Source: Drawing by Ian Agnew after Bayliss-Smith et al. (2005: Fig. 4), reproduced with permission.

Our most complete reconstruction of drainage networks for early Phase 5, late Phase 5 and Phase 6 is from blocks A10 and A11 (Fig. 15.13), based in each case on a graphical extrapolation of the ditches exposed in Station drains plus some evidence from open-area excavation. Although such maps cannot be wholly accurate, they should not contain systematic bias and so are valid sources for measurements of field size and drainage density. The area itself, in blocks A10 and A11, can be regarded as intermediate between the two extremes of seasonally dry swamp margins, like block A9, and deep low-lying swamps where drainage was always problematic, like block C9.

A comparison of early Phase 5 and late Phase 5 in the chosen blocks shows clear evidence for some reduction in drainage activity over this period, even though we might expect that surviving field evidence for early Phase 5 would be the more fragmentary. In fact, early Phase 5 ditches are the more numerous, forming a widespread network. The late Phase 5 ditches, including some with Tibito Tephra, form a less extensive network of slightly shallower ditches, but until the middle AD 1600s some activity continued in all parts of A10 and A11. It is in post-Tibito times (Phase 6) that drainage activity northeast of Simon's Baret virtually ceased, as described in Chapter 16.

The reduction in ditch-digging activity in this part of Kuk Swamp during Phase 5 is confirmed by the drainage density measure, which is the number of metres of ditch dug per hectare of wetland cultivated. For the area southwest of Simon's Baret in blocks A10 and A11 (see Fig. 15.13), there were on average, in early Phase 5, 1740 m of ditch per hectare cultivated. This is a density not much less than had been generated some hundreds of years previously in Phase 4 times. By late Phase 5, drainage density had declined to 1240 m/ha and there was to be a further small decline to 1090 m/ha in Phase 6.

The average dimensions of the 'fields' defined by the minor ditches also show the same trend of disintensification. Whereas early in Phase 5 the fields had average dimensions of 14 x 7 m, by the end of the phase fields were larger and more elongated, averaging 20 x 9 m.

Artefacts, houses and pigs

Compared with the evidence of ditches, other forms of archaeological evidence from Phase 5 are much more scattered and incomplete. However, as noted above, the ditches themselves suggest a change in emphasis from digging stick to paddle-shaped wooden spade as the primary tool of construction. The earliest dated wooden artefact from Kuk is one such spade, already mentioned as being found in a Phase 5 ditch and dated by associated wood to within the period between AD 1430 and 1650, which in the Kuk chronology is the second half of Phase 5 (cf. Chapter 19, section 'Long-handled implements'). It is in later Phase 5 also that definite houses appear for the first time at Kuk Swamp (Fig. 15.4), some situated on a low hill (Hed Mound) straddling the boundary between blocks A11 and A12, others on the margin of the swamp itself, all of them with a flanking runnel or ditch for drainage.

The firmest evidence for housing at Hed Mound begins with Harris's Periods V, VI and VII of activity there (Harris 1977: 7–9, Fig. 7; see Chapter 17, section 'Harris' excavations on Hed Mound 1977', Fig. 17.17C, D and E). The three periods are represented by three houses, labelled Houses 1, 2 and 3, replacing each other on the same spot on top of the hill. On the ethnographic evidence of a short lifespan for such houses and on the assumption that they were quickly replaced, Harris allows a duration of 30 years for his Periods V–VII. A fourth house and a perimeter fence belong here also, but cannot be precisely placed within the three periods (Harris 1977, Fig. 7, panel 7; Chapter 17 here, Fig. 17.17E). However, Harris argues (1977: 9) that the perimeter fence must have been at least partly in existence at the fall of Tibito Tephra, because some tephra was trapped at the base of posts. For him, therefore, the 30 years of Periods V–VII fall at the very end of Kuk Phase 5.

Where present, the lie of Tibito Tephra near the base of the handful of Phase 5 houses located within the swamp itself, where the house ditches are deeper, also points to a late Phase 5 date (see Fig. 15.4; cf. Fig. 17.3). This is the case for a house cut across by the south drain of E–W Rd 1 and for another at the very southeast corner of block C9, its ditch exposed in the walls of two converging road drains. Also, for a possible house on drain C9g/h, as well as for Lampert's Houses P and Q beneath the Phase 6 houses at the north end of block A9g (see Fig. 17.3), where the line of the house ditch could only be tracked at the surface of the grey clay. It is likely that there are more late Phase 5 houses at Kuk than the few discovered, either hidden below Phase 6 houses or elsewhere in the blocks between Station drains or with their house ditches unrecognised in drain walls. It may also be the case that there are others on top of the two uninvestigated hillocks in block A10, though the one cut through by drain A10f/g did not appear to show evidence of such use (Fig. 15.4).

Harris (1977: 7) also conceded that the features he assigned, 'somewhat arbitrarily', to Period IV at Hed Mound could be evidence of habitation earlier in Phase 5 than the complex we have been discussing, though he thought them more likely to be related to agricultural activities (1977: Fig. 7, panel 4; Chapter 17 here, Fig. 17.17B). The features in question, which he called 'gullies', are generally very shallow and of varying widths. They were found over most of the excavated area, but their full extent could not be recovered because they were only visible where they cut into the grey clay subsoil of the hill. Even so, the remnants show cases of the combination of straight and curving courses that is characteristic of the house ditches of Periods V–VII. Indeed, what might be proposed as the most fully preserved example, represented by features 37–39 of Figure 1 of Harris 1977 (see Fig. 17.18 here), looks very like the houses of succeeding periods, as shown in Figure 7.5–7.7 of Harris 1977 (cf. Fig. 17.17C, D, E here). In Figure 7 of Harris 1977, features 37–39 are part of his Period IV and postdate feature 8, a presumed garden ditch that belongs to his Period III. This ditch has Tibito Tephra high in its fill and so is early Phase 5 in the Kuk sequence. In Figure 1 of Harris 1977 (Fig. 17.18 here), however, feature 8 is shown as cutting across feature 37 and thus as later than it. In discussion of this matter here, in the Hed Mound excavation section of Chapter 17, Harris affirms his confidence in the field drawing that is Figure 1 of his 1977 report and Figure 17.18 here. This would result in the reversal of Hed Mound Periods III and IV as depicted in panels 3 and 4 of Figure 7 of that report and in Figures 17.17A and 17.17B here.

House P in the swamp and Houses 1–3 of Periods V–VII on Hed Mound are large enough structures for their excavators to interpret them as providing accommodation for people and pigs under the one roof in late Phase 5, in the way described in the ethnographic literature for the upper Wahgi. If features 37–39 of former Harris Period IV are really evidence of an earlier house, this would also have the size and shape to be interpreted as a structure for both pigs and people at an earlier stage of Phase 5.

We once thought that we had direct evidence of pig early in Phase 5 at Kuk, supplied by the discovery of pig bone in old subphases of Wai's Baret at two different locations: where it is crossed by drains of E–W Rd 1 (see section B in Figs 15.2 and 15.7) and of E–W Rd 3 some 650 m downstream. The bone at the first location was the back of a skull, allowing the specimen to be identified[4] as *Sus papuensis*, a stabilised hybrid between *S.* (cf. *scrofa*) *vittatus* of the Malay peninsula, Sumatra and Java and *S. celebensis* of Sulawesi (on which see Groves 1981: 64–66). The precise stratigraphic location of the find is unknown since it had fallen from the drain wall with slumping of Wai's Baret infill, but it was adjudged early because of the type of material in which it was included. However, it gave a calibrated radiocarbon age of AD 1670 or less,[5] which is Phase 6 in terms of the Kuk sequence. The second find, of two pig teeth from the basal fill of Wai's, is stratigraphically more secure. However, the calibrated age of the teeth is between AD 1490 and 1650,[6] or late Phase 5. This raises the possibility of downward movement of small objects in the stratigraphy, which has been a major problem for the dating of pig teeth from highlands rockshelters (Hedges et al. 1995: 428). As things stand, however, all directly dated highlands pig bone samples, as reported by Hedges et al. (1995: 428) and here, have returned dates of later than 400 radiocarbon years BP, roughly after AD 1450.[7]

4 By Colin Groves, School of Archaeology and Anthropology, The Australian National University.

5 Calibration of KIA-35647, 135±25 BP, at two standard deviations; courtesy of Keith Dobney (now Department of Archaeology, University of Aberdeen), who sponsored the dating.

6 Calibration of Wk-28559, 302±30 BP, at two standard deviations; courtesy of Elizabeth Matisoo-Smith (now Department of Anatomy and Structural Biology, Otago School of Medical Sciences, University of Otago), who sponsored the dating.

7 There is a single date for a directly dated pig bone from Indonesian New Guinea in the top level of Kria Cave on the Bird's Head, associated with the first pottery as well as the first pig at the site (Pasveer 2004: 57 and Table 3.2). The date in question is OZE 542, reported as >1840±40 radiocarbon years BP because of suspected younger contamination. We are told (Pasveer 2004: 654, fn 1) that this should be regarded as a minimum age.

Yet, as we saw in Chapter 14, pigs were present in the south Papuan lowlands by around 2500 years ago, with the potential to move or be moved into the interior. Particularly apposite for the upper Wahgi from this point of view is the site of Emo at the delta of the Kikori River at the Gulf of Papua, where definite pig bones have been found in association with pottery dating around 1600 years ago, and probable pig bones 200 years earlier (David et al. 2010: 49, 51). This is the period of Kuk Phase 4, which saw the development of the trade and exchange of axes made of stone from specialised quarries in the middle Wahgi and Jimi Valleys that was characteristic of the region at European arrival (see Chapter 14, section 'Kuk as a Phase 4 "hotspot"?' and Chapter 21, 'Ground axes and axe quarries' and following sections). As we shall see in Chapter 16, section 'Dating Phase 6 at Kuk', such axes have been found in the middle Kikori River region above the delta, contemporary with Kuk Phase 6 in the upper Wahgi, which was initiated by the arrival and adoption of the sweet potato. The question of the sweet potato's time and mode of entry into New Guinea and its spread into the highlands is discussed below and in Chapter 16. By this time, as we saw in the previous paragraph, pigs had already made their appearance in the highlands.

Interpretation

Phases 3, 4 and 5 compared

Interpretations of the Phase 5 evidence are made difficult by the absence of any direct evidence for the crops being grown in wetlands at this time. However, the difference in ditch morphology between Phases 4 and 5 suggests a change in agricultural technology and a switch from taro to other crops. In Phase 4, taro was cultivated with the digging stick, a tool used both to excavate the slot-like field ditches and also, by ethnographic analogy, to make planting holes. In contrast, as we have said, the flat-bottomed ditches of Phase 5 indicate the use of a spade of the paddle-shaped type, of which an example was excavated from a Phase 5 ditch. The increased volume of soil that was produced suggests an interest by the cultivator in soil tillage and the raising of beds for planting a different suite of crops. Whereas Phase 4 ditches are infilled with silty clay containing some fine soil aggregates, the fill in Phase 5 is a fine earth derived from garden soils that has had time to settle and compact.

In fact, Phase 5 ditches bear a stronger resemblance to late Phase 3 ditches than to those of the intervening Phase 4 (Fig. 15.14). Measurements taken from the cross-sections of samples of field ditches belonging to each phase reveal that late Phase 3 ditches have an average width of 341 mm at the base and 905 mm at the top of black clay, whereas Phase 5 ditches have equivalent dimensions of 406 mm and 679 mm respectively. In both cases, therefore, the Phase 3 and 5 field ditches are significantly wider features generating much more ditch spoil than Phase 4 ditches, whose average width is only 94 mm near the base and 474 mm at the top of black clay. When we measure their depth below black clay level, Phase 4 ditches have a similar modal depth to Phase 5 ditches, in both cases 300–400 mm, whereas those from Phase 3 appear to be somewhat deeper (mode 500–600 mm). However, the Phase 3 sample size is too small for us to draw firm conclusions about their depth being significantly different.

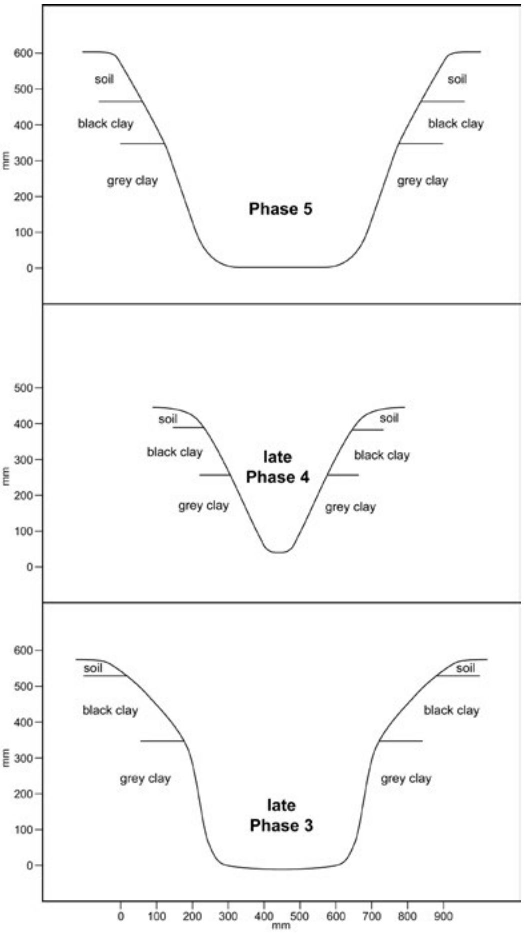


Figure 15.14 The 'typical' ditch in late Phase 3, Phase 4 and Phase 5.

For Phase 4 the cross-section is based on modal rather than mean widths and depths to avoid the distortion of the mean that results from a skewed frequency distribution (see Figs 15.11 and 15.12). For Phase 3 and Phase 5 average statistics were used because means are close to modes and therefore can be used to represent the 'typical' shape of a ditch. We interpret the different size and shape of Phase 4 field ditches compared with those of either Phase 3 or Phase 5 as resulting from the cultivators using a different tool in order to cultivate a different crop. In Phase 4, heavy digging sticks, not spades, were used in order to grow taro rather than the yams, sugarcane and bananas that, we believe, dominated Phase 3 and Phase 5 cultivation.

Source: Drawing by Philip Stickler based on measurements and calculations by Tim Bayliss-Smith on field data from the Kuk archive, 1972–76.

The more plentiful supply of soil in Phase 5 became a planting medium on fields or beds ('gardens'). The fields themselves tended to become larger and more elongated during the course of the phase. On these rectangular beds, various forms of cultivation would have been feasible and, although direct evidence is lacking, plants could have included yam, winged bean, banana and sugarcane. Taro, with its vulnerability to pest damage in grassland areas, had probably become a minor crop. Phase 5 ditches have also been found outside wetlands, in grid patterns antedating Tibito Tephra, for example at Mugumamp Ridge in the North Wahgi Swamp (Harris and Hughes 1978: 442–443) and at Kuk itself (Gorecki 1982: 283–284). It has been suggested that the cultivation of raised beds using ditch spoil was a practice that was initially developed in the wetlands of early Phase 5 and later transferred to the dryland sphere (Golson 1977a: 629–630; 1982: 119).

Alternatively, it is possible that Phase 5 represents an expansion into wetlands of an already established dryland system of soil tillage and raised-bed cultivation. At present, there is no evidence to indicate in which environment the Phase 5 technology of ditches and raised beds was first used, whether in drylands or wetlands, although the latter scenario seems more plausible. After reviewing the dating evidence for the onset of Phase 5 in an early section of this chapter, we concluded that it took place during the date range between AD 980 and 1410 and probably in the third quartile of this, around AD 1250. Its onset may have been in the context of El Niño droughts triggered by the huge volcanic eruption on Lombok in AD 1257, as previously discussed above. If so, then Phase 5 lasted about 400 years, providing an extended timeframe for lessons to be learnt in the swamp and later transferred to the dryland sector.

We suggest that the foregoing combination of circumstances—substantial ditches as the source of soil for raised gardens in dryland as well as wetland contexts, together with the paddle-shaped spades associated with their construction—indicates that taro was no longer the major crop that it had been in Phase 4 times. As discussed above, the interval between the end of Phase 4 and the start of Phase 5 was occupied by a period of warmer and more stable climate. We believe that in this period the changes in agricultural practice took place that characterise Kuk Phase 5, initiating a process of intensification of which both *Dioscorea esculenta* and pig may have been an integral part.

As previously discussed, pigs were present in the southern Papuan lowlands before the beginning of Phase 4 in the highlands, when there is evidence for the development of systems of trade and exchange in which the pig would have had a part to play, had it been there to do so. It also seems likely that the lesser yam (*Dioscorea esculenta)* moved into southern Papua following the Lapita settlement of Austronesian speakers there in the first half of the third millennium BP (see Chapter 14, section 'Phase 4 in its wider context'), finding its way into the highlands in the favourable climate of the Mediaeval Warm Period. Mike Bourke (pers. comm., 2013) says that the modern highlands climate is too cool for the lesser yam to thrive and points out (Table 4.1, note 3) that it is not common above 900 m. Nonetheless, as we shall see in Chapter 16, section 'An overview of the evidence', a large tuber fragment excavated from a Phase 6 house site at Kuk proved to be from lesser yam, not sweet potato, as expected.

At lower altitudes, *D. esculenta* can be a major staple supporting high population densities, as in the southern foothills of East Sepik Province (Swadling and Hide 2005: 314–317). Yams are also important in some grassland areas of the eastern highlands, as at Okapa (1600–1800 m), but here the greater yam, *D. alata*, is the important crop. Boyd (1975: 109–115) found 53 named varieties of yams growing in Okapa gardens, of which 43 were *D. alata*, six *D. bulbifera*, two *D. pentaphylla* and one each *D. nummularia* and *D. esculenta*. By the 1970s, yams were only a supplementary crop in the Mount Hagen area with sweet potato increasingly predominant (about 50 varieties). Nonetheless, there were still about 25–30 varieties of yams in cultivation, mostly *D. alata* with a few *D. esculenta* and *D. bulbifera*. By comparison, there were 31 varieties of taro still being cultivated, 22 of sugarcane and a remarkable 48 varieties of winged bean, *Psophocarpus tetragonolobus* (Powell et al. 1975: 15–27).

In Chapter 14, we reviewed evidence of severe yield losses from *Papuana* beetle attack for farmers attempting taro cultivation in grassland areas of the highlands. This is matched by the archaeological evidence from Phases 4 and 5 at Kuk, which suggests a change in cultivation practices as taro cultivation became increasingly problematic in the largely deforested upper Wahgi Valley. We have identified other crops, greater yam *Dioscorea alata* in particular, that could have formed the basis for a new cropping system in Kuk Swamp in Phase 5. Taro remained the staple for those with access to forest land for new swiddens, but in deforested areas such as the Wahgi taro could be supplemented with an alternative agricultural system in drained wetlands based on yams, bananas, winged beans and sugarcane. We hypothesise that this system was maintained at Kuk throughout Phase 5 until the sweet potato revolution of the last three centuries created a new set of opportunities, which we discuss as Phase 6 in Chapter 16.

Possible reasons for Phase 5 drainage

Whatever the date of the start of Phase 5 and the appearance of pigs at Kuk, there can be no doubt that by then the replacement of forest by secondary growth and grassland due to clearance for agriculture was well advanced in the Wahgi region (see the 'Mid to late Holocene' section of Chapter 9). With the availability of bush resources much reduced, pigs would have been a welcome replacement as a source of protein. However, because their opportunity to forage would have been limited in conditions of deforestation, there would have been need for them to be regularly fed from garden produce and for food gardens to be protected from them (see the 'House timbers and fence stakes' section of Chapter 19). As a result, pig-keeping would have been expensive in terms of the labour (mainly women's) invested in it, with pig ownership becoming a symbol of wealth and influence, as it has been in highlands societies of recent times. In these circumstances, pigs would have had a part to play in systems of exchange (cf. Golson 1982: 123–130; Golson and Gardner 1990: 398–405).

In Chapter 14, section 'Kuk as a Phase 4 "hotspot"?', we suggested that such systems of exchange had begun to develop in the highlands during Phase 4, characterised by the distribution of axes of valued quarry stone. The incorporation of pigs into such systems might have been the trigger for the inauguration of Phase 5 drainage to support and extend their role in ceremonial exchange.

How far was the renewal of swamp drainage in Phase 5 also driven by a crisis in dryland cultivation ('push' factors), rather than by the incentive of surplus production from the wetlands ('pull' factors)? As discussed earlier in this chapter, there is some evidence that the period before about AD 1250 was a time of warmer and more stable climate. Reconstructions of sea-surface temperatures based on ocean cores from Sulawesi confirm that the whole region experienced cooler temperatures between about AD 400 and 950 than during much of the Mediaeval Warm Period that followed (Oppo, Rosenthal and Linsley 2009: 1114). Sea-surface temperatures decrease during El Niño events, so that the regional cooling of the Little Ice Age after AD 1200 could reflect a more intense El Niño–Southern Oscillation (Conroy et al. 2008; Oppo, Rosenthal and Linsley 2009) and a southwards shift of the Intertropical Convergence Zone (Buckley et al. 2010).

If the New Guinea highlands began to experience more frequent and more severe ENSO droughts around AD 1250, then the greater security of production offered by wetlands sites such as Kuk would have been an additional reason for undertaking large-scale drainage. Parallel changes have been suggested for the Pacific islands by Patrick Nunn (2007; Nunn and Hunter-Anderson 2011), who sees evidence for an impact on settlement and agriculture following a shift in climate and a fall in sea level after AD 1300. In the Sigatoka Valley in Fiji, for example, episodic droughts and floods associated with ENSO events may have intensified the competition for resources and led to increased warfare during the period AD 1500–1700 (Field 2004). Did drought in New Guinea provide a comparable stimulus towards wetland drainage? An important step towards testing this hypothesis would be to establish with greater accuracy the date when Phase 5 began at Kuk and other sites.

There is evidence from elsewhere of Asian monsoon failure and resulting 'megadroughts' (Cook et al. 2010) that correlates with the Phase 5 chronology. Studies of tree-ring widths at Bidoup Nui Ba in Vietnam and of reservoir sediments near Angkor Wat in Cambodia have confirmed that intense droughts were experienced in southeast Asia in the mid-13th century. These were followed by the well-known Angkor Drought periods of AD 1345–65 and 1401–25 (Buckley et al. 2010: 6750; Day et al. 2012: 1048). Just as failure of the hydraulic network that sustained Angkor is now seen as contributing to its collapse, perhaps there is a parallel in New Guinea. It is tempting to see the onset of this period of increased frequency and intensity of drought as a regional phenomenon and as the trigger that initiated Phase 5 of drainage at Kuk. Can we also see the recurrence of drought problems in dryland agriculture as explaining the long duration of Phase 5 during the Little Ice Age period? Is it conceivable that the two Angkor Droughts (mid-14th century and early 15th century) are reflected in the evidence of Kuk Phase 5 major disposal channels and field ditches? Precise dating of the features is not possible, but the Kuk evidence suggests that subsequent to their initiation the channels and ditches of early Phase 5 were redug at least twice, enabling Kuk Swamp to continue in agricultural use.

Reasons for disintensification

Just as the network of minor ditches declined towards the end of Phase 5 (see above, 'Ditch networks and field systems'), so the disposal channels suffered some degree of neglect. We have already outlined the evidence for less maintenance work being carried out on the major disposal channel and one of its tributaries (see Figs 15.7 and 15.8). It is plausible to envisage a causal link between this declining investment in the major disposal channels and an increasing importance of the dryland sphere and products from that sphere, together with impacts on the wetland drainage system from erosion in the dryland catchments. If so, then one explanation for this declining investment is that by the end of Phase 5 (and especially afterwards, in Phase 6), Wahgi society became more and more focused on dryland tillage and raised-bed cultivation, pig husbandry and regional exchange. Perhaps in the wetland sphere, therefore, some increased crop losses due to flooding became acceptable in late Phase 5.

A strong focus on the dryland sphere of production was indeed the situation that prevailed in 1933, at the very end of prehistory, at a time when the wetlands in the Wahgi Valley had been largely abandoned. At contact the collective efforts of men, coordinated by influential big-men, were very largely focused on exchange activities, interrupted by spasmodic warfare. Strong gender divisions characterised Wahgi society and women's agricultural activities concentrated almost entirely on the dryland production of sweet potato (Strathern 1971: 8–10). Wetland drainage on any scale was no longer feasible partly because the social capital no longer existed that would have mobilised gangs of men to undertake the digging of major disposal channels.

Transposing these insights back in time, it is tempting to see the reasons for wetland abandonment after Tibito Tephra in the late Phase 5 disintensification process. Is it possible that an early arrival in the Wahgi Valley of the sweet potato was responsible for these changes? Answering this question would be easier if we could date more accurately the changes that occurred late in Phase 5, before its termination possibly in the AD 1660s. The earlier the decline in wetland use began, the more unlikely it is that sweet potato was implicated, given that it was a European introduction into Southeast Asia in the early AD 1500s and had to be transferred eastwards along traditional routes of trade and exchange. Partly on the basis of linguistic evidence, Pamela Swadling (1996: 155–165, 282) has argued for its transport from the Moluccas to the southern New Guinea coast by traders of Seram Laut, who from around AD 1645 to 1790 had contact with the Trans-Fly region. From here, the plant spread inland of Kikori into the Erave area of present-day Southern Highlands Province and thence into the upper Wahgi Valley, likely following the route by which pearl shells from Torres Strait were traded into the highlands (Swadling 1996: 156, 165; see Chapter 16, section 'Dating Phase 6 at Kuk'). A date of AD 1645 is, of course, possibly fewer than 20 years before the fall of Tibito Tephra and the end of Phase 5, and not long before the beginning of its successor, Phase 6.

Phase 6, as we shall see in Chapter 16, is a period when no agricultural drainage of any consequence was done at Kuk in the deeper parts of the swamp north and east of Wai's and Simon's Barets. By looking at the history of Phase 5 agricultural drainage in this part of the swamp, it should be possible to judge whether the arrival of the sweet potato was the decisive factor in the end of wetland cultivation at Kuk. The evidence for that history is provided by the stratigraphic relationships of Phase 5 garden ditches in the walls of modern drains to the visible time horizons provided in those walls by preserved remnants of two volcanic ashes, Kenta tephra, which fell at an early stage of Phase 5, and Tibito Tephra, which saw its end. Kenta is of limited value for this purpose since it is of rare occurrence. Tibito is much more frequent in appearance and we can use it as a rough measure of relative age for the ditches with which it is associated. Thus a ditch is early Phase 5 if the tephra lies level at the top of or above its fill, mid-Phase 5 if it sits in the middle to upper fill, late Phase 5 if it is at the bottom of the fill and Phase 6, of course, if the ditch cuts through it. Since we are particularly concerned with late Phase 5 ditches, we divide these into three rough categories: 'latest' when the base of the tephra is 0–20 mm above the base of the ditch; 'late' when it is between 20–60 mm above the base; and 'lateish' when it is 60–100 mm above.

Not every drain that we dug in the deep swamp east and north of Simon's and Wai's Barets was dug and recorded with the problems of Phase 5 in mind. As a result, we can only do the analysis of Phase 5 ditching described below using six of the 11 drains dug east of Simon's Baret in blocks A10–12 and seven of the 14 drains dug east of Wai's and Simon's Barets in blocks B10–12 (see Fig. 15.4). In the 13 drains that we are using, which are represented in all six blocks, ditches associated with Kenta and Tibito were recorded and could be allocated to the categories described in the last paragraph. There is a total of 170 Phase 5 ditches, of which 122 or just under 72 per cent are in the early to mid category, with 48 or just over 28 per cent in the late. The single drains C12e/f and D9g/h (see Fig. 15.4) are eligible for inclusion. The former has a count of 17 Phase 5 ditches, of which 12 (70 per cent) are in the early to middle category and five (30 cent) are late. Of the 19 ditches in drain D9g/h, 14 or 74 per cent are early to middle period and five or 26 per cent are late.

We can be sure that the counts for ditches of the early and middle periods are an underestimate, given the destruction or compromising of evidence by later digging. On the other hand, the late category of ditches as defined must belong to a relatively short period before the fall of Tibito Tephra, a period far shorter than that covering the middle and early categories that extend back to the beginning of Phase 5 before the fall of Kenta. This is certain despite the unsatisfactory dating of the Kenta ashfall, as discussed above: earlier than the overlying peat, whose radiocarbon date calibrates within the age range AD 1270–1640, and between AD 1340 and 1460 by rate of sedimentation. We can summarise by saying that wetland agriculture at Kuk in late Phase 5, while the subject of some neglect, was by no means in crisis (see above, 'Ditch networks and field systems'). No other conclusion seems valid, especially when we consider that although 72 per cent of the 170 ditches in the 13 drains of the A and B blocks belong to the early to middle period, as many as 28 per cent were dug in the late period despite it being much shorter in duration. Indeed, of the 48 late period ditches present in the A and B block drains under analysis, at least 11 belong to the latest subphase, with Tibito Tephra no more than 20 mm above the base of the ditches in question. These cases are well distributed across the area with which we are concerned (see Fig. 15.4)—two in drain A11a/b, four in A11f/g, one in B10e/f, one in B11a/b, two in B11d/e and one in B12c/d. In addition, there is one certain and one possible example in drain C12e/f and two certain ones in drain D9g/h. All these ditches were open at the fall of Tibito Tephra, but were they operating as part of a system? Certainly they were never used again.

There are a number of scenarios for a decline of wetland agriculture at the time of the Tibito ashfall and the appearance of the sweet potato. One is the fragility of the structures required for organising collective work projects like major ditch maintenance and their consequent vulnerability to disruption in circumstances of social change plausibly initiated by the appearance of the sweet potato.

An alternative view would see Phase 5 society in the Wahgi as one already marked by social stratification, big-men leadership and gender inequality (Golson 1982). The disintensification of wetland landuse during this phase would not reflect any fragility in organisational structures, but instead would signal the growing success of dryland agriculture based on soil tillage, ditching for raised-bed cultivation, surplus production of yams and women's labour. Whereas at the start of Phase 5 the wetlands still offered significant incentives for surplus, wealth and prestige, by the 17th century dryland agriculture was more productive—and of course became still more so after the boost to fertility provided first of all by Tibito Tephra and later by the sweet potato. In this dynamic society of escalating wealth, exchange and social inequality, political instabilities and intergroup warfare provided another reason for wetland agriculture to become less attractive, because of the increased risk of disruption to the major disposal channels.

Disease is another possibility. Paul Gorecki (1979a) has reconstructed the patterns of population movement that had led to the depopulation of most of the valley flats in the Wahgi, Baiyer and Nebilyer Valleys by the 20th century. He argues that if, hypothetically, one repopulates the valley flats with those tribes that had relocated to other valleys nearby, such as the Jimi, Kambia and Kaugel, then 'one gets a picture of a dense population living in and around the swamps prior to the introduction of the sweet potato some three hundred years ago' (Gorecki 1979a: 104). The abandonment of the valley floors, he suggests, came about as a result of the arrival of malaria, probably following traditional trade routes and apparently postdating the appearance of the sweet potato (Gorecki 1979a: 104–105). Nelson (1971: 206–207, 208–209) makes many of the same points about the inhabitants of the Nebilyer Valley immediately southwest of the upper Wahgi and their contacts with the people of the upper Purari drainage to the south, though he proposed a now unacceptable younger date for the events in question (on which see Blong 1975).

Conclusion

It may in future become possible to put Phase 5 at Kuk into some wider context of highlands prehistory, but at present the sparse nature of the evidence available beyond Kuk makes comparisons very difficult. By various lines of evidence, we have argued that this phase of drainage probably began in the later part of the period between AD 980 and 1410, perhaps soon after 1250, and did so for reasons that are unclear but probably related to a deteriorating environment for dryland production. Access to forests had become more difficult with the spread of grasslands, so that opportunities for hunting and gathering would have declined. Dryland crop production was also growing more difficult on degraded grassland soils that were subject to more frequent drought hazards from El Niño events. At the same time, we envisage a continuing expansion of pig husbandry and regional exchange, stimulated by what had become a highly differentiated mosaic of different environments and societies, integrated by exchange relationships that extended across the highlands and perhaps beyond. Therefore, both 'push' and 'pull' factors could be implicated, with subsistence crisis and incentives for surplus production, wealth and prestige lying behind this new phase of wetland reclamation.

What is clear is that Phase 5 was very different in agricultural technology from Phase 4, even if in broad hydrological terms the two phases functioned similarly. The use of spades, the construction of raised beds with soil tillage and a predominance of dryland crops like banana, yam and winged bean rather than taro seem likely. We envisage a social landscape of intensive cultivation based on growing social stratification extending far and wide across the upper Wahgi Valley and beyond.

The end of Phase 5 at Kuk, after the fall of Tibito Tephra and the Time of Darkness by which it is remembered, was sudden, but abandonment of swamp cultivation was short-lived, as discussed in the next chapter on Phase 6. The evidence suggests that Phase 5 was at its peak in its early subphase, in terms of coordination and intensity of effort. In the late subphase, sometime before Tibito Tephra fell, possibly in the AD 1660s, there is evidence of some decline in drainage effort. Whether the beginning of sweet potato cultivation was responsible or alternatively whether we should invoke purely sociopolitical factors—escalating warfare, disease, gender divisions in society, alternative male projects connected to widening exchange activity—is unclear at present. It may be that the important factor was the adoption in the dryland sphere of swampland techniques of ditching and raising garden beds, which became characteristic features of dryland sweet potato production in Phase 6. It was in that phase that the effects on wetland drainage caused by the sweet potato become apparent. Its coming unleashed a revolution in subsistence, but the evidence from Kuk shows that during Phase 5 the agricultural technology and the social relations of production necessary for this dramatic change were put in place.

16

Phase 6: Impact of the Sweet Potato on Swamp Landuse, Pig Rearing and Exchange Relations

Tim Bayliss-Smith, Jack Golson and Philip Hughes

Introduction

Is Phase 6 a separate drainage phase?

Whereas previous phases of drainage at Kuk Swamp began after long periods of abandonment of the wetland, Phase 6 started after Phase 5 with only a brief hiatus. In the previous chapter, we reviewed evidence for the end of Phase 5 following the fall of Tibito Tephra, possibly in the AD 1660s. This event seems to have disrupted drainage and wetland gardening, but not for very long. Although dryland agriculture must have benefited from the fertilising effects of the ashfall, the wetlands were not abandoned. Within a matter of decades, Kuk Swamp was again under cultivation and into its final phase of prehistoric drainage. This last period, termed Phase 6, came to an end in the early part of the 20th century.

Golson (1977a, 1982) has seen Phase 6 as a continuation of Phase 5 in agricultural technology, but with a switch of subsistence staple to the sweet potato, *Ipomoea batatas*, a root crop of tropical American origin introduced by the Portuguese into the Moluccas in the early 16th century AD. In Chapter 15, section 'Reasons for disintensification', we noted Pamela Swadling's argument (1996: 155–165, 282) for the plant arriving in the Papua New Guinea highlands from the Trans-Fly region of the south coast, where, she suggests, it had been introduced between about AD 1645 and 1790. It was pointed out that AD 1645 may only have been about 20 years before the fall of Tibito Tephra and the end of Phase 5 at Kuk.

A more recent review of the evidence has broadly confirmed Golson's earlier claims about Phase 6 (Bayliss-Smith et al. 2005), and this chapter is largely based upon that review. It would appear that Phase 6 is different from the previous phase mainly because of the effects of the transition in highlands agriculture to sweet potato. This process probably occurred about AD 1700, with ultimately far-reaching effects upon population, surplus production, pig husbandry, social organisation and, as a side-effect, wetland landuse itself.

The Ipomoean Revolution

There has been much debate about the environment in which the sweet potato was first adopted and whether adoption was a response to crisis or opportunity. Following Brookfield's (1989: 316–317) initial suggestion, Robinson proposed that adoption was partly a response by highlanders to extreme El Niño–Southern Oscillation events that caused severe droughts and famines around 1700 (Robinson 1999: 77–79). Others have seen the fall of Tibito Tephra, possibly in the AD 1660s, as a disaster that might have predisposed highlanders to sudden radical change (Modjeska 1977: 85–89). We need to begin, therefore, by setting Phase 6 within the context of highlands prehistory over the last three centuries, a period in which discussion is dominated by the so-called 'Ipomoean Revolution'.

The term 'revolution' was first used in this connection by James Watson (1965b: 305) to summarise the rapid, recent and far-reaching changes that he believed had been unleashed by the adoption of the sweet potato in the highlands. Its advantages for highlands cultivators include a shorter time between planting of its vines and harvest of its tubers, its tolerance of poorer soils and higher altitudes, its ability to sustain repeat harvests and its value as a fodder crop for pigs. Following its adoption, Watson envisaged a rapid switch from small-scale swidden agriculture based on taro to semi-permanent and intensive cultivation, as well as a transition 'from hunting and foraging to herding pigs and cultivating fodder gardens' (Watson 1977: 66). Population growth, deforestation and sociopolitical changes were related aspects of the sweet potato 'revolution' that Watson envisaged.

More recently, scholars have tried to base history upon evidence rather than speculation and they have emphasised the gradual beginnings of the Ipomoean Revolution. Polly Wiessner (2002, 2005), for example, has used oral histories to date the transition to sweet potato in eastern Enga as beginning nine to 12 generations prior to her fieldwork in 1985–95. If we use 25 years as the average interval between generations, her data would imply that the sweet potato first arrived between 1685 and 1760. She notes, however, that 'the sweet potato slipped into the garden regime of eastern Enga without note in historical traditions' (Wiessner 2002: 240). In Enga it was only after population growth, colonisation of the high-altitude zone and the emergence of the *tee* cycle of ceremonial exchange that the full social effects of the new crop were realised and its identity came to be mentioned in oral histories. Symptoms of dramatic social change occur only about four generations ago, around 1885–1915. This was the main period of agricultural intensification, when the *tee* cycle was expanded to finance an escalation of the Great Ceremonial Wars, which had first begun around 1825–55 (Wiessner and Tumu 1998).

In Southern Highlands Province, a similar sequence of changes has been reconstructed for the Tari region by Ballard (2001: 296). In Tari, the marginal wetlands have been used for agriculture periodically since about 2500 years ago, but the low-lying central swamps seem not to have been cultivated until long after the coming of the sweet potato. In Haeapugua Swamp, for example, the central area began to be reclaimed after the 1860s. Efforts to drain both marginal and central Haeapugua Swamp reached a peak in the 40 years or so between the 1890s and the 1930s and the reclaimed land was planted with sweet potato to produce more pigs for ceremonial exchange. In the Kopiago Basin, too, drainage of the wetland margins for sweet potato did not begin until after 1850 (Robinson 1999: 55–60). Chris Ballard argues that wetland drainage did not involve technical innovations, but there were certain social preconditions. To be successful, drainage projects required 'the organisational skill … of male leaders to assert claims to wetland blocks, to marshal labour resources for the drainage, and to negotiate the labour of larger work groups of female relatives than is normally required in dryland production' (Ballard 2001: 299–300).

It is interesting to note that in both Tari and Enga, the main period of agricultural intensification occurred sometime after an escalation of ceremonial exchange that had been fuelled by the sweet potato. To understand the situation in the upper Wahgi, the precise character of Phase 6 therefore needs to be critically reassessed. Was it Ipomoean in the full sense from the onset, with sweet potato cultivated in the swamp itself? Alternatively, do we see in Phase 6 merely a continuing but declining tradition of wetland landuse, still based perhaps on yam, banana, winged bean or taro? If the latter explanation is sustained, then the end of Phase 6 is the end of pre-Ipomoean wetland agriculture, which perhaps seemed obsolete and unproductive in the brave new world of dryland sweet potato production. Perhaps in the Wahgi Valley any kind of wetland landuse became problematic, because of malaria, excessive warfare or the breakdown of cooperation making wetland drainage projects less feasible.

Dating Phase 6 at Kuk

We have a clear marker for the end of Phase 5, which is signalled by the fall of Tibito Tephra, possibly in the AD 1660s. After this event not much time elapsed before we see evidence for renewed drainage, utilising some of the earlier network of disposal channels and field drains. These reused ditches must have been features still visible in the abandoned wetland, so that Phase 6 cannot have started more than a generation or so afterwards, probably around AD 1700. Other Phase 5 ditches, however, were relict features in the post-Tibito landscape and were not redug in Phase 6, as shown by the example in Figure 16.1.

In 1933, when Europeans came to the upper Wahgi, Kuk was uninhabited, the whole area being in a waterlogged state and covered in swamp grassland. This followed its abandonment by its customary owners, the Kawelka, as a result of their defeat in warfare, as told in oral tradition (Strathern 1972: 36–40; see Chapter 22, sections 'Histories of movement and warfare' and 'Kawelka settlement history', and Chapter 23, the first four paragraphs). The Kawelka big-man Ongka, who died in 2003 (Strathern and Stewart 2004: 166), was born in the hills of the Sepik-Wahgi Divide to the north of the upper Wahgi (Strathern and Stewart 2000b: 14 and footnote 10), where most of the Kawelka found refuge with related groups after their defeat. Since he was still a young boy when he heard the aeroplanes bringing the first white men into the upper Wahgi (Strathern and Stewart 2000b: 3), the Kawelka move from Kuk could not have predated 1933 by any great length of time and Golson suggests that it took place about 1920 (cf. Stewart and Strathern 1998: 94 with an earlier date of around 1914). Ongka was surprised by what we were finding in block A9 of the Research Station, where we started fieldwork in 1972, particularly the mounded house sites that were revealed in A9g as our workmen cut away the swamp grasses (see Figs 16.2, 17.1, 17.2). Ongka's reaction would accord with the general lack of an oral tradition of large-scale drainage among older inhabitants of the region that we report in Chapter 15, section 'The regional geography of Phase 5'. A round date of AD 1900 might be proposed for the end of Phase 6 at Kuk Swamp.

The abandonment of Kuk by the Kawelka is one example of a population movement that seems to have occurred more generally in the middle Wahgi, upper Wahgi, Nebilyer and Baiyer Valleys. As noted in Chapter 15, Paul Gorecki (1979c: 104) suggests that the movement was not so much from wetland to dryland as from valley flats to higher levels, linked to the arrival of malaria through contacts between highlanders and populations at lower altitudes where malaria is endemic (Gorecki 1979c: 104–105; cf. Nelson 1971: 206–207). Certainly, belief in swamps as an abode of evil spirits was common and only dispelled after the drainage of the upper Wahgi swamps in the late 1960s and early 1970s (Ketan 1998: 17). Gorecki (1979c: 105) thinks that the context for the interactions that led to the spread of malaria could have been 'trade'.

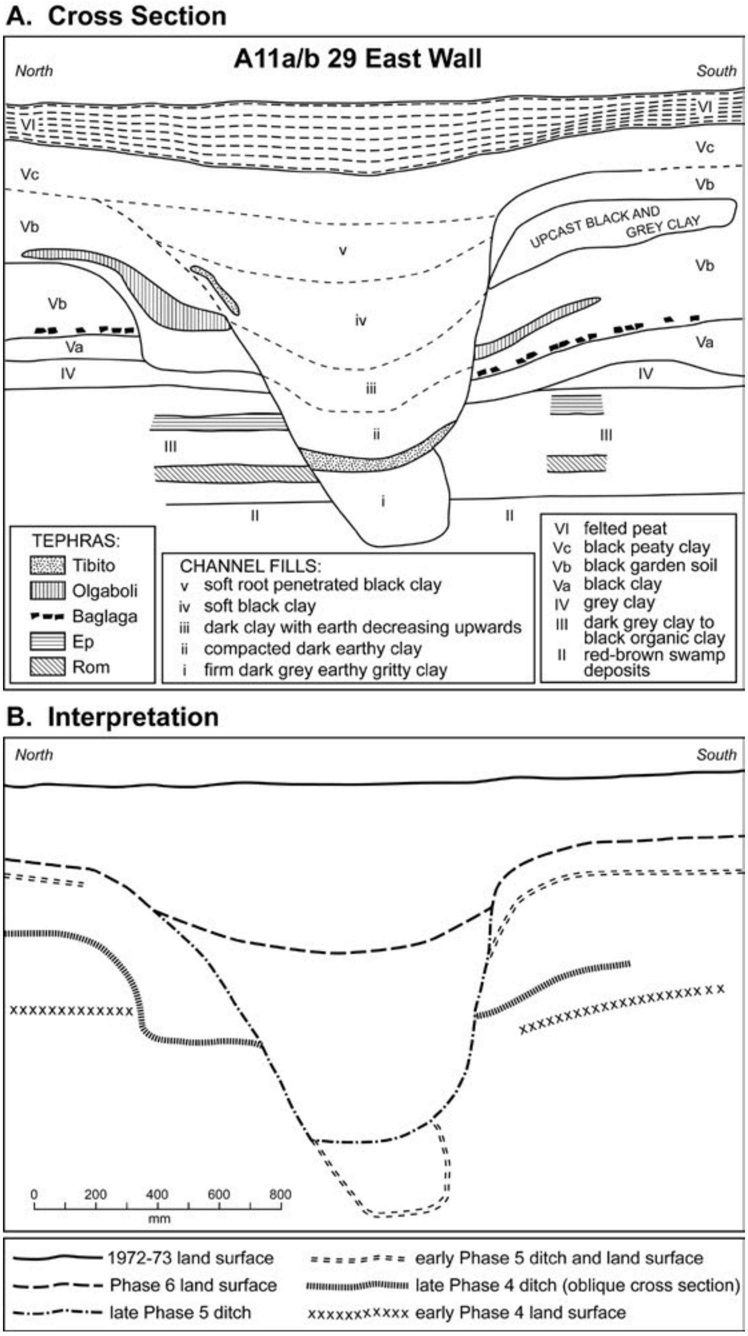


Figure 16.1 An example of a large Phase 5 field ditch in the east wall of drain A11a/b that was not reused in Phase 6.

However one interprets the evidence of the lower part of the south wall of the Phase 5 ditch—whether as it was originally dug or as the result of slumping—there seems to be little doubt about the existence of two stages to its history. The original digging cut through an earlier Phase 4 ditch, with Olgaboli Tephra in its fill, which ran somewhat obliquely across the modern drain. The spoil upcast from this activity is represented by a layer of black and grey clay thrown onto the south bank of the ditch. By the time that Phase 5 came to an end, possibly in the decade of the AD 1660s, the ditch had been redug, either immediately before the fall of Tibito Tephra, which sits at its very base, or because of a cleaning out of the new channel between its digging and the ashfall. The ditch was fully functional when the ash fell. However, as with so many Phase 5 ditches, it was not refurbished for use in Phase 6, but became a relict feature infilling through sedimentation, as shown by channel fills ii, iii and iv and by a lens of Tibito Tephra undoubtedly in secondary position close to the slanting upper wall of the structure. The ditch is an example of the disintensification of drainage that was a general feature of Phase 6.

Source: Drawing by Philip Stickler based on a 1973 field record, Kuk archive.

It was presumably along a 'trade route' composed of braided strings of local connections that the sweet potato had made its journey to the central highlands after its entry into New Guinea at the Trans-Fly coast, as proposed by Swadling (see Chapter 15). Indeed, it can be suggested that the trade route in question was the one that brought ornaments of gold lip pearl shell (*Pinctada maxima*), in the form of crescents and slivers, from Torres Strait to the upper Wahgi Valley and beyond (Swadling 1994: 142–145; Swadling, Wiessner and Tumu 2008: 277) and, in the reverse direction, took the products of Wahgi and Jimi axe factories down to the Gulf of Papua (Hughes 1977: 180–181; Rhoads and Mackenzie 1991: 42–43; see Chapter 15 here). The highlands axes at the Gulf are ascribed by Rhoads to his Proto-historic Period, whose onset is 'arbitrarily' dated to about AD 1700 (Rhoads and Mackenzie 1991: 38, 40). Recent work in the region has produced a chronology that 'corresponds well' (David 2008: 469) with Rhoads and Mackenzie's Recent Ceramic and Proto-historic phases, which they start at 500 years ago and end at sustained European contact (1991: Table 1).

Swadling has pointed out (pers. comm., 2010) that trade links with the Sepik lowlands offered a closer additional or alternative source for malaria in the highlands, and indeed perhaps for sweet potato, which Wiessner (2005: 123–124) reports as arriving in western Enga from the north (cf. Ballard 2005: 9 and footnote 17). In 1932, on the lower middle Yuat, a southern tributary of the Sepik with headwaters at the Sepik-Wahgi Divide immediately north of the upper Wahgi Valley, the anthropologists Margaret Mead and Reo Fortune recorded the valuables being traded from the highlands to the Sepik plain, which included pearl shell crescents and stone axes (Swadling 2010: 149; cf. Swadling 1994: 144–145 and Swadling, Wiessner and Tumu 2008: 277). At least some of the stone axes are likely to have come from the Jimi and Wahgi quarries, judging from the distribution of known finds of such axes (undated but less than 2000 years ago, see Gorecki 1989: 169) between the highlands and the lower Sepik in what Swadling calls her lower Sepik trade sphere (2010: 150 and Fig. 8). Swadling comments that the pearl shell crescents seem to have had a greater attraction for the people of her middle Sepik trade sphere and, in considering by what route they reached there, she notes the occurrence of pearl shell crescents in the rock art of the Karawari drainage on the northern slope of the central highlands. Like the highlands axes of the lower Sepik trade sphere, the rock art is undated. However, following Swadling (2010: 150), we note the accessibility of the Karawari area, via the Yuat drainage, from the upper Wahgi Valley, where the Taylor/Leahy patrol that made the first entry into the Wahgi region in 1933 noted the best quality and greatest number of pearl shell ornaments, coming in from the south via the Nebilyer and Kaugel Valleys (cf. Swadling 1994: 143).

This trade, together with its northern extension into the Sepik observed by Mead and Fortune, clearly predates the import of pearl shell into the upper Wahgi as trade items by Europeans. Though we have envisaged the sweet potato following the shell route from the Gulf of Papua to the highlands after an introduction in the later 17th century, there is no clear indication of the shell trade representing an unbroken line of activity going any distance back in time. This seems to be a conclusion we can safely draw from the field and documentary research on trade in interior New Guinea on the eve of European contact carried out by Ian Hughes (1977) in the late 1960s on a huge, almost rectangular block of highlands and highlands fringe defined latitudinally by the Ramu River on the north and the Purari on the south and longitudinally by the upper Wahgi Valley on the west and the lower Asaro on the east. Hughes describes how in the course of his fieldwork he received from his informants a consistent story of increased movement of ornaments of marine shell in the first 30 years of the 20th century, which supplanted existing ornaments of other materials. Compared with this, the picture at the end of the 19th century appears as one in which shells were in short supply or absent (Hughes 1977: 184, 187, 198, 201). Hughes (1977: 198–201) then looks back in search of earlier patterns of shell trading as revealed by the admittedly sparse archaeological record of marine shell occurrences in his study area.

He concludes that given the susceptibility to disruption of supplies of goods dependent on trade, particularly long-distance trade, it is likely that 'trade in sea shells was always subject to long-term interruptions and re-orientations' (Hughes 1977: 202, and see Appendix 16.1 here).

This digression on the shell trade arose out of a consideration of the mode of entry of the sweet potato into the New Guinea highlands. Going back to this question, we may note Chris Ballard's (2005: 8–9) conclusion from the literature on New Guinea terms for the two associated American plant introductions: tobacco and sweet potato. The distribution of terms is more complex for the latter than for the former, suggesting to Ballard that while tobacco followed trade routes, sweet potato 'diffused within New Guinea in a much more random manner' (2005: 9). That said, we return to Phase 6 to consider the evidence of what took place in the upper Wahgi until, at Kuk, it came to an end. The next drainage at the Kuk Swamp followed the establishment of a government Tea (later Agricultural) Research Station in 1969, initiating what we may call Kuk Phase 7 (see Chapter 23).

Evidence

In this chapter, we retain the framework used in the two previous chapters for separating evidence for Phase 6 from its interpretation. Some of the ground has already been covered in earlier discussion in Chapter 15. This is because, as indicated above, Phase 6 followed Phase 5 at no great remove in time and made use of much of the earlier infrastructure of disposal channels and to some extent of field ditches. We consider, first of all, the area of swamp that was in cultivation in Phase 6. We then review changes in the size and shape of the disposal channels, major (Wai's Baret) and minor (Simon's and Korowa's Barets), the minor ditches that served as field drains and the small fields ('plots', 'gardens' or 'raised beds') that they defined. Some of the best evidence for an Ipomoean transition comes from the swamp margins, where we see evidence for soil tillage and the formation of raised beds, possibly for sweet potato cultivation.

Fences in the swamp

Phase 6 saw the abandonment of cultivation over the greater part of the deeper swamp in the northern and eastern sections of the eastern half of the Research Station and the concentration of such activity on the swamp margins and the slightly higher ground to the south and west. Essentially, the line of the major Phase 6 disposal drain, Wai's Baret (Figs 15.2, 15.4, 16.2 and 16.3 here), marked the eastern limit of cultivation, with houses established close to it at intervals along its length. Though this was not the first appearance of houses in the swamp (correcting Bayliss-Smith et al. 2005: 118), it appears to have been the first substantial one.

In addition to what we can infer from the building of houses along Wai's Baret (see below), the evidence from Simon's Baret is particularly valuable in helping us to reconstruct Phase 6 landuse. Simon's Baret is another member of the Phase 5 drainage network (Figs 15.2 and 15.4) that reappeared in Phase 6 (Figs 16.3 and 16.4 here). However, instead of a channel flowing through drained cultivations as before, it now had cultivations only to its south and west (Fig. 15.13). Late in 1973, towards the end of the main digging season, Laurie Lucking started excavations at the western outskirts of a house that she had earlier investigated under Ron Lampert's supervision. It had been cut through by Station drain A11a/b and ended some metres east of Simon's Baret (Fig. 15.13, Phase 6 panel; see Fig. 16.3 for location). Here she found evidence of a fence line running parallel to Simon's Baret and 1–1.5 m east of it, which she traced for some 20 m as far as the east wall of Station drain A10/11, where Golson had recovered remains of fence posts when it had been dug earlier in the season.

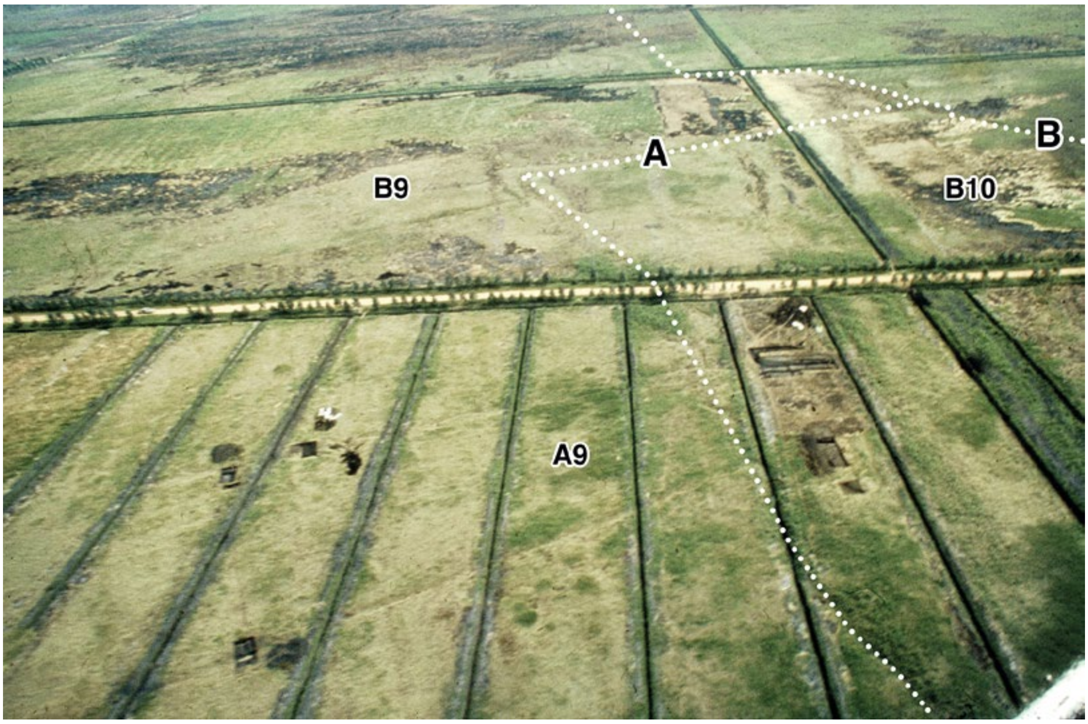


Figure 16.2 Looking north over what became in Phase 6 a frontier zone between crop planting and pig pasture.

In the southern part of the site, the frontier zone lies between Wai's (A) and Simon's (B) Barets, the former distinguished by right-angled bends, ENE in block B9 and NNW in block B10, where it is joined by Simon's Baret coming in from SSE (cf. Figs 15.2, 15.4, 15.5 and 15.6; the courses of these two drains have been digitally enhanced). West of Wai's was the tilled land, east of Simon's and Wai's lay the pasture. In between, besides some tillage, was a string of houses along the line of Wai's (see Fig. 16.3), interpreted as predominantly for women and pigs. Houses are under excavation in block A9g, one recognisable from the U-shape of the ditch defining its living area. This is House B (see Fig. 16.3 Inset), one of those presumed to be for women and pigs.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

In the 1974 season, Jim Rhoads and workmen carried out excavations for Hughes and Golson aimed at sorting out problems related to the course of drainage channels, specifically the Phase 4 channels Moni's Baret and Neringa's Baret (Fig. 14.4) and the Phases 5 and 6 channels of Simon's Baret (Figs 15.4 and 16.3), particularly in blocks A10g and A10h and blocks B10c and B10d (see the legend of Fig. 13.7 here, as well as Denham, Golson and Hughes 2004: Fig. 2). Three of the excavations associated with Simon's Baret are particularity relevant: cuttings 1 and 2 at the northern end of block A10g and cutting 25, the most northerly cutting of block B10d, just south of where Simon's Baret is crossed by Station drain B10c/d. They provided evidence of fence lines with the same characteristics of orientation and placement as the fence found by Laurie Lucking further south in 1973 as described above, that is, parallel with Simon's Baret and 1–1.5 m to its east (see Chapter 19, section 'House timbers and fence stakes').

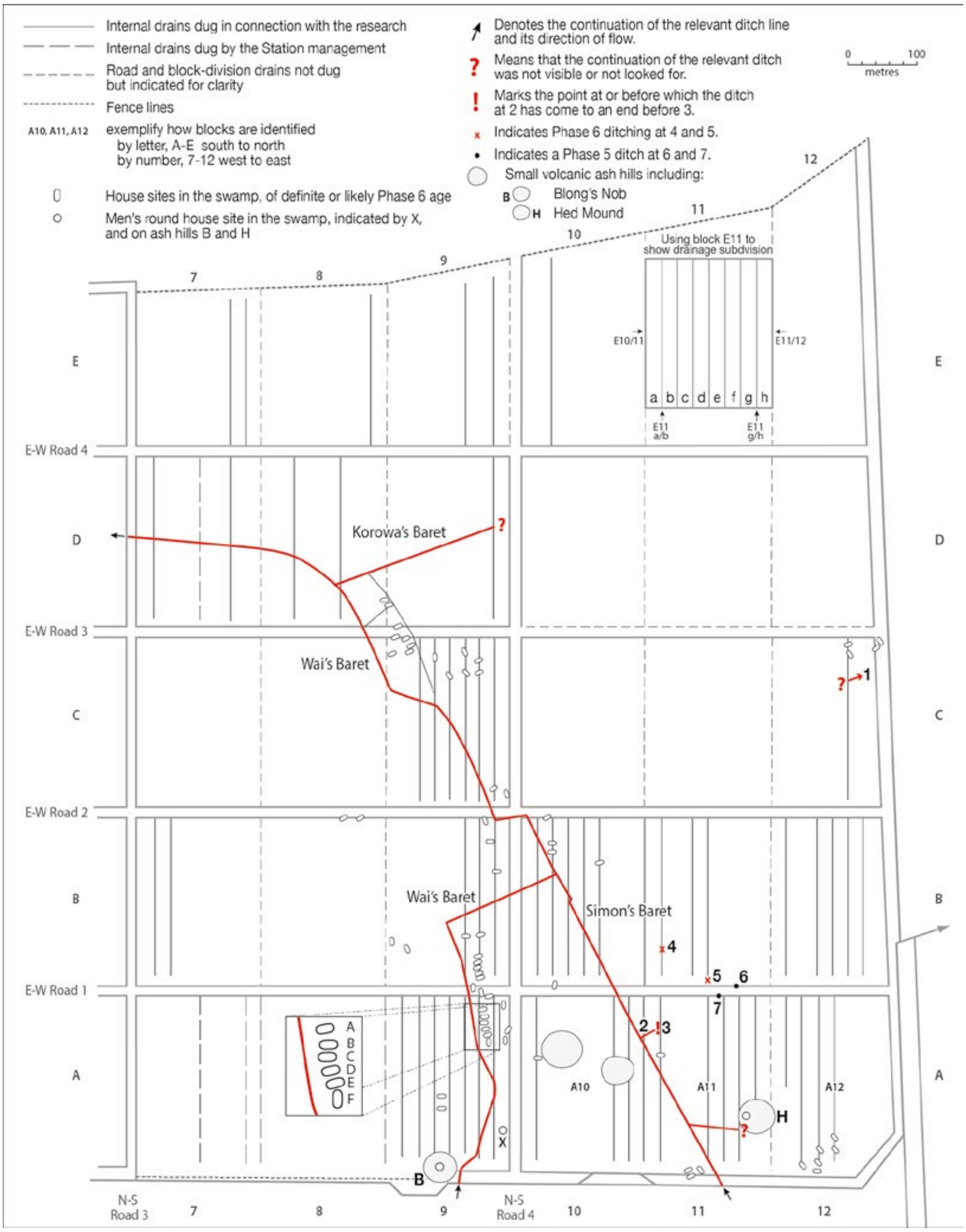


Figure 16.3 Map of the major drainage channels of Phase 6, which replicate those of Phase 5 (see Fig. 15.4).

The number and distribution of house sites reflect a major change in the use of the swamp, with cultivation largely restricted to the shallower swamp west of Wai's Baret and pig pasturage replacing it to the east. Numbers 1–7 on the map represent features of this change that are discussed, including special drainage measures to allow habitation at the margins of deeper parts of the swamp (see also Fig. 17.3 on housing).

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Figure 16.4 A ground view of Simon's Baret looking SSE. The western frontier of the pig pasturage of Phase 6 was marked by a fence line running parallel with Simon's Baret a metre or so to the east of it.

Source: Photograph by Murray Woods, Kuk archive, 1972.

Rhoads uncovered only a limited exposure of the fence lines in question because of the size and shape of the cuttings involved. However, although the evidence was fragmentary, the implication of what was being exposed was evident. Thus:

- in cutting 2 of block A10g, immediately north of the crossing of Simon's Baret by Station drain A10/11, where Lucking's 1973 work on the fence line coming north had ceased, the fence line's continuation was exposed across the 3 m width of the cutting, except for a 1 m gap in the middle;
- as regards cutting 1, the south wall of which is 12 m north of the north wall of cutting 2 measured along the line of Simon's Baret, its 2.5 m width is occupied by a 0.3 m stretch of fencing followed by a 1 m gap, beyond which is 0.7 m of fencing, then a 0.6 m gap to the north wall, which is 14 m south along the line of Simon's Baret from the south wall of the south drain of E–W Rd 1;
- concerns cutting 25 of block B10d, which starts at the north end of the kink in the course of Simon's Baret, some 154 m north-northwest of the south wall of the south road drain of E–W Rd 1. The cutting is 3.4 m long N–S, with evidence of a 1 m long stretch of fencing running parallel to Simon's Baret, 1 m to its west, starting 2 m north of the south wall of the cutting and finishing 0.6 m south of its north wall.

There are five cases where Simon's Baret is briefly exposed on its way north-northwest to cutting 25 but where no associated fence line is recorded, the more southerly of the occurrences being 24 m away, the more northerly 5 m. In these cases, however, less than a metre's width of ground was exposed east of Simon's Baret. Since a metre is the normal minimum between the drainage channel and the accompanying fence, the apparent absence of the fence line in these cuttings can readily be explained.

From all this evidence, we soon came to accept that Simon's Baret was a combination of channel and fence, but we did not test this conclusion further in the 60 or so metres of channel between Lucking's house site on drain A11a/b and the southern boundary drain of Kuk Station. Nor did we look at the junction between Simon's Baret and Wai's, 35 m along the line of Simon's from the northern boundary of cutting 25, to see what happened to fencing at and beyond this important point.

Because fences are so strongly associated today with the need to keep pigs out of areas under gardening, and since Simon's Baret has a presence in both Phases 5 and 6, it is important to establish the chronology of this particular fence line. In all the excavations by Lucking and Rhoads discussed here, with one exception, the fence lines are later than Tibito Tephra and so belong to Kuk Phase 6. The exception is cutting 25, the most northerly of the occurrences under discussion and the only one in the B blocks. Of this Rhoads reported 'age determination uncertain' in his summary of field results (typed set of notes in the Kuk archive, 1974).

We conclude that the fence line under discussion is shown by its appearance after Tibito Tephra to mark the frontier between the gardened land of Phase 6 of which the sweet potato was part and an area of deeper swamp. Furthermore, the evidence strongly suggests that in Phase 6 this swamp was now largely converted to grazing land for pigs.

Ditches in the swamp

Ditch digging did not stop altogether in the swamp east of Simon's Baret and north of Wai's, but certainly it became much less common (for what follows in this section, Fig. 16.3 serves as a guide). In some cases, new ditches were associated with housing areas like those at the southern end of block A12 and in blocks C9 and D8 close to E–W Rd 3, as well as, to a lesser extent, in the northeast corner of block C12. The evidence comprises the house ditches themselves, but also subsidiary ditching associated no doubt with local water control, such as was mapped from surface indications at the C9/D8 housing cluster. We should note that at least the first two of these locations are at the margins of the deeper swamp. At the third location, in the northeast corner of block C12 (no. 1 on Fig. 16.3), there was a ditch dug into the fill of a late Phase 5 ditch and appearing from aerial photographs to be trending east-northeast into uninvestigated territory across the Kuk Station boundary (cf. the isolated occurrence of Phase 4 ditching in this area described in Chapter 14, section 'Fields and fallows').

There is no evidence of Phase 6 ditching in any of the Station drains of block A12 apart from that noted above for the housing area at its southern end. Three drains of block A11—d/e, e/f and f/g—intersected the line of a Phase 6 ditch dug into the fill of a Phase 5 ditch, itself dug along the course of the Phase 3 channel that we called Kui's Baret and Denham numbered 106 (see Fig. 13.7). It seems to have run from the vicinity of Hed Mound, the site of occupation in Phase 6 (see Chapter 17, section 'Harris' excavations on Hed Mound 1977'), to join Simon's Baret. Another Phase 6 ditch almost certainly joining Simon's was dug into the fill of a Phase 5 ditch at drain A10/11 (no. 2 on Fig. 16.3). However, there is no evidence that it had been dug as far east along the line of that ditch as drain A11a/b, where Golson had recorded a composite structure (no. 3 on Fig. 16.3) with Tibito Tephra at the base of its latest phase showing this to be Phase 5. It seems likely that no. 2 was a feature belonging to the east bank of Simon's Baret, where indeed there was a Phase 6 house that we have already mentioned not far away to the southeast (Fig. 15.13). This comment about belonging to the east bank of Simon's Baret is probably also true of a case of Phase 6 ditching just to the north across E–W Rd 1, at the southern end of drain B11a/b. Here there is a large composite ditch (no. 4 on Fig. 16.3), the latest stage of which was later than the fall of Tibito Tephra and the only example of Phase 6 digging seen anywhere along the nearly 250 m long drain.

There was only one other example of a Phase 6 feature noted in the walls of the nine drains dug in blocks B11 and B12 to the east of Simon's Baret and the northern parts of the five drains in block B10, which Simon's crosses from southeast to northwest. It was found at the very southern end of drain B11d/e (no. 5 on Fig. 16.3), where a ditch had been dug on the line of an earlier ditch that had a layer of Tibito Tephra at the bottom of its infilling. There was no evidence of other Phase 6 digging with which it could be connected. It occurred quite close to a large ditch recorded by Jim Rhoads in 1973 in the south wall of the north drain of E–W Rd 1 that also had a layer of Tibito Tephra at the bottom of its fill with, however, no subsequent redigging. Rhoads gave this the identification number 2000 (no. 6 on Fig. 16.3) to anchor it in the record and his memory.

Rhoads had already recorded a similar ditch in the north wall of the south drain of E–W Rd 1 (no. 7 on Fig. 16.3) and realised that the two ditch exposures were in line with no. 3 of drain A11a/b and no. 2 of drain A10/11, both of which have been discussed above. Because of this, it was thought for a time that the alignment in question was a Phase 6 structure performing a similar function to that of the Phase 6 ditch running to Simon's Baret from the vicinity of Hed Mound (see Fig. 16.3). As we have just indicated, however, the new alignment belonged to Phase 5 and had only been reutilised in Phase 6 close to Simon's Baret.

The rarity of Phase 6 ditching in the A and B blocks east of Simon's Baret contrasts with the prominence of earlier ditching in these areas (cf. Fig. 15.13) and is likely to be equally true of the blocks to the north (see Fig. 16.5 here), where few drains were dug apart from road drains. Of course, not all the Station drains that were dug to the east of Simon's and Wai's were dug and recorded with the problems of Phase 6 ditching in mind. This is the same caveat as that we attached to our exercise in Chapter 15 using the lie of Tibito Tephra in relation to Phase 5 ditching to assess the degree of disintensification there had been during the course of the phase before it came to an end (see Chapter 15, section 'Reasons for disintensification').

Ditches continued to be maintained between Simon's and Wai's Barets, but their number decreased. Already during Phase 5 there had been a decline in drainage density, from an early level of 1740 m/ha to 1240 m/ha in late Phase 5 (see Chapter 15, section 'Ditch networks and field systems'). In Phase 6, this decline continued, with an average ditch density of 1090 m/ha.

Figure 16.5 Looking north to the slopes of Ep Ridge across the fossilised evidence of Phase 5 ditches and gardens on land that became pig pasture in Phase 6.

The two lines across the swamp belong to drains for the road grid in the eastern part of Kuk Station, specifically for E–W Rds 3 and 4 to the east of N–S Rd 4, View of future blocks C10 and 11 in the bottom of the image and D10, 11 and perhaps part of 12 between the Station drains.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

The major disposal channel: Wai's Baret

Wai's Baret, which was established at the beginning of Phase 5 and maintained throughout it, was still functioning at the onset of Phase 6 and only needed cleaning out. The need for channel maintenance must have become more pressing because of more intensive cultivation and pig rooting in the southern catchment of Kuk Swamp (Hughes, Sullivan and Yok 1991: 235). This led to an increased sediment load and the clogging up of disposal channels. Despite these growing drainage problems, the cross-sectional profiles of Wai's Baret show that the Phase 6 channel was a distinctly shallower and narrower feature than its Phase 5 predecessors (see Fig. 15.7).

The trend already established in the previous phase therefore continues, with a progressive decline in the investment needed to maintain a deep and hence efficient major disposal channel. The late Phase 5 channel had an area of about 2.0 m^2 in cross-section, which already implies something like a 33 per cent decline in hydraulic capacity since the beginning of Phase 5. The Phase 6 channel is even smaller, with an area of about 1.5 m^2. This represents a further 25 per cent reduction compared with the late Phase 5 channel. In summary, by Phase 6 Wai's Baret has shrunk to only half of the capacity that it had in early Phase 5 times.

Overall, these data suggest a continued decline in the amount of labour exerted in the maintenance of the major disposal channels. It seems unlikely that the discharge carried by Wai's Baret declined between early Phase 5 and Phase 6; indeed, we have cited Hughes, Sullivan and Yok (1991: 235) for its likely increase because of accelerated runoff in the catchments promoted by increasing cultivation there. The inference must be that Wai's Baret became less efficient in evacuating water and was progressively more prone to overbank flow during high-discharge events. As argued in Chapter 15, section 'The major disposal channel: Wai's Baret', the early Phase 5 cross-section of Wai's Baret was probably effective in preventing flooding of garden lands adjacent to the channel except for the 'once in a year' large flood. Unless we invoke a decline in rainfall because of climate change, and so less runoff, we must conclude that by Phase 6 times Wai's Baret would have been progressively less efficient at preventing flooding.

Minor disposal channels: Simon's and Korowa's Barets

We see the same decline in hydraulic capacity in the minor disposal channels. For example, Simon's Baret in block A11 had a depth of only 0.9 m compared to 1.4 m for its Phase 5 predecessor (see Fig. 15.8). As well as being deeper, the earlier channel had steeper sides and was probably narrower.

The same is true of Korowa's Baret in D9 (Fig. 16.6). Here we can extrapolate ditch shapes from their surviving traces and so generate an estimate of the cross-sectional area of Korowa's Baret where the upper level, equivalent to bank-full discharge, is defined by the height of the contemporary garden soil. The channel's capacity changed as follows:

- early Phase 5: 1.7 m^2
- mid-Phase 5, early: 1.8 m^2
- mid-Phase 5, late: 1.7 m^2
- late Phase 5: 1.5 m^2
- Phase 6: 1.2 m^2

Again, the Phase 6 channel is wider as well as shallower than its Phase 5 predecessors.

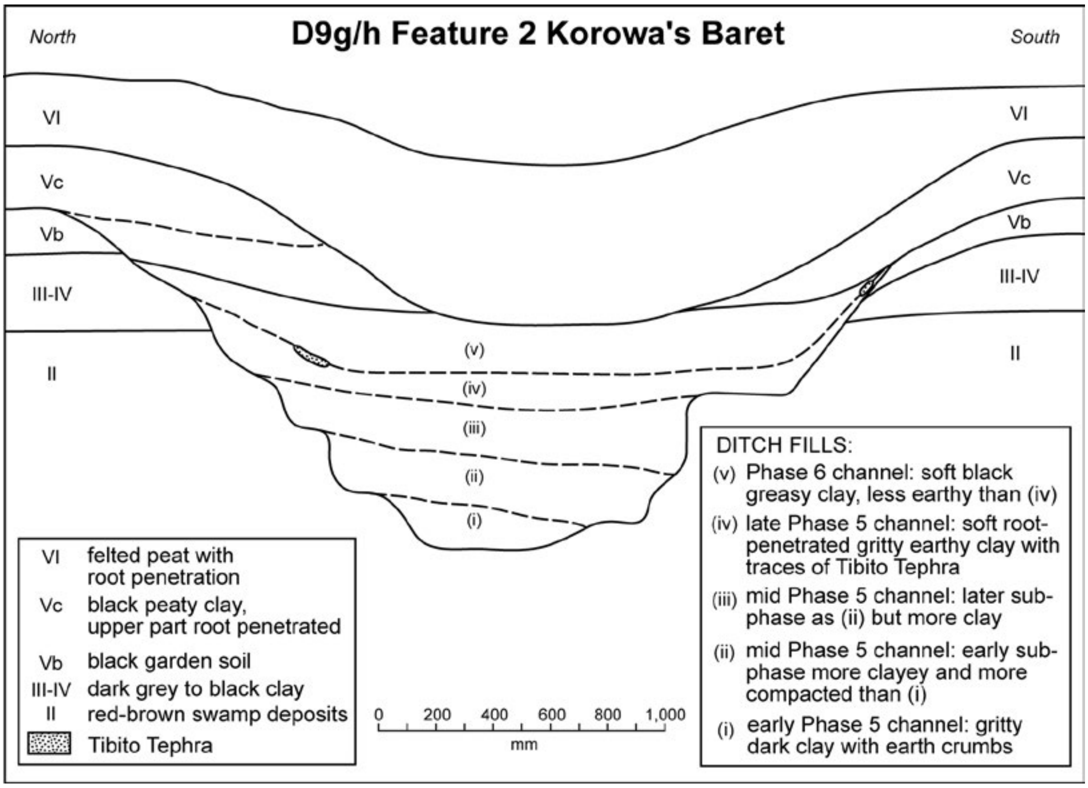


Figure 16.6 Cross-section through Korowa's Baret at drain D9g/h.

Korowa's Baret was a minor disposal channel, tributary to the major disposal channel, Wai's Baret, and draining the northeastern margins of Kuk Swamp. The stepped walls of the ditch give evidence of four subphases of construction before the fall of Tibito Tephra that marked the end of Phase 5 and there are four corresponding episodes of fill, i–iv. As with Wai's and Simon's Barets (Figs 15.7 and 15.8), the Phase 6 channel is much wider and shallower than its predecessor.

Source: Drawing by Philip Stickler based on a 1975 field record, Kuk archive.

The minor field ditches

How far are these changes in the major disposal channels mirrored in the size and shape of the field ditches that connect to them? A direct comparison can be more readily made near the southern margin of Kuk Swamp, as more Station drains were dug there and the recognition of Phase 6 ditches was easier. Thus, while six N–S drains were dug in block C9 (see Figs 15.4 and 16.3), they sampled more of the ground northeast of Wai's Baret, which was uncultivated in Phase 6 and used for housing, and less of the ground to the southwest, which was cultivated, as discussed above. The sampling adjacent to Wai's Baret in the D blocks was similarly skewed.

In contrast, block A9, which represents the swamp margins, remained in cultivation throughout Phases 5 and 6. Here Phase 6 ditches were dug while the drainage lines of late Phase 5 were still visible, so that most of the Phase 6 network is directly superimposed on that of Phase 5. The general shape of ditches is broadly similar (Figs 16.7 and 16.8). However, our measurements of the cross-sectional areas of samples of more than 20 ditches for each phase show that while their widths are scarcely different, in almost all cases the Phase 6 ditches were shallower features. As a result, their cross-sectional areas averaged only 0.225 m², representing a 24 per cent decline since Phase 5 and matching the smaller size of Wai's Baret.

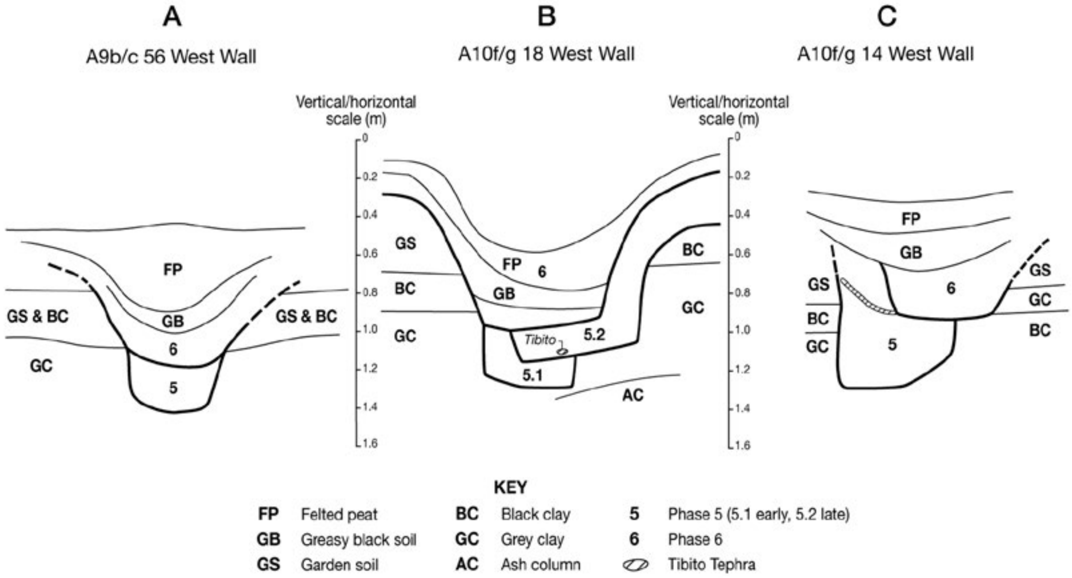


Figure 16.7 Contrasting examples of Phase 6 field ditches.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

The earliest stage of each ditch is deeper and narrower than anything later, as it is in the larger channels (see Figs 15.7, 15.8 and 16.6). In the case of C shown in Fig 16.7, the early structure is Phase 5 by the evidence of the Tibito Tephra lens high in its fill. In the case of B, Tibito is present in the form of a small nodule at the base of the second-stage ditch, suggesting that while the first stage is earlier than the fall of the ash, the second stage is not as decisively so, since the ash nodule could have arrived later via root activity. In the case of A, there is nothing to prove stratigraphically that the first stage is Phase 5, but the case could be argued on grounds of its fill, which is more consolidated than that of the stage above and described as typical of young deep ditch fills. The fill below the Tibito Tephra in the earliest stage of C is fine and firm, while that in the two early stages of B is a firm earthy clay much the same in both stages.

Turning to the later stages of each ditch, we note that B has a late Phase 6 stage with very little infill below the felted peat and the greasy black, both of which dip steeply into the ditch, leaving distinct evidence of the latter's presence in the form of a large hollow at the surface. In the case of ditch A, the primary fill dips deeply above its base and the greasy black and felted peat do the same above. In this case, however, as distinct from that of B, felted peat has gone on to fill the hollow below and to lie level with, or indeed slightly above, the ground surface. In the case of C, the Phase 6 ditch seems to be considerably younger than the deeper Phase 5 ditch into which it is dug, by virtue of the fact that its primary fill is very root-penetrated. Because this fill is thicker than at the other two ditches, there is only a slight dip of greasy black and felted peat above it and only a faint hollow at the surface.

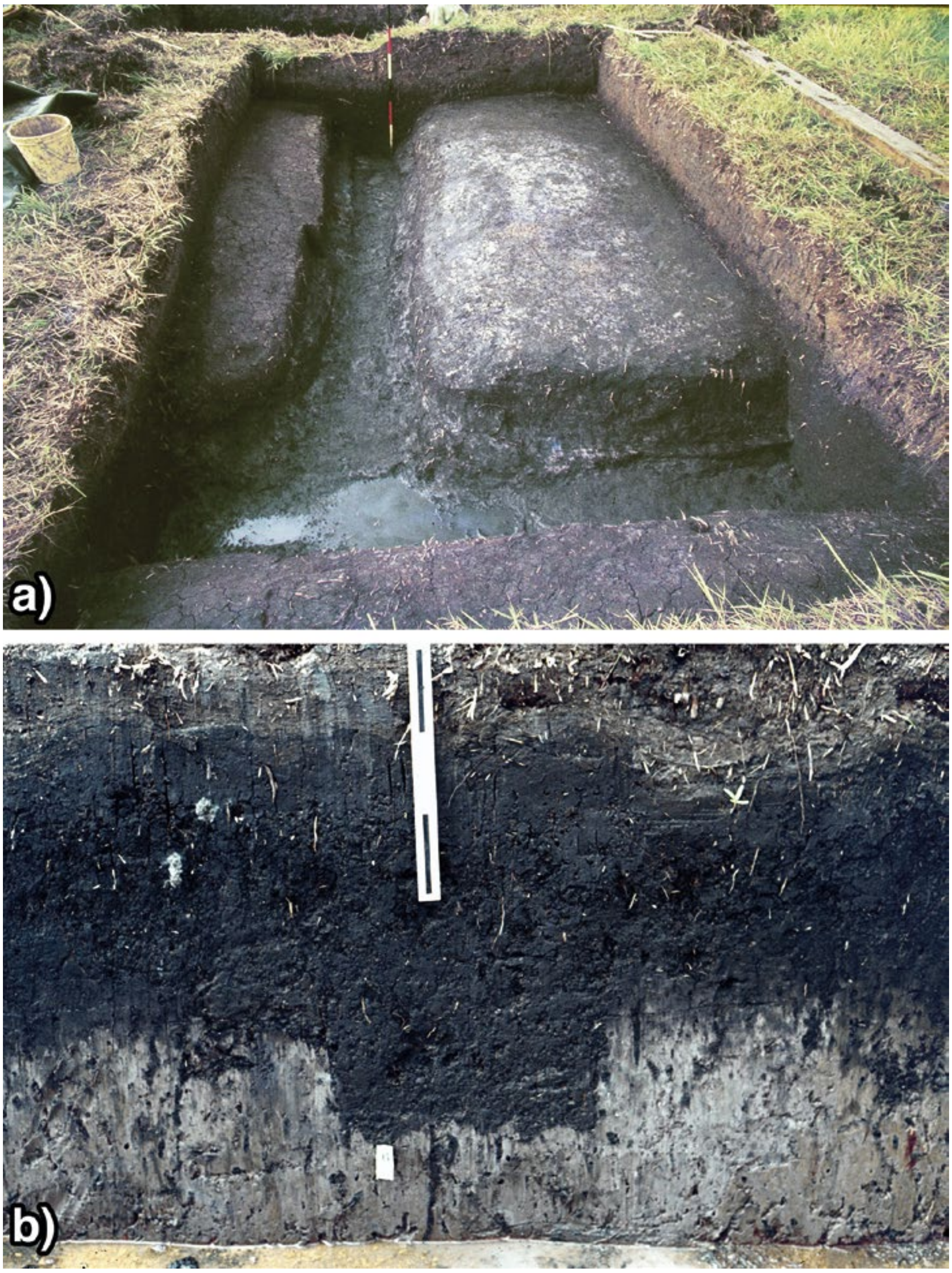


Figure 16.8 Phase 6 garden ditches.

In a) the view is SSE over Ambrose's 1972 excavation of the junction of two of the longer-lived ditches of the garden network. The site is block A9b, the second from the left of the N–S strips south of E–W Rd 1 in Figure 16.2, adjacent to the third drain from the left, A9b/c. The cross-ditch visible in the aerial view of Figure 16.2 is Baret 1 of Figure 16.12. Both ditches in a) show complex profiles from redigging. Ambrose's field record of the profile of the N–S ditch in the south wall of the excavation indicates four episodes of digging, each progressively wider and shallower than its predecessor. The fill associated with the third stage includes Tibito Tephra, meaning that only the fourth and last belongs to Phase 6. Note the rise in the ground surface in the back wall. The ranging pole is graduated at 200 mm intervals. b) shows a simple ditch of the Phase 6 garden grid in the west wall of drain A9E, dug down into the top of grey clay and visible in the garden soil above it. The overlying layers of felted peat and greasy black are well developed. The scale is graduated at 100 mm intervals.

Source: Photographs by Wal Ambrose, Kuk archive, 1972.

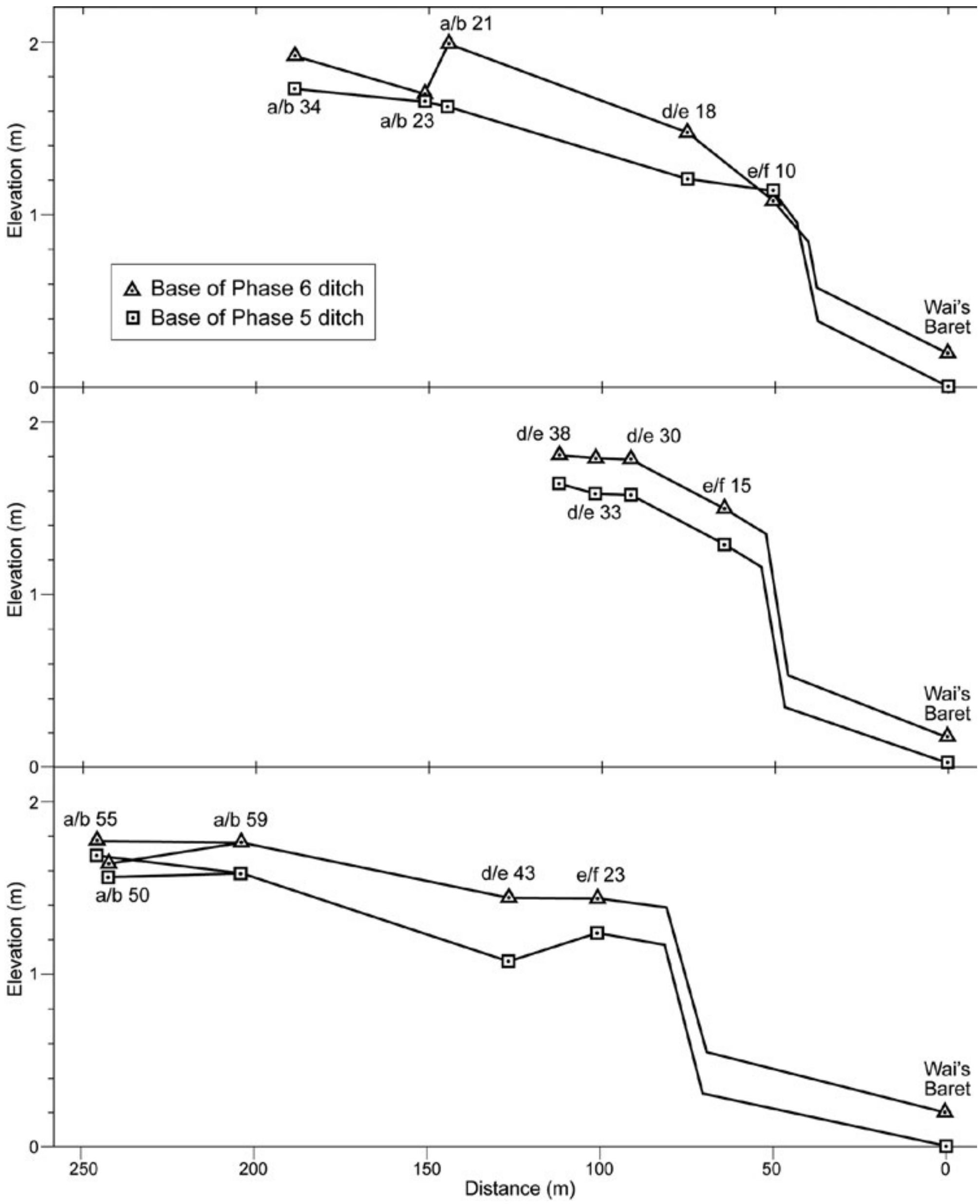


Figure 16.9 Hydraulic gradients along three lines of Phase 5 and Phase 6 drainage.

The presentation moves from minor field drains through major field drains to the major disposal channel, Wai's Baret (at Section A of Figs 15.2 and 15.7). The vertical scale has a 50x exaggeration.

Source: Drawing by Ian Agnew after Bayliss-Smith et al. (2005: Fig. 3), reproduced with permission.

For the bottoms of many ditches, levelling data are available that show their elevation relative to each other as we move 'upstream' from Wai's Baret (Fig. 16.9). Apart from a few cases of over-deepening, it is clear that at all times an efficient hydraulic gradient was maintained between the fields served by the minor ditches and the major disposal channel, Wai's. In both Phases 5 and 6, the field ditches are dug to an elevation about 1.6 m above the base of the disposal channel. However, although still functional in hydraulic terms, the Phase 6 network as a whole drains the land at a shallower level, about 0.2 m above the levels of Phase 5. As well as this shallowing of all ditches, there is the decline in cross-sectional areas, which makes it seem reasonable to describe the Phase 6 drainage network as less effective and more liable to flood hazard than the previous one.

Raised garden beds at the swamp margins

In block A9, surface indications of the youngest ditches of the Phase 6 system were revealed by clearing away the swamp grass cover after drains had been dug across it according to the Station plan (Fig. 16.10). The evidence of these visible ditches was supplemented by a systematic search for ditches of the same age that were not visible but were discoverable by probing the surface to detect their soft fill (Fig. 16.11). Identification of ditches and their mapping was carried out by Wal Ambrose and Winifred Mumford (Fig. 16.12). Comparing the ditches recorded in profile in the walls of four Station drains cut across A9 with those mapped by Ambrose and Mumford across the blocks between them indicates that the map gives a conservative and in places an incomplete picture of the latest Phase 6 activity. Nevertheless, it provides a reasonable basis for comparisons with other drained areas and other drainage phases.

Figure 16.10 Looking north to Ep Ridge from Blong's Nob, (for location see Figure 16.3) across the surface indications of Phase 6 ditches and gardens west and east of drain A9c/d at the centre of the image.

The linear hollows mark the course of ditches where with drainage the ditch infill and surface peat have shrunk, emphasising the built-up garden surfaces between them.

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

Figure 16.11 Mapping Phase 6 ditches in block A9.

Not all the ditching associated with the latest Phase 6 gardening system in block A9 was uniformly visible at the surface when Wal Ambrose and Winifred Mumford, helped by Mary-Jane Mountain, began mapping; compare ditch profile B of Figure 16.7 here with those of A and C. The problem was to find the dips in the surface below the felted peat and greasy black that would indicate the presence of a hidden ditch belonging to the youngest network. The answer was the use of a flexible spear with a small washer at the end to sense the firmer fill below the felted peat and greasy black. When a dip was found, sticks of *pitpit, Saccharum spontaneum*, of standard length were pushed down to mark its cross-section and single sticks to mark its course. The prodding was done at regular intervals to reveal a pattern that could then be mapped. The strips of land, looking south along block A9b, are at this stage of readiness, as indicated by the 'forest' of *pitpit* sticks across them, Ambrose's inspiration for the technique he employed was kauri gum digging in his native New Zealand and he had already pioneered it archaeologically there, as described by Shawcross (1976: 280).

Source: Photograph by Wal Ambrose, Kuk archive, 1972.

Figure 16.12 The Ambrose/Mumford map of Phase 6 ditches plotted in 1972 in block A9, as shown in Figure 16.11.

The map is based on ditches visible as surface features after vegetation clearance and partial drainage and on non-visible segments of the network found by prodding the surface to locate their fill. The appearance of the ditches in the walls of the drains that were dug across them was another source of evidence. The four drains of importance in this respect are shown on the map. A fifth drain, A9c/d, was dug but because of problems with wall collapse it could not be used to record ditch crossings in the drain walls. As a result, it is not shown on the map, though it is prominent in photographs, e.g. Figure 16.10, where it is the central feature.

Source: Drawing by Ian Agnew, after Bayliss-Smith et al. (2005: Fig. 6) (reproduced with permission) and based on a 1972 field map by Wal Ambrose and Winifred Mumford in the Kuk archive.

The map shows a higher density of Phase 6 ditches in A9 (1880 m/ha) than existed at lower elevations in blocks A10 and 11 at this time (1090 m/ha). As in Phase 5, the spoil served to raise the garden bed (see Fig. 16.8a). In addition, there is clear evidence that people were using other local sources of soil for the construction of raised beds. The evidence comes from three parts of the mapped area: Area A north of Baret 1, Area C north of Baret 3 and Area D south of Baret 3 (see Fig. 16.12). In all three areas, we see an increased thickness of the stratum of garden soil compared with Area B between Barets 1 and 2 and the replacement of the felted peat of Area B, which is the normal post-abandonment cover of the swamp, by a thinner root mat signifying an elevated land surface. Some of these observations would be relevant to the situation depicted in Figure 16.8a, which is at the place where the higher surface of Area A gives way to the lower surface of Area B.

The 100–150 mm of added material in Area A, which in places is visually differentiated in the stratigraphy, most probably came from sediments building up in Wai's Baret. It was perhaps the later dispersal of this added soil that obscured the ditches close to Wai's, which therefore were not mapped in 1972. About the same amount of added material in Area C, not stratigraphically visible, may have come from Baret 3 and/or the clays of Blong's Nob. Material from the same source(s), visible in the stratigraphy, raised the ground surface immediately south of Baret 3 in Area D to a level 150–340 mm above the surface elevation immediately to the north.

Interpretation

An overview of the evidence

Except at the swamp margins, the evidence suggests that in most parts of Kuk Swamp the transition from Phase 5 to Phase 6 involved some disintensification of landuse. Not only was the major disposal channel, Wai's Baret, in a state of relative neglect, but also other parts of the previous drainage network had fallen into disuse or were being dug on a smaller scale. The deep swamp was turned over to pig grazing, while intermediate areas saw a decline in drainage effort and the associated development of areas of housing. Judging from the area sampled in block A9, only at the swamp margins were the Kuk cultivators still producing a high density of field ditches, although almost all the ditches were shallower than in Phase 5, requiring on average about 25 per cent less spoil to be removed. Along these margins, using the ditch spoil and other material derived from Wai's Baret, raised beds were constructed similar to the ones that had been used in Phase 5, and similar also to the beds cultivated in modern times for the sweet potato.

The amount of runoff entering Kuk Swamp in Phase 6 is unlikely to have diminished; indeed a more likely scenario is one of increased flooding following the spread of sweet potato cultivation in the southern catchments. Yet the changes in ditch morphology suggest that the ditch systems of Kuk were less able to deal with the incoming runoff. At the swamp margins, we see evidence for a substantial effort to raise the level of beds in order to maintain productive landuse, perhaps avoiding intermittent flooding. The general impression is that the major disposal channels were being somewhat neglected, as dryland sweet potato gardens became a more important component in the overall landuse system.

We suggest that the declining efficiency of Wai's Baret, as of the minor disposal channels Simon's and Korowa's Barets, resulted from the increasing importance of the dryland sphere of agriculture and its products. According to this scenario, in Phase 6 times Wahgi society became more and more focused on the sweet potato, pig husbandry and regional exchange—which was indeed the situation that existed in 1933, at the very end of prehistory—and less and less able or willing to invest labour in the maintenance of the major disposal channels. Perhaps, because wetland production was becoming obsolete, the increased crop losses due to flooding became more acceptable.

The construction of raised gardens near the swamp margin investigated in block A9 is another likely response to the deterioration of drainage in the swamp, due to more frequent flooding because of the smaller capacity of Wai's Baret. An alternative possibility is that the employment of raised-bed technology obviated the need for deep disposal channels. In either case, we see evidence for a continued agricultural role for the swamp margins, even in the era of the sweet potato. We cannot be sure if the sweet potato itself was being grown in block A9 at this time. Given the use of raised beds at Kuk during Phase 5, we cannot regard raised beds in themselves as conclusive evidence for the sweet potato's presence, but the balance of probability surely favours the new crop.

This is certainly the assumption that was made by our workmen, and accepted by us, when charred fragments of tubers were excavated at Phase 6 house sites in 1972 and published as sweet potato (Golson 1982: 132). They included a substantial piece of the end of a tuber (Fig. 16.13), which was subsequently identified by Jon Hather (pers. comm., ~2000), then of the Institute of Archaeology, University College London, as *Dioscorea esculenta*, the lesser yam.

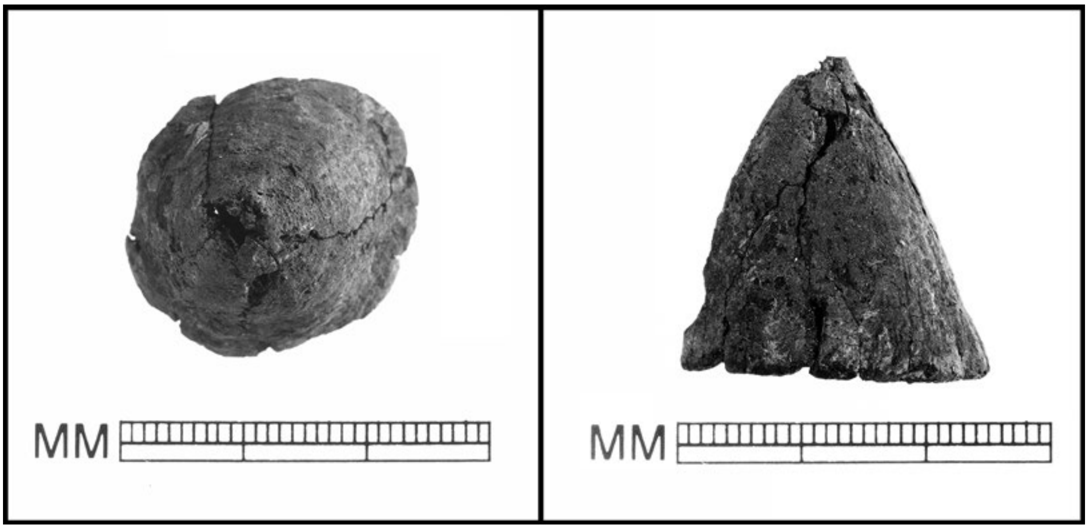


Figure 16.13 The charred end of a tuber excavated from a hearth in the front part of House B at Kuk (see Fig. 16.3 Inset and Fig. 17.5).

At left is the point of the tuber, at right is the point in profile. On discovery workers pronounced the piece to be part of a sweet potato and this was accepted by us outsiders as being the case. It was illustrated as such by Pamela Swadling (1981: 49) in her booklet on Papua New Guinea prehistory. Some 20 years later, it was identified as lesser yam (*Dioscorea esculenta*) by Jon Hather.

Source: Photographs by Bob Cooper and Darren Boyd.

Changing gender relations

The substantial appearance of houses in the swamp in Phase 6 is itself significant, as is the type of house that is found (see Chapter 17). The internal features of these houses match those observed by ethnographers in recent times and strongly suggest they were women's houses with space for pigs. Ethnographic analogy would point to the dispersed settlement pattern and the gendered division of labour that characterised the societies cultivating the sweet potato in the upper Wahgi in the 1930s (Vicedom and Tichner 1943–48: 143–145, 168–171; 1983: 159–161, 188–193). In the Mount Hagen area, since women had responsibility for daily sweet potato harvesting and pig husbandry, it was convenient for them to live near gardening and grazing areas (Strathern 1972: 54–60). In Kuk Swamp, the evidence strongly suggests an economy of sweet potato cultivation and pig grazing under women's management, within social space where women were important.

Emerging big-men and pig exchange

Although some men's houses were located not far away (see Fig. 16.3; cf. Fig. 17.3), perhaps the main focus of men's activities in Phase 6 was outside the swamp. We have already noted how ineffective were the efforts, presumably by men, to maintain Wai's Baret as a major disposal channel. By extrapolating from the reconstructed history of Enga (Wiessner and Tumu 1998; Wiessner 2002, 2005), we can suggest that by the 19th century most production at Kuk was coming from sweet potato gardens that were located in the dryland sphere. The social impact of this landuse change has been much debated.

Golson (1982: 130–135; cf. Golson and Gardner 1990: 407–408) proposed that the introduction of the sweet potato around AD 1700 initially served to 'democratise' access to wealth, especially wealth in the form of pigs foddered on surplus root crops. Previously, surplus root crop production supporting pig husbandry had been the preserve of a few privileged communities that had access to drained wetlands. After the sweet potato's potential to produce pig fodder on dryland sites had been demonstrated, even in grassland areas and at high altitude, the capacity to generate wealth became more widespread. In these circumstances, Golson suggested, big-men began to focus their attention on wealth items like pearl shell that were objects of genuine scarcity. It was an argument by analogy with the situation created by the arrival of Europeans in the upper Wahgi in the 1930s. Their possession of large quantities of previously scarce shells as payment for goods and services (Hughes 1978) threatened the exclusiveness of the regional system of ceremonial exchange (*moka*), whereby wealthy families monopolised pearl shell valuables and circulated them only amongst themselves.

An alternative model would emphasise a general escalation of exchange and the growing importance of large-scale pig production. Although direct evidence is lacking, we can envisage an escalation in the scale of *moka* activity during Phase 6 that parallels the growth of *tee* in Enga. Feil (1987: 263–268) has argued that *moka* and *tee* had an interrelated past, but that *moka* was the original institution. In the upper Wahgi Valley, participation in *moka* was organised under big-man leadership and was fuelled by the regional surplus of pigs. Perhaps we can find an ultimate explanation for swamp abandonment at Kuk in the competition for power that emerged between big-men and their rivals: 'potential antagonisms at most structural levels of the society … produced conditions inimical to the sustained operation of drainage systems' (Golson and Gardner 1990: 407).

Chris Ballard's ethnographic observations from Haeapugua in Southern Highlands Province confirm that ditching and garden projects alike fail principally through weaknesses of political coordination (Ballard 2001). The relative inefficiency of the Phase 6 disposal channels at Kuk could therefore reflect an extended period of political instability in the upper Wahgi Valley. Perhaps individual leaders found it increasingly difficult to assemble and coordinate labour, both male and female, on the scale necessary to sustain large-scale wetland gardens. In the 19th century, this unstable Ipomoean world culminated in the widespread abandonment of wetlands in the upper Wahgi, as escalating ceremonial exchange, warfare and perhaps epidemics undermined the fragile bond between big-men and their factions and diverted people's agricultural efforts in other directions.

Different histories for different regions

We should not expect this model necessarily to apply to other parts of the highlands. Each region has its own social history and particular landuse opportunities. In the upper Wahgi Valley, for example, large-scale wetland drainage, agricultural intensification and expanded exchange opportunities were already happening in Phase 4, 2000 years ago (Golson and Gardner 1990; Bayliss-Smith and Golson 1992a, 1992b, 1999; Chapter 14 here, section 'Kuk as a Phase 4 "hotspot"?'). Elsewhere, these features did not emerge until more recent times or not at all and exchange activity took different forms.

Wiessner (2002) has pointed out that in Enga it was the pig—previously circulated only for local feasts in the form of meat—that became the particular item of wealth that was targeted in Ipomoean times. The sweet potato's tolerance of marginal soils and higher altitudes encouraged population migrations that began to destabilise former intergroup relationships. In response, certain groups intensified the exchange relations that involved the movement of pigs over long distances and it was these expanded networks that evolved into the *tee* cycle.

To move pigs over long distances implies that the animals must be kept alive and therefore they will become troublesome if they are not fully tamed. The need for larger numbers of tame pigs requires a form of full domestication in which all stages of the pig's life cycle are regulated (Kelly 1988). In this new regime, piglets would be foddered from an early age by their owners, normally married women, making possible their easy transfer to new owners once the animals reached maturity. Among the Etolo, living on the fringes of the Southern Highlands, the piglets are kept with people day and night and are pampered and foddered for about six weeks before they become fully bonded. The young pigs can then be allowed to feed themselves in abandoned (but still fenced) sweet potato gardens, and when mature they can be traded (Dwyer 1990: 57–58). With adoption of the sweet potato, larger and more permanent settlements can be established, the forests are cleared and game animals become scarce (Dwyer 1990: 186). For the Etolo, these can all be seen as consequences of the transition from taro, yams and sago towards sweet potato as the main staple.

In Enga, a more intensive form of root crop production, a gendered division of labour and a distinctive settlement pattern are among the predicted consequences of the new pig husbandry (Wiessner 2002, 2005). If we transpose this model from Enga to Wahgi Valley, then any archaeological evidence for intensified root crop production and full pig domestication might signal similar changes in Wahgi society in the Ipomoean period, culminating in the ethnographically documented *moka* cycle. However, the chronology of such changes might well be different in the two areas, as the upper Wahgi Valley has a much longer prehistory of deforestation, agricultural intensification and regional exchange. John Burton (1984: 227–228), for example, shows how regional systems of trade, as inferred from the wide distribution of axes of high-quality stone from a few localised quarries, developed in the period between about 2500 and 1200 years ago. As Burton says (1984: 248), this can broadly be correlated with Phase 4 of drainage intensification at Kuk (cf. Chapter 14, section 'Kuk as a Phase 4 "hotspot"?', and Chapter 21, section 'The age of the axe trade in the upper Wahgi'). In contrast, in parts of Enga 250 years ago there was still a dependence on mixed swiddens, hunting and foraging (Wiessner and Tumu 1998: 56–66). Moreover, in the Wahgi the extensive dryland terraces, lower hill slopes and foothills represent a large and accessible land resource suitable for sweet potato, whereas in Enga a large expansion in the cultivated area had to await a colonisation of the high-altitude zone.

In the Wahgi, we might therefore expect to see an early and widespread abandonment of wetlands in the Ipomoean period. There are indeed indications that this happened, not just at Kuk but more widely, given the absence of evidence for post-Tibito drainage from the admittedly limited investigations at Warrawau Tea Estate, to the west at Minjigina on the slopes of Mt Hagen and down the valley to the east at Kotna and at the Kana site near Minj (Golson 1977a: 628; 1982: 121; Muke and Mandui 2003; cf. Chapter 15, section 'The regional geography of Phase 5'). The widespread patterns of former drainage that are visible from the air may represent very largely pre–sweet potato cultivation, i.e. Phase 5 in Kuk terms (e.g. in the North Wahgi Swamp as shown in Fig. 16.14).

We have already pointed out in Chapter 15, such a situation would explain the lack of an oral tradition of large-scale drainage among the older inhabitants of the Mount Hagen region questioned on the matter in 1972–73 by Ian Hughes (pers. comm., cited by Golson 1977a: 628). As noted earlier, the oral histories suggest that there were widespread population movements in the recent past, connected to warfare and perhaps also to the spread of malaria into the upper Wahgi Valley (see also Chapter 22, sections 'Histories of movement and warfare' and 'Kawelka settlement history'). In the process, localities like Kuk Swamp became deserted and new concentrations of population emerged on the volcanic apron of Mt Hagen and the slopes of the volcano itself to the west, areas where Strathern (1971: 15–19) notes the largest upper Wahgi tribes as now living (Fig. 16.15). He also points to the vast range, from 68 to 6749, in the populations of the recognised 'big name' tribes of the region and underlines the need to take diachronic processes into account when considering questions of group structure. We have indicated a number of potentially relevant factors in the upper Wahgi case: sweet potato, malaria and the demise of wetland cultivation.

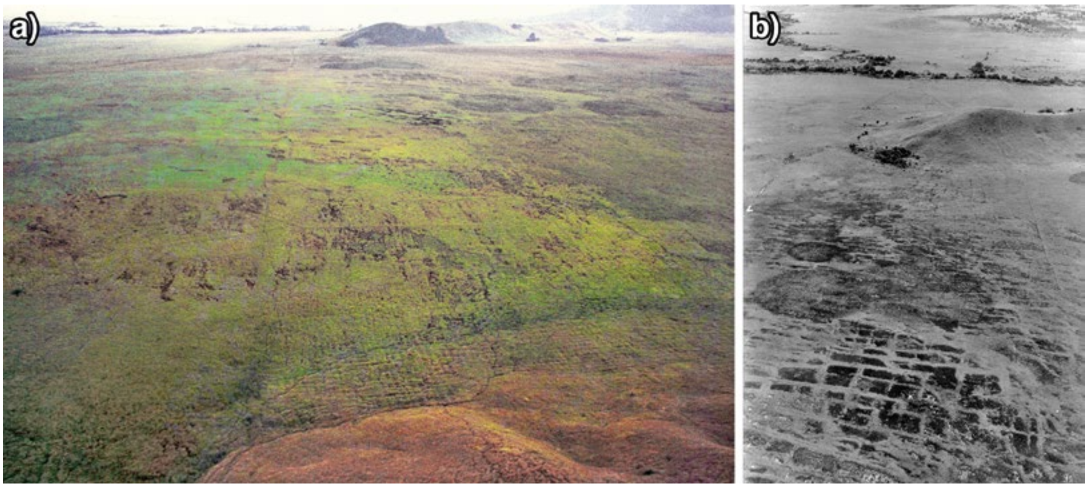


Figure 16.14 Looking across the North Wahgi Swamp between Ep Ridge and Mugumamp Ridge at fossil ditches and cultivations thought more likely to be Phase 5 than Phase 6.

a) is a wide view NE from above Ep Ridge in the foreground to Mugumamp Ridge, top centre right, and the tree-lined course of the Gumants River, top left. The first European patrol into the area in 1933 reported no signs of human presence or activity at Ep Ridge, the North Wahgi Swamp to its north or Kuk Swamp to its south (see Chapter 23). b) A closer view of one of the areas of old ditches and cultivations between Ep and the western end (cf. Fig. 12.19).

Source: Photographs by Wal Ambrose, Kuk archive, 1972.

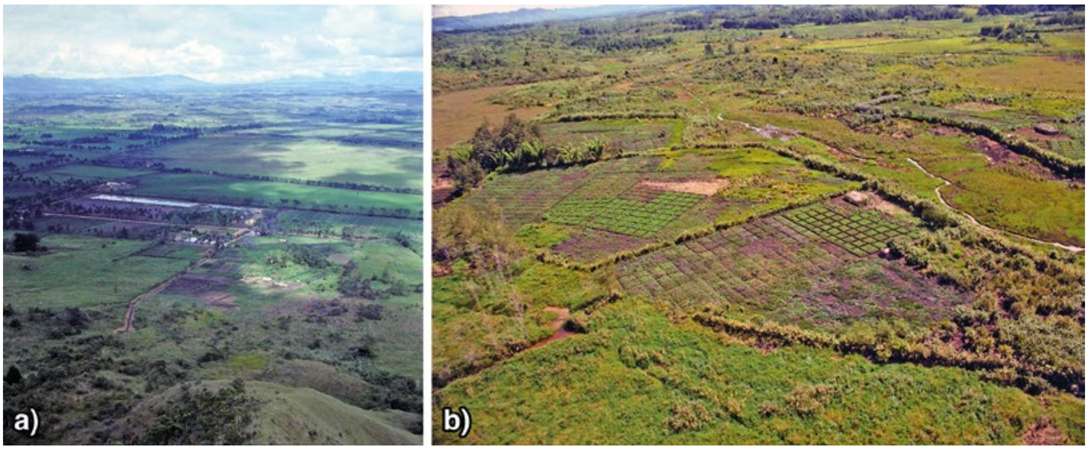


Figure 16.15 The changing distribution of upper Wahgi population. a) A view west from Ep Ridge and Baisu Corrective Institution over the upper Wahgi Valley floor.

The floor of the valley lost population in Phase 6 to what Russell Blong (1986: 288) calls the Mt Hagen volcanic apron, on which new population centres emerged. The apron edge can be recognised by the level line it forms across the picture above the irregular escarpment that separates it from the valley flats. The apron extends back from this edge to the higher country beyond. b) On the apron there is a managed landscape of grassland, shrubby regrowth and cultivation. The dispersed nature of settlement can be seen in the scattered distribution of the long round-ended women's houses and the clumps of planted bamboo and useful trees.

Source: Photograph A by Ed Harris and B by Paul Gorecki, Kuk archive, 1977.

Another history of population growth and movement following the introduction of the sweet potato is reconstructed from Engan oral histories by Polly Wiessner and Akii Tumu (1998: 49–52, 55–56, 75, Appendix 2; cf. Wiessner 2005: 121, 127). They estimate a foundation population of some 10,000–20,000 about 250–300 years ago, ranging from sedentary horticulturalists in eastern Enga between 1500 and 1900 m altitude to scattered mobile groups above 2100 m in the extensive high country of western Enga, heavily dependent on hunting and gathering. The new plant was readily accepted in areas of high altitude or poor soils, but there were significant population movements overall as subsistence strategies changed to take advantage of its arrival (Wiessner 2005: 127). Today, the region is home to 150,000 Engan speakers. A similar process of population growth can be envisaged for the upper Wahgi valley, but such estimates have not yet been attempted.

Conclusion

We conclude that the large-scale abandonment of wetlands, the establishment at Kuk of women's houses adjacent to the swamp that was used for cultivation and pig grazing and the neglect at Kuk of major disposal channels were all rather immediate symptoms of the sweet potato's arrival in the Wahgi and its subsequent social and demographic effects.

Phase 6 at Kuk corresponds chronologically exactly to the period after AD 1700, when an Ipomoean Revolution has been confidently reconstructed for the highlands of New Guinea from oral histories (e.g. Ballard 1995, 2001; Wiessner and Tumu 1998; Wiessner 2002). The archaeological evidence shows that at Kuk three kinds of wetland responded differently to the suggested adoption of the sweet potato within the regional economy.

a. The southeast–northwest line of the Phase 6 water-disposal channels, Simon's and Wai's Barets, came to mark the boundary between uncultivated deeper swamp to the north and east and cultivated swamp margin and higher ground to the south and west. The abandoned areas were used instead for extensive pig grazing. Women's houses with stalls for pigs were established on the banks of the major disposal channels. The maintenance of these channels was somewhat neglected.

b. Swampland of intermediate elevation (e.g. A10 and 11 southwest of Simon's Baret) saw continued cultivation, possibly of the same crops as in pre-Ipomoean times; but ditch maintenance was at a lower level of labour intensity.

c. Drier swamp margins (e.g. A9) saw continued intensive cultivation, maintaining a high level of drainage density, although the individual field ditches were somewhat shallower. There is evidence for soil being moved for raised-bed cultivation. We cannot be certain about what crops were being grown, but by ethnographic analogy, sweet potato is a strong possibility.

The archaeological evidence reviewed in this chapter has not so far been supplemented by archaeobotanical evidence of the crops themselves (cf. Chapter 20, the second paragraph above 'Conclusions'). As a result, we cannot identify with certainty the moment of the sweet potato's arrival in the wetland sphere of cultivation. Even the direct proof that was once cited for its presence no longer exists, since the claimed sweet potato fragment proved to be yam (see Fig. 16.13). Nor is it possible to reach firm conclusions about landuse on the basis of ditch morphology, network hydrology and inferences from abandonment, although the evidence does point towards wetland disintensification, which is consistent with the growing success of dryland sweet potato cultivation.

What we can reconstruct from Kuk is consistent with a process of intensification in the dryland sphere based on the sweet potato and associated with big-men, large-scale pig production and more coercive gender relations. By itself, the Kuk evidence of ditches and field systems is not unambiguous. However, when combined with the local evidence in Phase 6 of women's houses with pig stalls located adjacent to grazing land, plus the abandonment of large-scale swamp drainage throughout the upper Wahgi, then a clearer picture of the Ipomoean landscape is starting to emerge.

Appendix 16.1: A Final Note About the Shell Trade

Jack Golson

Since Ian Hughes (1977) wrote his treatise on New Guinea stone age trade, there has been an intriguing discovery, of presently unknown significance, at the Yuat River, some 120 km upstream from where Mead and Fortune saw pearl shell being traded down to the Sepik in 1932 (see Chapter 16). At the Ritamauda rockshelter, Paul Gorecki excavated evidence of five traditionally traded marine shell species, including two fragments of gold lip pearl shell (*Pinctada maxima*). The finds were made in the two lowest horizons, IV and V, of a sequence of fluctuating site use that may have ceased a couple of hundred years before European contact (for the excavations Gorecki 1989: 153–155; for the shells Swadling and Anamiato 1989: 226–227).

The trade shells were scattered through the 1.35 m depth of Horizons IV and V, with the two pearl shell pieces in the top spits of Horizon IV (Swadling and Anamiato 1989: Table 11.1). There are problems with the chronology of these lower horizons at Ritamauda (Golson 2005: 472). However, the radiocarbon dates for the top 100 mm of Horizon IV and the bottom 200 mm of Horizon III[1] give a calibrated range, at two standard deviations, of 3240–1820 BP.[2] This suggests

1 Respectively ANU-3947, 2670±180, and ANU-3946, 2090±120, Head and Gillieson 1989: Table 7.5.

2 ANU-3947 calibrates to between 3240 and 2340 BP and ANU-3946 to between 2340 and 1820 BP, rounded off to the nearest 10 years. BP (Before Present), is AD 1950 by radiocarbon convention.

that none of the trade shells at the site is younger than around 2000 or 3000 years, which is at the same time a reasonable estimate for the age of the two late-occurring pearl shell items. Swadling and Anamiato (1989: 226) say that these last shells would have come from slightly sickle-shaped slivers similar not only to those still worn by people in the upper Yuat as nose ornaments, and once common in the upper Wahgi, but also to pearl shell lengths strung in other ways in the Sepik lowlands and the upper Karawari.

Based on her study of the unpublished fieldnotes of Mead and Fortune on the middle Yuat in 1932, McDowell (1989: 31–32) notes of the riverine trading system by which mountain products moving downstream were exchanged for those of sea and river moving up, that there was one exception: 'the highlands shell breast ornament came down out of the highlands and went downriver in exchange for shells' (1989: 32). McDowell (1989: 33, footnote 8) says that while it is not clear what Mead meant by 'highlands shell breast ornament', it is likely to be the pearl shell crescent whose south coast provenance and importance in the upper Wahgi have been indicated in Chapter 16.

Perhaps the pearl shell at Ritamauda, though deriving from a pearl shell sliver and not a crescent, has the same ultimate provenance. Swadling (1994: 141–142) cites Landtman (1927) for the manufacture of both crescents and slivers of pearl shell at Torres Strait and their onward trade at the time of his fieldwork in the area. As yet, however, we know little of the chronology of the shell industry there.

17

Houses in and out of the Swamp

Jack Golson

In the 1930s, the settlement pattern of the upper Wahgi Valley was one of scattered homesteads. Our information comes from areas above the valley floor, so there is no mention of any swampland dwellings. According to Georg F. Vicedom, who in 1934 established the Lutheran Mission at Ogelbeng on what Russell Blong (1986: 288) calls the southeastern apron of the Mt Hagen volcano, homesteads were loosely grouped in settlements sharing the same name, which could contain from three to over 20 dwelling houses and averaged around eight to 10 (Vicedom and Tischner 1943–48: 143–145, 147, 156; 1983: 161, 165, 175). The focus of such settlements was a ceremonial ground established by a clan leader, who had his men's house there. The other houses of the settlement were built at varying distances. They consisted of the men's houses of other polygamous males of the clan, separate women's houses for each of their wives and her children, and family houses where monogamous couples lived with their offspring.

Houses at Kuk Swamp

Distribution and location

Traditionally, houses had some form of shallow ditch dug close to the wall to collect water from the eaves and channel it away, the spoil from its digging being piled against the wall (Vicedom and Tischner 1943–48: 163; 1983: 183). At Kuk, we discovered that in the past houses had also been built in the swamp, with ditches sometimes close to a metre deep to act as sumps. The material dug from the ditch was used to raise the floor above the level of the swamp and sometimes the underlying grey clay of the swamp stratigraphy came to form the floor itself (Fig. 17.1). The practice meant that house sites appeared as mounds in the swamp (Fig. 17.2). Most of the sites shown in Figure 17.3 were recognised because of this.

Most house sites were discovered in 1972, the first year of the Kuk project, when the dry season was long and very dry and major drainage was done in the eastern half of the Research Station (cf. Fig. 17.3 and Golson 1976: Fig. 3, which maps the house sites discovered in 1972). In the course of draining block A9, where our work started, we noticed that water from the last rains of the season was collecting in linear surface hollows across the corridors that our workmen had cleared through the thick swampgrass cover in preparation for the digging of north–south drains at 22.5 m intervals. We soon realised that these surface hollows marked the drainage lines of former field systems visible on the aerial photographs that we used to plan our archaeological strategy. We put our workmen to clearing, by bushknife, the whole of block A9. This exposed not only field systems and the major disposal channels that served them, but also, in the northeast corner of the block, the first house mounds.

Figure 17.1 Looking east over House B at an early stage of excavation.

The earth from the house ditch raised the level of the floor, making the site visible at the surface when the swamp grass was removed (cf. Fig. 17.2). The grey clay through which the ditch was dug served to make the floor itself. The plan of the house after excavation is shown in Figure 17.5 and its location in Figure 17.3 Inset 1a. The ranging pole lying along the north edge of the excavation is graduated at 200 mm intervals.

Source: Photograph by Ron Lampert, Kuk archive, 1972.

Figure 17.2 A mounded house site revealed at the swamp surface at the southern end of block B9 (see Fig. 17.3 for general location) after the removal of the swamp grass.

Source: Photographer unknown, Kuk archive, 1973.

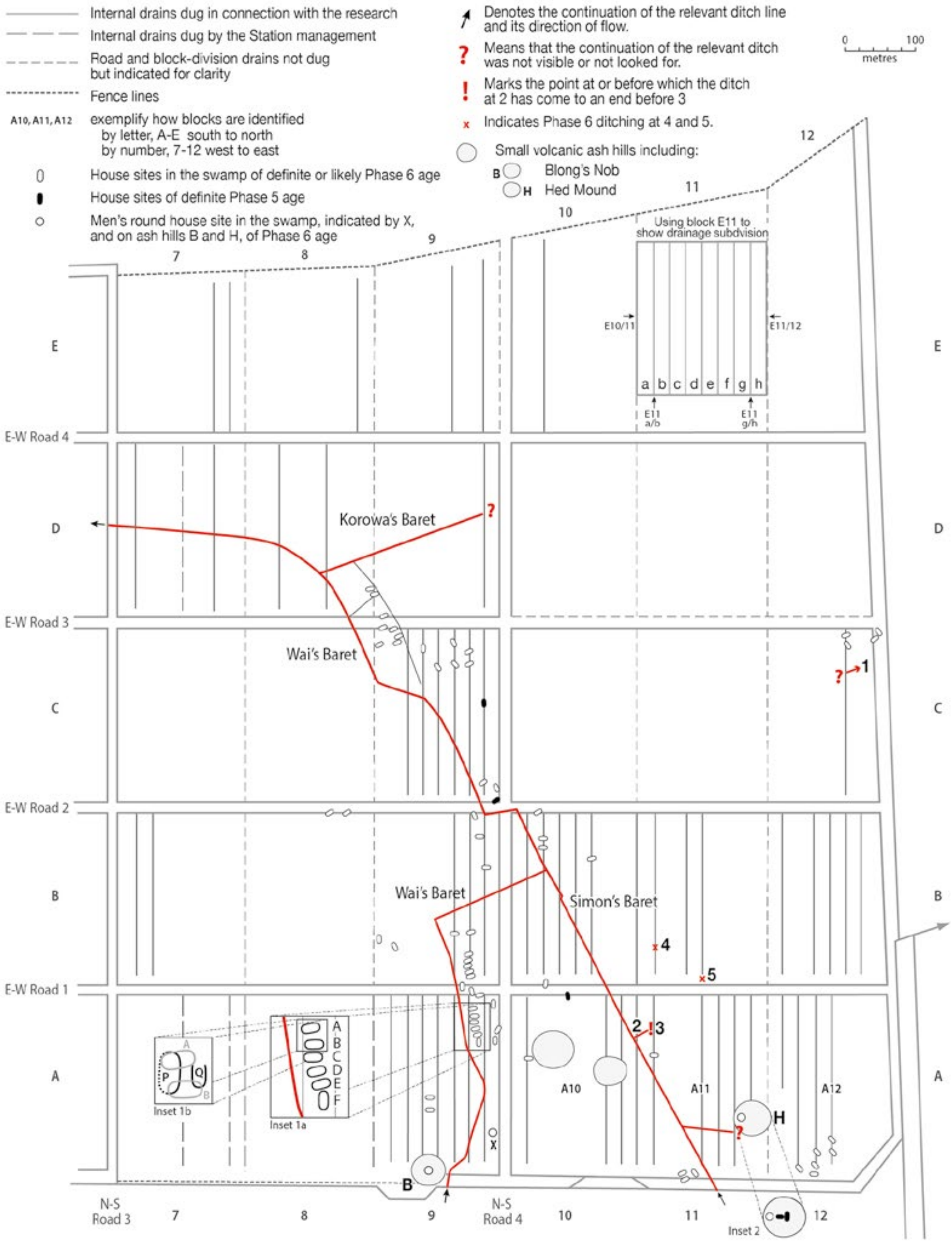


Figure 17.3 The distribution of known house sites of Phases 5 and 6 in the eastern half of Kuk Swamp.

Inset 1a shows the house sites of Phase 6 where excavation of swamp housing was concentrated, specifically at Houses A, B and F. Inset 1b shows Houses P and Q found under Phase 6 Houses A and B and until very recently accepted as Phase 5. Inset 2 shows two houses of late Phase 5 on Hed Mound.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Figure 17.4 Two photographs of a Phase 6 housing area at drain A12c/d (for which see Fig. 17.3).

The ranging pole is graduated at 200 mm intervals. Left: Looking south along drain A12c/d cutting through an area of Phase 6 housing and exposing house timbers in the process. Right: The ditch of a house exposed in the east wall of drain A12c/d. The looseness of the earth that fills the ditch and its heavy penetration by roots are evidence of the youthfulness of the feature.

Source: Photographer unknown, the Kuk archive, 1974.

As the dry season got under way and drainage proceeded, such features came to register themselves ever more clearly on the swamp surface as the felted peat that formed it shrank with the draining and the drying. We took advantage of the situation to look systematically for house mounds, among other evidence, along, between and, later, beyond the courses of Wai's and Simon's Barets. We came across a few other house sites by chance elsewhere over the rest of the season. The only grouping we found in the swamp in subsequent years was in the southeast corner of the Station as the result of digging drains A12c/d and d/e in 1974 (Fig. 17.3; cf. Fig. 17.4).

The distribution of house mounds in Figure 17.3 is striking in two respects. For one thing, most of them are strung out along the eastern side of Wai's Baret, which during Phase 6, the presumed sweet potato phase at Kuk (see Chapter 16), saw drainage and cultivation restricted to the shallower swamp to its west. Since it would make sense for cultivators to live close to their gardens, there was reason to think that all the houses visible immediately to the east of the channel belonged to Phase 6. In addition, there was the fencing along the eastern bank of Simon's Baret, discovered during the 1973 season and interpreted (see Chapter 19) as marking the western boundary of grazing land for pigs and serving to keep them there.

The second striking feature of the distribution of the house mounds is that some of them fall into seemingly orderly clusters, contrasting with the random distribution of recent houses described by Vicedom, admittedly in a dryland context, in the opening paragraph of this chapter (Vicedom and Tischner 1943–48; 1983). Indeed, when Andrew Strathern brought a group of Kawelka elders to see one of those clusters under archaeological investigation in 1972 at the northern end of block A9g (Fig. 17.3 Inset 1a), he mischievously used the term *haus lain* to compare it to the linear arrangement of houses at Lutheran missions in the district (cf. Strathern 1971: 8, footnote 1).

Relative chronology and absolute age

While the visible house mounds along Wai's Baret might, as argued, belong to Phase 6, there were indications from the surface evidence that they were not all of the same age, within the 200 or so years, that Phase 6 had lasted. Thus everywhere some mounds were more clearly defined than others, with flatter surfaces and sharper edges and a deeper dip of the peat surface above the house ditch, all suggesting that they were younger. However, there was a problem in establishing when mounds in different locations were occupied in relation to each other. Given that the phase to which the visible mounds were thought to belong was recent and of limited duration, radiocarbon dating was not precise enough a tool to employ for the purpose. It was suggested that thermoluminescence dating might be the answer, using the heated stones from earth ovens and other features associated with individual houses to supply a relative chronology. During the second season of Ron Lampert's investigations of houses, in 1973, such a programme was initiated.

Ovenstones from four adjacent house sites—A, B, P and Q—at the northern end of block A9g (Fig. 17.3 Insets 1a and 1b) were provided for Terry Bell, a doctoral student at The Australian National University who was beginning research into thermoluminescence dating in Australia and New Guinea (Bell 1978). The excavations at the four house sites are discussed below. House B was a prominent mounded site whose associated features—ovens, fireplace and house ditches—had been excavated in 1972 and any finds from there, including cooking stones, recorded and retained. Towards the end of the 1972 season, Lampert dug exploratory trenches into the mound to investigate its structure and earlier history. The most important result of this was the discovery of evidence of two earlier house sites, P and Q, beneath. These were the subject of full investigation in 1973, requiring the northward extension of the 1972 excavation area. The extension involved the excavation of House A (see Fig. 17.3 Inset 1a), a surface mound like House B, though less prominent, which overlay the northern end of House P. The evidence for earlier and later house sites on the spot encouraged the exercise of ovenstone dating. So did Lampert's report of Tibito Tephra in the fill of the house ditches of both P and Q, which might therefore predate the fall of the tephra and belong to Phase 5, while Houses A and B postdated it and belonged to Phase 6. Laurie Lucking, a graduate student from the University of Minnesota, became responsible for the three-dimensional recovery and record of ovenstones for the dating exercise.

In the event, the technique was unable to do what was asked of it (Bell 1976). While it proved possible to date the cooking stones to the general period some 300 years ago indicated by the presence of Tibito Tephra, their use for the chronological ordering of the houses from which they had been collected was impossible because of the large range of uncertainty in the individual ages. This seems to have been due to the particular composition of the stones used in ovens in the area.

Besides the two Phase 5 houses that Lampert's excavations were thought to have identified, there were three other examples where Tibito Tephra was associated with the fill of Phase 5 house ditches exposed in the walls of Station drains (shown in black in Fig. 17.3). This contrasts with the more than 40 cases distributed across the site where house sites were cut by the digging of Station drains with no signs of Tibito Tephra at all. On grounds of probability alone, this suggests that Phase 5 houses were of much more infrequent occurrence than those of Phase 6. This conclusion would be supported by the fact that the three Phase 5 houses in question, whose ditches were associated with Tibito Tephra in exposures in drain walls, seem not to have been visible at the surface, in contrast to a majority of the house sites overall. What is more, the evidence seemed to indicate a post-Tibito Tephra date for the clustering of house sites. In Chapter 15, this is attributed to changes in the location of settlement and cultivation following the adoption of sweet potato as the staple, which marked Phase 6 off from Phase 5, when it has been argued that yams were a main crop.

Investigations of houses at Kuk

This section is based on unpublished data from Ron Lampert, Paul Gorecki and Ed Harris, all of whom worked at Kuk in the 1970s. At the time, Lampert was on the staff of the Department of Prehistory at The Australian National University, where his field records of 1972 and 1973 are housed in the Kuk archive, together with the text of a lecture summarising his 1972 season (Lampert 1973). Paul Gorecki was a PhD student of the University of Sydney, who in 1977–78 investigated settlement and agricultural site-formation processes mainly through observation and enquiry of the Kuk community some 45 years after European contact (Gorecki 1982). Ed Harris was a PhD student at University College London, who developed the Harris Matrix (1979: vii, Appendix 2) in the early 1970s to cope with the complex stratigraphic records of excavations in Winchester (UK), on which he had been employed. This project led him to take up research of his own into the principles of archaeological stratigraphy, of which his work at Kuk was part (1977, 1979: 65, Fig. 19). The text that follows represents a recent attempt to pull together the evidence from these three sources and draw some conclusions. The recent nature of the attempt, together with the loss of some 1973 records, discussed later, explains the error made about the chronology of houses at Kuk Swamp published a decade ago (Bayliss-Smith et al. 2005: 118).

Lampert 1972

The house mound cluster B–F, on which Lampert began work in 1972, is at the northern end of block A9g (Fig. 17.3 Inset 1a). As plotted ahead of excavation, four of the house mounds, B–E, were between 14.5 and 16 m in length and 5.5 and 6.5 m in width. They were subrectangular in plan and consistently slightly higher at the western end than the other, as well as parallel to each other, fairly evenly spaced and at right angles to Wai's Baret. The fifth mound, F, at the southern end of the group, was also subrectangular, but shorter (11.5 m) and narrower (5 m), and parallel to Wai's. House B (Fig. 17.5) was almost totally excavated and House F (Fig. 17.6) substantially so, together with some of the house ditches and adjacent floors at House C (Fig. 17.5) and E (Fig. 17.6). House D was not touched at all. As a separate and more straightforward exercise, Lampert excavated the site of a round house (Fig. 17.7) discovered by Winifred Mumford at the southern end of Block A9h (see Fig. 17.3 at X) from surface indications.

Because from the outset the well-defined profiles of the mounds suggested them to be of no great antiquity, and in light of Vicedom's descriptions of Hagen houses in the 1930s (Vicedom and Tischner 1943–48: 158–171; 1983: 177–193), Lampert (1973: 2) combined his archaeology with ethnographic observation and enquiry of contemporary houses at Kuk and vicinity. Some he recorded in detail, with measured plans and elevations of all structures both internal and external. He paid particular attention to the parts of a structure likely to be registered in the ground archaeologically, like pits and posts. All these contemporary houses were on dry land, with one exception, a house for women, their children and pigs built right at the margin of the swamp, with a deep ditch and a raised floor, just like the house mounds that he was excavating.

House mound B

In the light of the ethnographic evidence, past and present, Lampert felt able to interpret his archaeological findings at House B (Fig. 17.5) as indicating a women's house of the same general type as the swamp-margin house just mentioned, the people living at one end and the pigs in somewhat larger quarters at the other, the two separated by a partition, as suggested by a line of postholes that he found across the middle of the house that he had excavated (see B on Fig. 17.5).

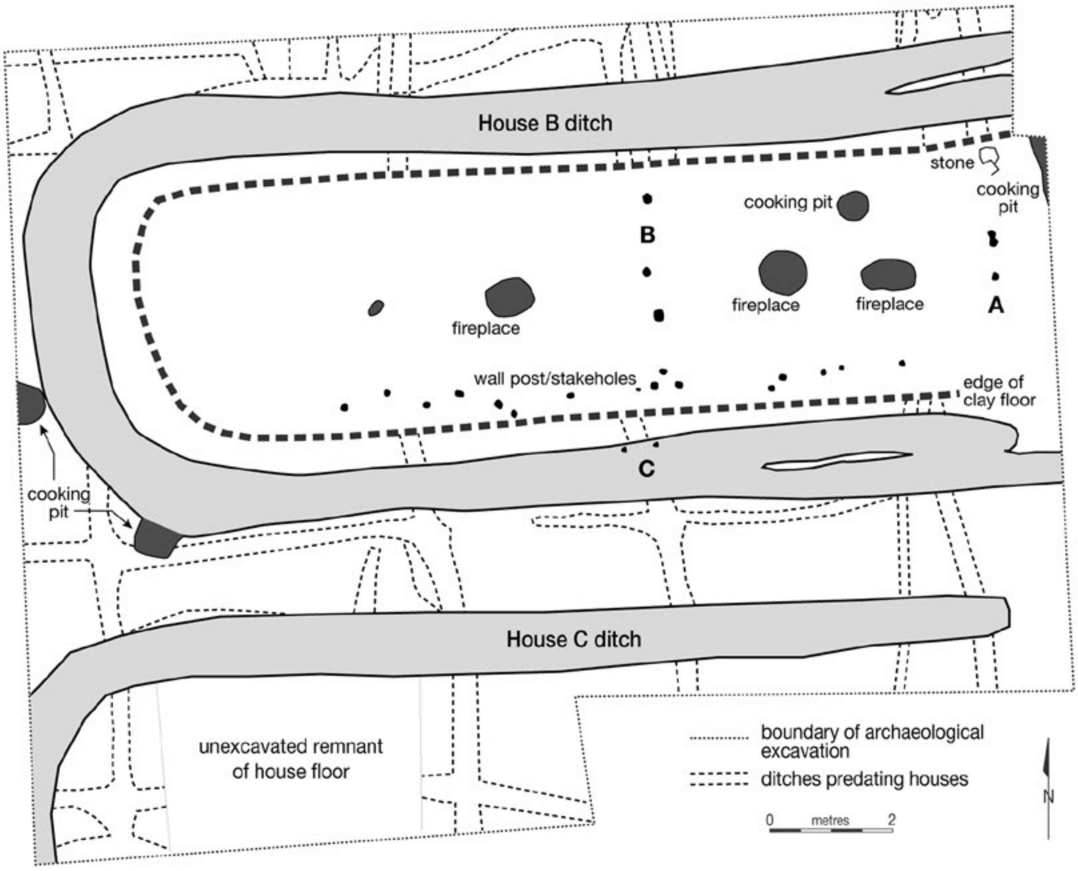


Figure 17.5 Plan of House B and part of C as revealed by excavation in 1972.

Source: Drawing by Anthony Bright, Cartography, College of Asia and the Pacific, ANU, from field originals by Winifred Mumford and Ron Lampert, final production by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

The horseshoe plan of the House B ditch and three postholes in a rough N–S line between its eastern ends (above A) suggest that the house had a straight termination at the east, contrasting with the curved one at the west. This would be an example, like House F (Fig. 17.6), of Gorecki's veranda house (see Fig. 17.14), from whom I borrow the term. There would have been a central line of posts supporting the ridgepole of the house, but it seems that only some of the holes dug for this purpose here were recovered by excavation.

The dotted features running at right angles to each other are the ditches of Phase 4 cultivation plots over which the houses were built (see Fig. 14.11).

The clear separation between people and pigs conforms to modern practice, as observed by Lampert at Kuk in the early 1970s, but seems to be at variance with Vicedom's report of room-sharing by women and pigs in the 1930s and their use of a single entrance. However, Figure 17.5 shows the rough position, at C, of two upright posts in the north wall of the house ditch just west of the partition presumed to have divided the pigs from the humans. According to Lampert's workmen at the time, the uprights could mark the position of a former bridge across the house ditch to a doorway, implying in this case a separate entrance for the pigs. There was no evidence of stakeholes for pig stalls, but stakeholes do not regularly survive archaeologically and stalls were indeed not always provided (Vicedom and Tischner 1943–48: 167, 168; 1983: 186, 189). Sharing of the space between pigs and humans, as reported by Vicedom, might explain the fireplace beyond the partition. On the other hand, Lampert (1973: 3) talks about fires being lit in small hearths to warm and dry pigs after foraging on a wet day, while noting an absence of cooking pit and cooking stones in the pig space.

Excavations in the front of the house produced some interesting finds. Among the charcoal of one of the hearths there charred sugarcane was found, together with the end of a tuber (Fig.16.13; cf. Swadling 1981: 49), immediately and understandably attributed to sweet potato by the finders, but subsequently identified as lesser yam (*Dioscorea esculenta*) (see Chapter 16; on these charred plant remains in general see Lewis, Denham and Golson 2016). The house ditch had been redug (as had that of House C) and, at least on the south side, lengthened. At the end of the earlier segment, five women's short digging sticks were found. As Lampert (1973: 5) noted, these were expectable finds at the bottom of a house ditch, since he saw women put their sticks there, at their own houses, after the day's work, to soak up water and keep them fresh and weighted for the morrow.

House mound F

For Lampert, House F (Fig. 17.6) could be readily interpreted as a men's house on the basis of its shorter length (because not providing space for pigs), the absence of women's digging sticks in the stretches of its ditch that were excavated and the presence of stone axe flakes in what he calls the central working area. By this he seems to have meant the living area marked by cooking pit and hearth, though this was by no means central, but towards the north end of the house. There was only a hint of evidence of a partition between the front activity area and presumed sleeping quarters at the rear and no evidence of house walls. We may note that at 11.5 m, House F was only 3.5–4.5 m shorter than the other four mounds of the group we are discussing, not the degree of difference to be anticipated from Lampert's statement (1973: 3) that men's houses were only a third to a half the size of women's. As at Houses B and C, there was definite evidence for the recutting of the house ditch at House F. At the north end of its west leg, the later, shallower ditch extended some 0.7 m further than the earlier deeper one.

It was because of their similarity in size, orientation and appearance to House B and in the absence of contrary evidence from the limited excavations at Houses C and E that Lampert interpreted Houses C–E as women's houses with pigs, like House B. Of these four women's house mounds and that of the proposed men's House F, Lampert (1973: 2) concluded that their 'even spacing and consistency of form suggested from the outset that all five structures were contemporaneous and of the same social complex'. The individual houses, he said (1973: 5), matched those in use today, the unusual feature being 'their spatial arrangement, laid out in the pattern of a formal village'.

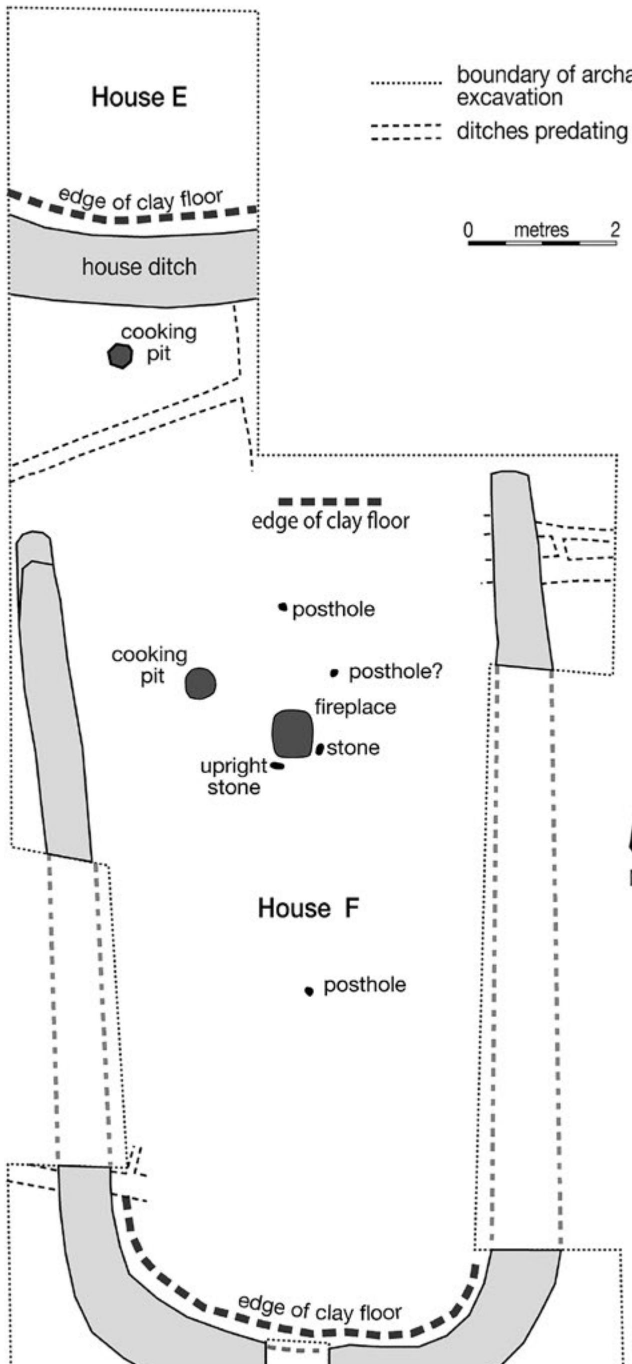


Figure 17.6 Plan of House F and part of E as revealed by excavation in 1972.

Lampert interpreted House F as a men's house, in part because it was shorter, if not dramatically so, than House B (Fig. 17.5). Note that there is a cooking pit as well as a fireplace in the front part of the house. For cooking pits and men's houses see the end of the next section. The horseshoe plan of the house ditch and the trace of the edge of a clay floor between the ditch ends suggest a straight termination to the structure at the north contrasting with the curved one at the south. Like House B (Fig. 17.5), this is a veranda house and, again like House B, its house ditch was redug and extended, at least at the end of its western leg.

Source: Drawing by Anthony Bright, Cartography, College of Asia and the Pacific, ANU, from field originals by Ron Lampert, final production by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Lampert and a men's round house excavation of 1972

The earthworks of men's round houses, consisting of a sunken floor surrounded by a bank except across the entrance (cf. Fig. 17.7), were found on some of the small hills of volcanic ash at the margins of the swamp. There were such earthworks on top of Blong's Nob (B on Fig. 17.3) on the southern boundary of the Station at the end of blocks A9c and A9d, which gave commanding views over the swamp to Ep Ridge (Fig. 16.10). Unfortunately, these earthworks were destroyed when material was quarried from the hillock in the course of Station development in 1972. Similar earthworks were found on a low but extensive rise in block A7 while the course of Kupalg's Baret (Phase 2, Denham's channel 105) was being mapped (see Fig. 12.3 upper).

Figure 17.7 A men's round house at a ceremonial ground at the foot of Ep Ridge on the north side of Kuk Swamp.

Source: Photograph by Paul Gorecki, 1978.

In the course of the field reconnaissance during the prolonged dry season of 1972, when the map of house sites shown in Figure 17.3 was largely produced, a single example of a round men's house was discovered in the swamp itself, towards the southern end of block A9h (at X in Fig. 17.3). It appeared as a low flattish circular mound up to 0.4 m above the level of the neighbouring swamp, with an accompanying ditch and outer bank appearing as a slight dip and a slight rise of the surface except at the north, where excavation subsequently showed the entrance to have been (Fig. 17.9). This surface evidence suggested that the house belonged to Phase 6, like Houses A–F already discussed, though not necessarily strictly contemporary with any of these. No excavation took place below the house floor, but the house ditch gave no evidence of having been redug.

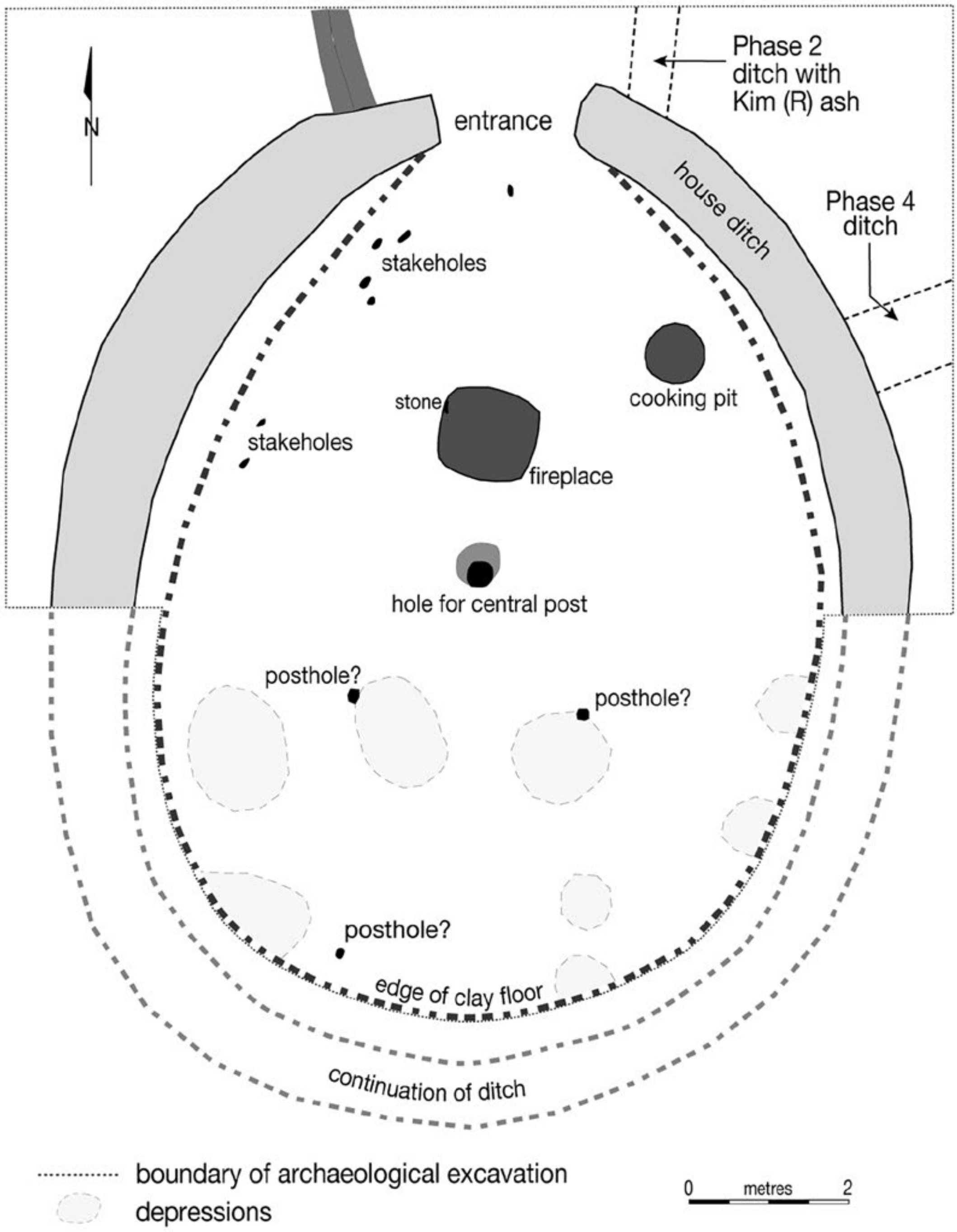


Figure 17.8 Plan of a men's round house as revealed by excavation in 1972.

Round houses supported by a central post were one of the types of house built by a clan leader at a ceremonial ground, which the doorway would have faced. The hole for the central post is clear in the house excavated by Lampert and some stakeholes from the wall are seen at top left.

Source: Drawing by Anthony Bright, Cartography, College of Asia and the Pacific, ANU, from field originals by Winifred Mumford and Ron Lampert, final production by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Figure 17.9 Looking south over the round house of Figure 17.8 after excavation.

The image shows a causeway giving entry to the house between the ends of the surrounding ditch. An axe fragment was found at the base, near the west wall of the causeway (see Fig. 20.13B). The ranging pole is graduated at 200 mm intervals.

Source: Photograph by Ron Lampert, 1972.

The front of the house was the living area, equipped with a fireplace and a cooking pit. The significance of the cooking pit is discussed at the end of this section. The back part of the house was the sleeping area and the two possible postholes found there may have had something to do with partitions. Lampert suggested that depressions in the house floor adjacent to these postholes were in fact associated with them and indicated doorways into the bedrooms. Other depressions at the rear curve of the house he thought might simply be soft areas in the make-up of the floor. The visibility of the site at the surface indicates a general Phase 6 date for the structure. The ditch to the west of the entrance that runs northwards was thought by Lampert to be of the same age because it did not seem to continue south of the house ditch.

The cooking pit plotted by Lampert (Fig. 17.7) needs comment. Vicedom says that no cooking was done in men's houses and his plans of men's houses of the 1930s, with their obvious relevance for the pre-contact situation, show no cooking pits (Vicedom and Tischner 1943–48: 166, Fig. 76; 1983: 186, Fig. 76), in contrast to the practice in later times. Lampert's round house excavation, however, produced clear evidence of a cooking pit in a men's house of pre-contact date, as he had previously done at House F (Fig. 17.6).

Gorecki 1977–78

Lampert's exercise illustrated a number of the problems that Paul Gorecki later highlighted as a result of his fieldwork with the Kuk community in 1977–78. This work included a study of houses and the homesteads of which they were part, where ethnographic evidence and observation (1982: 63–110) were complemented by excavation at living sites of recent remembered occupation (1982: 111–163). The aim was to understand the dynamics in the settlement process that lay behind the material evidence with which the archaeologist had to deal (Gorecki 1982: 65–81). We shall look at three aspects of the evidence: the ethnographic, the archaeological and the ethnoarchaeological.

Ethnography

Gorecki (1982: 82–84, 109) concluded that the use of ethnographic evidence to help with the interpretation of prehistoric house sites in the upper Wahgi is not straightforward. On the one hand, there are a number of house types described in detail by the missionary Vicedom, who was in the Hagen area from 1934 to 1939 and whose observations were obviously relevant for the period immediately preceding contact (Vicedom and Tischner 1943–48: 158–79; 1983: 177–202). On the other hand, it was evident that significant change had taken place during the contact period, including the disappearance of some house types, the modification of others and the appearance of a few innovations under European influence (Gorecki 1982: 81–110).

Gorecki described the problem as that of distinguishing the old from the new in the virtual absence of any documentation of the process of change between the 1930s and the 1970s. The danger was one of using anachronistic models in the interpretation of pre-contact structures.

Vicedom recorded three types of dwelling house: a subrectangular house with rounded ends; a similar house but with one end straight; and a round house (Vicedom and Tischner 1943–48, 1983: Fig. 76). With different internal arrangements, the first type could be a family house, a men's house or a women's house (numbers 1, 2, 4 of Fig. 76) and the second a men's or a women's house (numbers 3 and 5 of Fig. 76). Vicedom says that there were pigs in all women's and even in some family houses. The round house (number 6 of Fig. 76) was exclusively a men's house, only built at a ceremonial ground, as was the type of men's house with one straight gable end (number 3 of Fig. 76). The third type of men's house, a subrectangular structure with rounded ends (number 2 of Fig. 76), could be built both at the ceremonial ground and in the general settlement area.

By Gorecki's time, the round type of men's house (Fig. 17.8) was of lesser importance, while that with one straight gable end had ceased to exist as a men's house. The subrectangular house with rounded ends, Gorecki's oval house, was the most common kind. Some of them served as dwellings for women and children or for families (Fig. 17.10), while others were for women and pigs, where the two had separate entrances to separate quarters (Figs 17.11–17.13). The main differences between the two sorts concerned the features connected with pigs. This included the space allocated to them, which tended to make the oval house with pigs rather longer than the other type, though Gorecki found considerable overlap in size.

We can best appreciate the problem that Gorecki identified in the relationship between ethnographic and late prehistoric houses of the upper Wahgi by considering a particular aspect of Lampert's excavations. Thus the ditch at House F is horseshoe-shaped in plan, undug across the northern end of the house, while an edge of the clay floor there suggests that the structure to which it belonged had a straight termination to the north, not a rounded one as at the south (Fig. 17.6). The situation at House B (Fig. 17.5) seems to have been the same, though only one eastern end for the earlier ditch was actually excavated, and neither of the ends for the later ditch. In the case of this house, the evidence for a straight termination to the structure is a row of three postholes, marked by A on the plan, in line with the eastern end of the earlier ditch. Excavation indicates a horseshoe plan for the ditch of House C as well (Fig. 17.5).

Figure 17.10 Early morning view of a family house with rounded ends and central doorway.
Source: Photograph by Paul Gorecki, 1977.

Figure 17.11 Women's long house with stalling for pigs, at the southern foot of Ep Ridge at Kuning, 2–3 km NNE of Kuk.

Source: Photograph by Ron Lampert, Kuk archive, 1970.

Figure 17.12 Newly built women's house on low-lying ground at Kuk, with separate entrances for people and for pigs.

Source: Photograph by Paul Gorecki, 1977.

Figure 17.13 A former women's long house with separate entrances for people and for pigs.
Source: Photograph by Paul Gorecki, 1977.

Figure 17.14 A variety of veranda house at Kuk.
Source: Photograph by Paul Gorecki, 1977.

These house plans are reminiscent of what Paul Gorecki (1982: 96–98; Fig. 17.14 here) called the veranda house during his 1977–78 work at Kuk. Gorecki also used this name for one of Vicedom's three types of dwelling house, the subrectangular one with one end rounded and the other straight. There were two varieties of the type, with different internal arrangements serving in the one case for men and in the other for women, children and pigs. In Vicedom's plans and descriptions of these two varieties (Vicedom and Tischner 1943–48: 170, Fig. 76.3; 1983: 191, Fig. 76.3 for the men's house; and 1943–48: 171, Fig. 76.5; 1983: 192, Fig. 76.5 for the women's house), there is a living room at the front provided with an open or only partially closed gable and backed by a partition wall to the rest of the house, which at times was essentially the outside wall. In the veranda houses described by Gorecki, there is an open veranda at the front (Fig. 17.14), separated by a wall with doorway from the living room and the rooms behind it, the veranda acting as a temporary store, shelter and toolshed.

By the time of Gorecki's fieldwork, the veranda house was a family house that was losing favour. Gorecki recorded only 10 during his work at Kuk, all of them within the boundaries of one clan, and he considered this an unrepresentative sample.

Archaeology

In the last section, we saw from Vicedom how the same types of dwelling house could with different internal arrangements serve different functions. These internal arrangements in some cases involved walls and partitions that might leave some archaeological trace of their former presence but in other cases devices that left no trace at all, such as merely laying a pole on the floor. In fact, Lampert (1973: 4) and Gorecki (1982: 92), together with Ed Harris (1977: 16–17), whose house excavations at Kuk in 1977 we consider later, all report that they found little evidence for internal structures, or indeed external walls, in their work. This was the case whether the sites were on dry land, as they were for Gorecki and Harris, or in the swamp, as they were for Lampert.

Lampert (1973: 5) notes from his observations of dryland structures at Kuk that wall staves rarely entered the subsoil to have their presence registered there and this is likely to have been the case at house mounds in the swamp, where the floor might have been raised as much as 0.4 m by spoil from the house ditch. Gorecki (1982: 287–288) makes a distinction between features dug and those driven into the subsoil, the latter tending to be quickly lost to the archaeological record, the former preserved through the actual removal of material and its subsequent replacement by something visually different. Harris (1977: 17–18) offers somewhat different arguments for the situation but admits that whatever the cause, many aspects of New Guinea housing do not survive archaeologically.

What are likely to survive are house ditches, central postholes for the ridge pole, fireplaces and cooking pits. At existing or recently abandoned houses that he observed or excavated, Gorecki (1982: 157–158) found sufficient regularity, on the one hand in the number and location of central posts and on the other in the distances between them, hearths and cooking pits, to allow formal and functional interpretations of the structures involved. These interpretations could be tested against the distribution of cooking stones, by far the most numerous of the associated objects of domestic life. Lampert (1973: 5) had already noted how cooking stones were confined within cooking areas by walls and piled up against them when not in use and so could provide evidence for the location of walls for which no structural evidence was preserved.

The ethnoarchaeology of settlement

Gorecki pointed out that the number and type of houses comprising a homestead might vary greatly and could change over time. As an example (Gorecki 1982: 74–78), he took the history of a Kuk homestead that he recorded from its inhabitants through enquiries on the spot about the buildings that had formed part of it. The homestead was in existence by 1969, inhabited by Rea and his wives and children, and was radically expanded and rearranged around 1971, when Ru came with his wives and children to join his subclansmen. When Gorecki left Kuk in 1978, the occupation whose history he had recorded could not have much exceeded a dozen years in length.

The pre- and post-Ru phases of habitation saw the regular replacement of buildings, more as a result of fire than decay. In the earlier period, fire destroyed two subrectangular houses, two menstrual houses and a toilet, while decay accounted for one subrectangular dwelling house and one women's house (with pigs). In the later period, a house for women and pigs, three sub-rectangular dwelling houses and one menstrual house were burnt down and two toilets succumbed to decay.

As regards the replacement houses of the later period, all of them were built at the same place as their predecessors, but in the case of the three subrectangular dwelling houses only two locations were involved, since the first and second houses in a sequence of three burnt down on the same spot. These two houses belonged to Ru and Gorecki described how, in building the third in 1978, Ru reused the central postholes and the oven pits of the previous house, but totally rebuilt the two hearths at a new location some 0.8 m away from the previous ones. Gorecki noted that in other cases at Kuk, he saw buildings of a different type replacing the structures that had previously occupied a particular location.

Sometimes a replacement structure was built right next to the old one. This was the case with two subrectangular dwelling houses of the first phase (Gorecki 1982: Fig. 8, J). These were appropriately spaced for an owner systematically to use the old house as a source of firewood for the new and as little as a metre might separate them (Gorecki 1982: 78–79). Simultaneous occupation of houses required more space between them.

A new look at the 1972 excavations

In the light of the work described above, Gorecki (1982: 160–161) questioned the general conclusions that Lampert (1973) had drawn from his 1972 excavations. He did so on the basis of access to Lampert's detailed plan of the excavated features at House B and the partially excavated House C, as well as the relevant field notes.

The point about close spacing of houses made in the final paragraph of the previous section is relevant to Gorecki's suggestion (1982: 160) that the parallel Houses B–E (Fig. 17.3 Inset 1a) with house ditches only 1.5–2 m apart, represent successive, not simultaneous occupations. Also important in this respect is the possible evidence for different phases of occupation at Houses B and C, represented most directly by the redigging of the house ditches there. Gorecki thought there might have been at least three houses at House B, of at least two types, and two houses at House C, of perhaps the same type. In the process, Lampert's (1973: 5) 'pattern of a formal village' becomes Gorecki's (1982: 161) picture of a single family reusing house sites in the same fashion as today.

Gorecki did not find convincing evidence for Lampert's interpretation of Houses B–D as houses for women and pigs. He thought that only the suspected length of some houses, particularly what he called the 'earlier' on House B, suggested that we might be dealing with this type. However, Lampert's records indicate that, to judge from the redug house ditch, the longest house at the mound was the later (or latest), not the earlier (or earliest), since the eastern end of the final house ditch went further east than that of at least the southern arm of the earlier ditch (Fig. 17.5). Strictly speaking, because it goes into unexcavated ground, we do not really know whether it curved around to form a closed end to the house or, as at House F (Fig. 17.6) and other excavated house ditches of the mound group, terminated with the front end of a veranda house.

Lampert 1973

At the end of his 1972 season, Lampert dug two test pits through the floor of House B, producing evidence of curving ditches that suggested that there were two houses underneath. He investigated this situation in 1973 (Fig. 17.15), not only confirming the presence of the two houses, which he called P and Q, but claiming them to be of Phase 5 date by the evidence of Tibito Tephra in the fill of their accompanying ditches. House P had a ditch that appears to have encircled it. The other structure, House Q, somewhat shorter, was a veranda house, opening north. The two houses were parallel to each other and close together.

The 1973 investigations meant extending the House B excavation area of 1972 to the north, totally removing the House B floor and taking in the surface mound called House A in the process. The plans of these excavations have been long lost, but I have used Lampert's field notebooks of the time to reconstruct the layout that is displayed in Figure 17.15. There was sufficient detail in the 1973 notebooks to tie in with the information about the southern ends of Houses P and Q that had been recorded in 1972 and about the departure of the House P ditch from the 1973 excavation area near its northwest corner and so give confidence in the general size and placement shown for them in the figure. The same is not as much the case, however, with the Phase 6 house, A, which was not touched by the 1972 excavations. Given the circumstances overall, I have only plotted hearths and cooking pits for which information about age and location is sufficient or where there is some other purpose in doing so. In any case, at the time of his excavations, Lampert frequently found it difficult to discriminate features belonging to the earlier houses from those intrusive from later phases of housing and other activity. As a result, there are limits to what can be said about the structures uncovered in 1973.

Although not fully excavated, House A appears to have been one of the veranda type that was prominent among the investigated houses of the 1972 season and, as with most of those, its house ditch had been at least partially redug. Though not completely exposed, the surface and excavated evidence for it suggests a structure more like House F than the others of the group.

House P, built in a space 15 m long and more than 5.5 m wide as defined by its encircling ditch, could in terms of shape be compared with family, men's or women's houses as described by Vicedom (numbers 1, 2, 4 of Fig. 76, Vicedom and Tischner 1943–48 and 1983), the first and third also providing room for pigs. Its potential length falls at the extreme end of the range of Gorecki's oval houses used by women or a nuclear family (1982: 87 and Table 6), but around the middle of that of the similarly shaped structures that Gorecki called woman and pig houses (1982: 93 and Table 7).

House Q, of veranda type in an 8 x 4.5 m space defined by its associated horseshoe-shaped boundary ditch, is oriented north–south, parallel to House P and just over 4 m to its east. In terms of Gorecki's reinterpretation of Lampert's 1972 excavations, this was far enough apart for the buildings to have been simultaneously occupied. For Lampert, its small size, just over half the length of House P, would indicate a men's house and the central location of the fireplace might support this. In addition, a lump of red ochre excavated from the house ditch was explained by Lampert's workmen as used in connection with men's ceremonial display of pearl shell decorations (cf. Strathern and Strathern 1971: 20, 26, Plate 9 and Colour Plate 13). There was a fireplace at the southern end of House P, though not originally thought to belong to it, which proved to be associated with stones of a type that his workmen told Lampert had traditionally been used only to line the hearths in men's houses. Note, however, in the preceding paragraph the size and shape of House P were seen as suggesting its use for accommodating pigs as well as people.

Figure 17.15 shows the northern end of the eastern arm of House Q as stopping short of a purported latrine, so that the stratigraphic relationship between the two is unknown. Neither is there any information about the structure's place in the general stratigraphy of the site, so that we do not know whether it is likely to belong to Phase 5 or Phase 6. The latrine is generally thought of as being a European introduction, i.e. later than Phase 6 at Kuk. The feature in question is a vertically sided pit some 0.75 m in diameter and 0.55 m deep. The bigman Ongka identified it as a latrine and his opinion is never to be lightly dismissed, though by shape and size it could have been an oven pit. Harris describes as a cesspit a rather deeper pit on Hed Mound (1977: Fig. 9J). It dates within Periods V–VII of the mound complex (Fig. 17.17C–E), which, as discussed in the next section, belong to Phase 5 of the Kuk sequence and are thus definitely pre-European. However, the source of the latrine identification in this case is unknown.

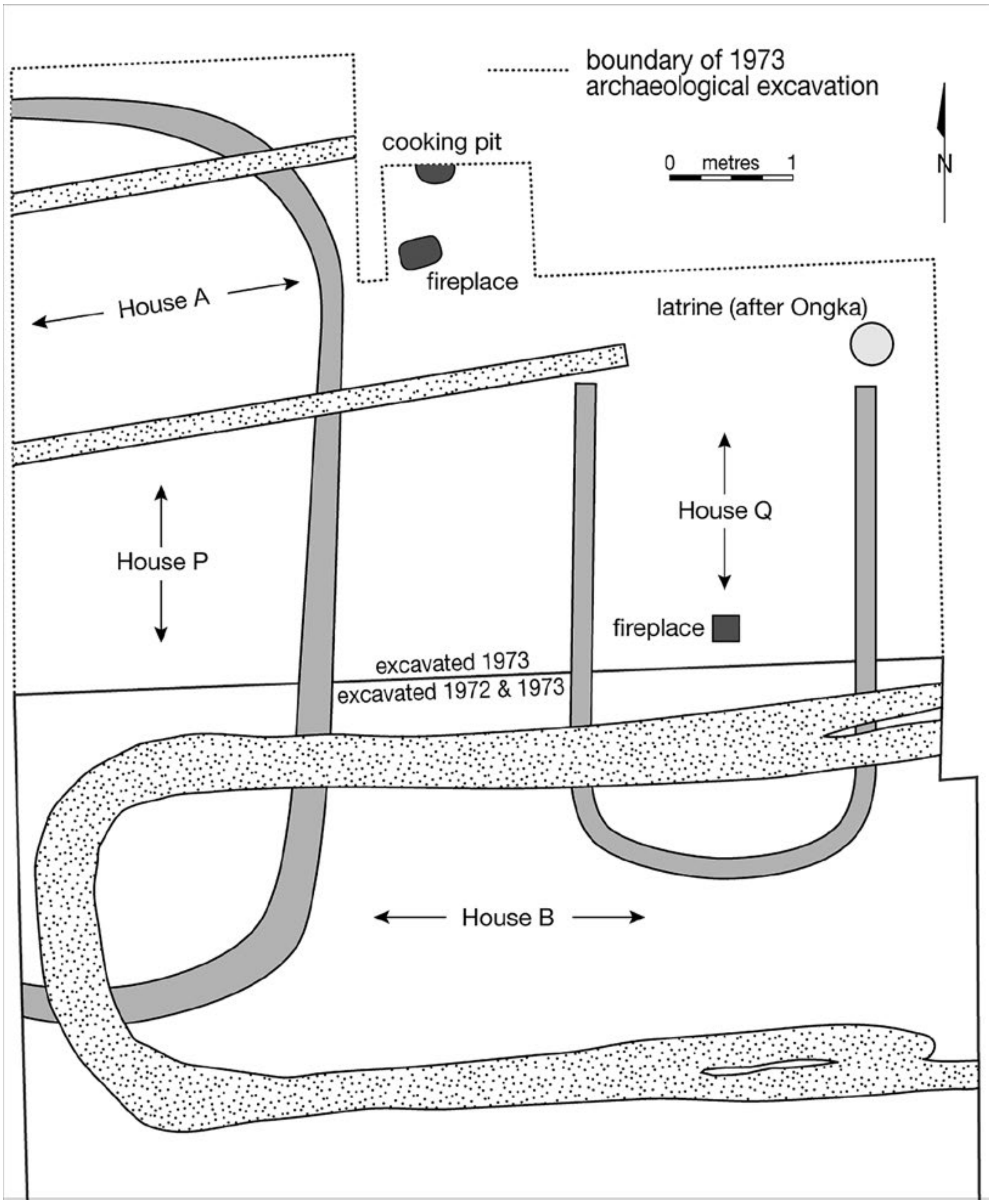


Figure 17.15 Plan of Houses P, Q and part of A as reconstructed from Ron Lampert's records of his 1972 and 1973 excavations.

Because of the loss of the field plans of the 1973 excavations, the position and direction of the boundary ditch of House A is less certain than those of Houses P and Q, the location of whose southern ends had been established in the 1972 excavations. However, a 1972 plan of house sites visible at the surface at the northern end of blocks A9g and A9h shows House A as narrower and more diagonally placed across block A9g than House B, as it is in the reconstruction here.

Source: Drawing by Anthony Bright, Cartography, College of Asia and the Pacific, ANU, with amendments by Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

There has been a recent reevaluation of Lampert's conclusions as to the chronology of Houses A, B, P and Q in relation to the fall of Tibito ash (Lewis, Denham and Golson 2016). For Lampert, A and B were younger than the ashfall and so Phase 6 in the Kuk sequence, while P and Q were older and thus Kuk Phase 5. The evaluation was made in the context of an archaeobotanical analysis of charred plant remains found in association with the houses. New AMS results for House Q overlap with those for House B and are supported by those from Bell's (1976) palaeomagnetic exercise, suggesting that the Tibito ash in the ditch of House Q is not in primary position (see Tables 3 and 1, respectively, of Lewis, Denham and Golson 2016).

Harris' excavations on Hed Mound 1977

The hill on the line of drain A11g/h towards the southern end of block A11 (Fig. 17.3H) was extensively excavated by Ed Harris in 1977 (Fig. 17.16) and called Hed Mound by his workmen (Harris 1977). It was a complex site where successive structures had been superimposed at the surface of the basal clay, with little stratigraphic differentiation between them in the shallow deposits above and not much stratigraphic connection between them spatially.

Figure 17.16 Aerial view just east of north over the completed excavations on Hed Mound.
Source: Photograph by Ed Harris, Kuk archive, 1977.

Harris identified eight periods of activity overall at Hed Mound (1977: 4–11, Figs 1–3) and displayed the major features inferred for each period in Figure 7 of his 1977 report. This has been adapted here as Fig.17.17 to help with discussion of the site.

Periods I–IV

Periods I–III (Harris 1977: 4–7) saw activity at the margins of Hed Mound connected with drainage and cultivation in the swamp during Phases 2, 3 and 5 of the Kuk sequence. For Harris (1977: 7–9), the first firm evidence of housing at the mound is Period V and subsequent rebuilding constitutes Periods VI and VII. The houses were archaeologically best defined by the shallow eavesdrip ditching dug horseshoe-fashion along two walls and around one end (Fig. 17.17C–E). Some of the remnants of shallow ditching assigned to Period IV of the Hed Mound sequence, immediately preceding the house ditches of Periods V–VII, show similar combinations of straight and curving courses (Fig. 17.17B). Harris conceded (1977: 7) that the features as a whole might have belonged to houses predating Period V, though his first suggestion was that they were ditches with an agricultural function. Gorecki's opinion (1982: 161) was that they were for houses, not agriculture, though it should be noted that dryland agricultural ditching made an appearance in Phase 5 at Kuk and elsewhere (see Chapter 15, 'Interpretation').

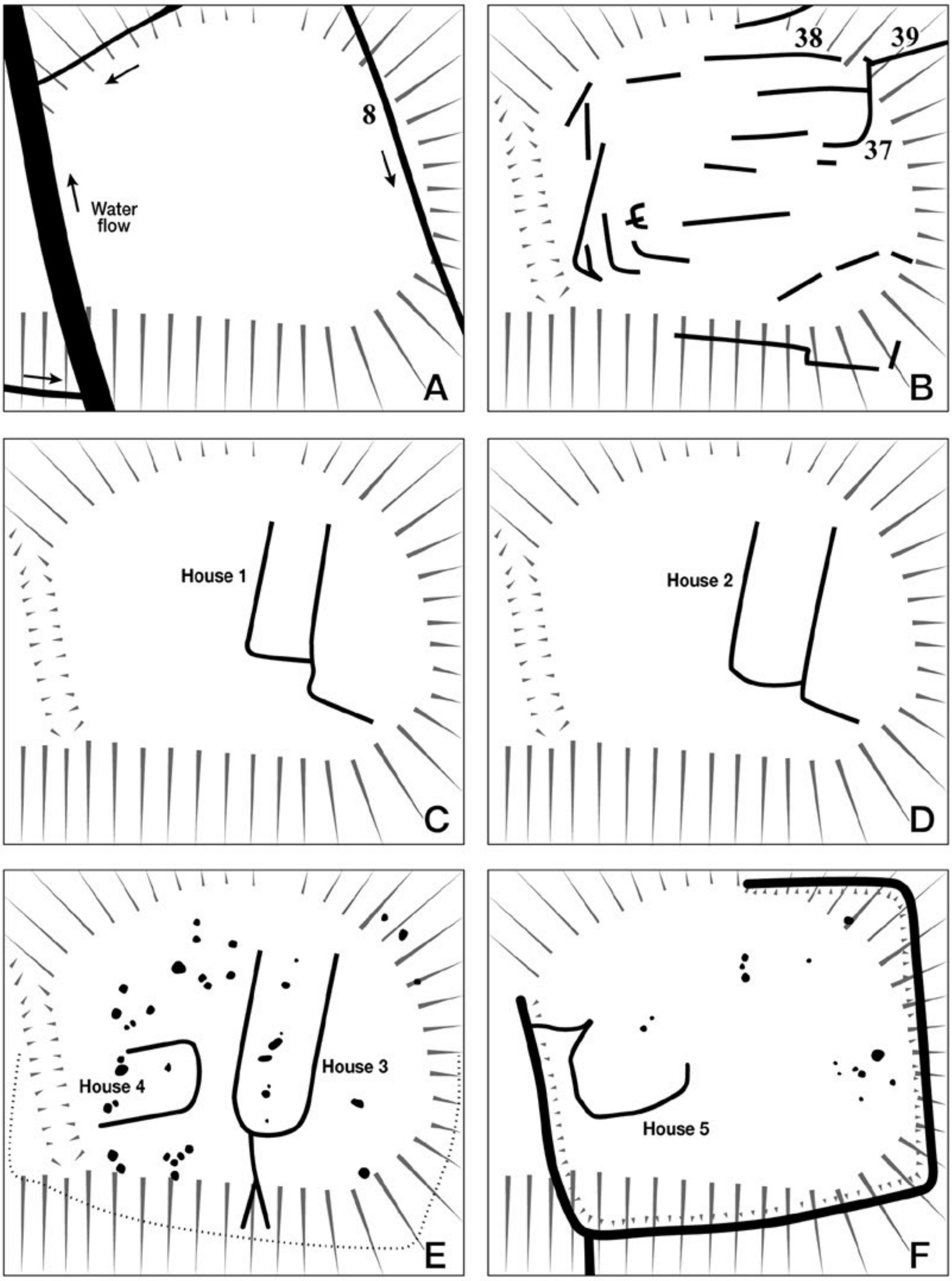


Figure 17.17 Periods III–VIII of the archaeological sequence on Hed Mound.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

There has already been discussion in Chapter 15 (section 'Artefacts, houses and pigs') about features 37–39 of Figure 1 of Harris 1977 (reproduced here as Fig. 17.18) as the most convincing evidence for housing in Hed Mound Period IV, which dates to Kuk Phase 5. The features in question form part of a complex of ditching, up to 0.50 m wide and 50–100 mm deep, found widely over the excavated area, though only visible at the surface of the grey clay subsoil that occurs sporadically beneath the features of Periods V–VII (Fig. 17.17B). There was limited evidence as to the stratigraphic relationship between the majority of these ditch features, which Harris (1977: 7) admits to having been 'somewhat arbitrarily assigned' to Period IV, as well as between them and the four field ditches that formed the total archaeological content of Period III (Fig. 17.17A). The strongest evidence of relationship is provided by features 36 and 37 of Period IV and feature 8 of Period III, a substantial field ditch that had Tibito Tephra at the top of its fill and so was dug early in Kuk Phase 5. Figure 1 of Harris' 1977 report (Fig. 17.18 here) shows feature 8 cutting across features 36 and 37 and thus being younger than them. In recent correspondence, Harris has confirmed his trust in the field drawings on which Figure 1 of the 1977 report is based. Since this provides support for features 36 and 37 being Period III and feature 8 being Period IV, we might further suggest that Periods III and IV as a whole, as depicted here in panels A and B of Figure 17.17 (3 and 4 of Harris 1977: Fig. 7), should change chronological place. If the structure represented by features 36 and 37 was in fact a house, it would have been a veranda house and with enough space within its proposed defining ditch, 14 m N–S by 8 m W–E, to have housed people and pigs (see Fig. 17.18).

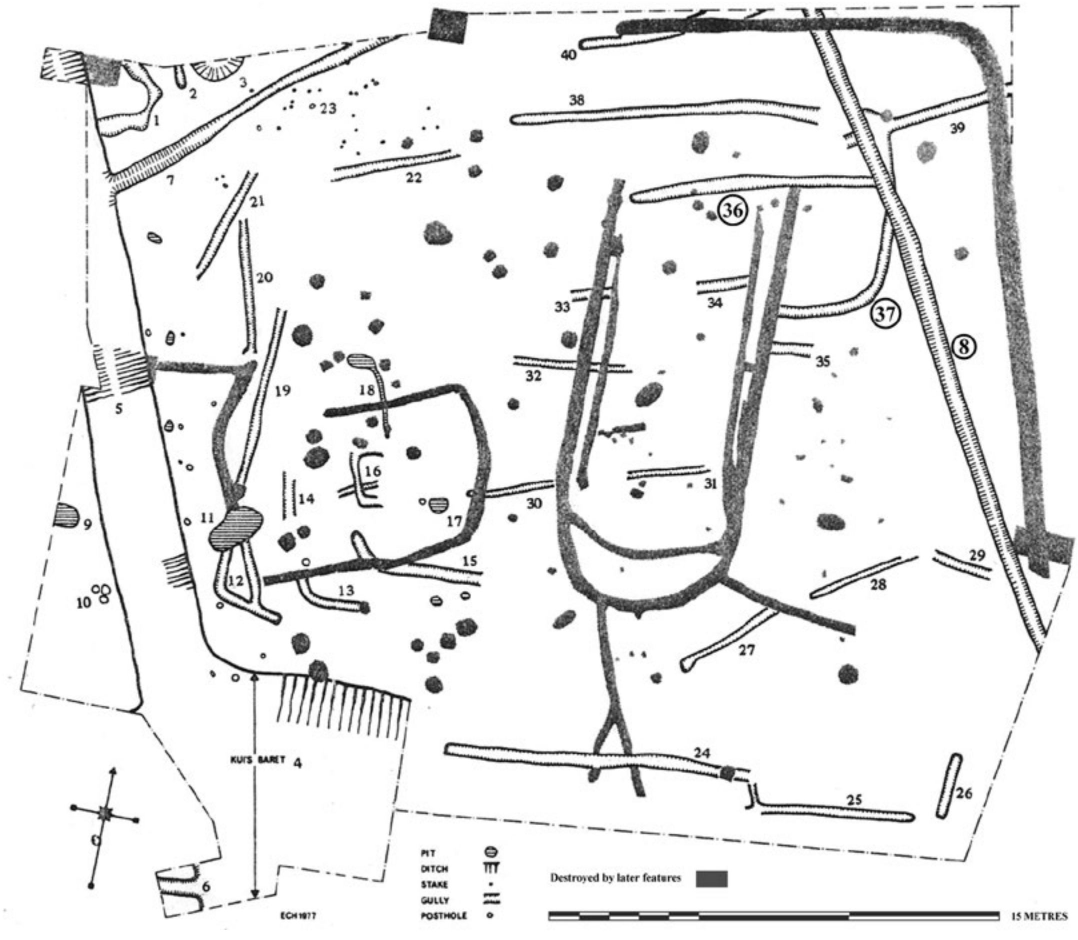


Figure 17.18 Hed Mound, showing features assigned to Periods I–V.

The relationship between feature 8, on the one hand, and features 36 and 37, on the other, indicates that feature 8 is later than the others, not earlier, as stated in the explanatory text attached to the original figure and its discussion in panels 3 and 4 of Fig. 7 of Harris 1977 (panels A and B of Fig. 17.17 here).

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Periods V–VII

The clearest picture of the building sequence of Mound Periods V–VII (Harris 1977: 7–9) is presented by Period VII. At this stage, there was what Harris interpreted as a house for women and pigs running north–south across the top of the hill (House 3 of Fig. 17.17E; cf. Fig. 17.18). The horseshoe plan of the ditching, which provided a building space of 15 x 5 m, indicated a subrectangular house of the veranda type, like those in the swamp, where the living quarters were at the front. There were some holes for posts that had carried the ridgepole. A fireplace and cooking pits found in the front part of House 3 were appropriate for a women's house, while two irregular hollows in the space behind could equally appropriately be seen as pig wallows. Harris, however, used the model of an abandoned house that he recorded at the northern foot of Ep Ridge (1977: 15) to suggest that House 3 had had living quarters at the two ends and pigs in the middle.

There had been two earlier ditches of horseshoe plan at the site of House 3, representing Periods V and VI on the mound (Houses 1 and 2 of Fig. 17.17C and D here; cf. Fig. 17.18 and Harris 1977: Fig. 2). Though they were of smaller size than House 3, they were presumed to have had the same layout (Harris 1977: 21) and therefore function.

House 1, the smallest of the three houses built north–south on the same spot, was represented by what were interpreted as the remnants of a house ditch on its long sides, with a now lost outlet at its southeast corner. The house space allowed by the estimated ditch line is 10 x 4 m. No other features could be assigned to the period of the house. House 2 is represented by even fewer remnants of its suggested house ditch than House 1, except that what is taken as the curved section of its southern end was fully preserved. Like House 1, it is reconstructed as a veranda house, with 12 x 5 m available within the suggested line of the ditch. As with House 1, it was impossible to identify other features, internal or external, that were in use at the same time as House 2.

Allowing double the conventional estimates of four or five years for the lifespan of a house, Harris (1977: 13) gave a duration of 30 years for Periods V–VII (citing Lampert 1973: 4 for Kuk and Brown 1972: 34 for Simbu, based on Brown and Brookfield 1967: 130). During this short period of activity, there was another veranda house on Hed Mound (House 4 of Fig. 17.17E and cf. Fig. 17.18; Harris 1977: 9 and Fig. 2), running east–west across its western flank somewhat obliquely to the lines of Houses 1–3, whose lines were only a few metres east of House 4's rounded end. The small size of House 4, half the length of House 3, was consistent with its having been a men's house, with no provision for pigs. There was no way of knowing to which, if any, of the three periods of the women's house it had belonged.

The same was true of a perimeter fence enclosing a habitation area of some 900 m^2 centred on these houses (Harris 1977: 9 and Fig. 2, features 76–79). It consisted for the most part of preserved stubs of posts, but as postholes on the shoulder of Hed Mound in the southern half of its western side (Harris 1977: Fig. 2, feature 77). It was not investigated in the northeast corner of the site. On the west, north and east there was a single line of posts, in the south a double line. Tibito Tephra was commonly found around the preserved butts of fence posts, suggesting to Harris (1977: 9) that the fence was still in use at the time of the ashfall. It was difficult for him to assign pits and postholes across the site to their place in the occupation sequence. Harris (1977: 8) treated them as part of Period VII because they could not be stratigraphically shown to belong to Period V or VI.

Period VIII

The final phase on Hed Mound before European contact, Period VIII (Harris 1977: 10–11), began sometime after the fall of Tibito Tephra in the AD 1660s, possibly separated by a short time from the end of Period VII. On the other hand, the ditch that was dug for House 5 (Fig. 17.17F) used part of the corresponding ditch of House 4, which might suggest that House 4 remained in use into Period VIII. However, Harris argues (1977: 10) that Period VIII was preceded by the deposition of Layer 2 of the site stratigraphy, a stratum of consistently dark and compact character that buried all the features of Phases V–VII and could have resulted from a period of gardening following Period VII. It was into this new formation that the two major features of Period VIII were dug—the ditch associated with House 5 and a boundary ditch around the top of the hill. These ditches appeared as surface features when the grass was removed prior to excavation (Harris 1977: 11 and Fig. 3; see Fig. 17.17F). They themselves were covered with Layer 1, a humic soil differing mainly from Layer 2 in that it was less compact (1977: 3). The only stone artefacts from the Hed Mound excavations, discussed in Chapter 20, came from Layers 1 and 2.

Though the ditch of House 5 does not completely surround it, it provided a space 6.5 m north–south and 8.5 m east–west for what seems to have been a round or roundish men's house. Because of the gap in the ditch, it is not certain whether three small pits—two probable cooking pits and one hearth—were internal to the house, but they are the only candidates. The house ditch articulated with the ditch dug around the hill, which enclosed an area of some 750 m^2 and had an outlet at the southwest corner. Within the compound thus defined, there were hearths and cooking pits. Harris (1977: 21) suggests that Hed Mound may have served as a ceremonial ground at this stage, but admits (1977: 11) that he found no local knowledge of any recent occupation there. It is interesting, however, that workmen found plant remains in small holes at the northwest point of the house (Harris 1977: 10–11, Fig. 3, feature 82) and similar occurrences in the compound (Harris 1977: Fig. 3, features 88–89), which they identified as *tanket* (*Cordyline*), whose leaves are used to cover men's buttocks. This would have been appropriate for a ceremonial ground (Strathern 1971: 8, cited by Harris 1977: 21).

An overview of the evidence

House mounds with accompanying ditches were a feature of the swamp surface at Kuk, mainly clustered along and to the east of Wai's Baret, the major disposal channel of Phases 5 and 6 of the Kuk sequence. Wai's marks the eastern boundary of wetland cultivation in Phase 6, when, it has been suggested, the adoption of the sweet potato as staple allowed the abandonment of the deeper swamp north and east of Wai's Baret at Kuk, as well as much drained and cultivated swamp elsewhere in the upper Wahgi Valley. At Kuk, houses were built to give ready access to the sweet potato gardens across Wai's Baret to the west and to pig-grazing ground that had replaced cultivation to the east. A fence line along the eastern bank of Simon's Baret was evidence of protective measures against pig depredations.

In 1972, Ron Lampert selected a cluster of Phase 6 house mounds at the northern end of block A9g for archaeological investigation, on the basis of which he identified a homestead of four houses for women and pigs and a men's house. All five houses were accompanied by ditches of horseshoe plan, suggesting that they were of what Paul Gorecki subsequently called the 'veranda' type. In the light of his 1977–78 investigations, Gorecki highlighted problems in the interpretation of the form and function of the structures due to the complexity of the ethnographic evidence available for comparison and the limited character of the archaeological evidence. He saw all this as pointing not to a cluster of buildings of a single date, but to the relocation and rebuilding of structures by a single family over 'a surprisingly long period of time' (1982: 161), by which he meant, in terms of his Kuk experience, 'probably much longer than 15 years'.

Lampert's excavations of 1973 recovered evidence of two houses of an earlier date beneath the Phase 6 mound cluster of 1972, one of them a veranda house, both allocated to Phase 5 because of the presence of Tibito Tephra in the house ditches. A subsequent review of the dating evidence (Lewis, Denham and Golson 2016) has indicated the ash to be in secondary position.

Veranda houses of Kuk Phase 5 were excavated by Ed Harris in 1977 on top of a small hill, Hed Mound, in the swamp in block A11. There was a sequence of three houses interpreted as being for women and pigs (Mound Periods V–VII) and a smaller structure interpreted as a house for men, with the likelihood of earlier houses now thought of as belonging to Mound Period III, still Kuk Phase 5 but early in it. Harris (1977: 22) considered that the sequence of houses constituting Mound Periods V–VII might mean either their immediate rebuilding at the same location or the repeated use of this over a longer period of time. For Gorecki, the evidence of both the Harris and the Lampert sites pointed to 'the intensive use of house sites at specific locations' (1982: 162) and we might extend this to the evidence of house site distribution as a whole. Gorecki envisaged a stability of economic, social and political life and contrasted it with the unstable situation in the 1970s at Kuk, which he saw as resulting from the regular intake of migrants into the community (see Chapter 23).

This is an interesting interpretation in the light of the fact that the evidence for stability comes from two periods, Phases 5 and 6, the transition between which saw the adoption of a new staple, sweet potato, and the wholesale reorganisation of activities in the swamp. We have limited evidence about the presence and distribution of Phase 5 houses in the swamp, though the appearance of houses then, both in the swamp and on Hed Mound, might be connected with the appearance of raised-bed agriculture in the swamp. Raised-bed cultivation has been argued elsewhere to characterise Phase 5 (see Chapter 15), with a switch from taro to yam as staple, possibly coinciding with the arrival of the pig and perhaps the lesser yam (*Dioscorea esculenta*) from Austronesian settlements in the lowlands, both of which would have reinforced the new agronomy of raised-bed cultivation. The new agronomy of Phase 5, of course, continued into Phase 6 to become that of the sweet potato.

It can be also argued that the changes in house style that occurred during the contact period in the upper Wahgi Valley were a reflection of the growing importance of pig rearing, which was advantaged by raised-bed cultivation, especially that associated with the sweet potato. Reporting in the early years of contact, Vicedom noted the presence of pigs in all women's and even some family houses and a single entrance shared by pigs and people (Vicedom and Tischner 1943–48 and 1983: Fig. 76). Forty years later, whenever they lived under the same roof, women and pigs had separate quarters and different entrances (Gorecki 1982: 93). Side by side with this change went simplification in other respects, for example, the disappearance of men's houses of subrectangular and veranda type and the lesser importance of veranda houses as a type overall (Gorecki 1982: 87, 97). Gorecki (1982: 93–94) noted a tendency for the houses for women and pigs at Kuk in the 1970s to be longer than simple dwelling houses, though there was great variability in the space provided for pigs, as well as in arrangements for them by way of stalls, such things depending on an individual's 'will, wealth and expectations'. We can expect these developments of the contact period to have had their roots in pre-contact times.

Acknowledgements

I am grateful to the three members of the Kuk team, Ron Lampert, Ed Harris and Paul Gorecki, whose work on the archaeological, ethnographic and historical aspects of human settlement at Kuk it has been the aim of this chapter to integrate, for their contributions to a cooperative endeavour at the time of fieldwork and subsequently. I thank Winifred Mumford, then illustrator and cartographer in the ANU Department of Prehistory, whose mapping of the surface indications of drainage channels and house sites exposed in the course of grass cutting and drain digging during the initial fieldwork in 1972, laid the basis for the large-scale plans characteristic of the book as a whole. Finally, I acknowledge the cooperation of Terry Bell, who as an ANU doctoral student in the early 1970s included ovenstones from the Kuk house excavations in his studies of thermoluminescence dating.

Part Four: Artefacts of Wood and Stone

18

The Kuk Artefacts, an Introduction

Jack Golson

The next three chapters deal with stone and wooden objects recovered in the course of investigations of the cultivation and living areas that have been the subject of previous chapters or collected from adjacent properties. The stone material is divided between Chapter 20, mainly flaked and ground tools with use wear and organic residues giving evidence of subsistence, and Chapter 21, mainly ground and polished axes and fragments giving evidence of trade. The wooden finds are dealt with first, in Chapter 19. Before we embark on these chapters, however, we need to consider the circumstances in which the finds were made, processed and stored, because these are relevant to a consideration of their contribution to our understanding of the site.

The circumstances of discovery and retrieval

There are a number of points to be made about the discovery and retrieval of artefacts at Kuk.

There were fewer finds made by archaeological excavation than during the drain digging carried out to give us access to the swamp deposits for our investigation. This was particularly the case with the more than 12 km of major channels that were needed to drain the eastern half of the Research Station, where we were to work, and to provide the infrastructure of roads for its future development. The job was started by Station workmen in mid-1972 and went on for about three months. The 15 km of mainly minor drains for which we were responsible over the years 1972–77 were dug for our own purposes, by our own workmen, in conformity with the Station plan. These workmen were aware of the need to watch out for finds of stone and wood, even though drain digging often did not allow certainty about the location of the finds that were made.

The areas of the site used for cultivation or pasture in the prehistoric past were much poorer in associated finds than the housing areas, apart perhaps from the wooden stakes of fences, while most of the houses belonged to Phase 6. Two of the small number of identified Phase 5 houses were unknown until excavations revealed them beneath Phase 6 houses, so it is difficult to make a realistic assessment of the extent of Phase 5 housing and associated items. Not only were houses unknown in the swamp before Phase 5, so too were preserved wooden artefacts, as discussed in Chapter 19, section 'The Steensberg catalogue' (cf. Powell 1982b: 28, 30).

The cultivations of Phases 4–6 were characterised by grid patterns of long straight ditches crossing at right angles. They were mapped from the appearance of the constituent ditches in the walls of the Station drains that were dug at intervals of 22.5 m across, as discussed and depicted in Chapters 14–16. It was in general unnecessary to dig out the ditches to study the organisation of the cultivation system, but this meant forgoing recovery of any stone and wooden objects that might be there. Because there were no Phase 4 houses in the swamp, Phase 4 is impoverished in associated finds in comparison with Phase 6, while Phase 5 should be less so. In addition, these three phases belong within the 'garden soils' of the Kuk stratigraphic column (see Figs 6.10 and 6.11). There is a large category of stone finds that cannot be dated more precisely than Phases 4–6 because of uncertainty as to where they had belonged in those soils before being unearthed by drain digging.

Like Phase 4, Phase 3 is poor in associated material because it lacks houses in the swamp and because it has a field system that was studied with a minimum of excavation of the constituent ditches. The organisation of the Phase 3 system could not be reconstructed from the appearance of its ditches in drain walls, because this was not systematic as in Phases 4–6, so it was necessary to follow the ditches using their clear imprint at the surface of the grey clay that is a marked feature of the Kuk stratigraphy (cf. Fig. 13.10).

To understand Phases 1 and 2 required total excavation and recovery in area excavations in the southeast corner of the Station, which therefore included attention to any evidence from later phases. However, the areas selected, in blocks A11 and A12, had had minimal interference from Phase 4 and 6 activity.

The circumstances of curation, and its failures

Wood

It was, of course, the waterlogged wood that was of immediate concern from a curatorial point of view. Conservation facilities for such material had been developed at ANU by Wal Ambrose over the five years since the Manton excavations, in which he had taken part. These had shown the potential of the upper Wahgi wetlands for archaeological research into agricultural history and encouraged us to commit our department to the task. Ambrose aimed to provide a method of conservation for waterlogged timber that promised more efficient operation and superior results to the techniques of the time. He developed the freeze-drying procedure that has become standard practice (Ambrose 1975; cf. Golson 1996: 158–159).

The problem was one of preventing objects from drying out before and during their shipment back to the Canberra laboratory. This was particularly the case during the long 1972 season when the major drainage lines were being dug and large amounts of wood unearthed. Ambrose was at Kuk over this period with various responsibilities, including giving appropriate treatment in the field to waterlogged wooden objects of different kinds and at different stages of deterioration. We were occasionally lucky enough then, and in later years, to arrange for material to be flown from Mount Hagen to the Royal Australian Airforce base outside Canberra on aircraft returning empty from official missions to Papua New Guinea. After each major season of wood recovery—1972, 1974 and 1975—there were always pieces too degraded to be sent off from Kuk or not in a good enough state, or of sufficient importance, to justify the time and effort of conservation, for which there was always a queue.

Storage for the conserved specimens was never satisfactory at ANU during the 1970s and early 1980s. There were changes of location and supervision of the items and their records during which some losses of each occurred. This was partly because the wooden objects did not attract the same level of attention as the stone items. Laurie Lucking, a University of Minnesota student who came to work at Kuk during summer breaks in 1973 and 1974, developed a strong interest in the wooden finds, both artefactual and not, and their botanical identification. After the 1975 PNG season, she was employed by the ANU Department of Prehistory to work on the wood finds stored there, after which she took part in the 1976 season at Kuk. Her direct involvement with the project ended when her application for an ANU scholarship to continue her Kuk wood and seed research was unsuccessful. Her records form a part of the Kuk archive that has not been much used since she left in 1976. In 1983, Axel Steensberg, who had worked at Kuk in 1975, came to the Department of Prehistory as a Visiting Fellow and compiled a catalogue of the wooden artefacts from Kuk and elsewhere (see Chapter 19).

Stone

Each Kuk field season contributed to a growing collection of stone artefacts in Canberra, which was housed separately from the wooden artefact collection. Material from these collections was withdrawn in batches for cataloguing by Golson with two ANU undergraduate students of archaeology, Kieran Hotchin and Peter May. By the beginning of the 1980s, a catalogue of some 750 cards had been compiled, identifying each object or collection of closely associated objects by a code comprising the site, the year of collection, S for stone (W for wood in the parallel, pre-Steensberg, wood catalogue) and a unique number for the object itself, e.g. K/72/S12, K/75/S18A, B. Information entered on each card included a brief description of the object or objects in question, details of the findspot and sometimes, from this, the relative age, as well as observations about the context of the discovery as it was then understood. The stone finds were then ready to make their contribution to the study of Kuk and its place in the wider world of the PNG highlands.

In 1980, John Burton came to ANU from the UK as a PhD scholar to study axe manufacture and the axe trade in the Wahgi region, for which he made use of archaeological finds of axes and parts of axes found at Kuk. The results of this and associated work on stone sourcing are discussed in Chapter 21.

In 1987, we hired Tom Loy of the Royal British Columbia Museum, a pioneer in the study of organic residues on stone tools, to set up a residue laboratory at ANU. Loy was joined in 1988 by Barry Fankhauser, who had a doctorate on the chemistry of residues from Maori earth ovens and the thermoluminescence dating of their ovenstones. In 1991, Loy inspected stone material from Kuk and made a selection of items with potential for usewear and/or organic residue analysis. Loy recorded his examination of 88 items, out of which he selected 58, which were stored in the residue laboratory for future attention. That attention came in the later 1990s when Tim Denham commenced a PhD at ANU for a project of field and laboratory research into the early phases of the Kuk agricultural sequence. His aim was to test the claims that had been made on the basis of the Kuk work of the 1970s for early and independent origins of agriculture in New Guinea. Denham thus became heir to 19 items from Phases 1–3 that were part of the Loy selection of 58 Kuk items with organic residues and usewear, 13 of the 19 being from the 1975–77 investigations in the southeastern blocks of the Station. Denham enlisted the services of Richard Fullagar, then of the University of Sydney, for their study.

By the time of Denham's work, most of the department's archaeological collections, comprising all the Kuk stone but only some of the wood, had been moved off campus into a store at Weston on the urban fringe of Canberra. The materials that Denham had used for his research had not been reunited with the main Kuk stone collection when the Weston store went up in flames during a daytime firestorm that hit Canberra's western suburbs on 18 January, 2003 (Swete Kelly and Phear 2004). The concrete slab ceiling of the archaeology store and its brick walls collapsed and compacted the materials underneath. Before the fire, these had been densely packed by region and site. With the destruction of the boxes and bags in which most of the objects had been stored, remains were mixed up and identifying labels largely destroyed.

The aftermath of the Weston fire

Salvage efforts over subsequent months consisted of excavation to recover the archaeological materials horizontally in terms of a grid of excavation squares and vertically in terms of the stratigraphy of the deposit. This first step in the salvage process was the subject of Swete Kelly and Phear's 2004 report.

The second step was to use the locational information provided by the salvage excavations to track down the collections to which items might have originally belonged by reference to catalogues indicating where particular collections had been situated in the store. Other evidence such as surviving labels or catalogue numbers, distinctive features of particular collections and the like then came into play. The university made space and basic facilities available for this painstaking work at Spring Valley Farm, a rural property some 6–7 km from the burnt-out store. It resulted in a large report discussing the results achieved and the basis they provided for further work (Swete Kelly and Hunt 2006). However, as Richard Fullagar points out in Chapter 20, there was limited success in making use of the material that the salvage operations had identified as likely to belong to Kuk. Adam Black, a recent ANU student who had had good results in digitally enhancing the legibility of photographs of Australian rock art, was recruited to work with Fullagar and Golson to provide digital images of potentially readable catalogue numbers on stone artefacts or information on labels associated with them. However, the results did not warrant the time and labour involved.

As Denham and Ballard have said (2003: 131), the Weston episode highlights the danger of delay in the study and publication of excavated materials. We were essentially unable to use some 90 per cent of the stone recovered at Kuk between 1969 and 1977 and very fortunate that the 10 per cent available for study was as productive as it proved to be.

The wooden finds have their own story to tell. We are concerned here with the material brought down from Mount Hagen to Australia and catalogued at ANU in 1983 with numbers prefixed by 'A'. This was to distinguish them from other catalogued items that remained in PNG, as described in Chapter 19. In the introduction to his 1983 catalogue, Steensberg says that he drew all the A-catalogued items at full scale, and that they numbered 504, but he actually dealt with 511 (see Table 18.1). A small number of these wood finds was transferred with the Kuk stone collection to the Weston store when it was set up. Those left on campus were there until 2003, when they were sent to Spring Valley Farm to join the material recently salvaged from the Weston store. When Golson and Adam Black later inventoried the wooden material at Spring Valley, they found that 61 pieces were missing from the 511 items catalogued in 1983. Some of them were, no doubt, victims of the fire.

There is, however, another part to the story of the wooden items catalogued by Steensberg. In the catalogue, these are arranged in groups according to the purposes for which they were used—digging sticks, spades and so on. Within these groups each entry is identified by the designation given to it in the field, usually in the form described for the stone finds, i.e. site, year, material and a unique number, thus K/75/W12. These entries begin with the finds from Kuk, followed (in the main) by those from elsewhere in the upper Wahgi and concluding with others lacking any field identification. One hundred of the 511 wood finds that Steensberg had catalogued (Table 18.1) reflect the loss of labels or field documentation in the conditions described above. The annotations that subsequently appeared in the Steensberg catalogue, as work on the wood collection proceeded, testify to continuing difficulties with the harmonisation of the field records and, to a minor extent, disagreements with Steensberg's ascription of function to particular items.

Because of uncertainty over the findspot of many items, the treatment of the wooden artefacts in Chapter 19 is a straightforward account of the objects recovered, with little attempt at analysis in the context of the site, except, to some extent, for the fence stakes.

Table 18.1 Wooden tools catalogued, with an A prefix, by Steensberg in 1983 by category and provenance, followed (in brackets) by the numbers missing from the inventory undertaken in 2003.

Category	Kuk	Upper Wahgi	Unknown	Totals
(I) levers and planting sticks	39 (16)	5 (3)	20 (4)	64 (23)
(II) women's sticks for tuber harvest	49 (4)	25 (0)	22 (2)	96 (6)
(III) long paddle spades				
a) spatulate	2 (0)	10 (4)	7 (1)	19 (5)
b) shouldered	1 (1)	6 (0)	11 (2)	18 (3)
(IV) paddle spades with counterweights	0 (0)	1 (1)	3 (0)	4 (1)
(V) double paddle spades	2 (0)	1 (1)	0 (0)	3 (1)
(VI) short paddle spades	2 (0)	2 (1)	3 (0)	7 (1)
(VII) axe hafts	2 (2)	6 (6)	1 (1)	9 (9)
(VIII) headrests	5 (0)	0 (0)	3 (0)	8 (0)
(IX) clubs	1 (0)	0 (0)	4 (0)	5 (0)
(X) weapons	2 (1)	1 (1)	0 (0)	3 (2)
(XI) house timbers and fence stakes	195 (6)	29 (1)	17 (1)	241 (8)
(XII) unidentified items	24 (2)	1 (0)	9 (0)	34 (2)
Total	324 (32)	87 (18)	100 (11)	511 (61)

Acknowledgements

ANU undergraduate archaeology students Kieran Hotchin and Peter May were hired to help with the original cataloguing of the Kuk stone, which they did with intelligence and good humour. I thank Adam Black for his assistance with the inventory of wooden artefacts in the wake of the 2003 bushfire and Alexandra Chiragakis for its tabulation.

19

Artefacts of Wood

Jack Golson

The starting point of this chapter is the catalogue compiled by Axel Steensberg on an academic visit to Canberra in 1983. As a former student of his, I had invited him to take part in the Kuk work because of his long experience as an ethnographer, historian and archaeologist specialising in peasant life and labour. His role at Kuk was to work with older members of the community in the investigation of the tools and procedures of traditional agriculture in order to provide a better understanding of relevant aspects of the evidence that was being archaeologically recovered.

The Steensberg catalogue

Steensberg came to Canberra in 1983 to make a catalogue of the wooden artefacts that had been recovered during the course of work at Kuk, the majority of which were agricultural implements, with a few of other types. He also included material from other locations of drainage with which we had become familiar after the Manton excavations of 1966 made us aware of the archaeological interest of the upper Wahgi Valley as a whole (Chapter 1, section 'The choice of Kuk'). Items salvaged from such drainage operations tended to be the larger and more spectacular items of agricultural equipment, which were only present in small numbers in the more representative Kuk collection. The people in possession of such pieces were often happy to donate specimens to us and these were sent to Canberra with the finds made in the course of our own work.

As reported in Chapter 18, Steensberg described, measured and drew some 511 items from these sources (Table 18.1), giving each of them a catalogue number prefixed by A, from A1 onwards. In the catalogue itself, he arranged them in functional categories as set out in the Table 18.1. Within each of these categories, the items belonging to it were entered in a specific order: first the finds made at Kuk; then those from other sites, mainly in the upper Wahgi Valley and neighbouring areas; finally those with no provenance, which might include pieces from both Kuk and the upper Wahgi that had lost their labels.

There were records of other relevant material that were included in the catalogue as items without an A number because they were not sent to Canberra. They were pieces that belonged to public and private collections that Steensberg had seen in the course of his Papua New Guinea (PNG) visits, such as in the PNG National Museum and at the University of Papua New Guinea in Port Moresby and, in Mount Hagen, at the high school, the local agricultural college and the short-lived Western Highlands Cultural Gallery. The records of such items were catalogued in the relevant category after the A-labelled pieces. The total listing amounted to some 540 items.

However, the A numbers bear no systematic relationship to the overall listing of which they are part. Thus in Group I, levers and planting sticks, nos 1–6 correspond to A numbers 24, 25, 99, 137a, 137b, 154. This was a result of the scattered and often temporary nature of the storage available for the wooden items at ANU after their conservation, as described for the archaeological storage overall in Chapter 18. It meant that items belonging to the same Steenberg group sometimes came to him from different stores or the same store at different times in the course of his work and were given their A numbers in isolation from other objects of the same class.

There was a potential problem with Steensberg's interpretation of the catalogued material. In the field, his procedure was to observe the current practices of highlanders in their gardens and settlements and ask the older men to set up demonstrations of what had been done before the arrival of Europeans some 40 years before. He described these demonstrations in a book, *New Guinea Gardens* (Steensberg 1980), and included the tools that were made for them as Group XIII of his catalogue, called Modern Replicas.

The specific problem with this strategy raised by Kuk, as distinct from other places where he worked, concerned the fact that the area had been abandoned in the early 20th century by its Kawelka inhabitants following defeat in warfare and they had moved to the territory of related groups in the mountains of the Sepik-Wahgi Divide to the north (see Chapter 22, the section 'Kawelka settlement history' and Chapter 23, the opening paragraph). Ul (Fig. 19.1a) and El (Fig. 19.1b) were two older men who made the tools and demonstrated the technology of swamp cultivation at Kuk in 1975. In fact, they still lived in the mountains and were at the time visiting kinsmen at Kuk, who had themselves only moved back over the previous 10–15 years after a lifetime spent in a context of dryland agriculture. As regards the upper Wahgi Valley more widely, when the first Europeans saw it in the early 1930s, they found the swamplands on the valley floor largely unutilised agriculturally, with settlement and sweet potato and mixed crop cultivation taking place on higher ground (Brookfield 1964: 22, Fig. 2; cf. Chapter 16, section 'Different histories for different regions').

In an article of 1985, Golson and Steensberg looked at the agricultural implements reviewed in the 1983 catalogue in the light of the evidence about both wetland and grassland cultivation in the New Guinea highlands overall, together with evidence as to their chronology. The stratigraphy of the *in situ* finds at Kuk showed them to be restricted to Phases 5 and 6 of the sequence. There were natural timbers of greater age in the swamp, at depths where the waterlogging responsible for their preservation had not been affected by changes in the watertable associated with periodic agricultural drainage of the swamp. The alternate wetting and drying produced by such fluctuations led to the decay of any wooden artefacts of phases earlier than Phase 5. The entire area of our investigations was associated with Phase 5, as well as Phase 6, which overlay Phase 5 to a limited extent. After the abandonment of cultivation at Kuk Swamp around AD 1900 (see Chapter 16, section 'Dating Phase 6 at Kuk'), the area became waterlogged until 1969, when drainage associated with the development of the Research Station began. The effects of that drainage on the condition of Phase 5 and Phase 6 artefacts were becoming obvious by 1977. The actual digging of the major drains across the eastern half of the Station, by Station labour in 1972, to allow us to get to work also took its toll on the wooden remains because some were damaged or broken in the process.

Figure 19.1 Ul and El.

a) Ul is the older of the two men in this picture. His younger companion is Korowa, from Kuk, who appears in Figure 12.6. The men are holding paddle-shaped spades recovered from the swamp during early drainage for the establishment of the Research Station and put away in the Station store. b) Here El is felling a tree with a stone axe as part of the demonstrations and experiments organised during Axel Steensberg's visit to Kuk in 1975.

Source: Photographs by Philip Hughes in the Kuk archive, 1975.

Agricultural tools and technology at Kuk

Digging sticks and tools of clearance

By far the most common agricultural tools recovered from Kuk Swamp were digging sticks of a wide range of sizes. They could be seen as encompassing the two types commonly described in the literature of New Guinea highlands agriculture in both wetland and dryland contexts (Golson and Steensberg 1985: 370–372) and represented by Groups I and II of the Steensberg catalogue: the shorter, lighter, smaller-diameter stick used by women (Group II, see Fig. 19.2h) in weeding and harvesting the sweet potato tubers planted in the soil; and the men's longer, heavier, larger-diameter digging sticks (Group I, see Fig. 19.2i), which had roles in soil formation through the clearing of swamp vegetation and in the digging of planting holes. Mostly the tools were found in the bottom of ditches, where they had been deliberately put so that water could conserve them and lend them extra weight. The women's sticks were typically in the perimeter ditches of their houses and the men's were in field ditches.

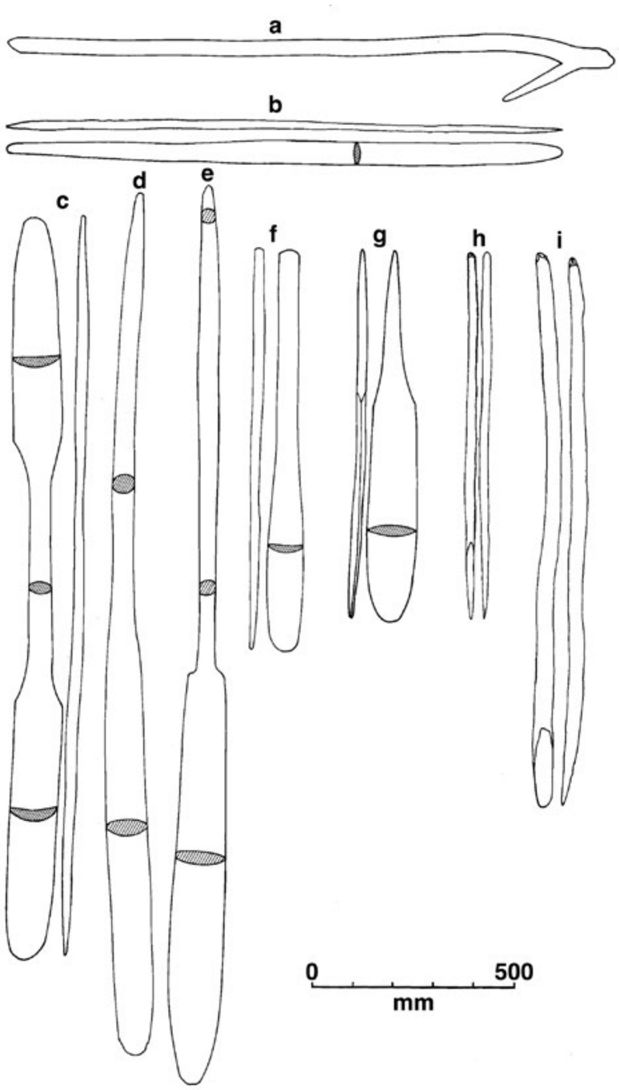


Figure 19.2 New Guinea agricultural implements discussed in the text.
Source: After Golson and Steensberg (1985: Fig. 1), reproduced with permission.

Both sticks are simple tools made of straight lengths of timber, single- or double-bevelled at one end to form a working edge. From their descriptions, one would expect the two categories to be readily distinguishable by their length and thickness, but Golson and Steensberg (1985: 373–374) show this not to be so in the case of the collection from Kuk and other upper Wahgi sites. From a statistical analysis of 63 complete or virtually complete specimens, they suggest that 23 sticks 40 mm or more thick belong to the heavier type associated with men, while 37 sticks 30 mm and less thick belong to the thinner type associated with women. Only three of the latter group are more than 1.1 m long and only three of the former group are less than 1 m. In this situation, it cannot be assumed that double bevelling would be characteristic of men's digging sticks and single bevelling of women's. In the collection of sticks from Kuk itself, the nature of the bevelling could be seen on 28 of the 39 sticks considered to be men's and on 36 of the 49 considered to be women's. Of the 28 sticks presumed to be men's, three are bevelled with a double facet for every one with a single facet. Of the 36 sticks presumed to be women's, there are three bevelled with a single facet for every two with a double facet. It is understandable in the light of all this that there were, at times, differences of opinion among project members in the field, and even among the workmen, as to which category a particular digging stick was likely to have belonged.

The demonstration of swamp grass clearance that was organised for Steensberg by the two older Kawelka men, El and Ul, revealed a set of tools and practices that it would have been difficult to reconstruct from existing evidence (Golson and Steensberg 1985: 355–358; cf. Steensberg 1980: 53–59). These included two uses of the stone axe: chopping cane grass at its base before removing its clump of roots with a heavy digging stick; and cutting through the swamp's short grass cover, which was then pulled back from the line of the incision by men using single-pronged long-handled wooden hooks (*mak*; see Fig. 19.2a), while others freed it from its roots by slashing them with what they called a 'wooden bushknife' (Steensberg 1980: Figs 38–41; see Fig. 19.2b here). The name for this is *yakla* in the local language, after the palm species from whose wood it was made.

The use of stone blades to cut cane grass conforms with the observations of the early missionary Vicedom, who during the 1930s lived at Ogelbeng above the Wahgi Valley on what Russell Blong (1986: 288) calls the southeastern apron of Mt Hagen, not far from the present Mount Hagen township (Vicedom and Tischner 1943–48: 185 and 1983: 209). Vicedom, however, makes no mention of either *mak* or *yakla,* presumably because they were tools of swampland clearance that had no place in the grassland operations with which he was familiar. For their part, El and Ul used both implements presumably because the Kawelka, on the occasion of their defeat in war, carried knowledge of them from the swamp at Kuk to the mountains of the Sepik-Wahgi Divide, where there may have been occasion to continue to employ them. Certainly, the two old men readily identified two *yakla* among the wooden implements uncovered during early drainage work at Kuk Station and stored at the Station. In addition, shortly after Steensberg had left Kuk in 1975, what was interpreted as a broken *yakla* was found in a Phase 5 ditch under excavation in the southeast corner of the Station (Golson and Steensberg 1985: 377). As regards the hook, while no example has been reported from Kuk or any other upper Wahgi swamp site, Ballard (Fig. 5.11) illustrates its current use in swampland agriculture in the Tari Basin in Southern Highlands Province, while Golson and Steensberg (1985: 358) report the discovery of an archaeological specimen at 1–1.5 m depth in a swamp in the same region.

Long-handled implements with paddle-shaped blades

Implements of this general description but varying form are widely distributed through the New Guinea highlands, where they are associated with wetland ditching, dryland trenching and the earth shifting that accompanies both in the preparation of gardens (Golson and Steensberg 1985: 351–355). Steensberg's catalogue deals with the upper Wahgi corpus of such tools under the name of long paddle spades and in four varieties. The first two varieties, both belonging to Group III, are either 'spatulate', where the blade tapers gently into the shaft (Fig. 19.2d; cf. also Fig. 19.3), or 'shouldered', where the top of the blade is angled into the shaft (Fig. 19.2e; cf. also Fig. 19.3). The other two varieties form two classes: Group IV, which has implements where the upper part of the long handle has some form of thickening serving as a counterweight (Fig. 19.3 shows three or four examples), while Group V has double paddle spades with blades at both ends (Fig. 19.2c).

The most common forms in the Wahgi collection are the spatulate and the shouldered paddles, though they were only found in low numbers during our own investigations at Kuk Swamp (three examples) compared to those uncovered during drainage work elsewhere on the Station and around the upper Wahgi wetlands (16 examples; see Table 18.1). A few examples from the Station store were in a good enough state of preservation to be used in a demonstration of their use and performance in ditch digging that Ul and El conducted on Station land (Steensberg 1980: 87–95). When they were asked to make replicas for us in 1975 to increase the number available for the demonstration, we were surprised when they supplied not only two single-bladed specimens, but three double-bladed ones as well.

Figure 19.3 Long-handled implements with paddle-shaped blades from the upper Wahgi, leaning against an end wall of the expedition house at Kuk Station.

There are a variety of implements on display: two or three cases where spatulate paddles (Steensberg Group IIIa), and one case where a shouldered paddle (Steensberg Group IIIb), are combined with a long handle with a thickening of the upper part to serve as a counterweight (Steensberg Group IV). Korowa's spade in Figure 19.1a combines the features of Group IIIa and Group IV.

Source: Photograph by Axel Steensberg, 1975.

At the time, there were no double-bladed tools on the published record or in the material recovered from Kuk and other upper Wahgi sites. However, at the end of the 1972 season, Golson had asked one of the workmen, Ivan Kuri, an Elti man from Baglaga (on the edge of the eastern apron of Mt Hagen just west of the North Wahgi Swamp and 6–7 km north-northwest of Kuk) to get his father to make a set of traditional gardening tools before our return in 1973. The only two that were produced were both double-bladed paddle spades. This was one of the reasons why initially we thought of them as tools of dryland cultivation (e.g. Steensberg 1980: 80–84). However, evidence was soon forthcoming to suggest their use in both dryland and wetland cultivation (Golson and Steensberg 1985: 359), including an example from Kuk Swamp itself (Gorecki 1978), though outside the boundaries of Kuk Station and too close to the swamp margin to be put decisively in the wetland sphere.

The replicated double-bladed tools of the 1970s and fossil specimens subsequently reported are broadly similar in dimensions. They fall in the middle range of the upper Wahgi archaeological collection of single-bladed tools, where the spatulate and shouldered forms are considered together because they are not separable in terms of their dimensions (Golson and Steensberg 1985: 363–367, Tables 4–6). Their size range is so wide as to suggest that implements of different function are represented, though plots of total length, blade length and blade width, separately and together, failed to isolate any groupings. The data show a strong relationship to exist between blade length and total length, a much weaker one between blade width and total length and none between blade length and blade width (Golson and Steensberg 1985: Tables 5 and 6).

Figure 19.4 Long-handled paddle spades in use at an early stage in the preparation of garden beds with spoil from the grid of garden ditches whose pattern is marked out on the surface in the foreground. There is what seems to be a hafted axe on the ground in the middle of the picture.

Source: M.J. Leahy collection, 1933–34, general Kuk-Baisu area, courtesy of John Black, reproduced with permission.

Forty-eight of the 62 complete specimens in the total upper Wahgi collection (meaning all catalogued items whether accompanied by an A prefix or not) fall between 1.5 and 2.5 m in length, as do both of the single-bladed implements made in 1975, while 18 of the 48 are between 2.0 and 2.2 m, as is one of the 1975 pieces (Golson and Steensberg 1985: 365). The upper Wahgi examples are thus clearly longer than those ethnographically recorded for other highlands locations of swamp drainage (Golson and Steensberg 1985: Table 4)—the Huli of Southern Highlands Province of PNG and, in Indonesian New Guinea, the Kapauku of the Paniai (formerly Wissel) Lakes and the Dani of the Grand Baliem Valley. It seems reasonable to suggest that the differences in length reflect differences in use, the Huli, the Kapauku and the Dani slicing the swamp mud into blocks for removal by hand (Golson and Steensberg 1985: Table 4, notes 7–10), while in the upper Wahgi, by the evidence of the 1975 demonstrations, the implements were used as shovels (see Steensberg 1980: 87–95). This suggestion is supported by the fact that the blades of the fossil examples have cross-sections approaching the plano-convex (Fig. 19.2c–e), which is typical of the implements made for the demonstration, single-bladed and double-bladed alike. The flat or slightly hollowed face of these was used for defining the sides of the drain being dug and removing the earth when digging it. Such implements can be seen in use in photographs of dryland agriculture taken in the early days of European contact with the upper Wahgi (Fig. 19.4).

The gridiron pattern of raised bed gardening, whose operation is shown in such photographs, is typical of recent upper Wahgi agricultural practice, whether wetland or dryland, where the grassland sod is not turned over to produce the garden soil, but is instead provided by the spoil from the digging of the intervening grid (Fig. 19.5). This is characteristic of the sweet potato and mixed cropping of Kuk Phase 6, but goes back beyond the arrival of the sweet potato, with evidence for gridded patterns of dryland trenching paralleling the wetland practice of Kuk Phase 5, when *Dioscorea* yams are suggested as the staple crop (see Chapter 15, section 'Phases 3, 4 and 5 compared'). One of the long-handled paddle spades thought to have been the main tool in cultivation of this sort was found in the fill of a Phase 5 ditch cut across by the digging of Station drain B12c/d (for location see Fig. 17.3) during one of the demonstrations of wooden tools in use that were set up for Steensberg in 1975. He was so delighted that when a piece of wood was excavated in association with the spade, he offered to have it dated at the Copenhagen Radiocarbon Laboratory. The radiocarbon age was reported as 370±70 BP (K-2643), which calibrates to between 300 and 520 years BP (Before 1950) at two standard deviations, making the spade in question the oldest dated wooden artefact found at Kuk Swamp.

The unsatisfactory aspect of such demonstrations set up for Steensberg lay in trying to use them to compare the performance of wooden spades with that of steel spades (Steensberg 1980: 87–95). The main difficulty was that the wooden spades were being asked to dig a steep-sided drain to specifications of the Station management based on the use of the steel spade, i.e. some 0.9 m wide at the top reducing to some 0.4 m at the base about 1.6 m below (Golson and Steensberg 1985: 361–362), whereas the larger prehistoric ditches in the swamp, dug with wooden spades, tended to be as wide as they were deep. For discussion of the matter of performance, see Chapter 5, section 'Social contexts for wetland drainage', and Chapter 14, section 'Digging the major disposal channels'.

Figure 19.5 Fully formed garden beds made from the spoil produced by the digging of the garden grid.
Source: M.J. Leahy collection, 1933–34, general Kuk-Baisu area, courtesy of John Black, reproduced with permission.

Shorter paddle tools

One of the implements made for the demonstration of agricultural tools and techniques in 1975 was a short paddle spade of spatulate form and plano-convex cross section (Fig. 19.2f), said to have been used by women for breaking up the clods of earth that the men threw on to the surface when digging the garden grid with their long paddle spades (Golson and Steensberg 1985: 367–368). Of the few upper Wahgi archaeological examples of this kind listed in the Steensberg catalogue there was only one definitely from Kuk Station (1983: 54, no. 228, A328), recovered from an old ditch that was cut across when Station workmen were digging the south drain of E–W Rd 3 at the beginning of our work in 1972. The place where it was found, we came to realise, had in Phase 6 been an area of women's housing at the northwest corner of block C9 (for location see Fig. 17.3). However, another example (catalogue 1983: 55, no. 236), not taken to Canberra, was said to have come from gardened land just beyond the southern Station boundary at its western end.

These three short paddle implements, one replicated, two archaeological, are joined by a small number of other archaeological examples from upper Wahgi sites to form Group VI, short paddle spades, in the Steensberg catalogue. With lengths of up to about 1.5 m, they fall at the lower end of the range for the upper Wahgi archaeological collection of Steensberg's category of long paddle tools (Group III). Only 14 of the 62 complete implements in that collection are less than 1.5 m in length (Golson and Steensberg 1985: 365), so it is possible that these in fact belong in Steensberg's short paddle spade category.

The 1983 catalogue category of short paddle spades includes a few that Golson and Steensberg (1985: 369–370) regarded as a separate type, following Jocelyn Powell (1974: 21). Powell used the botanical term 'hastate-shaped' or 'hastate' for two short paddle spades in a small archaeological collection of wooden agricultural tools from the Mount Hagen region that she was putting on record. The distinctive feature of these was the combination of short overall length with a blade both longer than the shaft, the opposite of all other single-bladed paddle tools, and wider in relation to total implement length than normal in such tools (Powell 1974: Fig. 3, C1 and C2). One of the Powell spades (C2) came from Tibi Plantation immediately east of Kuk, the other (C1) from the Minjigina Tea Estate some 15 km north of Mount Hagen town at an altitude of 1900 m. The example shown here as Figure 19.2g is a drawing by Steensberg of a spade in the former Western Highlands Cultural Gallery said to have been found in the Kuk village area, but there is confusion in the Steensberg catalogue (1983: 56, no. 237) about when it was found and when Steensberg drew it.

Powell (1974: 22) was given a list of uses for the hastate spade in cultivation, none of them a function exclusive to the type (cf. Golson and Steensberg 1985: 370). An additional function (Powell et al. 1975: 13) was its use in straightening trench walls and Golson and Steensberg (1985: 370) refer to an illustration of a young man working the sides of a dryland trench with an implement of short-handled and long-bladed type at a Kapauku village at the Paniai Lakes in the highlands of Indonesian New Guinea (Ishige 1977: 103, top right; Fig. 13.14). This was interesting in the light of the find of a hastate spade in 1976 during the drainage of swampy ground at the High Altitude Experiment Station of the Department of Agriculture, Stock and Fisheries at Tambul in the upper Kaugel Valley 45 km west of Mount Hagen town (Golson 1996; cf. the preliminary notice in Golson and Steensberg 1985: 369–370, 376). Steensberg included the tool in his catalogue (1983: 54, no. 231, A2), concluding from the use wear on the blade and the balance of the tool that it must have been used with the right hand at the top of the handle and left hand holding the edge of the blade and he made a schematic drawing of the tool to this effect. This was before I had introduced him to the Ishige photograph, which shows the young man's hands deployed in precisely this way. He later (1986: 96–98) published his schematic drawing with the Ishige photograph to make the point.

The Tambul spade is the oldest agricultural implement of wood yet dated in New Guinea, with a radiocarbon age of 3930±80 BP (ANU-2282) and a calibrated age range at two standard deviations of 4564–4130 BP. In terms of the Kuk Swamp sequence, this is early Phase 3, which sees the first appearance of rectilinear ditch networks at the Kuk site. These are characterised by substantial ditches with steep sides and flattish base like those of Kuk Phase 5, when they are associated with the use of long-handled paddle spades. The ditch in which the Tambul spade was found is of the same type, as much as 0.7 m below the surface from which it is thought to have been dug and with a slightly sagging base some 0.25 m across widening to 0.5 m above (Golson 1996: Figs 3a–3c). The hastate type of spade, of which it is an example, evidently had a role in the making and maintenance of such ditches.

As seen in Chapter 13, section 'Regional processes in the upper Wahgi Valley and beyond', the Tambul evidence, from 2240 m above sea level, indicates the expansion of agriculture into altitudes marginal for many of the known cultivars (cf. Table 4.1). Golson (1996: 163–167) discusses the issues arising from a proposition that the most likely candidate is *Colocasia* taro, *Colocasia esculenta*, with its greater altitudinal tolerance than other potential staples and its appropriateness for swampland cultivation.

Other artefacts from the swamp

I now turn briefly to other upper Wahgi swamp finds in the Steensberg catalogue that are present in such small numbers and/or come with such poor information as to have only a limited contribution to make. They include:

a. nine pieces from the wooden hafts of stone axe or adze blades (catalogue Group VII);
b. eight headrests (Group VIII), five from Kuk, one find predating the archaeological project, the others found during its first season; and
c. five or six clubs (Group IX), of whose agricultural purpose, if any, Golson and Steensberg (1985: 379) could not be certain, though they cite the use of specific clubs in an agricultural context.

Somewhat more informative are the items listed in Group X, weapons, though they are few in number. They include an arrow tip of black palm found in the fill of a late ditch at Kuk and an arrow shaft of bamboo found at Kindeng, 20 km east down the Wahgi Valley from Kuk. Missing from Steensberg's catalogue, and from the surviving Kuk wooden artefact collection, are two arrowheads found in 1974 in the early Phase 5 stage of a composite ditch dug in the fill of the Phase 3 palaeochannel we called Joseph's Baret (Denham's 107 of Fig. 13.7), which crosses the southern margin of a small ash hill cut through by Station drains A10f/g and g/h. In the Phase 6 stage of the same ditch, lying horizontal directly above the arrowheads in drain A10g/h, there was a man's digging stick, which survives as no. 28 (A344) in Steensberg's catalogue (1983: 10). They are all presumably linked with male use of the small hill in the past, as during the final occupation of Hed Mound (Fig. 17.3, marked H, and Fig. 17.17F) and, less clearly, Blong's Nob (Fig. 17.3, marked B), which had the earthworks of a men's house on it before their destruction during early Station development (cf. Chapter 17, section 'Lampert and a men's round house excavation of 1972)'.

Steensberg's catalogue (1983: 62) also has in Group X, as no. 266, A427, a long billet of black palm, the raw material for arrowheads and spears. This was found in the fill of a highly surface-visible Phase 6 ditch running across the northern margin of Blong's Nob where it was dug through by Station drain A9c/d in mid-1972 (see Baret 3 of Fig. 16.12, where the absence of drain A9c/d itself from the drawing is explained). The billet, recorded by Steensberg as 3.38 m long, 30 mm wide and 20 mm thick, was lost to the 2003 fire discussed in Chapter 18.

House timbers and fence stakes

Group XI is by far the largest of Steensberg's categories (Table 18.1), numbering 195 pieces from Kuk alone, while there are fewer than 50 in total in the Wahgi and unknown columns because these are items that attract little interest. Besides the matter of discriminating between house timbers and fence posts, which is considered below, there is the more difficult one of separating fence stakes from digging sticks, which are often made of lengths of timber of similar thickness. In principle, digging sticks are bevelled at the end on one side to produce the appropriate edge for their particular functions, while stakes are worked around the circumference to make a point for sticking in the ground. Even when ends have been lost or damaged or do not conform to the 'rules', a distinction between stake and digging stick may still be possible when the piece is from a split timber unsuitable for a handheld tool. There is also the consideration that while digging sticks were normally found lying horizontally in ditches, it is the lower part of vertical posts and stakes that was likely to be preserved, the upper part being above water. Thus, while the 66 digging sticks in the upper Wahgi archaeological collection for which a length measurement is available range between 0.49 and 1.85 m (Golson and Steensberg 1985: Table 12), the 195 posts and stakes from Kuk in the Steensberg catalogue fall between 0.11 and 1.4 m, with 143 below 0.4 m and only 10 above 0.6 m. The possibility of separation by preserved length, however, was considerably reduced by the circumstances of recovery, where, during drain digging, objects were easily broken and their findspot was uncertain.

All house posts and fence stakes will have been pointed to serve their purpose, but the timbers of central posts that bore the weight of the structures built around them or from the less bulky posts used in the walls should be distinguishable from stakes by being thicker or wider. In the house timber/fence stake grouping of Steensberg's catalogue, besides one item identified as a ridgepole, there are 44 thicker or wider items for which he used the terms 'pole'/'post' or 'plank'/'board' compared with 195 items for which he used the term 'stake'. By this criterion, fence stakes are five times as common in the Kuk wood corpus as the next most common object, women's digging sticks, and three times as common as men's and women's digging sticks combined. This does not seem unreasonable given that digging sticks were personal items cached in ditches for maintenance, while stakes formed the infrastructure of fencing that controlled the movement of pigs that were stalled overnight in women's houses and let out to forage during the day in fallow land outside the cultivations.

In a discussion of fencing against pigs, Steensberg (1980: 120) makes the point that topography and subsoil are among the factors determining the type of fencing used. In the case of the soft subsoil of the drained swamp at Kuk, the main evidence is of fences consisting of a single line of stakes set into the ground at intervals (Fig. 19.6). On the ethnographic evidence, the gaps between such stakes might be filled with other stakes not appreciably penetrating the ground and held in place by stringers of vine or cane grass (Fig. 19.7). We do not have much archaeological data because few fence lines were discovered during excavation, they were not systematically followed, unlike ditches, and, again unlike ditches, there were sporadic gaps in the evidence for their course.

Figure 19.6 Part of the fence line running parallel to Simon's Baret.

a) with the bottom ends of stakes preserved in place (length of tape exposed, plus the case, 0.46 m); b) stakeholes with little wood preserved (length of tape exposed, plus the case, 0.3 m).

Source: Photographs by Jim Rhoads, Kuk archive, 1974.

Our fullest evidence comes from the fence lines found at various places along, and about a metre east of, the east bank of Simon's Baret, as described in Chapter 16, section 'Fences in the swamp'. In all of these cases, the single line of holes, typically retaining the pointed ends of stakes, is often irregular and interrupted, the stakes and their holes varying in thickness, typically between 30 and 60 mm, and in distance from their neighbours, typically between 0.1 and 0.2 m. The indications are that the fence line along Simon's Baret was put in place after the fall of Tibito Tephra and thus belongs to Phase 6. It is argued in Chapter 16, sections 'Is Phase 6 a separate drainage phase?', 'Fences in the swamp' and 'Ditches in the swamp', that this phase was the time of the arrival of the sweet potato and its adoption as the staple crop. Gardening largely gave way to the grazing of pigs in the area of Station land to the north and east of Simon's and Wai's Barets, with the fence providing protection against them for gardens south and west. However, we do not know whether or how far the fence continued beyond where Simon's Baret joined Wai's Baret near Station drain B10b/c (see Fig. 16.3).

Figure 19.7 Stake fencing on dryland at Kuk, combining different styles but including known or likely features of fence lines erected in Kuk Swamp: wooden stakes separated from their neighbours and held together by a stringer of vine.

Source: Photograph by Paul Gorecki, 1977.

The great majority of the stakes recovered at Kuk came from fence lines discovered and displaced in the process of drain digging, particularly during the most intensive period of that activity that took place in 1972. While the information provided under these circumstances is limited, it appears that fences were being widely installed, with NNW–SSE and ENE–WSW orientations like the ditches of both Phases 5 and 6. Though it is impossible to attribute these stakes to the phase to which they originally belonged, it may be suggested that during Phase 5, when the whole of the eastern half of the Station shows evidence of a continuous history of localised drainage and cultivation (see Chapter 15, section 'Reasons for disintensification'), fencing became an integral part of the system because pig-keeping had definitely been incorporated in it by late Phase 5. During Phase 6, when drainage and cultivation had largely withdrawn to the south and west of Simon's and Wai's Barets, there was still need for fencing in the localised areas of housing and associated drainage that were maintained to the east on the borders of the pig-grazing land (see Fig. 17.3).

Our assumption has been that the fence at Simon's Baret was a stand-alone defence against pigs, backed by a ditch but not associated with an earthen rampart of ditch spoil enclosing the fencing, as seen in Paul Gorecki's photographs from his ethnographic research of the late 1970s (Gorecki 1982: Plate 23; see Fig. 19.8 here) and, indeed, others from the contact period nearly 50 years earlier. In the field there was no reason to suspect the presence of large mounding on either bank of Simon's Baret (cf. Fig. 15.8 cross-section) or indeed of Wai's Baret (cf. cross-sections in Figs 15.6 and 15.7, respectively). The fact that the fence line along Simon's Baret was built after the fall of Tibito Tephra indicates that there was no fence line there in Phase 5. This is understandable in view of the fact that in that phase, when there were cultivated blocks on both sides of Simon's Baret (Fig. 15.13), there may have been no pigs in early Phase 5 and in late Phase 5, when there were, anti-pig measures took a different form from that instituted in Phase 6.

Figure 19.8 Swamp fencing at South Kuk.

This image is similar to an example reproduced in Gorecki's 1982 thesis as Plate 23, which is described as being built to enclose a future communal garden, with the land across the ditch used as pig land.

Source: Photograph by Paul Gorecki, 1977.

The role of *Casuarina*

A comprehensive programme of timber identification carried out on the wooden artefacts from Kuk by Laurie Lucking in 1975 and 1976 showed that overwhelmingly the fence stakes were made from *Casuarina* and the same was true of the great majority of the agricultural implements that she inspected. Jocelyn Powell (1974: 21, Table 3) had reported similar results for a collection of gardening tools from the Hagen area, in which 18 of the 25 tools in question were made of *Casuarina*. The genus shows a marked rise in importance in upper Wahgi pollen diagrams around 1200 years ago. This may have been due to its deliberate planting, with that of other fast-growing trees, to provide supplies of timber in the conditions of deforestation that accompanied the agricultural process. There is also its possible role in a system of tree-fallowing that is important in some highlands areas today. These issues are discussed in Chapter 14, section 'Dryland agriculture after Phase 4'.

20

Kuk Stone Artefacts: Technology, Usewear and Residues

Richard Fullagar with Jack Golson

Introduction

The collection of 58 stone artefacts discussed here consists of all available examples that can be securely related to particular phases of the Kuk archaeological sequence reviewed in previous chapters of this volume. They were items from a total of some 750 registrations made in 1979 and 1980, resulting from the 1970s investigations. They comprised individual finds and stone collections from the same location, like oven stones and broken pebbles, which were grouped under one number with an accompanying letter for the constituent items. Chapter 18 provides further background to the matters discussed here, including the vicissitudes of storage and the destruction of the archaeological store in the Canberra bushfires of January 2003.

The broad aim is to document stone technology and tool function as determined from usewear and residues. Previous work has already provided evidence for the early (Phases 1–3) exploitation of starchy plants (taro, yam, palm and banana) at Kuk, with studies of starch grains and phytoliths extracted from stone tool edges (Denham et al. 2003; Fullagar et al. 2006). Evidence for later phases has not been previously published and summary stone artefact data for all phases are presented here for the first time.

The story starts in the late 1980s with Tom Loy and Barry Frankhauser, who set up a laboratory for residue analysis in the ANU Department of Prehistory. Loy recorded his examination of 87 items from the Kuk stone collection, from which he selected 58 items that showed promising evidence of usewear and residues. In the late 1990s, Tim Denham commenced PhD research at ANU on the early phases of the Kuk agricultural sequence, so becoming heir to the Loy selection, specifically 18 items belonging to Phases 1–3. At Denham's invitation, Richard Fullagar studied the items and there were significant results (see Denham 2003a; Denham et al. 2003; Fullagar et al. 2006). Fifty-five stones, including 54 of the promising items selected by Loy, became the subject of a report on the usewear and residue analyses that focused on 12 early phase stones, including one (K/98/217) from Denham that postdated Loy's work at ANU (Fullagar et al. 2006). In these initial studies, summarised again here, residues, including starch grains, originally identified by Fullagar and Michael Therin (then University of Sydney), were taxonomically identified by Judith Field (then University of Sydney), while phytoliths were similarly identified by Carol Lentfer (then University of Queensland).

Table 20.1 Kuk stones available for analysis.

Phase	Non-artefacts	Stones from cooking pit	Grinding and pounding stones	Axe fragments & flakes (includes recycled items)	Club fragment	Flake tool	Core tool	Utilised fragment	Total utilised	Total examined by RF
1	0	0	1	0	0	3	0	0	4	4
Between 1 & 2	3	0	2	0	0	0	2	0	4	7
2A	20	0	0	0	0	0	2	0	2	22
2B	5	0	0	0	0	2	1	0	3	8
2C	13	0	1	0	0	0	0	0	1	14
2D	4	0	1	0	0	1	0	0	2	6
2D/3	0	0	1	0	0	0	1	0	2	2
3	19	0	1	1	0	0	1	0	3	22
4	0	0	1	0	0	1	0	0	2	2
Between 4 & 5	0	0	1	0	0	0	0	0	1	1
4–6	6	19	1	0	0	0	2	3	6	31
5	1	0	1	2	1	0	0	0	4	5
6	1	0	3	10	0	4	3	4	24	25
Total	72	19	14	13	1	11	12	7	58	149

Source: Authors' data.

Notes:

1 Regarding axe fragments and flakes, see footnote 1 in the main text.

2 The cooking stones entered for Phases 4–6 are treated as non-artefacts.

3 All flakes and cores had traces of use of some kind; none was definitely unused.

After the 2003 destruction of the archaeological store where the Kuk stone collection was housed as described in Chapter 18, Fullagar proceeded to analyse the rest of the Loy selection, as planned. To this he added a collection of some pieces excavated in the southeastern corner of the Kuk Station in the 1975–77 seasons. The focus was on Phases 1–3 activities in this area, although expectably materials from later phases were excavated at the same time. The overall collection had been withdrawn from the Kuk stone store for Denham's use and luckily not returned there by the time of the fire.

A further 19 pieces came from the work of Golson, Fullagar and Adam Black on the collections salvaged from the Weston fire. Damage to artefact labels and stone surfaces was considerable. Although 366 stones were selected, only 19 items in Black's final analysis could be completely read or related to the Kuk catalogue and so assigned a secure stratigraphic context. Nine artefacts from the Loy selection are also not reported here because of uncertainty in provenance.

In total, Fullagar examined 149 stones that had sound stratigraphic provenance (Table 20.1). Of these, 58 (including 49 from the original Loy selection) were identified as artefacts or possible artefacts on the basis of manufacturing and/or utilisation traces. This chapter discusses these 58 securely provenanced stone artefacts. A summary description of each artefact leads to a discussion of technology and tool function from Phase 1 to Phase 6 of the Kuk archaeological sequence.

Methods

Three broad technological and functional classes of stone artefact are identified: flaked stones, including flakes, cores and utilised fragments; grinding and pounding stones, including unmodified plant-processing tools; and ground stone implements, including axes[1] and a club head. There is potential overlap between these classes because stones can be flaked or ground and then used for grinding and pounding. Moreover, functional analysis can identify episodes of recycling when, for example, a flake from a ground and polished axe might have been further modified and used as another kind of implement like a knife, a scraper or a small chisel. The starting point is to determine whether a stone is a core, a flake, a grinding/pounding stone, a ground stone implement or a piece from any of these (see Textbox 20.1).

The standard methodology adopted here has been outlined in Textbox 10.3 on tool usewear and residues (see also Fullagar 1991, 1992 and 2006). All artefacts were examined under an Olympus™, Zeiss™ or Nikon™ stereoscopic microscope with oblique incident light, magnifications ranging from 6x to 100x. All artefacts identified as tools were also examined under Olympus™ or Zeiss™ metallographic microscopes with vertical incident light, brightfield/darkfield, polarising filters and magnifications of 50x, 100x, 200x, 500x and 1000x.

1 One of the pioneers of New Guinea archaeological research, Sue Bulmer, pointed out in an early paper (1964: 247–248) that '[a]lthough axe, adze and swivel haftings were applied to recent polished blades in various parts of the highlands, there is no positive evidence as yet that there is any diagnostic feature of the blades, such as markedly asymmetrical bevelling or gripping, correlated with form of hafting, which could be used to interpret unhafted blades found in excavations'. So she grouped them together in one general class. In a paper of the same date (Bulmer and Bulmer 1964: 53), she used the terms 'axes' or 'axes-adzes' for this class. 'Axes' is used here.

Textbox 20.1: Artefact classification

Richard Fullagar with Jack Golson

Flaked stones are defined here as ‘flakes’, ‘cores’ or ‘utilised fragments’ (for these and other terms see Holdaway and Stern 2004). Flakes have diagnostic indications (bulbar surface, impact marks or a striking platform) that they were struck and detached from another stone, i.e. a core. A core bears the negative features of flake scars. A flake sometimes has retouch, which is in the form of distinct negative flake scars (with cones of percussion and Hertzian initiations) that were made on the flake only after it was produced and can be distinguished from use-scars. As defined here, cores cannot be flakes (see Hiscock 2007), although it might be demonstrated that the primary function of some flakes was to produce other flakes. Similarly, it might be demonstrated that the primary function of some cores was not to produce flakes but to process various animal or plant tissue.

Utilised fragments, as defined here, do not have negative flake scars diagnostic of a core, nor any unambiguous characteristics diagnostic of a flake. Utilised fragments are only identified as artefacts on the basis of usewear and residues that indicate tool use or manufacturing. Fragments themselves may be artefacts of technological processes (e.g. debris from smashing a quartz core); some may be artefacts unrelated to stone knapping technology (e.g. fire-cracked oven stones); and some may be naturally broken stones (i.e. not produced by any human activity). Contextual evidence may be able to demonstrate that some fragments are byproducts of knapping, naturally occurring rocks or manuports, i.e. stones that must have been brought on-site by people.

‘Ground stone’ is a potentially confusing term that refers to both ‘manufacture-ground’ and ‘use-ground’ implements, both being distinct from flaked stone artefacts (Odell 2004: 75). However, in the Australia/PNG region, the terms ‘ground stone’ (e.g. edge-ground hatchet) and ‘grinding stone’ (e.g. seed-grinding dish) are sometimes used to make this very distinction. Here, ‘ground stone implements’ refers to those artefacts that have been manufactured by grinding ‘for the purpose of producing an object of specific size and shape’ (Odell 2004: 75). By contrast, ‘grinding and pounding stones’ commonly refers to unmodified cobbles (e.g. pestles and hand stones) or tabular slabs (e.g. millstones and mortars) that were used for grinding other stones like axes or processing substances like tubers, seeds, bone and wood.

However, these distinctions (between flaked stone and ground stone) and functional terminologies (for use-ground and manufacture-ground implements) remain problematic. For example, some tools are the product of several manufacturing processes—flaking, grinding, pecking and polishing. Similarly, the function of implements can be complex, involving percussion and grinding; and they can be multifunctional. Some implements ground during manufacture can be so fragmented and altered by grinding during use that traces of manufacture are difficult to identify.

The artefacts by phase

The following section provides technological and functional descriptions for each of the 58 artefacts together with discussion of some non-artefacts. The artefacts are dealt with by phase from oldest to youngest and by artefact class: flake tools (Table 20.2), core tools (Table 20.3), utilised fragments (Table 20.4), grinding and pounding stones (Table 20.5), a ground stone club head (Table 20.6) and axes (Table 20.7).

Phase 1 (c. 10,000 cal. BP)

Four stones are catalogued in Phase 1: three flakes (Table 20.2) and one grinding and pounding stone (Table 20.5).

Artefact K/75/S178 is a schist cobble that is unmodified macroscopically, but is slightly more polished and smoothed on one side (cf. Fig. 10.T3.3). Smeared plant residues on the more pointed end (to the left in Fig. 20.1 top) include *Dioscorea* sp. starch granules (Fig. 20.1 bottom), most likely *Dioscorea alata* or *pentaphylla* (Fullagar et al. 2006: 601, 603). Artefact K/76/S28 is the distal end of a broken chert flake tool (Figs 20.2A and 20.3A), used for scraping and slicing starchy and siliceous plants. Artefact K/76/S29A (Fig. 20.2C) is an ignimbrite retouched wood scraper. K/76/29B is also an ignimbrite retouched flake (cf. Fig. 10.T3.2). Extracted residues include an abundance of 3–5 µm diameter starch granules (singly and in sheets) typical of *Colocasia esculenta* taro (Figs 20.2B and 20.3B). The tool was used to scrape wood and subsequently to slice taro.

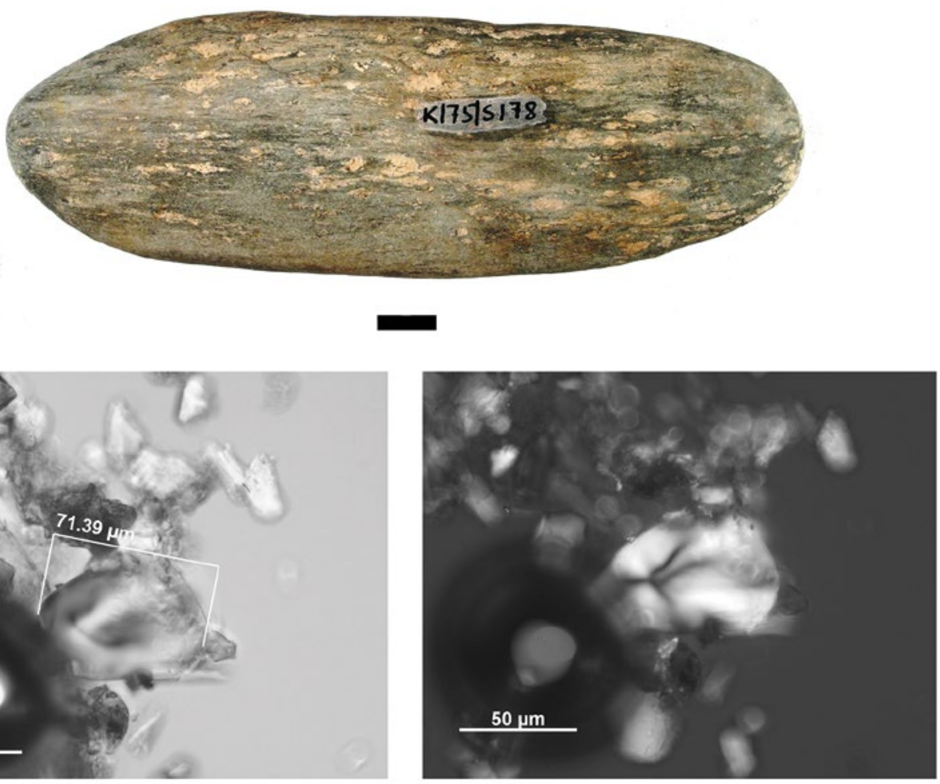


Figure 20.1 Upper image: grinding stone (pestle) K/75/S178. The scale bar is 10 mm. Lower image: large starch (*Dioscorea* sp.) grain from the residue extraction.

Source: Photographs by R. Fullagar and J. Field. Images reproduced with permission from Fullagar et al. (2006: 607, 609).

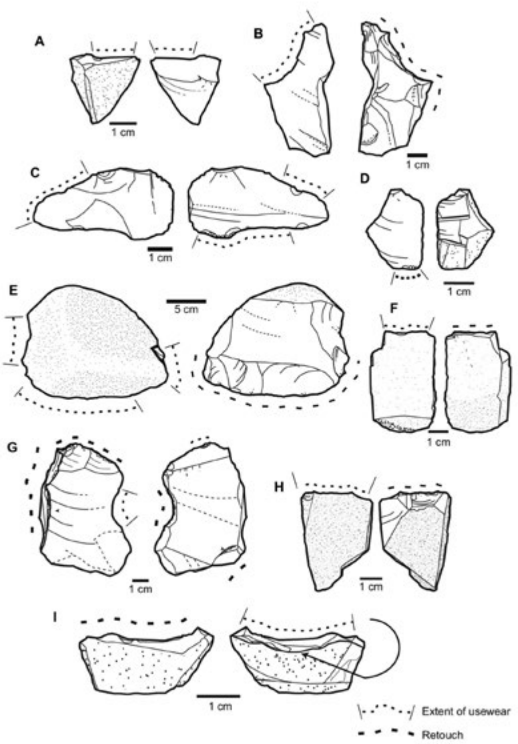


Figure 20.2 Kuk stone artefacts, (A): K/76/S28; (B): K/76/S29B; (C): K/76/S29A; (D): K/76/36; (E): K/75/S179; (F): K/77/S20; (G): K/98/217; (H): K/77/S4; (I): K/76/S19.

Source: Illustrations by R. Fullagar. Image reproduced with permission from Fullagar et al. (2006: 608).

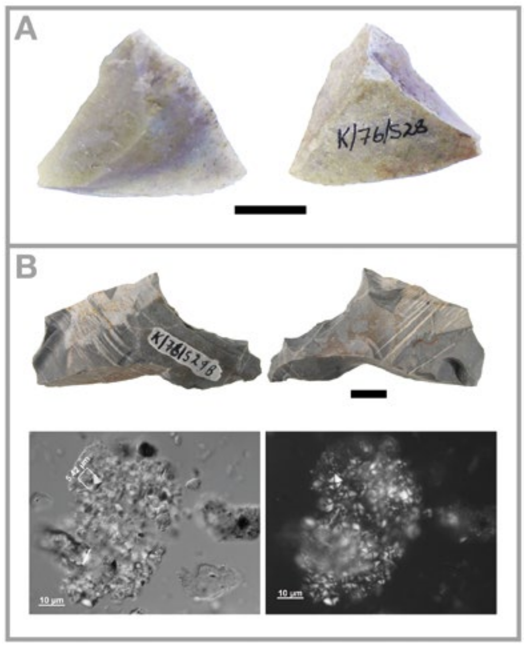


Figure 20.3 A: Distal portion of flake K/76/S28. B: Upper image: retouched flake K/76/29B. The scale bar is 10 mm. Lower images: *Colocasia esculenta* starch grains from the edge of retouched flake K/76/29B; lower left is under DIC (Differential Interference Contrast) and the lower right image is under cross-polarised light. The scale bars are 10 microns.

Source: Photographs by R. Fullagar and J. Field. The lower images are reproduced with permission from Fullagar et al. (2006: 606).

Between Phases 1 and 2

Seven stones catalogued from the grey clay layer between Phases 1 and 2 were examined microscopically by Fullagar (Table 20.1). Four of these seven were found to be utilised artefacts and are described below. The other three, K72/S90I, K and N, which were salvaged from the Weston store, are fragments of possible cooking stones found when the southern end of drain A9b/c was being dug at the base of the small hill, Blong's Nob, at the site's southern boundary (see Fig. 17.3, the hill marked B). Of the catalogued stones that were not microscopically examined, five (K/77/S35 and S36A-D) were associated with K/77/S34, one of the artefacts described below, and have been discussed with S34 by Golson (2000: 234–235).

We begin the discussion of the artefacts from the grey clay with two cores (Table 20.3), one felsic volcanic, K/75/S179, and one chert, K/98/217. Both have had usable flakes struck from them and both have distinct usewear (with marked rounding) on one or more edges. Artefact K/75/S179 (Fig. 20.4A) is a split waterworn felsic volcanic cobble core tool with unifacial flaking around most of the edge. Usewear, mostly marked edge rounding, is associated with residues (including resin-impregnated fibres) with starch grains of both *Dioscorea* sp. yam and *Colocasia esculenta* taro (Fullagar et al. 2006: 605; Fig. 20.4B here). Other unidentified starch grains are present. Phytoliths along this edge include morphotypes typical of *Saccharum* and *Themeda*. Artefact K/75/S179 was probably used to chop or mash *Dioscorea* yam and *Colocasia* taro.

Chert artefact K/98/217 was classified as a retouched chert flake by Fullagar et al. (2006: 605). Reexamination after sonic cleaning of the surfaces indicated that neither a bulbar surface nor an impact point can be identified unambiguously. Consequently, it is described here as a core that has three identified utilised edges with usewear and with residues (notably phytoliths) that indicate it was used to scrape siliceous woody plants, grass, reeds and/or palm (Fullagar et al. 2006: 605, 607; Figs 20.5B and 20.5C here).

Artefact K75/S173 is an intrusive gabbro cobble with traces of use indicating a lower grinding stone (Table 20.5; Fig. 20.6A). There is pitting in the centre that is the result of pounding or, more likely, setting up an anvil for flaking stone (Fig. 20.6B).

Golson (2000) has described artefact K/77/S34 (Fig. 20.5A) as the rim of a bowl made from tholeiitic andesite, later reclassified as tholeiitic basalt in Appendix 21.1, an igneous rock not found locally. This artefact has no clear manufacturing marks, diagnostic usewear or visible residues, but has obviously been shaped symmetrically. It is classified here as a grinding and pounding stone (Table 20.5).

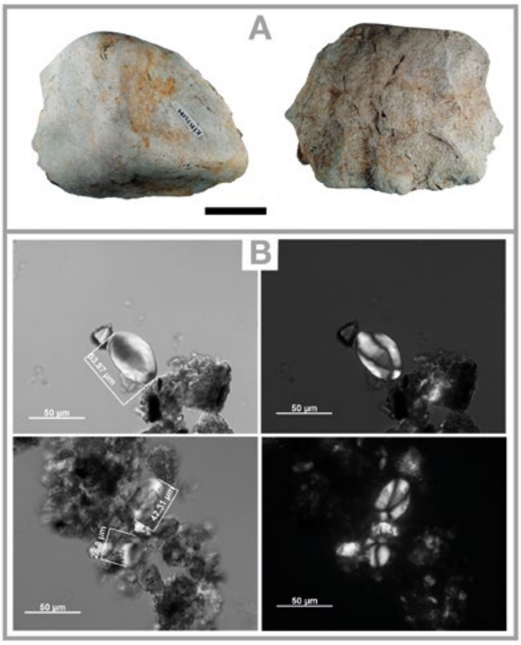


Figure 20.4 A: Core implement K/75/S179. B: Starch grains from *Dioscorea* yam (cf. D. alata and D. pentaphylla) extracted from core implement K/75/S179.

Source: A: photograph by R. Fullagar; and B: photograph by J. Field. Images reproduced with permission from Fullagar et al. (2006: 606).

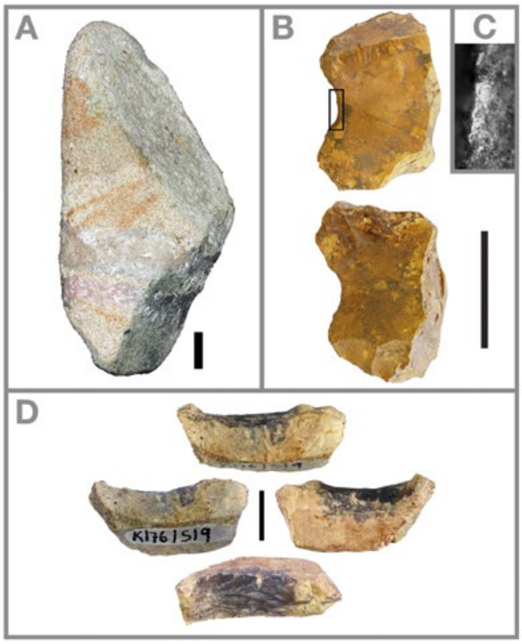


Figure 20.5 A: Lower grinding stone fragment K77/S34 may be the rim of a shaped bowl. The scale bar is 10 mm. B: Core implement K/98/217. Black rectangle indicates location of most developed usewear (see also Figure 20.2). Scale bar is 50 mm. C: Use-polish on the edge of core implement K/98/217 (near rectangle of Figure 20.5B). This polish is consistent with scraping siliceous plants such as grass, reeds and palm. Height of field is 0.3 mm. D: Core implement K/76/S19 with step scarring. The scale bar is 10 mm.

Source: A and B: photographs by R. Fullagar; C: photographs by R. Fullagar and J. Field, with images reproduced with permission from Fullagar et al. (2006: 611); D: photograph by R. Fullagar.

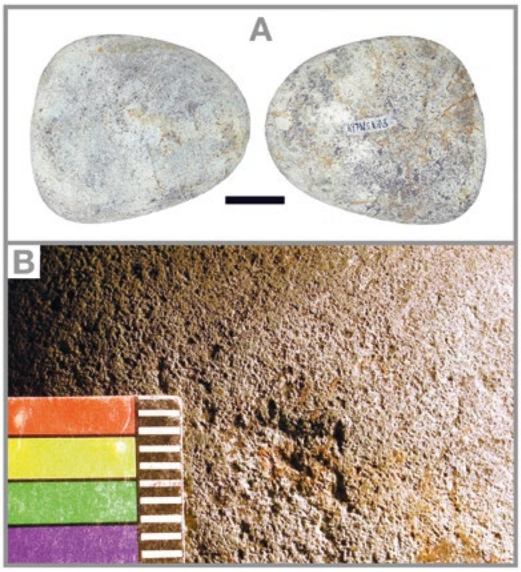


Figure 20.6 A: Lower grinding stone K75/S173. Anvil pitting is present on the surface in the centre of the left image (see Figure 20.6B). The scale bar 30 mm. B: Detail of anvil pitting at the centre of K75/S173.

Source: Photographs by R. Fullagar.

Phase 2 (6950–6440 cal. BP)

Phase 2 has been subdivided into four contexts by Denham (2003a: vol. 1, Table 5.3): 2A, the fill of features dug at the surface of grey clay; 2B, the surface of the grey clay between features; 2C, the red and white sediment (called Komun in Tables 7.1 and 7.2) sometimes present in the fill of features; and 2D, which is late Phase 2. Table 20.1 shows that 60 stones are catalogued for these units, of which 50 were examined by Fullagar, all are from Golson's excavations of the 1970s: 22 from 2A, eight from 2B, 14 from 2C and six from 2D.

Phase subdivision 2A

There are two artefacts identified in Phase 2A, both cores (Table 20.3). Artefact K/76/S19 (Figs 20.2I and 20.5D) is a small chert core with usewear consistent with scraping bone or wood. Phytolith morphotypes (*Saccharum* and Palmae) suggest woodworking (Fullagar et al. 2006: 608). Artefact K/77/S4 is a chert core with slight rounding and polish (Figs 20.2H, 20.7A and 20.7B), which indicate the scraping of soft siliceous plant tissue (Fullagar et al. 2006: 607).

Phase subdivision 2B

There are three artefacts identified in Phase 2B. Chert flake tool K/74/S4 (Table 20.2; Fig. 20.7C) has usewear and residues that indicate scraping. Chert flake tool K/76/S36 (Table 20.2; Figs 20.2D and 20.7D) is a small chert flake with cortex (Fullagar et al. 2006: 607). Usewear and residues indicate that it was probably used for scraping wood or other plant tissue. Core implement K/77/S20 (Table 20.3; Figs 20.2F and 20.7E; Fullagar et al. 2006: 607), made on a chert-like silicified volcanic rock, has one flaked edge with scarring and a thin band of polish that suggests scraping of dense wood.

Phase subdivision 2C

There is one artefact identified in Phase 2C, K/77/S17 (Table 20.5; Fig. 20.7F). It is a heavily weathered basalt cobble (upper) grinding/pounding stone with phytoliths and *Colocasia esculenta* taro starch grains (Fullagar et al. 2006: 607). A bright red clay pigment or ochre is smeared on one surface.

Phase subdivision 2D

There are two artefacts identified in Phase 2D. Flake tool K/74/S28 (Table 20.2) is a very weathered felsic volcanic, but has distinct continuous bifacial scarring with edge rounding on the left lateral margin (Fig. 20.7G). Artefact K/77/S33A (Table 20.5) is a broken cobble of intrusive felsic igneous rock with crushing on small areas of the surface and along the acute edge, indicating possible use as a hammer or a pounding tool (Fig. 20.8A).

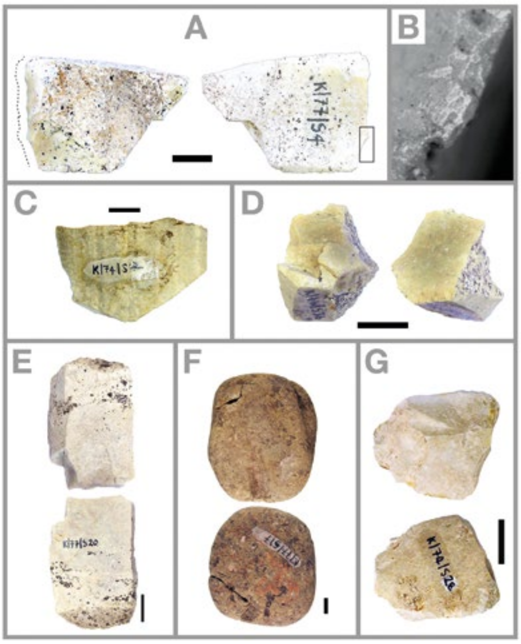


Figure 20.7 A: Core implement K/77/S4 with scarring. Note the negative flake scars along the left margin (dotted line); at right of image: the inset indicates location of use polish shown in Figure 20.7B. B: Use-polish on K/77/S4. The use-polish, rounding and scarring along this part of the retouched edge are most likely from working hard siliceous plant, probably wood (width of field is about 0.3 mm). C: Flake K/74/S4 has usewear on the distal margin (upper edge). D: Flake K/76/S36 dorsal (left) and ventral (right). The utilised edge is the distal image. E: Core implement K/77/S20. The utilised edge is at the upper margin of the lower image. F: Upper grinding/pounding/hammerstone K/77/S17. G: Proximal flake K/74/S28 (bottom: ventral; top: dorsal). The utilised edge (left lateral margin) is the edge to the top of the dorsal image. Scale bar is 10 mm.

Source: Photographs by R. Fullagar. Images B and F reproduced with permission from Fullagar et al. (2006: 609, 611).

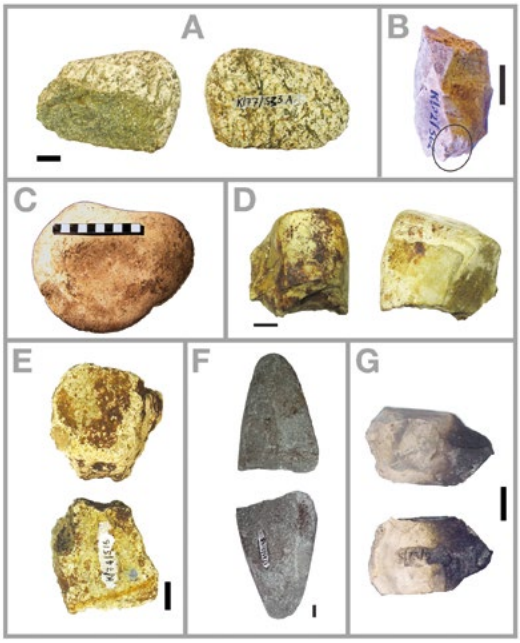


Figure 20.8 A: Possible grinding/pounding stone fragment K/77/S33A has crushing on the broken acute edge and phytoliths (unidentified) were recovered from the same surface. The scale bar is 10 mm. B: Core implement K/72/S62, showing one of the utilised edges with 'retouch' (circled). C: Lower grinding stone K/75/S145B has a natural depression (just below the scale bar) with striations and smoothing. More recent cut marks (from excavation or recent handling) are also visible macroscopically. No residues were recovered from this surface. The scale bar is 100 mm. D: Core implement K/74/S15 with overlapping step scars, red pigment and brown sediment. E: Grinding stone fragment K/74/S16. The macroscopically visible brown residue is sediment. F: Possible axe butt fragment K/75/S193. G: Flake tool K/73/S31 (bottom: ventral; top: dorsal). The distal tip has marked edge rounding. The blackening is from the Weston Creek fire. Although utilised, the precise function is uncertain. Scale bar is 10 mm.

Source: Photographs by R. Fullagar.

Phase 2D/3 (c. 6950–2400 cal. BP)

There are two artefacts catalogued in Phase 2/3, which indicates a location in black clay where neither Kim (R) nor Baglaga (Y) ash is present to suggest whether we are dealing with Phase 2D or Phase 3. Chert core tool K/72/S62 (Table 20.3) has a retouched edge and usewear with reticular polish that indicates wood scraping (Fig. 20.8B). Grinding stone K/75/S145B (Table 20.5) is a large weathered andesite cobble, slightly dished on one surface with abrasive smoothing (Fig. 20.8C). A third item, K/75/S195, is a large stone that was not removed from its field position because of its size and the lateness of the field season. No signs of working or tool-use were seen (Jack Golson, pers. comm., 1990).

Phase 3 (c. 4350–2400 cal. BP)

The 22 stones catalogued in Phase 3 (Table 20.1) were examined by Fullagar, who identified three as artefacts with signs of manufacture and use. The others are various volcanic rocks with no signs of manufacture or use, including one basalt item, K/73/S56 (from the Weston store). Stones K/77/S12A-F comprised six volcanic fragments that fit together, and probably broke apart after excavation. Some of these stones are manuports, brought on to the site for use as oven stones.

Artefact K/74/S15, a mudstone core tool (Table 20.3), has numerous overlapping step scars along one edge that is markedly rounded (Fig. 20.8D). Bright red ochre, visible macroscopically, was noted by Loy in his initial study. One unidentified starch granule and a few phytoliths were recovered from extractions. Grating or scraping ochre was the most likely task. Artefact K/74/S16 (Table 20.5) is a grinding stone fragment made of felsic volcanic breccia with at least two smoothed surfaces (Fig. 20.8E).

Artefact K/75/S193 is a weathered volcanic stone with no diagnostic traces of use or manufacture (Table 20.7; Fig. 20.8F). However, there are striations (visible only under low magnification with low-angled light) and there is pecking near the pointed butt end. The shape in plan and cross-section suggests it may be the medial/butt piece of an axe. If it is part of a broken axe, it is the oldest axe from Kuk, and is discussed further below.

Phase 4 (2000–1230/970 cal. BP)

There are two stones catalogued as Phase 4. Both were examined and both were identified as artefacts. Artefact K/73/S31 is a felsic volcanic flake with usewear (Table 20.2; Fig. 20.8G). This flake was recovered from the Weston store and had been damaged by fire. Artefact K/74/S19 is a tabular basalt cobble with pitting on one surface, indicating use as an anvil (Table 20.5; Fig. 20.9A).

Between the end of Phase 4 and the beginning of Phase 5 (1100 years ago to AD 1250)

One sandstone artefact, K/73/S15, is catalogued in this context. It is a small fragment from a grinding stone damaged by fire at the Weston store (Table 20.5; Fig. 20.9B). It came from slightly above the level of Olgaboli (Q) ash in the wall of drain A11a/b, about 25 m south of E–W Rd 1. Olgaboli ash marks the end of Phase 4 and predates the start of Phase 5.

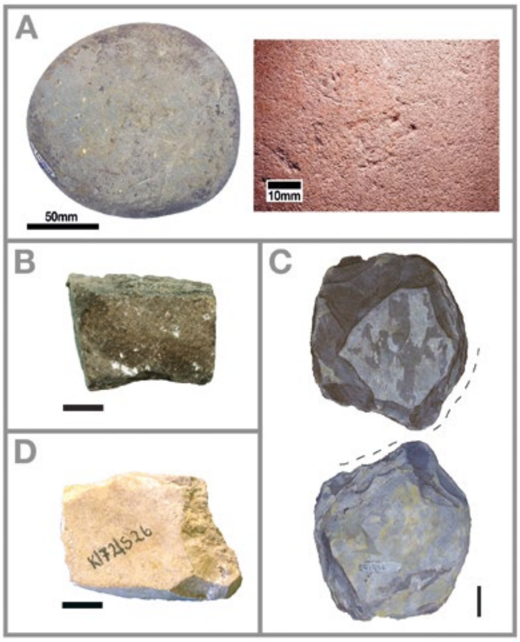


Figure 20.9 A (left): Lower grinding/pounding/anvil stone K/74/S19; (right): Details of smoothing and pitting (cf. anvil) visible under low-angled light. B: Grinding stone fragment K/73/S15. The scale bar is 10 mm. C: Utilised fragment K/72/S6, the dashed line indicates flaking. D: Core implement K/72/S26, the utilised edge is at the left side. Scale bar is 10 mm.

Source: Photographs A, B and C by R. Fullagar, photograph D by A. Black and R Fullagar.

Phases 4–6 (from 2000 years ago to AD 1900)

This grouping is stratigraphically represented at the site by the 'garden soil' towards the top of the Kuk sequence (see Fig. 6.10), where the volcanic ashes that serve to distinguish the three phases in question—Kuning (Sandy 2), Olgaboli (Q), Kenta (Sandy 1) and Tibito (Z)—are not regularly preserved.

In various Phase 4–6 contexts there are 31 catalogued stones, all of which were examined (Table 20.1). Six artefacts have been identified. The 25 non-artefacts, including 19 stones from a cooking pit discussed separately below, are mostly volcanic, igneous and metamorphic rocks, with one mudstone item and one quartz crystal. Since quartz crystals are highly valued for their magical qualities among the Melpa speakers of the upper Wahgi (see Appendix 22.1), we shall look briefly at this occurrence at Kuk before dealing with the six artefacts of Phases 4–6.

The one quartz crystal mentioned above is K/72/S108 of Golson's catalogue (Kuk archive), which records it as having been found in the material making up the raised floor of House B of Phase 6 (see Fig. 16.3 Inset). The fact that this raised floor material may have been dug from deposits somewhat older than Phase 6, is why the crystal is assigned to Phases 4–6, though its value in the eyes of the local population may have meant that it had been deliberately buried at the house site at the time of building. Another quartz crystal in the Golson catalogue, K/72/S107, is also associated with House B, though found during the stripping of the turf and topsoil above it, which might point to its accidental as much as its deliberate association with the site. The Golson catalogue refers to the second as 'somewhat defective', whereas the first example is described as a 'fine example'.

Chert artefact K/72/S26 is a core with edge-rounding, slight polish, phytoliths and starch grains (Table 20.3; Fig. 20.9D). It was probably used to scrape plant material. Artefact K/72/S86 is a small chert core with steep flaking, like backing, opposite a more acute unretouched edge (Table 20.3; Fig. 20.10B). The use traces on both edges are similar, indicating a woodworking tool. Abundant grass phytoliths suggest a fibrous wrapping, either as a haft or perhaps some ritual attachment to empower the stone (cf. Hampton 1999: 151).

Artefact K/72/S6 is a flat slate fragment probably shaped by flaking to form a tang (cf. the 'round-bladed spade' of Bulmer 2005: 425) that has been broken (Table 20.4; Fig. 20.9C). It is not classified as a core or flake because surfaces lack the characteristics of unambiguous flake scars. Both edges have starch and phytoliths. One edge on the tang is more rounded and polished than others, which could be a result of contact with a handle. The opposite edge is also polished, with striations perpendicular to the edge. Usewear and residues suggest the tool had been used for chopping materials like soft fibrous plants (e.g. pandanus fruit) or possibly digging matted peat. It was found in the road drain, A10W, that forms the western margin of block A10, not far from the housing area at the north end of blocks A9g and A9h (see Fig. 17.3).

Artefact K/72/S51 is a long narrow basalt fragment with flake scars along one lateral margin (Table 20.4; Fig. 20.10A). Starch and phytoliths suggest it was used for cutting and scraping starchy and siliceous plant material. Artefact K/75/S30 is a glassy basalt fragment (Table 20.4; Fig. 20.10C). Both lateral margins have usewear and residues indicating intensive scraping and cutting of wood. Artefact K/77/S9 (Table 20.5; Fig. 20.11C) is a felsic intrusive igneous rock with grass phytoliths and traces of grinding and smoothing. It was previously assigned to Phase 2 (see Fullagar et al. 2006: 607), but has been reassigned to a Phases 4–6 context.

We return to the 19 stones mentioned previously and catalogued as K/75/S191A-S (Fig. 20.11A). These stones were recovered from a cooking pit dug into the fill of a Phase 3 channel in the southeastern part of the site, marked by C in Figure 13.7. It cannot be more precisely dated, so its contents are included in the Phases 4–6 class (Table 20.1). Interpreted as oven stones, they include six that are possibly recycled pieces of grinding stones, which fit together into two groups: A191B, J and R and K, M and P (Fig. 20.11B bottom). Similar collections of stones were excavated from similar pits both in housing areas and away from them, as in the case we are discussing. Similar stones were also widely found across the site, singly or scattered, in ditch fills and other situations. Most of these stones did not survive the 2003 fires with their catalogue numbers intact. The present collection of 19 constitutes one of three cases of which special mention is made in the text. The others, K/72/S90I, K, N (between Phase 1 and 2 in age) and K/77/S12A-F (Phase 3 in age) have already been described.

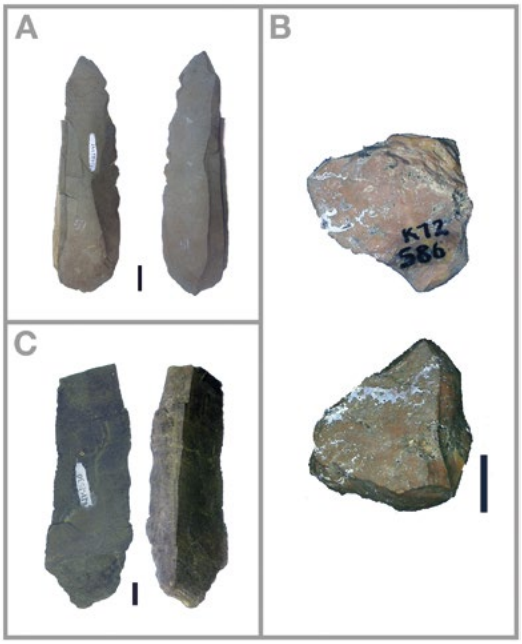


Figure 20.10 A: Utilised fragment K/72/S51. Smoothing, polish and rounding are present along the edge with macroscopically visible scarring, which is most likely from use. B: Core implement K/72/S86. The grey-white inclusions are chert. The platform ridge (top image) has the most developed usewear (cf. wood working). C: Utilised fragment K/75/S30. Scale bar is 10 mm.

Source: Photographs by R. Fullagar.

Phase 5 (AD 1250 to possibly the AD 1660s)

Five stones are catalogued in Phase 5, of which four have signs of manufacture and/or use (Table 20.1). K/76/S4P (Table 20.5; Fig. 20.12C) is a tabular basalt cobble with a natural bevel and triangular shape—not unlike some ooyurka of north Queensland rainforests (McCarthy 1967: 62, 70; Cosgrove 1984). The surfaces are differentially smoothed and individual grains polished in the process. The natural bevel has abrasive smoothing together with residues, the combination suggesting the grinding of soft plant tissue. The tool was found in the base of a ditch sealed by Tibito (Z) Tephra in drain E7g/h at the northern margin of Kuk Swamp on the lower slopes of Ep Ridge (for the general location see Fig. 17.3).

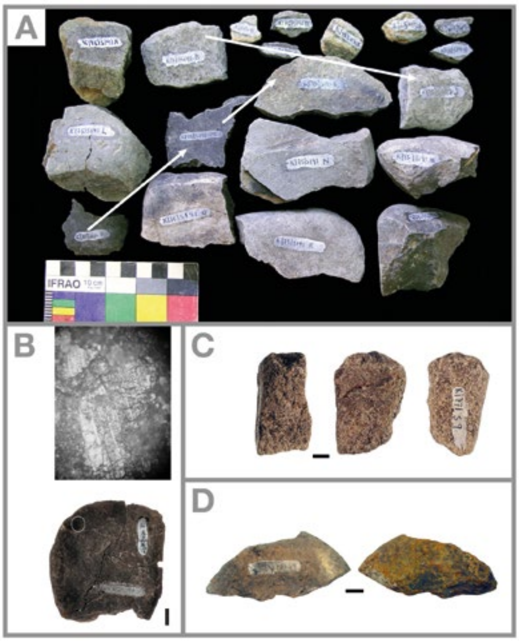


Figure 20.11 A: Oven stones K/75/S191A-S have no unambiguous traces of edge utilisation or grinding (but see 11B). All stones are fire-cracked and discoloured from utilisation in an earthen oven. B: Refitted oven stones K/75/S191K, M and P. The white circle shows location of the top image, showing striations and smeared residue on crystal surfaces. The height of field is about 0.6 mm. The source of these marks is uncertain, but may be post-depositional. C: Broken upper grinding stone fragment K/77/S9, with one smoothed/polished surface facing in the far left image. D: Club head fragment K/73/S61. Scale bar is 10 mm.

Source: Photographs A, B and D by R. Fullagar; photograph C by R. Fullagar and J. Field, reproduced with permission from Fullagar et al. (2006: 609).

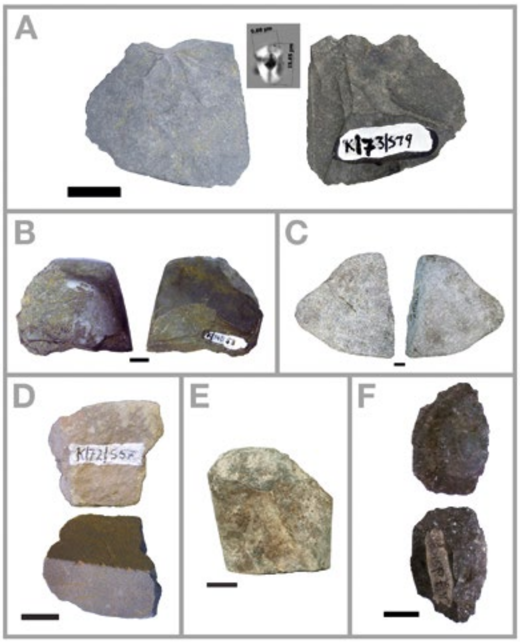


Figure 20.12 A: Ground and polished axe flake K/73/S79 was recycled as a wood scraper. Starch grains were found in extractions from the working edge (centre image). The scale bar is 10 mm. B: Ground and polished adze edge K/74/S8. The scale bar is 10 mm. C: Upper grinding stone K/76/S4P. A natural facet (right image) has sustained most abrasive smoothing along the acute edge. D: Grinding stone fragment K/72/S57. Scale bar is 10 mm. E: Medial axe fragment K/72/S98. F: Flake K/72/S105. The scale bar is 10 mm.

Source: Photographs A, B, C and D by R. Fullagar, photograph E by A. Black and R. Fullagar.

A basalt club head fragment, K/73/S61 (Table 20.6; Fig. 20.11D) was excavated from the ditch of House P, which was found side by side with House Q beneath the Phase 6 housing area at the north end of blocks A9g and A9h (Fig. 17.3 Insets 1a and 1b). The central hole was made by pecking from both sides. It was recovered from the Weston store during salvage in 2003. Artefact K/73/S79 is a complete flake from a ground and polished axe (Table 20.7; Fig. 20.12A). It had been recycled as a hafted wood scraper or chisel. It was found in the ditch of House Q.

Artefact K/74/S8 is the broken blade of a ground and polished axe with asymmetrical blade bevel (Table 20.7; Fig. 20.12B). Bright spots (Rots 2003, 2010) and abrasion on lateral margins suggest hafting. Usewear and residues are typical of woodworking. The find was made above a Phase 4 ditch in the profile of drain B10e/f away from any signs of housing (see Fig. 17.3). Golson's catalogue notes that it is not securely Phase 5, rather Phase 5 or Phase 6.

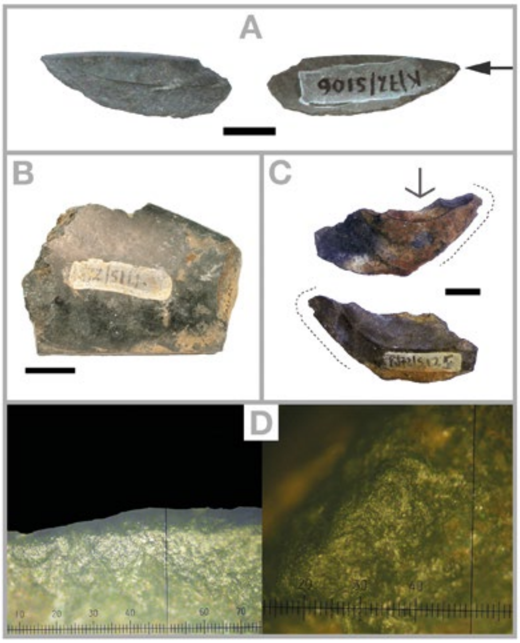


Figure 20.13 A: Flake K/72/S106 is from an edge-ground axe. At right, dorsal (original ground axe surface). The arrow indicates the most developed usewear suggesting the flake was recycled as a graving tool. The scale bar is 10 mm. B: Medial axe fragment K/72/S111. Discolouration is from fire at the Weston Creek store. The scale bar is 10 mm. C: Flake K/72/S125 (top is ventral, bottom is dorsal). For usewear within inset, see Figure 20.13D. Note retouch (dashed line) extending on to the ventral surface, along the proximal, right lateral margin. The arrow indicates the striking platform. The scale bar is 10 mm. D: Marked edge rounding and grainy polish on flake K/72/S125 suggesting skin scraping. Scale units are 0.01mm.

Source: Photographs A, C and D by R. Fullagar, photograph B by A. Black and R. Fullagar.

Phase 6 (AD 1700–1900)

Twenty-five stones were catalogued as Phase 6 and all were examined (Table 20.1). Twenty-four were identified as artefacts, with signs of manufacture and/or use (see Fig. 17.3 for location, and Fig. 17.17F in relation to the men's compound on Hed Mound).

There are four flakes in Phase 6 (Table 20.2). Flake K/72/S125 is made of a volcanic stone similar to that of the ground and polished axes, but no surfaces were ground (Figs 20.13C and 20.13D). An edge has fine retouch and usewear indicating scraping of wood or skin. This flake is from the Weston store, which makes residue identification problematic. It was found at or above the floor of House F in block A9g in the housing area at the north end of blocks A9g and A9h. Artefact K/73/S72 is possibly the distal end of a chert biface thinning flake. It has low-angled striations indicating use for cutting and slicing (Fig. 20.14B). It was found, together with much wood and cooking stone, in the south ditch of House A in block A9g of the housing area at the northern end of blocks A9g and A9h (Fig. 17.3).

Chert flake K/73/S81 was detached from a large woodworking implement (Fig. 20.15A) and was subsequently used along its distal edge for fine woodworking tasks. It was found on the floor of House A. Artefact K/77/S42, also from a housing context, is a chert bipolar flake (Fig. 20.15C) with developed polish from slicing soft siliceous plants (Fig. 20.15D). It was also found in the men's compound on the top of Hed Mound (see Fig. 17.17F), in the northeastern quadrant of the area enclosed by its perimeter ditch.

There are three cores in Phase 6 (Table 20.3). Two edges of a felsic volcanic core implement, K/73/S69 (Fig. 20.14A) from the housing area of block A9g, are flaked and all edges have usewear and residues indicating wood scraping, probably with a hafted implement. The object was found in the south ditch of House A in a <2 m stretch that also produced the grinding stone fragment S68, with flake S72 found elsewhere in the ditch. Core K/73/S80 (Fig. 20.14C) is from the floor of House A (the same house as flakes S72 and S81), and has been used to produce flakes. It has three used edges, one of them involved in scraping wood (Fig. 20.14D).

A fine-grained volcanic core, K/77/S58A, is too weathered to interpret tool function (Fig. 20.16A). It was found near the southwest quadrant of the men's compound on Hed Mound (cf. K/77/S42 in the listing of flakes above), just outside its perimeter ditch.

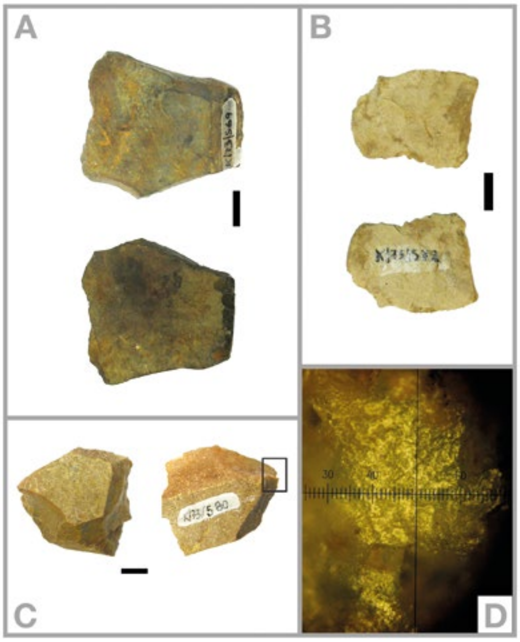


Figure 20.14 A: Core implement K/73/S69, used for wood scraping. The left and right edges have been 'retouched'. All edges have been used. B: Chert distal flake tool K/73/S72. Distal end is left. Both lateral edges have usewear. C: Core implement K/73/S80. Scale bar is 10 mm. Inset: see 20.15D. D: Polished edge of K/73/S80. The scale units are 0.01 mm.

Source: Photographs by R. Fullagar.

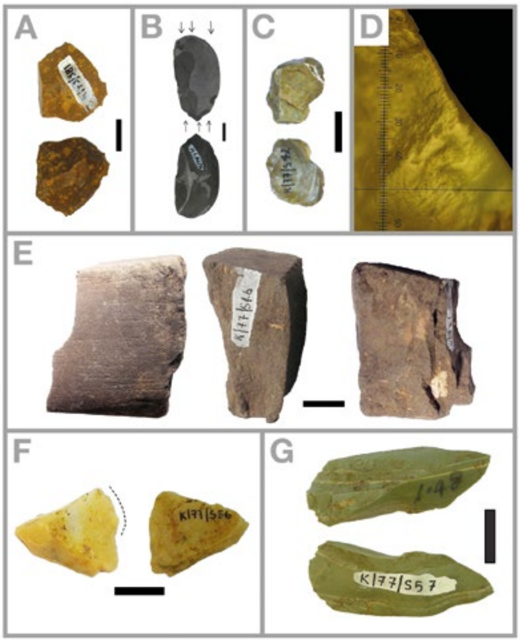


Figure 20.15 A: Flake tool K/73/S81 (bottom is dorsal, top is ventral). Most developed usewear is on the proximal dorsal edge of the platform. The distal edge is also utilised. B: Flake tool K/74/S71 was recycled from an edge-ground axe. Bottom is ventral, top is dorsal (original ground axe surface). In the top image, the lower arrows indicate location of haft wear; and upper arrows indicate location of the utilised edge of the flake tool. C: Flake K/77/S42. Scale bar is 10 mm. D: Edge rounding, striations and polish on right lateral margin of flake K/77/S42. The scale units are 0.01 mm. E: Grinding stone fragment K/77/S46, possible from the butt of an axe. F: Fragment K/77/S56. Edge scarring is indicated by the bracket. G: Ground and polished axe flake K/77/S57. The scale bar is 10 mm.

Source: Photographs by R. Fullagar.

There are four utilised fragments in Phase 6 (Table 20.4). Artefact K/73/S65 (Fig. 20.17B) is a fragment from a larger felsic volcanic implement used to scrape wood. It is thought to be from the turf or topsoil in the vicinity of House A at the northern end of block A9g, but could, however, be from House B.

Artefact K/77/S56 (Fig. 20.15F) is a chert fragment said to have been found in the southeast quadrant of the Hed Mound men's compound, but is also mentioned in connection with the ditch of the men's house, which is in the southwest quadrant. The usewear and residues indicate wood scraping. For Hed Mound finds see S42 in the listing of flakes above and S58A in that of cores, as well as the next two entries of this section and S46 in the next.

Artefact K/77/S71 is a fragment of chert with usewear along one edge (Fig. 20.16C). Fibres suggest plant processing, while wear near the tip suggests use as an awl. It was found on Hed Mound in the northwest quadrant of the area enclosed by the perimeter ditch of the house compound.

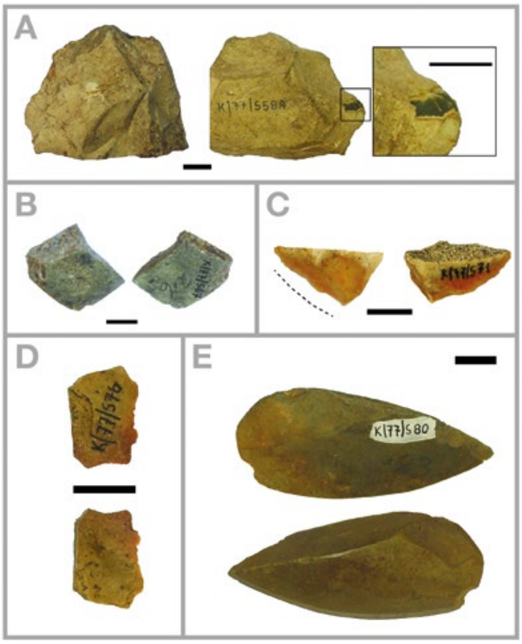


Figure 20.16 A: Core implement K/77/S58A. Note extreme weathering in contrast with fresh fracture scar (inset to right). B: Ground and polished axe fragment K/77/S67. C: Utilised fragment K/77/S71. Use-scars are present as indicated by the dashed line. D: Utilised fragment K/77/S76. E: Ground and polished adze fragment K/77/S80. Scale bar is 10 mm.

Source: Photographs by R. Fullagar.

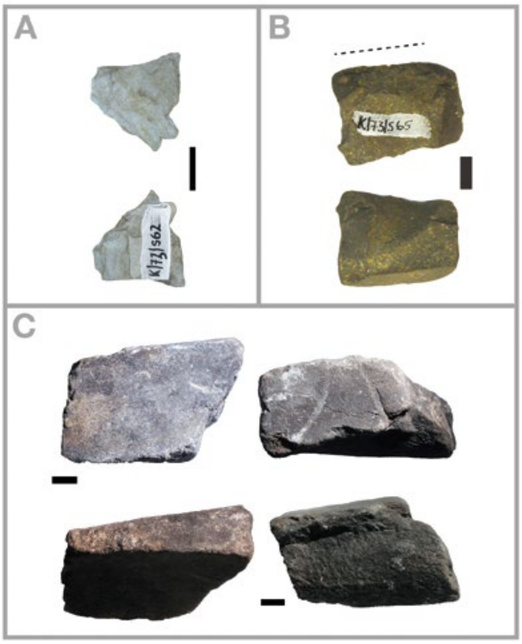


Figure 20.17 A: Ground edge axe flake K/73/S62, recycled as a wood scraper. Bottom is dorsal ground surface, top is ventral surface with broad-bending initiation suggesting that it was detached during use. B: Utilised fragment K/73/S65. The dotted line shows the utilised edge. C: Grinding stone fragment K/73/S68 is probably part of a whetstone. Scale bar is 10 mm.

Source: Photographs by R. Fullagar.

Artefact K/77/S76 is a chert fragment with usewear suggesting the cutting/slicing of soft tissue (Fig. 20.16D). Tom Loy attached a Hemastix™ strip to its container with a note indicating that he had taken a sample from a cracked yellow-red residue which tested positive for blood. He also noted that no blood cells could be observed. How these presumptive results link with the use of the tool is uncertain. The artefact was found in the southeast quadrant of the Hed Mound house compound.

There are three grinding and pounding stones in Phase 6 (Table 20.5). Artefact K/72/S57 is a basalt fragment with two grinding facets probably used to grind stone tool edges (Fig. 20.12D). The grinding facets are relatively flat with distinct longitudinal alignments and striations, but there are no use-related residues or developed polish. The findspot, in the surface peat at road drain B9E that marks the eastern perimeter of block B9, is about 40 m from the nearest house site. This is the most northerly of the line of houses at the southern end of block B9g (see Fig. 17.3 for location).

K/73/S68 is a sandstone fragment with three smoothed surfaces possibly used to grind stone tool edges (Fig. 20.17C). Two surfaces are concave and the narrowest grinding surface is slightly convex. Blackened residues are the result of the Weston fires.

The find was made in the ditch of House A close to S69 (see under cores above).

Artefact K/77/S46 (Fig. 20.15E) is a fragment of weathered metamorphosed sedimentary rock with three smoothed facets possibly used to grind stone tool edges. Grass phytoliths are common, but only one starch grain was recovered. The symmetry of the cross-section suggests that it was deliberately shaped, not unlike that of an axe or, as Loy suggested in his notes (1991, page 17), a possible 'bowl fragment'. The find was made at Hed Mound in the southwest quadrant of the area enclosed by the perimeter ditch of the men's house compound.

In Phase 6 there are 10 ground stone artefacts, including broken butt, medial and blade edge fragments (n=5) and flakes (n=5) (Table 20.7). Artefact K/72/S98, recovered from the Weston store after the fire, is a medial and butt fragment of a ground and polished axe (Fig. 20.12E). The tool stone is basalt. The piece was found at the southern boundary drain some 60 m east of N–S Rd 4, with no evident housing area nearby (see Fig. 17.3 for location).

Flake K/72/S105 has been damaged by the Weston fires. The flake, detached from the margin of an axe blade, has numerous scars with step terminations along the proximal dorsal edge (Fig. 20.12F). The thin distal edge has usewear and residues indicating subsequent use as a knife for cutting plant tissue. The piece was found in topsoil in the vicinity of House B in block A9g in the housing complex at the northern end of this block and of block A9h (Fig. 17.3 for location).

Artefact K/72/S106 (Fig. 20.13A) is a basalt flake from the medial edge of a ground and polished axe, probably an asymmetric blade bevel. The flake has been subsequently ground on the ventral edges and used for scraping and engraving wood. It was found in the same location as flake K/72/S105. Axe fragment K/72/S111(Fig. 20.13B) was excavated in block A9h at the bottom of the ditch of the men's house there (Fig. 17.3 at 'x' and Fig. 17.9). There are neither utilised edges nor evidence of recycling after the tool was broken. The piece was stored at Weston and there is staining and cracking damage from the fires.

Flake K/73/S62 was probably detached during use from a ground and polished axe (Fig. 20.17A). The flake had been subsequently used along the distal edge as a wood scraper. It was found in the topsoil near House A in the complex at the northern end of blocks A9g and A9h (Fig. 17.3), which is also a possible locality for the discovery of utilised fragment K/73/S65. K/74/S71, from near a house ditch on drain A12b/c, is a flake from the medial part of an axe possibly broken during use. The flake was ground again to make a small wood scraper or chisel (Fig. 17.15B). The piece had probably been thrown out on the side of the drain when this was being dug across the line of the house ditch (Fig. 17.3).

Artefact K/77/S57 is from the medial part of a ground and polished axe, close to the original working edge (Fig. 20.15G). After detachment it was used for wood scraping/adzing or engraving. It was found in the southeast quadrant of the area on top of Hed Mound enclosed by the perimeter ditch. Artefact K/77/S67 is a felsic volcanic fragment from the working edge of an axe that probably broke during use (Fig. 20.16B). Along the worked edge are residues and usewear typical of axe blades. The findspot was towards the northwest corner of the area enclosed by the perimeter ditch of the Hed Mound house compound.

Artefact K/77/S80 is a basalt fragment from the used blade edge of a ground and polished axe with asymmetrical blade bevel (Fig. 20.16E). The fragment has been reshaped, ground on fresh surfaces and rehafted at the more pointed end to make a small wood scraper. It was found in the northeast quadrant of the enclosed area on the top of Hed Mound. Artefact K/77/S81 is a near-complete basalt ground and polished axe (with asymmetric blade bevel) with typical usewear and residues from woodworking. It is considerably worn and was reworked by flaking to maintain a symmetrical shape (Fig. 20.18). It was found in the northeast quadrant of the Hed Mound house compound.

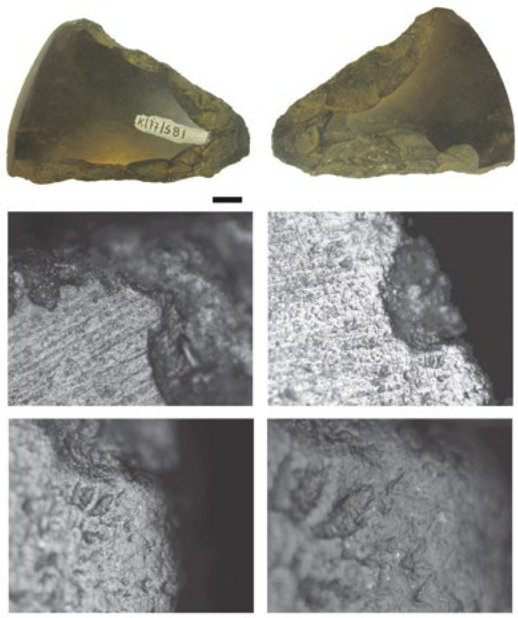


Figure 20.18 Top: ground and polished axe K/77/S81 (with asymmetric blade bevel); bottom: images with microscopic polish detail at increasing magnifications from left to right and down the page (x50, x100, x200 and x500).

Source: Photograph by R. Fullagar.

The artefacts discussed by class

Stone artefacts are present but rare in each phase, with notably more in Phase 6 (Table 20.1). The artefact frequencies are far too low within phases to permit statistical analysis. The two most common artefact classes in Phases 1–3 are those including flake tools (Table 20.2) and core tools (Table 20.3) on the one hand, and grinding/pounding stones (Table 20.5) on the other. Flakes and cores rarely appear in the same phase (the exceptions are Phases 2B and 6), while utilised fragments (Table 20.4) only occur in Phase 6 contexts and in the garden soil that stratigraphically represents Phases 4–6. Retouched flakes are present (n=4), but there are no recurring tool forms. This is a feature of the New Guinea highlands flaked stone assemblages of the last 10,000 years, which are characterised by progressively fewer retouched flakes (White 1977: 23; Evans and Mountain 2005: 371).

When reading what now follows, readers should refer to the corresponding classes of the previous section, when specific items are under discussion.

Flakes (Table 20.2)

There are 12 flakes overall. Complete flakes (n=4) are small: weight range 5–22 g; axial length range 18–30 mm. Retouched flakes (n=4) are also small: weight range 1–26 g; axial length range 12–23 mm. Retouched flakes are present in early and late phases. Two of the oldest flakes in the collection (from Phase 1) have retouch, which is probably an edge-sharpening technique modifying the cross-section and unrelated to modifying the general shape (plan view) of the tool. Fine retouch on flake K/72/S125 may have been for shaping a sharp distal tip, where usewear is most developed. A Phase 6 retouched flake, K/77/S42 (Figs 20.16C and 20.16D), has a steeply retouched (backed) edge that might have facilitated holding or hafting. Flakes were used for scraping and cutting soft starchy plants and wood. The processing of starchy plants is less well represented in Phases 4–6 than in Phases 1–3.

Cores (Table 20.3)

Cores (n=12, weight range 11–1250 g) are generally larger than flakes. The longest scars on cores range from 8 mm to 35 mm, compared with flake tool axial lengths ranging from 12 mm to 34 mm. Cores are likely to have been used both to create flakes and to be utilised themselves as implements for cutting and scraping starchy plants and wood. The longest flake scar on any of the five smallest cores (weight range: 5–36 g) is less than 12 mm, suggesting that flaking of these small cores was not to produce flakes for use, but rather to sharpen and shape core edges for use.

Utilised fragments (Table 20.4)

Utilised fragments (n=7) range in weight from 1 g to 185 g and in length from 17 mm to 30 mm. Utilised fragments were only found in contexts associated with either the Phases 4–6 grouping or Phase 6. The three largest tools (weight range 63–185 g), all from Phases 4–6, are naturally sharp-edged slate or basalt fragments. The four smallest tools (weight range 1–16 g), all from Phase 6, are chert fragments. Utilised fragments were mostly employed in cutting and scraping starchy plants and wood. One utilised fragment (K/77/S76) had possible blood traces identified by Tom Loy.

During the period of garden soil formation that stratigraphically represents Phases 4–6, one utilised fragment of slate (K/72/S6) may have been used for digging the soft swamp sediments, though with fewer striations and less bright polish than commonly found on other sod cutting and digging implements (e.g. van Gijn 1990: 46, 48; Yerkes et al. 2003). The suitability of PNG slate for such tasks has not been tested experimentally as it has elsewhere for other stone (e.g. quartz, see Rots and van Peer 2006). The nature of the local peaty sediment may partially explain the lack of striations and local tool-use experiments need to be undertaken to evaluate this proposition raised by Allen (1970, 1972) and discussed by Golson (1977c: 159–160) and Bulmer (2005: 425–426).

Grinding and pounding stones (Table 20.5)

Upper and/or lower grinding/pounding stones (n=14) are present in all phases and near-complete implements (n=6) range in weight from 239 g to 1740 g. Phase 1 has an unmodified elongated cobble (K/75/S178) used as a pestle for pounding *Dioscorea* yam and other starchy plants. There is also, from the grey clay between Phases 1 and 2, a fragment of a very smooth grinding stone (K/77/S34) symmetrically shaped and described as from a stone bowl (Golson 2000). In Phase 2/3, a lower grinding stone (K/75/S145B) has evidence of starchy-plant processing. The pounding stones were used for grinding and pounding starchy tubers, with likely hammerstone, anvil and ochre-grinding functions as well in early phases. In Phases 6, there are three artefacts with numerous broad striations and flat or concave surfaces, K/72/S57, K/73/S68 and K/77/S46, which are probably whetstone fragments.

Axes (Table 20.7)

Ground and polished axes in the collection under review are represented by fragments of and flakes from the original implements. With one possible exception, they make their appearance in Phase 5 (1 fragment, 1 flake) and more prominently in Phase 6 (5 fragments, 5 flakes). As discussed in the previous section (Fig. 17.3), it can be seen that nine out of the 10 Phase 6 specimens and one of the two from Phase 5 are closely connected with habitation areas, in many cases individual houses. The two pieces not so connected are both fragments.

The possible exception referred to above is K/75/S193, which is described as belonging to Phase 3. It was found at the base of a late Phase 3 tributary channel under investigation in excavation trenches shown in Figure 13.7 (specifically see A). It was made of a different stone from all the other axe pieces in the collection, a volcanic rock so weathered that its interpretation as an axe fragment is uncertain. As a result, it is not considered further in this discussion.

Of the remaining 12 axe fragments and flakes from Phase 5 and Phase 6, at least 10 have traces of plant tissue——starch, cellulose, phytoliths——on polished surfaces (Table 20.7). In at least two instances (K/77/S57 and 67 of Table 20.7), ribbons of smeared fibrous woody tissue are remarkably similar to microscopic traces observed by Fullagar on experimental axes used in a study of axe making in the Wahgi by John Burton (1984: Chapter 6). The residues are mostly embedded in a waxy coating and could not be removed in water by pipette or ultrasonic cleaning. With further analysis, it may be possible to distinguish residues from hafting and use and to take samples of them for radiocarbon dating.

Six flakes and one fragment have been recycled as tools with traces indicating use as wood scrapers (some probably hafted as small scrapers) and one cutting implement. One of the flakes is from Phase 5, the others, including the fragment, are from Phase 6.

Two significant features of the 12 axes under study are pointed out above: their first appearance in Phase 5 and their close association with houses and habitation areas. Both are confirmed by information from John Burton (1984: 296), who made use of 31 excavated items of which 28 are no longer available following the bush fires (see Chapter 21, section 'Axe distributions at Kuk'). Burton's work on sourcing the raw material of the 31 axes in question supplies a third and most important dimension to the Kuk material: the fact that all of them, with one exception, are of foreign origin, made of stone from specialised quarries and widely distributed through the mechanism of trade and ceremonial exchange (see Tables 21.2 and 21.4). The excavated fragments can sometimes be large enough to reveal something of the typology of the original specimens, like the planilateral axes of the Jimi quarries with transversely curving surfaces and narrow flat sides and the quadrangular-sectioned axes of the middle Wahgi quarries, thicker and flatter of surface (Burton 1984: 112–113, Fig. 6.1). Examples of the two classes of axe are illustrated in Chapter 21, a Jimi axe (Fig. 21.4) and a Tuman axe (Fig. 21.3).

Artefact classes over time

Despite the low numbers of artefacts that have survived (Table 20.1), it may be possible to distinguish Phases 1–3 from those that followed on the basis of stone artefact classes and archaeological context. The tools from Phases 1–3 (six flake tools of Table 20.2, seven core tools of Table 20.3 and seven grinding/pounding stones of Table 20.5) were all recovered from garden areas in the southeastern corner of the site, while the great majority of Phase 6 tools (Table 20.1) came from houses or housing areas. These included all four flake tools (Table 20.2), all three core tools (Table 20.3) and two out of three of the grinding/pounding stones (Table 20.5), as well as nine out of 10 axes (Table 20.7) and all four utilised fragments (Table 20.4), two classes of tool that appear for the first time in Phase 6. The same could be true of Phase 5, there is the first evidence of housing in the swamp, though artefact numbers are too few to show. There are four catalogued artefacts (Table 20.1), of which two, a club head fragment (Table 20.6) and a recycled flake from an axe (Table 20.7), were found in the house ditches of neighbouring structures P and Q beneath the Phase 6 housing area at the north end of block A9g (see Fig. 17.3). The other two, part of an axe blade edge (Table 20.7) and a grinding/pounding stone (Table 20.5), had no evident association with a house or housing area (see Phase 5 house distributions in Fig. 15.4).

Apart from axes, there are remarkable similarities across phases. The range of functions for cores, flakes and utilised fragments appears to overlap considerably through time, mainly covering the cutting and scraping of soft starchy plants and wood. The grinding and pounding stones have similar functions, although there are differences: hammerstones, an anvil and a possible ochre grater were identified in early phases, while possible whetstones for grinding axes were, expectedly, only found in Phase 6. The low frequency of artefacts in Phases 1–3, from large excavations, where some of the stone finds had not been returned to store before the 2003 bushfires, suggests that the artefacts were not close to stone-knapping areas. Rather, the implements are most likely to be associated with expedient maintenance tasks and some food preparation. A possible context for stone tool tasks in Phases 1–3 would be places where fieldworkers cultivated the gardens, sharpened and repaired wooden implements of various kinds (cf. Chapter 19) and occasionally prepared food, including yam and taro, out in the fields.

The long period between the beginning of Phase 4 around 2000 years ago and the appearance of housing in the swamp in Phase 5, say 500 years ago, is poorly served with artefactual evidence (see Table 20.1). As discussed, there are four artefacts catalogued for Phase 5, which is thought to have started about AD 1250. There is one stone artefact catalogued between Phases 4 and 5 and two for Phase 4. There are six artefacts in the composite grouping Phases 4–6, established to include material from the garden soil complex that could not be allocated to one of the three phases of swamp drainage and cultivation within it. Two of these are core tools (Table 20.3) and a third is a grinding/pounding stone (Table 20.5), none with any obvious housing connection. The other three are utilised fragments (Table 20.4), a class otherwise only represented in Phase 6. Two of these artefacts may be connected with housing areas: the slate fragment K/72/S6 with the houses at the northern end of blocks A9g and A9h and the other item, K/75/S30, on the fringe of houses on drains C9f/g and C9g/h. We may note that the Phases 4–6 collection does not include any axe fragments or flakes (Table 20.1).

It can be argued that the distribution of artefacts across phases at Kuk is affected to some degree by the excavation strategies employed. Thus, the relative abundance of artefacts attributable to Phase 6 might be explained by the targeted investigation of a small number of the many house sites that were prominent surface features from that period and the exposure of similar house sites to disturbance by the digging of Station drainage lines (see in particular Fig. 17.3). In fact, the presence of large numbers of houses in the eastern part of the Station during Phase 6 is seen as related to a massive change in the organisation of landuse there with the adoption of the sweet potato (*Ipomoea batatas*) as a staple in the upper Wahgi by around AD 1700 (Chapter 16). It is true that there were Phase 5 houses in the swamp, probably late in the phase, around AD 1500. Only a few were found because they were not necessarily visible at the surface and were difficult to identify in drain walls (see Chapter 15, section 'Artefacts, houses and pigs'). However, it is also likely that they were not common in a situation where the whole of the eastern half of the site was under drainage for gardening. As far as is known, there were no houses in the swamp in early Phase 5 or Phase 4.

However, there is another reason, besides the absence or fewness of house sites, for the low numbers of artefacts that can safely be allocated to Phases 4 and 5. This is that in both phases the minor ditches subdividing drained areas into garden plots were dug to a grid pattern. This made it possible to reconstruct the organisation of a gardening system and its changes over time, from the profiles of these minor ditches in the Station drain walls that cut across them at regular intervals. As is clear from Chapters 14 and 15, this made it unnecessary to excavate the lines of ditches over wide areas. This was even more the case with Phase 6, where the ditches were visible as depressions at the surface of the swamp. Large-scale disturbance of surface layers at Kuk was not something that the Research Station management would have permitted in the early years of the Project, until it became obvious from its work that Kuk had been thoroughly disturbed by ditch digging and gardening during previous millennia. The large-scale excavations that became possible from the mid-1970s is reflected in the total numbers of objects recorded in Table 20.1 for Phases 1, 2 and 3 as compared with Phases 4 and 5.

The transition from waisted axes to ground and polished stone axes in Papua New Guinea is linked with tool design, hafting technology and forest clearance for cultivation in the Holocene (Golson 2005: 451–452). Waisted axes and edge-ground axes (see Bulmer 2005; Golson 2005) are one of several potential archaeological indicators of constituent practices (e.g. forest disturbance) and plant exploitation that can be documented in the upper Wahgi Valley spanning at least 30,000 years (Denham, Fullagar and Head 2009: 37). In the new circumstances of the ground and polished stone technology that started at Kuk in Phase 5, there is clear evidence of more intensive use of artefacts; six axe flakes and one fragment were recycled, all belonging to Phase 6 except for one flake from Phase 5 (Table 20.7). Despite this evidence of recycling and the stone working associated with it, there still appears to be relatively little primary flaking of stone on-site and the use of several edges also seems to be common. Multifunctional tools used on more than one plant species or in different modes of use have been identified in earlier phases (e.g. in Table 20.3, the core tool K/75/S179 from the grey clay between Phases 1 and 2).

No animal residues were found on any artefact, apart from possible blood residues on utilised fragment K/77/S76 from Phase 6. Starch grains are reported for four artefacts: K/77/S46 from Phase 6, which is a grinding/pounding stone with one grain; and three artefacts in the Phases 4–6 grouping, K/72/S6 and S51 (Table 20.4) and K/72/S26 (Table 20.3). The grains have not been taxonomically identified, but there is no good match with taro, yam or sweet potato (Loy, Spriggs and Wickler 1992; Horrocks et al. 2004; cf. Fullagar et. al. 2006;).

A possible scenario is that stone tool tasks in the housing era at Kuk Swamp were undertaken in places close to where woodworking tools were used and repaired, sometimes involving edge grinding and the use of small woodworking tools to prepare wooden hafts and to manufacture other wooden implements. There is also evidence that axe flakes were recycled to make small woodworking tools. More intensive woodworking activity distinguishes the tools of the housing period from those in Phases 1–3.

Conclusions

Fifty-eight stones (30 per cent of the 149 examined microscopically) have signs of use. All flakes and cores have traces of edge utilisation. Stone tool use was related primarily to processing wood and other plants, including cultivated food plants (e.g. *Dioscorea* sp. yam and *Colocasia esculenta* taro in Phase 1, 10,000 years ago). It is likely that different starch grain assemblages relate to different contexts and tasks during Phases 1–3 (in the gardens/fields with more food-processing activities and one possible instance of digging peat) compared with Phases 4–6 (near houses with more woodworking activities). Further work is needed both in taxonomic identification of starch grains and in experimental studies to evaluate certain wear patterns that have not yet been characterised for the study area.

Evans and Mountain (2005: 367) have argued that although functional studies have been successful in identifying tool use and resource use in highlands flaked stone assemblages, the study of tool edges (e.g. White 1972) and of use-wear and residues (e.g. Fullagar 1989) has failed to overcome the problem of dealing effectively with apparently amorphous stone artefacts. They have promoted (Evans and Mountain 2005: 368–369) the concepts of risk and provisioning as a means to explain change in artefact form, with a transition identified between the Pleistocene (provisioning of individuals) and late Holocene (provisioning of place). At the highlands rockshelter of Nombe, they found early Holocene volcanic cores in all stages of reduction (indicating provisioning of place) and chert only in later stages of reduction (indicating mobility and provisioning of individuals). They found no such dichotomy in the Pleistocene. This they interpret as indicating a trend from provisioning individuals to provisioning place.

Although artefact frequency is too low at Kuk to permit statistical analysis, volcanic flaked stone is rare in all phases while volcanic grinding stones are present in all phases. Retouched chert flakes and cores are present in all phases. Utilised chert fragments are only present in Phase 6. Following the Evans and Mountain logic, the grinding stone material can be interpreted as a strategy to provision place. Volcanic stones were brought up from the river and utilised in various ways—grinding, pounding, cooking—and the stones could be recycled. The chert artefacts were brought in as small flakes, fragments, cores and retouched tools, suggesting later stages of reduction. In contrast, the largest core (K/75/S179) is made on a volcanic rock, which is an order of magnitude heavier than any chert artefact and which suggests provisioning of place for subsequent use. The Kuk assemblage indicates provisioning individuals with chert, as flake and core tools, and provisioning place with volcanic stone, in the form of grinding, pounding and cooking stones, and a single large core. Provisioning of place from the early Holocene at Kuk seems to be consistent with the Nombe flaked stone patterns identified by Evans and Mountain (2005: 380), marking a transition between the Pleistocene and the late Holocene and indicating more sedentary living patterns.

Acknowledgements

Part of this research published previously (Fullagar et al. 2006) was undertaken in collaboration with Judith Field (then University of Sydney, now University of New South Wales) and Carol Lentfer (University of Queensland), who provided expertise on phytolith and starch grain identification. For comments and direction since embarking on the study of selected Kuk artefacts in 1999, we are indebted to Tim Denham (then Monash University, now ANU) and Tom Loy (1942–2005) who laid the groundwork for this study in 1991. Adam Black (ex-ANU) is especially thanked for photography and image analysis of artefacts salvaged from the Weston store after the 2003 bushfires. Thanks also to David Ellis, Philip Hughes and Marjorie Sullivan for advice on tool stone terminology.

Table 20.2 Kuk flake tools.

A	B	C	D	E	F*	G	H	I	J	K	L	M	N	O	P	Q	R	S
K/76/S28	1	chert	medial	absent	2	starchy plant	4	25	22	6.8	na	na	1	90	unident.	unident.	no	broken from scraper
K/76/S29A	1	ignimbrite	retouched	hinge	3	wood, starchy plant	19	23	51	9.6	11	10	3	5	unident.	absent	no	wood scraper
K/76/S29B	1	ignimbrite	retouched	step	3	wood, starchy plant	26	22	38	20	32	12	9	10	*Colocasia esculenta*, unident.	grass, palm, ginger	no	wood scraper
K/74/S4	2B	chert	complete	axial	2	uncertain	22	30	42	12	20	7	4	40	absent	absent	no	scraper
K/76/S36	2B	chert	complete	axial	3	wood	5	24	16	9	5	3	3	45	unident.		yes	wood scraper
K/74/S28	2D	chert	proximal	absent	2	uncertain	6	27	24	7	8	3	4	0	absent	absent	no	cutting soft tissue
K/73/S31	4	felsic volcanic	complete	feather/axial	2	uncertain	12	34	22	12	11	7	5	25	no extraction		no	distal usewear on tip
K/72/S125	6	volcanic	retouched	feather	2	uncertain cf. skin	7	20	43	4	8	2	2	0	no extraction		no	scraper
K/73/S72	6	chert	distal	hinge	3	wood or skin	4	32	22	3	na	na	4	0	absent	absent	yes	cutting & scraping
K/73/S81	6	chert oxidised	complete	axial	3	wood	5	18	25	8	18	6	7	10	absent	absent	no	wood scraper
K/77/S42	6	chert	retouched	hinge	3	siliceous plant	1	12	17	3	5	2	2	30	absent	rare	no	cf. backing on 'thumbnail' scrapers

A Label and Kuk catalogue reference **B** Phase **C** Tool stone **D** Artefact form & technology
E Termination **F** Tool use (0–3)* **G** Material worked **H** Weight (g)
I Axial length (mm) **J** Axial width (mm) **K** Axial thickness (mm) **L** Platform width (mm)
M Platform thickness (mm) **N** No. dorsal scars **O** Cortex % **P** Starch
Q Phytoliths **R** Resin **S** Comments

* Tool use (F) refers to Fullagar's level of confidence in his microwear interpretations. 0: No traces of use; not used; 1: Possible traces of use; 2: Probable traces of use; 3: Definite traces of use.

Source: Authors' data.

Table 20.3 Kuk core tools.

A	B	C	D	E	F*	G	H	I	J	K	L	M	N	O	P	Q	R	S
K/75/S179	Between 1 & 2	felsic volcanic	core implement	chopper	3	starchy plant	1250	50	93	129	56	3	9	35	*C.esculenta* & *D.alata* or *pentaphylla*	*Saccharum* and/or *Themeda*	yes	chopping plants
K/98/217	Between 1 & 2	chert	core implement	scraper	3	wood, starchy, siliceous	117	30	25	70	37	3	7	22	unident.	palm, grass, ginger	yes	scraping, cutting plants
K/76/S19	2A	ignimbrite	core implement	scraper	3	wood, bone	5	70	29	12	9	1	5	10	unident.	unident.	no	wood or bone scraper
K/77/S4	2A	chert	core implement	scraper	3	starchy siliceous plant	16	70	10	27	33		4	11	unident.	unident.	no	scraping plants
K/77/S20	2B	silicified volcanic	core implement	scraper	3	hard wood	24	70	8	28	47	1	5	8	absent	absent	no	tabular chert fragment
K/72/S62	2D/3	chert agate	core implement	scraper	3	cf. wood	11	80	19	17	31	3	5	13	unident.	absent	no	wood scraper
K/74/S15	3	mudstone	core implement	scraper	3	ochre?	129	50	37	52	40	1	3	26	unident.	rare	no	scraper; ochre
K/72/S26	4–6	chert agate	core implement	scraper	2	uncertain	18	30	9	29	34	1	3	10	unident.	present	no	scraper
K/72/S86	4–6	chert agate	core implement	scraper/ graver	3	wood	15	0	20	29	25	1	5	12	abundant grass	absent	no	wood scraper
K/73/S69	6	felsic volcanic	core implement	scraper	3	wood	36	50	10	39	44	3	7	9	unident.	unident.	yes	wood scraper, carbon, hair
K/73/S80	6	chert quartz	core implement	scraper	1	siliceous plant	62	40	26	46	40	3	7	22	no extraction	no extraction	no	plant scraper, rotated core
K/77/S58A	6	chert	core implement	uncertain	1	uncertain	91	20	44	44	38	1	4	20	absent	absent	no	possible tool; too weathered

A Label and Kuk catalogue reference
B Phase
C Tool stone
D Artefact form & technology
E Tool type
F Tool use (0–3)*
G Material worked
H Weight (g)
I Cortex %
J Block length (mm)
K Block width (mm)
L Block thickness (mm)
M Number of used edges
N No. scars
O Longest scar length (mm)
P Starch
Q Phytoliths
R Resin
S Comments

* Tool use (F) refers to Fullagar's level of confidence in his microwear interpretations. 0: No traces of use; not used; 1: Possible traces of use; 2: Probable traces of use; 3: Definite traces of use.

Source: Authors' data.

Table 20.4 Kuk utilised fragments.

A	B	C	D	E	F*	G	H	I	J	K	L	M	N	O	P	Q
K/72/S6	4–6	slate	utilised fragment	scraper/ chopper	3	fibrous starchy plant	181	30	108	102	12	chopping, scraping	unident. 10-18 micron	no	grass	hafted? plant chopper
K/72/S51	4–6	basalt	utilised fragment	scraper/ knife	3	fibrous plant and other?	185	10	196	45.3	19	scraping and cutting	unident.	no	grass	
K/75/S30	4–6	glassy basalt	utilised fragment	scraper	3	siliceous woody plant	63	50	103	33	16	scraping and cutting	absent	yes	unident.	
K/73/S65	6	felsic volcanic	utilised fragment	scraper	3	wood	16	20	33	22	12	scraping	absent	no	absent	wood scraper
K/77/S56	6	chert	utilised fragment	scraper	3	wood	3	30	22	15	10	scraping	unident.	yes	unident.	wood scraper
K/77/S71	6	chert	utilised fragment	uncertain	3	uncertain	3	20	22	12	9	uncertain	absent	yes	absent	uncertain
K/77/S76	6	chert	utilised fragment	uncertain	1	uncertain	1	0	17	11	3	uncertain	absent	no	absent	uncertain

A Label and Kuk catalogue reference
B Phase
C Tool stone
D Artefact form & technology
E Tool type
F Tool use (0–3)*
G Material worked
H Weight (g)
I Cortex %
J Block length (mm)
K Block width (mm)
L Block thickness (mm)
M Mode of use
N Starch
O Resin
P Phytoliths
Q Comments

* Tool use (F) refers to Fullagar's level of confidence in his microwear interpretations. 0: No traces of use; not used; 1: Possible traces of use; 2: Probable traces of use; 3: Definite traces of use.

Source: Authors' data.

Table 20.5 Kuk grinding and pounding stones.

A	B	C	D	E	F	G*	H	I	J	K	L	M	N	O	P
K/75/S178	1	highly deformed chlorite schist	pebble	complete	handstone pestle	3	starchy plant	239	133	44	27	100	*Dioscorea* sp. & unident.	absent	pounding starchy plants
K/75/S173	Between 1 &2	intrusive gabbro	pebble	complete	lower grinding stone, anvil	3	uncertain, anvil	1232	124	106	47	100	absent	absent	anvil flaking
K/77/S34	Between 1 & 2	tholeiitic basalt	ground stone	broken	lower grinding stone, bowl	3	uncertain	121	90	42	32	50	absent	absent	stone dish; too weathered for usewear
K/77/S17	2C	weathered basalt	pebble	complete (3 refits)	handstone pounder	2	starchy plant, plus ochre?	286	70	62	38	90	*Colocasia esculenta* & unident.	unident.	pounding starchy plants
K/77/S33A	2D	intrusive felsic igneous	pebble	broken (5 refits)	handstone pounder	1	uncertain	69	58	40	20	75	absent	unident.	?possible hammer stone
K/75/ S145B	2D/3	hornblende andesite	pebble	complete	lower grinding stone	2	starchy plant	1740	200	150	34	100	unident.	absent	grinding starchy plant
K/74/S16	3	felsic volcanic breccia	pebble	broken	lower grinding stone	1	uncertain	68	37	34	32	50	absent	absent	?pecked surface; possible hammer
K/74/S19	4	basalt	pebble	complete	lower grinding stone, anvil	2	uncertain	1600	144	131	43	100	unident.	unident.	?pounding starchy plants
K/73/S15	4–5	sandstone	fragment	broken	grinding stone	3	uncertain	34	35	24	24	25	no extractions		uncertain
K/77/S9	4–6	felsic intrusive igneous	pebble	broken	handstone	1	uncertain	60	49	32	25	30	unident.	Panicoid trichome	?grinding plant
K/76/S4P	5	basalt	pebble	complete	handstone pounder	2	soft plant	334	100	99	21	100	absent	unident.	pounding starchy plants
K/72/S57	6	basaltic volcanic	fragment	broken	grinding stone	2	uncertain	12	31	29	11	50	absent	absent	?whetstone
K/73/S68	6	sandstone	fragment	broken	grinding stone	3	uncertain	147	60	48	22	30	no extractions		?whetstone
K/77/S46	6	metamorphosed sedimentary	fragment	broken	grinding stone or axe butt?	3	uncertain	37	37	27	19	20	unident.	common grass	?whetstone

A Label and Kuk catalogue reference; **B** Phase; **C** Tool stone; **D** Artefact form & technology
E Completeness; **F** Tool type; **G** Tool use (0–3)*; **H** Material worked
I Weight (g); **J** Block length (mm); **K** Block width (mm); **L** Block thickness (mm)
M Cortex %; **N** Starch; **O** Phytoliths; **P** Comments

* Tool use (G) refers to Fullagar's level of confidence in his microwear interpretations. 0: No traces of use; not used; 1: Possible traces of use; 2: Probable traces of use; 3: Definite traces of use

Source: Authors' data.

Table 20.6 Kuk ground stone implement: Club head fragment from Phase 5.

Label and Kuk catalogue reference	Tools tone	Artefact form & technology	Tool use (0–3)*	Material worked	Weight (g)	Block length (mm)	Block width (mm)	Block thickness (mm)	Completeness	Residues	Comments
K/73/S61	volcanic basalt	club fragment	1	uncertain	69.8	77	33	21	1/3 donut	none	very weathered; no distinct usewear; macroscopic pecking, flaking

* Tool use refers to Fullagar's level of confidence in his microwear interpretations. 0: No traces of use; not used; 1: Possible traces of use; 2: Probable traces of use; 3: Definite traces of use.

Source: Authors' data.

Table 20.7 Kuk axes, including axe flakes and fragments.

A	B[1]	C	D	E[2]	F	G[2]	H	I	J	K	L	M	N	O	P	Q	R	S
K/75/S199[3]	BE	3	Possible axe butt fragment possible ground surface	1	no			162	91	54	21							broken
K/73/S79	RF	5	Flake from medial (?) part of axe	3	yes	Scraper (3)	wood	8	25	31	7	feather	16	3	unident.	unident.		re-grinding on distal bulbar
K/74/S8	RF	5	Part of used axe blade edge	3	no			65	51	56	12				absent	absent		hydrophobic, B: carbonised material
K/72/S98[3]	WC	6	Medial & butt fragment of axe	1	no			79	48	45	20							residues surviving
K/72/S105	WC	6	Flake from medial (?) part of axe	1	yes	Possible knife (1)	uncertain	6	22	31	7	feather	10	2				flake from axe; possible use scar
K/72/S106	RF	6	Flake from used axe blade	2	yes	Scraper (2)	fibrous wood	1	6	31	4	axial	30	6	absent	unident.		woody tissue; axial measurements if use flake with bending initiation
K/72/S111[3]	WC	6	Medial axe fragment	1	no	no		50	47	35	16							drilled for thin section, no working edge
K/73/S62	RF	6	Flake from used axe blade	3	yes	Scraper (3)	wood	3	22	16	4		3	1	absent	unident.		carbonised material rare
K/74/S71	RF	6	Flake from medial part of tool	3	yes	Hafted scraper (3)	wood	11	20	42	7	feather	38	8	unident.	absent		cellulose sheets

A	B[1]	C	D	E[2]	F	G[2]	H	I	J	K	L	M	N	O	P	Q	R	S
K/77/S57	RF	6	Flake from medial part of axe	3	yes	Scraper (3)	wood	3	35	12	6	feather	6	2	absent	absent		cf. Burton experiments' residues
K/77/S67	RF	6	Blade edge axe fragment	3	no			12	27	21	11				absent	absent	yes	Cf. Burton experiments
K/77/S80	RF	6	Blade edge axe fragment	3	Yes	Scraper	wood	28	68	29	14				unident.	unident.		recycled and re-ground to make small scraper, hafting wear present
K/77/S81[3]	RF	6	Blade edge axe fragment	3	Re-shaped	Same axe edge	wood	105	82	42	18				unident.	grass (haft)	yes	re-shaped from larger axe

A Label and Kuk catalogue reference
E Tool use (0–3)
I Weight (g)
M Termination
Q Phytoliths
B Storage
F Recycled tool
J Length (mm)
N Platform width (mm)
R Resin
C Phase
G Recycled tool use and confidence
K Width (mm)
O Platform thickness (mm)
S Comments
D Artefact form & technology
H Material worked
L Thickness (mm)
P Starch

Source: Authors' data.

Notes:

[1] Storage. BE: ANU collection (boxed); RF: University of Sydney collection (bagged and boxed); WC: Weston Creek collection (bagged, boxed and burnt).

[2] Tool use (E) and recycled tool use and confidence (G) refer to Fullagar's level of confidence in his microwear interpretations. 0: No traces of use; not used; 1: Possible traces of use; 2: Probable traces of use; 3: Definite traces of use.

[3] Item appearing in Table 21.4.

21

Stone Sources and Petrology of Kuk Swamp Artefacts

Marjorie Sullivan, John Burton, David Ellis, Jack Golson and Philip Hughes

Stone artefacts and manuports

No stone occurs naturally in the Kuk swamp deposits, and any stone found there has to have been carried in by people. Possible exceptions are the rocks of the volcanic debris avalanche from Mt Hagen, which reached the southern margins of Kuk Swamp (see Chapter 6, section 'Kuk Swamp in its local setting' and Fig. 6.5). These rocks formed mounds that protruded through the swamp surface. However, since the mounds are generally mantled with tephra and the rocks seldom exposed, they would have been a minor source of supply, if utilised at all.

Stone was brought to the swamp for various purposes: for manufacture of or use as stone artefacts; as 'cooking stones' or heat retainers in cooking ovens; or for other, unknown purposes. This latter group of stone pieces with no discernible use makes up what are called 'manuports', meaning 'carried in by hand'. They could have been used as ammunition in slingshots, which are now mainly used for killing birds, as heavy objects to deliver blows in killing animals, as blocks to sit or sleep on, as objects associated with ritual or as potential sources for artefact manufacture. All had been brought into the area.

Of major archaeological interest are the stone artefacts found in the swamp. They comprise ground and polished axes (for a definition see footnote 1 of Chapter 20), a variety of flaked artefacts, grinding implements and a drilled and pecked piece from a club head. Hearth and cooking stones mark places of domestic activity, including dwellings.

Stone sources for Kuk Swamp

Kuk Swamp lies within a broad basin in the Wahgi River floodplain. In the immediate surroundings of the swamp there is no shortage of excellent quality stone for human use. The geology and landforms of the area have been summarised by Löffler (1977: 26–27). The Wahgi River tributaries drain parts of two structural regions: the New Guinea Mobile Belt, which comprises ancient rocks that have been block-faulted and folded and intruded by old to very recent volcanics; and the Kubor Anticline, with heavily folded and deformed sequences of Palaeozoic basement, igneous and metamorphic rocks and non-metamorphosed sedimentary rocks. Kuk is surrounded by high, steep volcanic mountains and ridges formed on these structural units, which are drained by a network of gravel-bed streams.

Rocks within the Wahgi catchment above Kuk, identified from field observations and geological mapping (Bain, Mackenzie and Ryburn 1975) include: intrusive and volcanic igneous rocks ranging from basic to acidic, and comprising intrusive gabbro, diorite, granodiorite, tonalite and pegmatite together with a range of volcanics, particularly basalt; mixed sedimentary rocks including lithic sandstones/greywackes, tuffaceous sandstones, shales, siltstones, limestones and dolomite; and a wide range of metamorphic rocks including schists, phyllites, gneisses, metavolcanics, hornfels, anorthosite and serpentinite.

Boulders and cobbles from the beds of the Wahgi, Gumants, Guga and other rivers within a few kilometres of Kuk therefore include a very wide range of rock lithologies, many of which were used for specific purposes. In a sample of cobbles collected in 1975 from the Wahgi River immediately below Kuk, Sullivan identified: pink and grey granitic rocks, mainly granodiorites and pegmatites; acidic, intermediate and basic volcanic rocks—rhyolites to basalt—many of the basics being very rounded with deeply weathered yellow-brown cortex; sub-rounded and fractured high-grade metamorphic rocks—schists to gneisses—mainly quartz-rich and containing prominent mica; metasediments, mainly metamorphosed greywackes, hornfels and quartzites; and limestone. Of 107 cobbles inspected the percentages were:

- Volcanics (46 per cent)
- Acid igneous intrusives (32 per cent)
- High grade metamorphics (6 per cent)
- Metasediments (mainly meta-greywacke, and hornfels) (14 per cent)
- Limestone (2 per cent)

We have already mentioned the mounds in the major debris avalanches from Mt Hagen that shaped the local landscape. They contain lava—mainly basalt, but also more acidic volcanics—and other stone collected by the high-energy mudflows and occur both within and adjacent to the margins of the swamp. It was noted that generally the softer sedimentary rocks such as shales and indurated mudstones, and the vesicular volcanic rocks common in the lahar mounds do not survive as cobbles in the high-energy streams.

Stones used as heat retainers in cooking

In 1985, at Golson's request, Alan Watchman, a consultant geologist and geoarchaeologist, recently graduated from ANU, carried out a petrographic examination of 12 stones identified by local villagers as suitable for use as ovenstones, i.e. heat retainers in earth ovens. They had been collected by Golson from three rivers at or near Kuk (see Fig. 23.2). There were five from the Guga at Kenta, a Kuk hamlet; four from the Wahgi near the southeastern corner of Kawelka land; and three from the Gumants at the road bridge near the Gumanch Plantation (see Fig. 22.1). Later David Ellis (1994), head of Geology at ANU, compared these rocks with 19 others described by local people as unsuitable for use in ovens when collected by Golson at the same times and places as those they identified as ovenstones.

With the exception of one from the Wahgi (#4), all of the heat-retaining stones are fine-grained basaltic lavas. Watchman (1985) identified them as basalt, weakly metamorphosed basalt, vesicular basalt or ignimbrite/tuff. They ranged from glassy to finely crystalline and all contained basic igneous minerals, like plagioclase feldspars and pyroxenes, as well as secondary metamorphic minerals such as epidote and albite.

Wahgi #4 is a fine-grained metamorphosed sedimentary rock dominated by even-grained quartz, with biotite and muscovite (sericite), which Watchman described as hornfels. It was heat-affected during formation by proximity to an igneous intrusion. Its even, non-foliated structure and the absence of hydrous metamorphic minerals would have made it suitable as an ovenstone, as would its slight recrystallisation, which produced interlocking grains that enhanced its ability to resisted fracturing when heated.

Ellis (1994) concluded that the favoured rock for ovenstones is fine-grained basaltic lava flow material. While the Hagen Volcanics are an obvious source, there are numerous others. Of the 19 stones pronounced by local villagers to be unsuitable for use as oven stones, Ellis said that only one, a fresh volcanic rock labelled Rock R, was ever likely to have been so used. The 18 unsuitable rocks belonged in the main to a wide range of very fine- to very coarse-grained basic to acidic igneous rocks, some of them metamorphosed. A few were sedimentary rocks.

Stone used for artefacts

Flaked stone artefacts

In Chapter 20, Fullagar describes the flaked artefacts from Kuk as including flakes, cores and utilised fragments. These artefacts are listed by raw material in Table 21.1.

There is no evidence that people in the highlands traded or imported finished flaked artefacts. Instead they selected cobbles or blocks of rock available locally for flaking. The stone materials that were chosen generally did not tend to shatter along fracture planes inherent in the rock. The flaked artefacts at Kuk were all made on coherent fine-grained or crystalline rocks which distributed the force of hitting or flaking uniformly throughout the rock mass. With such materials, the flaking process can be controlled to produce the required shape of flake or core.

The petrology/lithology of a sample of flaked stone artefacts from Kuk Swamp was examined by Ellis (1994) and his terminology has been refined here to reflect the following petrological descriptions appropriate to the Mount Hagen area.

Chert is a term that refers to very fine-grained rock composed mainly of cryptocrystalline quartz. Cherts are generally pale-coloured siliceous rocks. Because the term 'chert' is used loosely, material that has been so classified may be of a kind with an origin that technically belongs to one of the rock types described below. Material loosely described as chert could be altered rock that originated as material ejected from a volcano (ignimbrite) or slightly indurated very fine-grained sedimentary rocks (siltstones or mudstones). It might be true chert formed as precipitated or replaced silica in altered limestone or dolomite. In its finest translucent form chert may be banded and referred to as agate (or another gemstone term).

Ignimbrite is material ejected from a volcano that has cooled rapidly and which varies greatly in composition and form. The ignimbrite used for artefacts in the study area is fine-grained or glassy pale-coloured siliceous rock. It is chiefly a fine-grained rhyolitic tuff formed mainly of glass particles (shards) in which crystals of feldspar and quartz, as well occasionally as altered hornblende, are embedded.

Acid (felsic) volcanic is fine crystalline igneous rock that flowed or was ejected (as an airfall deposit) from a volcanic eruption and cooled quickly. Chemically such rocks have the composition of granite/tonalite or granodiorite. If they are flow-banded, they are referred to as rhyolite or trachyte.

Basic (mafic) volcanic is fine crystalline igneous rock that flowed or was ejected from a volcanic eruption and cooled quickly. Chemically such rocks have the composition of gabbro or diorite, if solidified as an intrusive igneous rock, or of a basalt, if an extrusive igneous rock.

Volcanic glass is a glass naturally produced by the cooling of molten lava, or some liquid in it, too rapidly to permit crystallisation. Basic volcanic glass is black, dark brown or greenish and as an extensive outcrop is referred to as tachylite. Acidic volcanic glass or obsidian is less frequent and is commonly dark brown to yellow or cream. The light-coloured form may also be classed as ignimbrite. It is not possible to distinguish between the darker-coloured acidic and basic forms in hand specimen.

Mudstone or **siltstone** is very fine-grained sedimentary rock, rich in silt and clay particles. Commonly mudstones were hardened or indurated by heat from a nearby igneous source or by secondary silicification as silica-rich water moved through initially soft rock. When hardened, they are suitable for flaking. When metamorphosed under high pressure they can be transformed into slate.

Table 21.1 Raw materials for flaked artefacts at Kuk.

Cultivation phase	Total no. flaked artefacts	Raw material for flaked artefacts					
		Chert +agate	Ignimbrite	Acid volcanic	Basic volcanic/ basalt	Volcanic glass	Indurated mudstone
Phase 1	3	1	2				
Between Phases 1 & 2	2	1		1			
Phase 2	6	5	1				
Phase 2/3	1	1					
Phase 3	1						1
Phase 4	1			1			
Phases 4–6[1]	5	2			1	1	1
Phase 6	11	8		3			

Source: Data from Tables 20.2, 20.3, 20.4.

Note:

[1] These artefacts came from the garden soil incorporating Phases 4, 5 and 6, but their precise location was uncertain.

The number of flaked artefacts recovered from all but the most recent phase is very low. Fullagar (in Chapter 20) notes that most of the flaked artefacts from that phase are fragments of axes, later reworked. Apart from the fine-textured or glassy basic volcanic materials resulting from such recycling, most of the flaked stone artefacts were made on siliceous rocks, including acidic volcanic materials.

Grinding artefacts

Rock used for grinding must be abrasive, and necessarily contain large angular grains or crystals that can score other rocks. Coarse sedimentary rocks, slightly weathered intrusive igneous rocks and contorted metamorphic rocks all have such properties, especially if they contain large quartz or fresh feldspar crystals or grains. The 14 grindstone fragments or whole grinding artefacts recovered from Kuk are listed according to cultivation phase in Table 21.2.

Table 21.2 Grinding artefacts at Kuk.

Cultivation phase	Artefact	Raw material
Phase 1	Handstone pestle	Deformed chlorite schist
Between Phases 1 & 2	Lower grindstone/anvil Mortar rim	Intrusive basic volcanic (gabbro) Tholeiitic basalt
Phase 2	Handstone pounder Handstone pounder	Weathered basalt Intrusive acid igneous
Phase 2/3	Lower grindstone	Hornblende andesite
Phase 3	Lower grindstone	Acid volcanic breccia
Phase 4	Lower grindstone/anvil	Basalt
Phases 4–5[1]	Grinding stone	Sandstone
Phases 4–6[2]	Handstone	Intrusive acid igneous
Phase 5	Handstone/pounder	Basalt
Phase 6	Grinding stone Grinding stone Grinder/axe butt?	Basic volcanic Sandstone Metamorphosed sediment

Source: Data from Table 20.5.

Notes:

[1] These artefacts came from the garden soil incorporating Phases 4 and 5 but their precise location was uncertain.

[2] These artefacts came from the garden soil incorporating Phases 4, 5 and 6 but their precise location was uncertain.

Golson (2000: 236) has previously claimed that one grinding artefact from Kuk, a probable rim fragment from a stone mortar (K/77/S34), is the oldest of its type found in New Guinea—from some 7000–7500 years ago. The piece was examined by David Ellis and Douglas Mackenzie, an expert on the volcanics of the PNG highlands, to determine its composition and the source of the material from which it was made. The results were unexpected on the basis of composition and inconclusive on that of provenance (Golson 2000: 233–234). A full account is told in Appendix 21.1.

Ground axes and axe quarries

The discussion so far has dealt with two of the three classes of stone artefacts excavated at Kuk and identified by Fullagar as flaked stones, including flakes, cores and utilised fragments, and grinding and pounding stones, including unmodified plant-processing tools. We have noted that the raw materials from which they were made are all present within the Kuk catchment, with the possible exception of the mortar rim discussed by Noreen Evans and Brent McInnes in Appendix 21.1. For ground stone axes the situation is the reverse, in that for the most part they are not made of local stone, but were imported. This is true both of the small numbers of mainly fragments and flakes of axes recovered in the course of excavation (Table 20.7) and of the large numbers of often whole axes discovered during the establishment of the Research Station, before the start of the archaeological project, and in the course of its operations after that. As a result, they constitute the major stone artefact class at Kuk. Most of the axes were made from metamorphosed sedimentary rocks not found at Kuk, but manufactured from material supplied by specialised quarries and traded in. This indicates that they served to integrate Kuk into the networks of trade and exchange that characterised the Wahgi Valley and neighbouring areas at European contact in the early 1930s, in which axes played a key role. The axes, their sources, their manufacture and their distribution were the subject of a major study in the Wahgi in the early 1980s (Burton 1984), and the discussion here is based on that work.

Burton (1984: 3) points out that many sources of axe stone in the highlands of Papua New Guinea are known to have been exploited, but the most productive are confined to the Wahgi and the Jimi Valleys, where 'overall output is likely to have run into hundreds of thousands of axes per century'. These were the major sources of the axes found at Kuk (Figure 21.1), where the relevant quarries fall into two main geographic groups: quarries in the Jimi Valley and at the Sepik-Wahgi Divide 20–35 km north to northeast of Kuk; and those in the Wahgi Valley 22–75 km from east to southeast of Kuk.

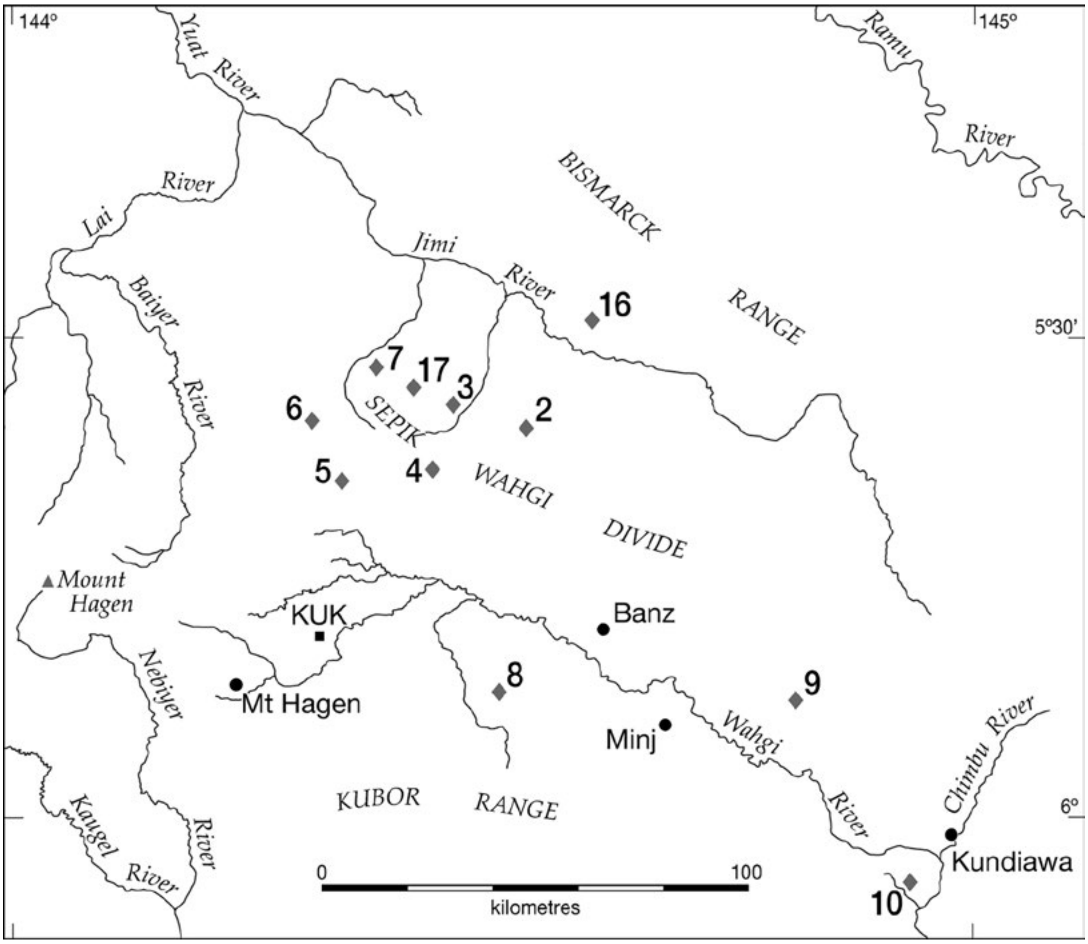


Figure 21.1 Quarries with axes represented at Kuk.

Note the quarries named are part of the listing in Burton (1984: Table 1.1). 2 Tsenga; 3 Ganz River; 4 Mala Gap; 5 Mbulk; 6 Pukl; 7 Yambina/Kraep; 8 Tuman; 9 Kerowagi; 10 Dom gaima; 16 Repeng/Golum; 17 Apin.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

Axe distributions at Kuk

As with the wooden artefacts discussed in Chapter 19, most axes were found when Kuk Swamp was drained from the late 1960s. There was disturbance of the swamp by ditching, building and planting associated with the establishment of the Research Station in 1969 and its initial development in the western part of the property. In 1972, when the archaeological project began, team members were shown the axes and wooden implements found over these years and stored for their interest by its personnel. From 1972, axes were still being found with the continued cultivation of the beds in the established half of the Station. The full range of finds appeared again with the beginning of drainage in the eastern half of the Station to allow archaeological investigations to be carried out there. The axe finds up to this date are entered in Table 21.3 under Golson's name because he catalogued them.

Table 21.3 Identification of axes from surface collections in three environments at Kuk.

Environment		Collection	Number	Weight (g)
Swamp		Golson	37	5704.6
		Gorecki	20	4445.0
		Burton	5	968.8
	Total		**62**	**11,118.4**
Dryland		Gorecki	24	7983.0
Ep Ridge		Golson	4	583.6
		Gorecki	30	5543.2
		Burton	13	2533.0
	Total		**71**	**8659.8**
	GRAND TOTAL		**133**	**27,761.2**

Source: Based on Burton (1984: 293–295).

When in 1977 Paul Gorecki began his ethnoarchaeological research at Kuk, into the dynamics of agricultural site and settlement site formation, he moved widely over Kawelka territory (see Fig. 23.2), and made or was given axe finds from different parts within it. It was the same case for John Burton, who came in 1980 and again in 1981 to do fieldwork on axe makers of the Wahgi. Both Kuk and the Wurup Valley, on the other side of the Wahgi River, where Ole Christensen worked in 1973 and 1974 (White et al. 1977), were places that provided large axe collections ideal for the examination of the source areas from which they had been traded and of the relative importance of the different sources in that trade.

Burton (1984: 293–295) lists the weights, lengths and most likely sources of axes from Kuk and its surrounds, in the collections made by Burton, Gorecki and Golson 1972–81 described above. The three environments are the swamp itself, the dryland around its margins and the slopes of Ep Ridge to the north. Axes recovered during excavation work of the archaeological project at Kuk Swamp, over the years 1972–77, were described in a listing by Burton (1984: 296). The data originally presented by Burton have been updated here and are summarised in Tables 21.3 and 21.4. Six of the 144 axes in Burton's original table do not appear in Table 21.3 because they are not from Kuk (K/M/S1, K/M/S3, K/72/S63, K/72/S64, K/76/S24 and K/76/S25). Another five have been removed because their locational/stratigraphic data are sound enough for them to be transferred to Table 21.4, which is based on Burton's original data (Burton 1984: 293–294). These are K/72/S9, K/72/S11, K/74/S27, K/74/S38 and K/75/S193.

If the last of these five is accepted as an axe, it is the oldest from the site, being found near the base of a late Phase 3 ditch. However, Fullagar reports in Chapter 20, section 'Axes', that it is made of a different stone from other axes in the collection and is so weathered that its interpretation as an axe is uncertain. In consequence he considers it no further in his discussion, though he retains it in his table on axes (Table 20.7). We retain it in Table 21.4 because it was seen by Burton (1984: 294), who recorded it as of 'local' rock on hand inspection.

Table 21.4 Sources of axe fragments from stratified contexts at Kuk.

Catalogue no.	Findspot	Stratigraphic location[1]	Weight (g)	Likely source[4]
K/72/S9[2]	During digging of east end of E-W Rd 3 south drain at junction with eastern boundary drain	Possibly associated with housing area here	81.9	[5]Tsenga gaima
K/72/S11[2]			489.8	[5]Tuman
K/72/S38	During digging of E-W Rd 3 south drain at block C7e	400 mm deep in surface peat	97.1	Tuman
K/72/S52	During digging of E-W Rd 3 drains at junction with N-S Rd 4	Base of peat in housing area	164.3	C
K/72/S94	During digging of E-W Rd 2 north drain at SE corner of block C9	150 mm above base of young ditch close to housing area	104.9	[5]Tuman
K/72/S98[3]	Wall of S Boundary N drain about 80 m E of the middle of N-S Rd 4	540 mm below surface in base of greasy organic layer underlying felted peat	78.9	[5]Tuman
K/72/S102A	During excavation at House C at N end of block A9g	In the earlier stage of the house ditch on N side of house	42.7	A
K/72/S109	During excavations at Houses B & C at N end of block A9g	Found on spoil heap from the excavations	40.7	D
K/72/S111[3]	During excavation of men's House at S end of block A9h	Bottom of ditch surrounding the house	54.1	C
K/72/S119	During excavation of House F at N end of block A9g	From soil over house floor	42.1	[5]Tuman
K/72/S120			50.5	C
K/72/S121			74.0	[5]Tuman
K/72/S123		On floor of house	37.1	[5]Tuman
K/73/S60	During excavations between Houses A & B at N end of block A9	Topsoil	67.4	C
K/73/S66	During excavation of House A at N end of block A9g	From ditch on S side of house	95.9	C
K/73/S114	During excavations at house cut by drain A11a/b	Edge of house ditch in block A11b	67.1	Mbukl
K/74/S27[2]	In grey clay 50 mm below base of large young ditch in A10f/g	A10f/g, area of Phase 5 and 6 field activity, garden area	127.5	[5]Tuman
K/74/S38[2]	Excavation by Jim Rhoads of field ditch in block A10g	Ditch articulates with early phase of Simon's Baret and is thus Phase 5	97.1	[5]Tuman
K/75/S13	During drain digging, N end of C9g/h	Associated with floor & ditch of possible Phase 5 house	609.2	Tuman
K/75/S20	During drain digging, S end of C9g/h	Fill of younger phase of redug surface-visible house ditch	110.3	Dom gaima
K/75/S50	During digging of drain C9d/e	In vicinity of possible house	46.5	Local
K/75/S64	During digging of N end of drain C9c/d	Fill of later stage of slightly surface-visible house ditch	432.0	[5]Tuman
K/75/S78	During digging of N end of drain C9b/c	In ditch 3, younger phase	54.9	Dom gaima
K/75/S193[2,3]	During excavations in block A12e	Base of late Phase 3 ditch	161.9	[5]Local
K/77/S38	Hed Mound NE quadrant	In topsoil close to perimeter ditch of house compound	62.5	C
K/77/S45	Hed Mound NW quadrant	In topsoil, [from plan] within the perimeter ditch of house compound	54.5	[5]Tuman
K/77/S47	Hed Mound NW quadrant	In topsoil, [from plan] on line of W arm of perimeter ditch where no ditch dug	32.2	C
K/77/S51	Hed Mound SW quadrant	In topsoil, [from plan] just outside S arm of perimeter ditch	87.4	[5]Tuman

Catalogue no.	Findspot	Stratigraphic location[1]	Weight (g)	Likely source[4]
K/77/S62	Hed Mound SE quadrant	In topsoil, [from plan] just outside S arm of perimeter ditch	78.5	[5]Tuman
K/77/S63	Hed Mound NW quadrant	Layer 2, [from plan] between perimeter ditch and ditch at S of men's house	35.9	Ganz
K/77/S64	Hed Mound NW quadrant	Layer 2, [from plan] within area enclosed by perimeter ditch	76.9	[5]Tuman
K/77/S66A	Hed Mound NW quadrant	Layer 2, [from plan] close to NW corner of area enclosed by perimeter ditch	109.3	[5]Tuman
K/77/S66B	Hed Mound NW quadrant		56.4	Ganz
K/77/S72	Hed Mound SE quadrant	Layer 2, [from plan] outside S leg of perimeter ditch near SE corner	80.9	Ganz
K/77/S81[3]	Hed Mound NE quadrant	Layer 2, [from plan] just inside of perimeter ditch	108.6	Ganz
K/77/S82	Hed Mound NE quadrant	Layer 2, [from plan] just inside E arm of perimeter ditch	64.9	A

Source: Based on Burton (1984: 296).

Notes:

[1] All entries are Phase 6, except K/75/S193, which is late Phase 3.

[2] These pieces were transferred from Burton's original list (1984: 293–295, summarised in Table 21.3 here), because they proved to be from a known stratigraphic location or association with houses.

[3] These pieces survived the 2003 bushfire to be examined by Fullagar (see Chapter 20).

[4] The sources identified by an uppercase letter are Burton's (1984: 305) 'Unidentified Groups A–D' of Appendix H on infrared spectroscopy of quarries in the study area, but included by him in the Jimi Valley group (1984: 215).

[5] Indicates hand identification only, the rest being identified using infrared spectroscopy.

There is in fact little overlap between Burton's (1984: 296) listing of excavated axes at Kuk, which dates from well before the bushfires of 2003 (see Chapter 18), and what remained in the collections as a result of them (Table 20.7). Aside from the possible Phase 3 axe that we have discussed, there are only three pieces and all are associated with Phase 6. One of these, K/77/S81, survived because, like the Phase 3 piece, it had been removed from the artefact store for study. The other two, K/72/S98 and S111, were found during salvage work after the fire. The other 28 axes of Burton's listing had been lost. Nine axe pieces in Table 20.7 did not appear in the Burton lists, two of them belonging to Phase 5, the other seven to Phase 6. This may be put down to the problems of storage that Golson discusses in Chapter 18, section 'Stone'.

Sourcing stone axes in the upper Wahgi

While some axes were made on volcanic rocks, most were made on metamorphosed sedimentary rocks with sediments derived mainly from volcanic minerals that ranged from very dark black to green basic minerals to more acidic pale siliceous minerals. These metasedimentary rocks tend to split along cleavage planes.

Like Chappell (1966: 105–106), Burton found that Tuman, black Jimi Valley, light-coloured Tsenga gaima and Dom gaima axes could be identified with confidence through visual inspection. His numerous informants at the Tuman River (Fig. 21.2) were especially helpful in describing the finer differences of the local products. Tuman axes are typically dark olive green in colour with a distinctive patterning revealed by grinding and polishing, usually in the form of lighter green or even white swirls in the stone. Also the 'classic' Tuman axe shape is fatter in cross-section with the sides of planilateral form often left partially ground. The shape is easily seen in Figures 21.2 and 21.3 and other images in Burton (e.g. 1984: Plates 6.1, 6.2, 6.5, 6.6, 6.14). It is also seen in historic photographs such as Frank Hurley's 1923 image of a man demonstrating the sharpening of a Tuman blade at Goaribari Island in the Kikori River delta, where an adze style of hafting was in use (Specht and Fields 1984: V.4233). It also made it possible for Ian Hughes (1977), to identify a Tuman axe purchased from local traders in the Torres Strait by those on board HMS *Rattlesnake* in 1848, and now in the collections of the British Museum (Burton 1984: 229). It was not possible to differentiate between any of the seven Tuman sources. In rare cases, Tuman axes with a dark patination could be confused in hand specimen with the amphibole-rich black axes from the Jimi Valley, especially if they did not have the distinctive shape of the typical Tuman planiform.

Axes made in the Jimi Valley style are flatter and broader, flared at the cutting edge and with the sides of planilateral form almost always ground. This is seen in Figure 21.4 and in other Burton images (e.g. 1984: Plates 6.3, 6.4). Among the Jimi sources only Tsenga gaima axes could be identified visually.

Figure 21.2 Numndi, born about 1900, and Kandel, born about 1896, with Tuman River axes at Orpakl, Tuman River.

Source: Photograph by John Burton, 1980.

After Chappell's (1966: Table 1) identification of the four main mineral constituents of highlands axes as epidote, albite, quartz and tremolite-actinolite, Burton (1984: Chapter 10) experimented with various laboratory techniques to distinguish between the products of different sources. X-ray fluorescence was able to make a clear separation between samples from the Ganz Ketepukla, Tsenga Tingri and Mbukl quarries (Burton 1984: 214, Fig. 10.3), while axes made there are thought to be indistinguishable in hand specimen. Unfortunately, the technique could not be used on a large number of samples because of limited laboratory capacity. Infrared spectroscopy showed that some sources had strong quartz signatures (Tuman, Repeng, Mbukl, Tsenga gaima), while others contained amphiboles, most probably actinolite (Tsenga Tingri, Apin, Yambina and some Ganz), albite (Pukl and most Ganz) and prehnite (Dom gaima). Confusion over the infrared spectra of Tuman and Mbukl axes was possible; examples of the former were common at Kuk, while the latter was a minor source. The Tsenga Tingri, Apin and Yambina sources could not be distinguished using infrared spectroscopy; the first is a major source and the other two minor sources.

Figure 21.3 Hagener with Tuman axe (from the Michael Leahy Photographic Collection, National Library of Australia).

Source: Burton (1984: Plate 6.8), reproduced with permission.

Figure 21.4 Hagener with Jimi axe, probably Tsenga gaima (from the Michael Leahy Photographic Collection, National Library of Australia).

Source: Burton (1984: Plate 6.9), reproduced with permission.

The infrared signatures also revealed four types of source material (labelled A, B, C and D in the tables) that cannot be matched at present with samples recovered from known quarries. In all probability these were axes made from small outcrops at the known Jimi quarries or from distinct sites in the same general area that have not yet been located. Since the major Ganz River source Ketepukla could not be distinguished by the infrared method, it is possible that sources A and/or C represent Ketepukla or sources of similar composition. For the time being A, B, C and D are classified as Jimi sources, however, this is a conjecture and there is ample scope for future research to elaborate on or refute this claim.

Burton (1984: 211) was able to examine 196 axes of known provenance in Christensen's ethnographic collection from Wurup (presumed to have been lost in the Weston fire described in Chapter 17) and 144 in the Kuk collection (since changed to 133 in Table 21.3). There were 31 fragments (since changed to 36 in Table 21.4) large enough to be drilled for infrared analysis in the collection of stratified finds from Kuk. The provenance of the 169 axes from Kuk is presented in Table 21.5.

Most of the Tuman axes could be identified by eye (Burton 1984: 211). In the Wurup collection there were 78 and 60 at Kuk, after the correction of the original listing for Kuk (Burton 1984: 293–295) with the elimination of one non-Kuk intruder, K/76/S25, and the transfer of two specimens, K/74/S27 and 38, to Table 21.4. A minor type that could often be classified visually was the local (non-quarry) axe (e.g. Wurup 36 and Kuk 15). The latter reduces Burton's listing by two with the elimination of a non-Kuk intruder, K/76/S24, and the transfer of K/75/S193 to Table 21.4). Two other minor types amenable to visual identification were Tsenga and

Dom gaima. Three of the former and one of the latter were initially reported by Burton for both Wurup and Kuk. However, the Kuk total for Tsenga gaima here is reduced from three to two with the transfer of K/72/S9 from Burton's listing to Table 21.4.

Despite alterations to the total number of Kuk axes that Burton identified by visual inspection, his conclusion (1984: 211) that a minority of axes in both collections remained to be sourced by infrared spectroscopy still holds. Infrared spectroscopy was used to source 78 axes from Wurup and 55 from Kuk (after the removal of four non-Kuk intruders, K/M/S1, K/M/S3, K/72/S63 and K/72/64 and the transfer of K/72/S11 to Table 21.4). Additional candidates for spectroscopic analysis were 20 of the 31 axe flakes and fragments with locational and stratigraphic information from the archaeological work of the 1970s listed separately by Burton (1984: 296). This list of 31 forms the basis of Table 21.4, but totals 36 because it includes five transfers from Burton's main listing, as described above. One of these additions, K/72/S11, was also a candidate for spectroscopy.

Besides the Kuk axe fragments that underwent infrared spectroscopy for sourcing, Burton (1984: 211) also put 11 axe pieces from Ole Christensen's Wurup excavations and Mary-Jane Mountain's excavations at Nombe rockshelter in Simbu Province through the same procedure. We address the Wurup results below.

As Burton says (1984: 214–215), the proximity of the Tuman quarries makes it unsurprising that Tuman axes account for more than half the numbers in the Wurup and Kuk collections. Half of the remainder is made up of axes from the Jimi Valley (Ganz, A, B, C, D, Tsenga gaima, Yambina) and the Sepik-Wahgi Divide (Pukl, Mbukl), with the rest consisting of axes of local rock or from more distant sources like Dom gaima and Repeng. Tuman axes are slightly better represented at Wurup than at Kuk (Burton 1984: 216). While axes from Mbukl (Sepik-Wahgi Divide) and Yambina (Jimi Valley) are reported from Kuk, these quarries are not represented at Wurup (Burton 1984: 215). Given the fact that Wurup and Kuk are quite close to one another, less should be read into the small differences in distance to source than the fact that the Kawelka people, the recent owners of the Mbukl quarry (Burton 1984: 213), have strong historical links with Kuk (cf. Chapter 22), so that the appearance of axes from there at Kuk would not be unexpected. Burton found that the Mbukl and Yambina sources could not be identified with confidence (1984: 215 and cf. 206, 212, 213), so that Lampert's earlier claim (Lampert 1972) that as many as 28 per cent of finds from the Warrawau Plantation area at the mouth of the Wurup Valley were from Mbukl cannot be substantiated (1984: 216).

Table 21.5 shows that the axes from surface collections and excavations were broadly similar in provenance, in that most of them were from Tuman and Jimi Valley quarries. The contrast between the size of the excavated axe flakes and that of the surface axes and axe fragments is well illustrated by the weight column.

Burton looked at the possibility of functional differences being reflected in the representation of axes from different sources in the different environments in which they were found at Kuk (1984: 216, Table 10.4). Though numbers are on the low side, chi-square tests on the three most numerous axe types (Tuman axes, locally made axes and Ganz River axes) show that there are no significant differences in their rates of discovery in the dryland gardens, the swamp and on Ep Ridge. The Mubkl axes were all found in the swamp, but the identifications are too uncertain for conclusions to be drawn.

Table 21.5 Summary of Kuk axe sources.

Quarry	Number	%	Average Weight (g)
Surface axes (mainly whole axes) (taken from Burton 1984: 293–295)			
Tuman	69	51.9	208.2
Ganz River	14	10.5	298.6
Pukl	5	3.8	311.7
A	2	1.5	274.8
B	2	1.5	381.8
C	6	4.5	149.1
D	2	1.5	119.7
Tsenga gaima	3	2.3	574.8
Yambina	3	2.3	171.2
Mbukl	6	4.5	162.2
Repeng	1	0.8	175.6
Dom gaima	3	2.3	72.1
Unknown	1	0.8	291.7
Local	16	12.0	196.2
TOTAL/AVERAGE	**133**	**100**	**242**
Axe fragments from stratified and housing contexts (see Table 21.4)			
Tuman	16	44.4	164.4
Ganz River	4	11.1	70.5
A	2	5.6	53.8
C	7	19.4	75.3
D	1	2.8	40.7
Tsenga gaima	1	2.8	81.9
Mbukl	1	2.8	67.1
Dom gaima	2	5.6	137.8
Local	2	5.6	104.2
TOTAL/AVERAGE	**36**	**100**	**88.4**
All axes combined			
Tuman	85	50.3	200.0
Ganz River	18	10.7	247.9
Pukl	5	3.0	311.7
A	4	2.4	164.3
B	2	1.2	381.8
C	13	7.7	109.3
D	3	1.8	93.4
Tsenga gaima	4	2.4	451.6
Yambina	3	1.8	171.2
Mbukl	7	4.1	148.6
Repeng	1	0.6	175.6
Dom gaima	5	3.0	76.3
Unknown	1	0.6	291.7
Local	18	10.7	186.0
TOTAL/AVERAGE	**169**	**100**	**215**

Source: Based on Burton (1984: 293–296).

Note: The means of axe identification were IR spectrum 42 per cent and hand inspection 58 per cent.

The age of the axe trade in the upper Wahgi

Dating the appearance of traded axe stone at Kuk is of prime importance, but difficult to determine. Limiting factors include the greater representation of axes at house sites than in gardens and the greater likelihood that they can be dated more reliably there than elsewhere. For the axes listed in Table 21.4 here and those in Fullagar's list (Table 20.7 here), omitting the Phase 3 example as only a possibility, the association with houses predominates. In the Fullagar list the earliest date is later Phase 5, when the first houses appear in the swamp.

Burton's discussion of the chronology of traded axes excavated by Christensen at rockshelters in the Manim Valley is important in this context, and unique (1984: 227–228, Tables 10.7 and 10.8, Fig. 10.15; cf. Chapter 14 here). The rockshelters in question are within the wider Wurup area of Christensen's archaeological reconnaissance and axe collecting of the 1970s. Burton bases his argument on two of four excavated sites, Etpiti and Kamapuk, where sufficient fragments of polished stone were present to make a statistical exercise worthwhile. The finds were sorted by inspection into two groups: those that were evidently from quarries; and those made of stone from local sources or of unknown provenance. Most of the pieces from recognised quarries were from Tuman axes or a Jimi Valley source. Three Kamapuk fragments and one from Etpiti were tested spectroscopically.

Burton (1984: Table 10.8) gives the quarried stone for each site as a percentage by weight of all polished stone by excavated level and then smooths the percentages with a simple running average calculation. Both sets of values appear in Figure 21.5 here. From these data, the balance of probability is that quarried stone entered the archaeological record of the Wurup Valley sometime between about 2500 and 1000 years ago[1]. Following the running averages, the proportion of quarried stone at both sites rose from zero before this period to almost 100 per cent of the assemblages by the end of it. This conclusion (Burton 1984) was based on imperfect data. Then, and now, it requires confirmation from well-stratified sites in the region. Nonetheless, it is on this particular evidence that the Wahgi wealth economy, of which the axe trade is a product, can be said to date back to the Phase 4 period, between 2000 and 1100 years ago (see Chapter 14).

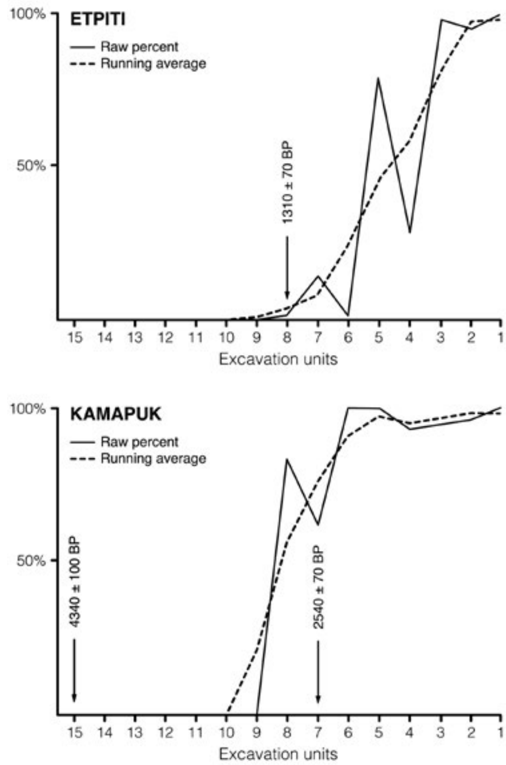


Figure 21.5 Manim Valley rockshelters: quarried stone as a percentage by weight of all axe stone.

Source: Drawing by Harrison Pitts after Burton (1984: Fig. 10.15), reproduced with permission.

1 Golson and Gardner (1990: 404) note that Burton originally said 'between about 2500 and 1500 years ago' (1984: 228). As the rise in quarried stone at Etpiti is steepest in Level 6, and whereas the 1310±70 (ANU-1324) radiocarbon date for this site is from Level 8, the broader range is preferred (cf. Burton 1989: 256).

Appendix 21.1: Petrography, Geochemistry and Chronology of Stone Artefact K/77/S34: A Probable Rim Fragment from a Stone Mortar

Noreen Evans and Brent McInnes

Petrographic description

On 1 November 1999, David Ellis gave Jack Golson a brief report on samples from four associated pieces of stone excavated at Kuk Swamp, one of them a proposed mortar rim. He described this as comprising a fine-grained equigranular volcanic rock of broadly intermediate composition. A most unusual feature is the abundance of weakly aligned apatite laths (phenocrysts; see Fig. A21.1). The dominant phenocryst phase is well-shaped plagioclase feldspar grains. Minor pyroxene and opaque oxide are also present. The finer-grained groundmass has been partly replaced by secondary (green) minerals, but unaltered groundmass is still preserved. Such distinctive grains of apatite, which crystallised early from the magma, are not typically associated with igneous rocks containing groundmass quartz.

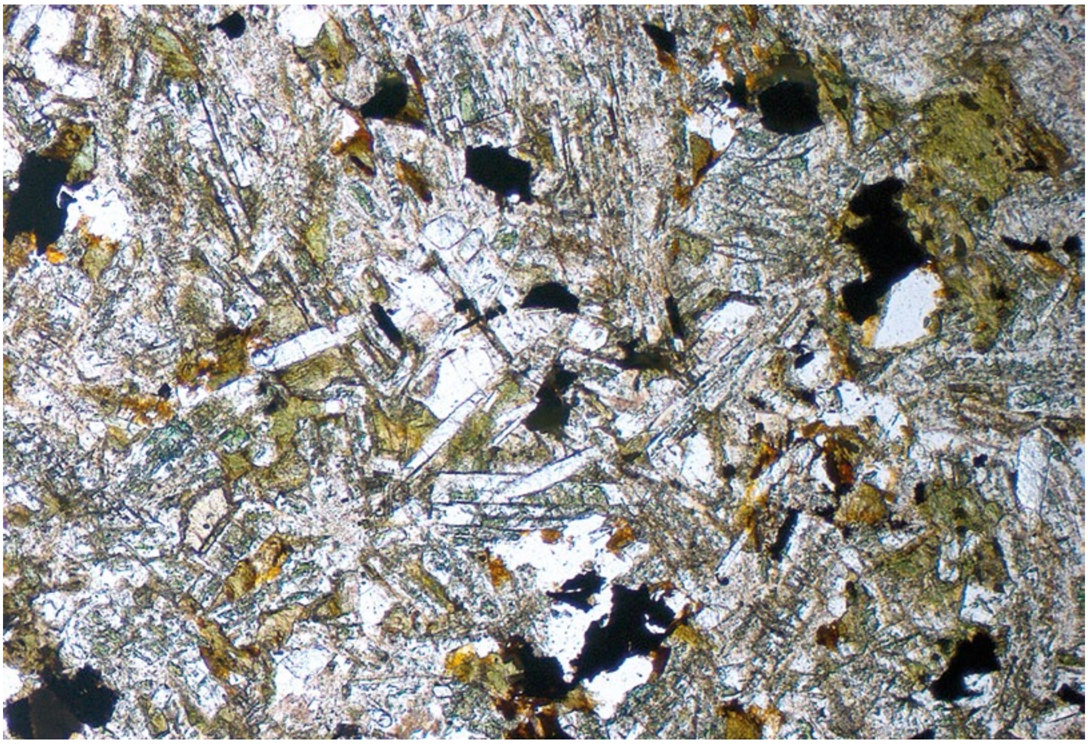


Figure A21.1 Photomicrograph of tholeiitic basalt viewed in plane polarised light.

The image shows aggregations of altered feldspar laths (cloudy) intergrown with mafic minerals (clinopyroxene altered to chlorite and amphibole), titanomagnetite (black) and acicular apatite crystals (clear). The field of view is 2.4 mm.

Source: Photograph by Brent McInnes.

Details of petrography

The following information comes from Doug Mackenzie, who submitted a final report to Golson on 2 February 2000 following his examination of a thin section from K/77/S34 by polarising petrographic microscope. He described the rock as being an andesite. However, as discussed below, Evans, McInnes and Ellis subsequently concluded that it was a basalt.

Observations

The rock is a metamorphosed and/or intensely altered, apatite-rich hornblende-2 pyroxene quartz tholeiite or tholeiitic andesite made up of a mixture of primary and secondary minerals.

The primary minerals (crystallised from magma) are:

- Plagioclase (60 per cent by volume), composition An_{30-47}, intensely altered to sericite/illite, chlorite and epidote
- Magnetite + ilmenite/Ti-rich magnetite (10 per cent by volume)
- Apatite (5 per cent by volume), long prisms
- Clinopyroxene (5 per cent by volume), very pale brown augite
- Quartz (3 per cent by volume)
- Hornblende (3 per cent by volume), medium pale green to greenish brown, largely altered to chlorite
- Orthopyroxene (<1 per cent by volume), very pale pink to faint green/colourless, partly altered to chlorite
- Biotite (<1 per cent by volume), deep yellowish brown to straw, partly altered to chlorite

The secondary minerals (crystallised in solid state) are:

- Chlorite (8 per cent by volume), bluish green to yellowish green
- Sericite/illite (2 per cent by volume), colourless
- Lawsonite (2 per cent by volume), pinkish brown to deep green or blue green
- Epidote (1–2 per cent by volume)
- Titanite (<1 per cent by volume), dark brown; associated with magnetite (ilmenite)

Interpretation

Mackenzie described this as a rock of unusual mineralogy. The abundance and coarse grain size of the apatite [$Ca_5(PO_4)_3(OH,F,Cl)$] and the presence of biotite are characteristics that he had not observed before, nor was aware of, in any rock from mainland New Guinea. He went on to comment on the results of the geochemical analysis, to which we now turn.

Geochemistry

David Ellis had emailed Golson on 7 December 1999 to say that the analysis of the geochemical composition of the rim sample had just been completed at The Australian National University (ANU). He headed his message 'Glum News'. This was because the sample had turned out to be an arc volcanic, a fractionated tholeiitic basalt, meaning that a specific source location could not be defined. He mentioned Doug Mackenzie saying to him with regard to the geochemical picture, that he had seen nothing like it from the Papua New Guinea (PNG) highlands.

On Christmas Eve, Ellis followed up with a second email giving major oxide and trace element geochemistry results (for the former see Table A21.1), and confirming their interpretation as characteristic of an evolved tholeiitic basalt that formed in an active plate margin where subduction occurs. In order to determine the likely source of such a rock, he said it would be necessary to do a literature survey of the distribution of tholeiitic series magmas within PNG, combined with isotopic dating to determine the age of crystallisation of the lava.

Table A21.1 Geochemical results for oxides from the mortar rim.

Oxide	SiO_2	TiO_2	Al_2O_3	Fe_2O_3 (tot)	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
Concentration (%)	50.38	3.17	14.11	12.96	0.247	3.48	6.72	3.98	0.815	1.51	97.6

Source: David Ellis 1999.

As things stood, we were left with Mackenzie's 2000 report conclusions, from the petrographic and geochemical data that we review here. Mackenzie offered three alternative explanations for the source of the stone of the Kuk mortar rim, which Golson (2000: 233–234) published in his paper on the subject:

1. that it is probably not of local (Mt Hagen) origin and unlikely to have come from elsewhere in mainland PNG, or from mainland Australia or the Torres Strait Islands, with the most likely source area in PNG itself being the islands running parallel to the east coast of New Ireland, or New Ireland itself, though admittedly the published geological information made this a remote possibility;
2. that the raw material is a 'foreign' rock (xenolith) that was enclosed in a very different rock type and 'freed' by subsequent weathering, given that the different rock type could exist in the crust beneath the PNG highlands region and have been caught up in the magma erupted from a volcano like Mt Hagen. However, the scenario seemed to Mackenzie unlikely given the calculated size and weight of the mortar from which the rim had come, and therefore of the parent rock; and
3. that the raw material belonged to the Indonesian region (other than West Papua), perhaps Sarawak or Kalimantan, this being Mackenzie's favoured option, though he admitted that he did not have relevant information to be more specific.

At the end of his report Mackenzie mentioned the possibility of dating the rock to help to resolve the question of origin. Ellis had also recommended this in his December 1999 email to Golson, when reporting on the results of the geochemical analysis of the rim fragment.

It is to this dating that we now turn.

Thermochronology

By this stage Golson was, through David Ellis, in touch with Brent McInnes and Noreen Evans at CSIRO Exploration and Mining, North Ryde, Sydney, currently of Curtin University, Perth. He was interested to learn about the new radiometric technique of (U-Th)/He thermochronometry, which was appropriate for dating the raw material of the Kuk mortar rim because it was rich in apatite. The aim of the dating was to narrow the search for the volcanic province where the parent rock originated. McInnes and Evans agreed to take on the task and by mid-2000 had produced results.

Methods

Apatite grains for (U-Th)/He thermochronology were selected under the microscope in order to avoid grains with cracks or U- and Th-rich mineral/fluid/gas inclusions that may contribute excess helium to the analysis. Grain measurements were taken for the calculation of an alpha correction factor (Ft; Farley, Wolf and Silver 1996), and every effort was made to select grains with a diameter larger than 70 microns in order to maximise helium gas values and minimise the Ft correction.

Helium was thermally extracted from a weighed aliquot of apatite, loaded into platinum micro-crucibles and heated using a 1064 nm Nd-YAG laser. ^{4}He abundances were determined by isotope dilution using a pure ^{3}He spike, calibrated daily against an independent ^{4}He standard tank. The uncertainty in the sample ^{4}He measurement is <1 per cent.

For degassed apatite, the U and Th contents were determined by isotope dilution using ^{235}U and ^{230}Th spikes. 25µl of a 50 per cent (by volume; approximately 7M) HNO_3 solution containing approximately 15 ppb ^{235}U and 5ppb ^{230}Th was added to each sample. The apatite was digested in the spiked acid for at least 12 hours to allow the spike and sample isotopes to equilibrate. Standard solutions containing the same spike amounts as the samples, in addition to 25µl of a standard solution containing 27.56 ppb U and 28.38 ppb Th, were treated identically, as was a series of unspiked reagent blanks (just 25µl of the 50 per cent HNO_3). Prior to analysis 250µl of MilliQ water was added on a Perkin Elmer 5000 mass spectrometer (at the University of Technology, Sydney). U and Th isotope ratios were measured to a precision of <2 per cent. Overall the (U-Th)/He thermochronology method utilised has a precision of 2.5 per cent for apatite, based on multiple age determinations (n=70) of Durango standard which produce an average age of 31.5±1.6 (2σ) million years (Ma). More detail can be found in Evans et al. 2005.

Results

(U-Th)/He thermochronology on the apatite from the mortar rim sample yielded reproducible ages of 2.72 ± 0.13 and 2.61 ± 0.38 Ma as shown in Table A21.2 below. This puts it in the Late Pliocene, older than the local Hagen Volcanics, which formed less than two million years ago in the Early Pleistocene.

Table A21.2 Apatite (U-Th)/He dating of the mortar rim fragment.

	He (ncc/g)	U (ppm)	Th (ppm)	Th/U	Ft	Corrected Age (Ma)	± 2σ
K/77/S34-1	483	1.14 ± 0.02	3.72 ± 0.07	3.37	0.73	2.72	0.13
K/77/S34-2	850	2.18 ± 0.03	7.60 ± 0.14	3.60	0.68	2.61	0.38

Source: GeoHistory Facility, John de Laeter Centre, Curtin University, Perth.

Note: Ft is the alpha correction applied to the helium content of the sample to account for daughter product lost from the crystals during radioactive decay (Farley et al. 1996).

Conclusions

On the basis of the petrographic and geochemical data discussed in the first part of this Appendix, Mackenzie ruled out mainland New Guinea as the source of the raw material of the Kuk mortar rim. He suggested New Ireland and the string of islands along its east coast as a remote possibility, but favoured Indonesian regions like Sarawak and Kalimantan (but not West Papua). The thermochronological data that we have reviewed by no means points categorically to a PNG origin, but the dating of the rim material to the Late Pliocene makes it a possibility. As Hugh Davies wrote in an email to Golson in mid-2001 (Kuk archive 2001), 'we simply don't know enough about the compositions of the Late Pliocene volcanics in PNG to confidently exclude a source from within PNG'.

There is other recent evidence that might indirectly support the Davies' conclusion. Fieldwork conducted by Brent McInnes in north Sumatra in 2001 uncovered andesitic dykes exposed in a riverbed. Basic petrography revealed acicular, elongated apatite crystals, similar to those observed in the mortar rim sample. The particular crystal habit exhibited by both samples is likely to originate when intermediate magma cools quickly, such as when magma is injected as a dyke into the crust. While such distinct rock material has not been reported in PNG, it may well have been overlooked by geologists not interested in quarry material. It is probable that this type of rock material was more resistant to erosion than surrounding country rock, and may have been exposed in a riverbed or valley slope. The relative hardiness of the material, coupled with its non-brittle alkaline-phosphatic nature would have meant that it was easier to work with than other rocks available in the local environment.

Part Five: The Traditional Owners

22

Hagen Settlement Histories: Dispersals and Consolidations

Andrew Strathern and Pamela J. Stewart

Introduction

In 1998, we coedited the volume *Kuk Heritage: Issues and debates in Papua New Guinea*, which brought together the writings of archaeologists and social scientists on the Kuk site project (Strathern and Stewart 1998a). The collection included a chapter by Andrew Moutu of the Papua New Guinea National Museum discussing the archaeological heritage at Kuk (Moutu 1998), reports by Herman Mandui and Nick Araho of the Papua New Guinea National Museum on the archaeological site itself (Araho 1998; Mandui 1998), contributions from Jack Golson and Pamela Swadling (Golson and Swadling 1998) and John Muke (Muke 1998). These contributors, as well as everyone working at Kuk, understand that although archaeology can reveal the deep history of the Kuk site, more recent stories about Kuk are also significant and are an important part of the heritage of Papua New Guinea (Strathern 1972: 37). In this chapter, we present a brief history of some settlement patterns of groups in the Kuk area during the 20th century (Fig. 22.1).[1]

Histories of movement and warfare

The long-term history of groups of people in the highlands of Papua New Guinea is a history of movements. Either in search of new areas to cultivate or as refugees from warfare, people have constantly been in quest of secure and fertile ecological niches for themselves. In Western Highlands Province, among the Hageners or Melpa speakers, we see another correlate of these patterns of movement: certain named groups became large and powerful, while others dwindled and were made peripheral. In between, there were many groups of medium size who maintained balanced relations of power among themselves. The Kawelka people, who currently inhabit the Kuk area, fall into this third category of medium-sized groups, and their history accordingly is one of making and remaking alliances, struggling for survival and expanding at times when they have been locally successful.

1 For the orthography of Melpa names and places used in this chapter, the spellings we use are consistent with those employed in the corpus of our work since 1965. Other writers follow the spellings used in administrative reports for placenames, such as Buk for our Mbkul, and tribal names, such as Jika for our Ndika. Ndika was the spelling used by the earliest ethnographer of the Central Hagen area, Georg Vicedom. Another spelling is Dika, which does not represent the pre-nasalised character of the initial consonant. As a guide to readers, we prefer to put in the N to indicate this standard linguistic feature. For extensive discussion of orthographic issues see Stewart, Strathern and Trantow (2011).

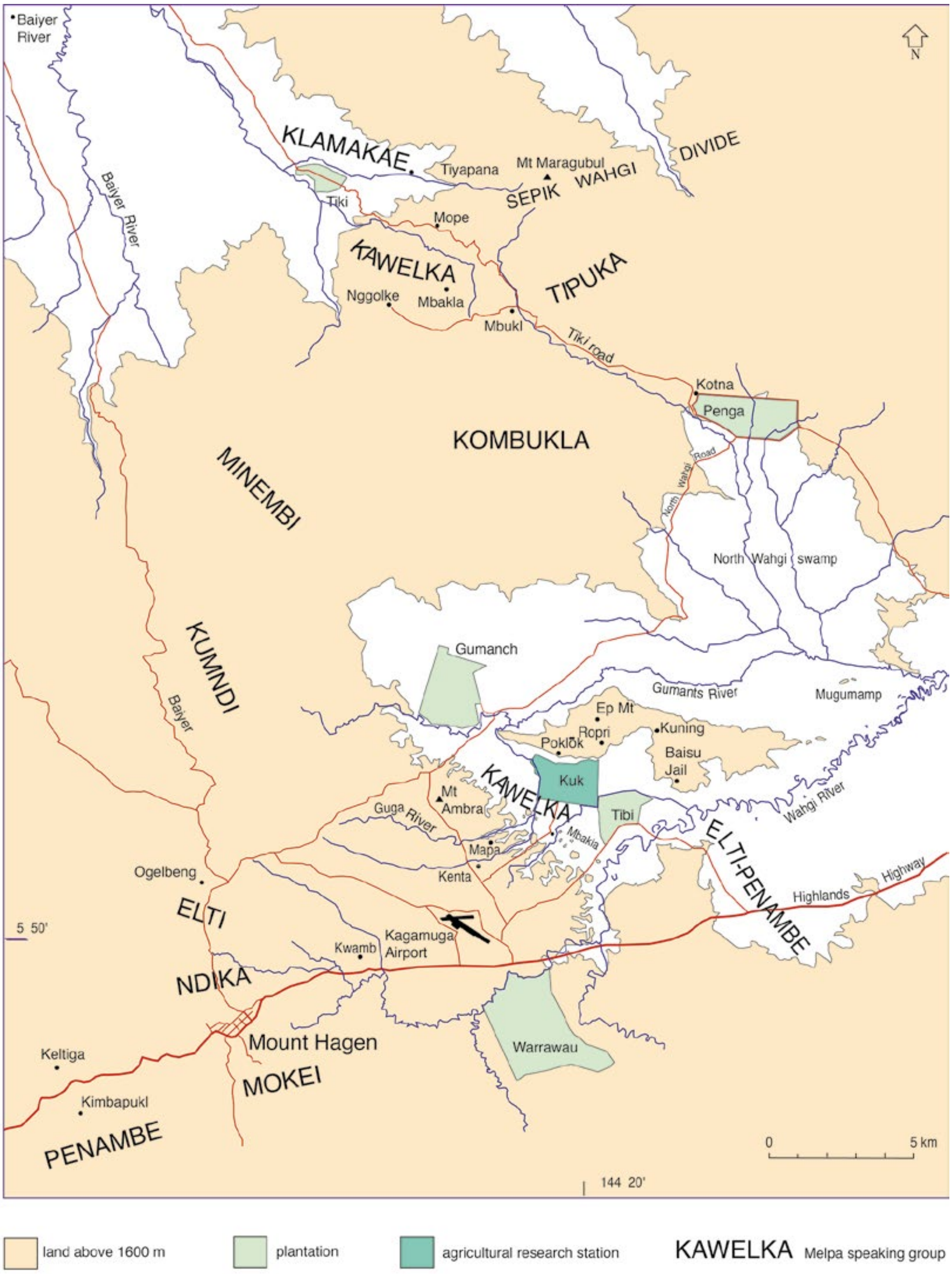


Figure 22.1 The location of Kuk Station, Melpa-speaking groups and places mentioned in the text (based on Hagen sheet PNG 1:100,000 topographical survey and sketch map by Andrew Strathern and Pamela J. Stewart).

Source: Drawing by Pamela Swadling.

Population figures gathered in the general Hagen area from the early 1960s give an idea of these differences in size between the named tribal groups at the time. This pattern is close to the pre-colonial situation at the beginning of the 1930s, when Australian explorers first entered into the highlands from the eastern part of the country. Of a total of 56 such groups in four local government council areas, the overall population according to census return calculations was 58,123 persons, giving an average tribe size of 1037. At that time the Kawelka, with a population of approximately 860 persons, were positioned slightly below the average size. A more detailed breakdown of the figures indicates that large disparities existed between the sizes of groups. Three very prominent groups—Ndika, Mokei and Kumndi—each had populations of between 5000 and 7000; five groups, including among others the Minembi, enemies of the Kawelka at that time, and the Tipuka, their allies, had populations between 2000 and 5000. A further seven groups, including the Kombukla, paired with the Minembi as their allies at the time, had between 1000 and 2000 persons. The total population for these 15 groups was 41,759, more than two thirds of the overall population total. Below this set of groups in size, a further 11 groups had populations between 500 and 1000, while 26 groups had less than 500. Together, these 37 groups totalled only 16,364, less than one-third of the overall total and fewer than the combined total of 18,362 for the three largest groups (Strathern 1971: 230–231; Strathern and Stewart 2000a).

These figures make it clear that we are not dealing with groups in demographic balance with one another, but rather with complex effects of warfare on groups, resulting in expansion, decline and migration of groups to peripheral territories over time in response to immediate or imminent pressures. The groups acted to some extent as political units, so it is meaningful to speak of them in these terms. Moreover, these census figures conceal a vital pattern. The largest groups tended to offer protection to smaller ones, while driving away others to different locales. Warfare between the dominant groups, as well as between them and weaker groups around them, contributed to a pattern of groups splitting up and migrating elsewhere as refugees, and this is precisely the pattern we find for the Kawelka. Further, the Kawelka were driven out of their territory at Kuk in the early 20th century by an alliance of groups centred on the Mokei, their former allies. Some sections of the Kawelka were reestablished back into the Kuk area from their northern territory around the place Mbukl with the help of a section of the Ndika people, political rivals of the Mokei at that time (Strathern and Stewart 1998b). Ndika and Mokei are two demographically dominant groups in the Central Hagen area. We can see how the historical position of the Kawelka has been set into the context of their being a small group, which originally migrated into Kuk from elsewhere, living in the interstices of two very powerful groups (namely, the Mokei and Ndika).

Kawelka settlement history

The Kawelka habitation of Kuk belongs, then, to this overall historical picture. The Kawelka people's own ethnohistory indicates a narrative of travel from Kimbapukl, a putative origin place to the southwest of Kuk, that is paralleled by stories of the northward spread of other neighbouring groups such as the Elti and the Penambe, with whom they were anciently aligned under the overarching name of Pal-Nur, a designation that also included the Mokei people. It also implicates a story of ritual sites where cults such as the Male Spirit cult (*Kor Wöp*), conducted at the place Kwamb, were held and then abandoned as people moved on (see Stewart and Strathern 2001a: 99–112 on the *Wöp*). Kawelka settlement at Kuk was accompanied by the naming of several main residence sites throughout the area, which are recorded in ethnohistorical accounts (Strathern, fieldnotes, 1964–65, 1969; Strathern 1972: 36–39). When they began to return to Kuk after colonial efforts at pacification, Kawelka leaders, along with their followers, reestablished settlements at these old remembered sites, for example Kenta, Mapa, Kuk, Kuning, Poklök and Ropri (Strathern 1972: 37). They held on to most of them, although conflicts with neighbouring Ndika groups caused them to withdraw from some areas. Such competition over land no doubt had to do with the perceived quality of the land itself and the fact that the members of large groups lived close by to those of smaller ones, setting the stage both for the making of alliances and for the possibility of disputes and power struggles.

During colonial times, before independence in 1975, Australian Government officers were often involved in setting boundary markers between groups, and it appears that at times they had cement posts physically installed between Kawelka lands and those of their neighbours. The placement of these posts was then appealed to by disputants as a permanent record of land rights, although this did not always hold subsequently. Sections of the Kawelka also paid compensation to some of the Ndika for their occupation of gardening ground, in recognition both of the need to settle disputes and to acknowledge the help given them by the Ndika to resettle in the vicinity. After an agricultural station was set up at Kuk in 1969, government officers attempted unsuccessfully to forbid further Kawelka from migrating back there from the Mbukl area.

Reasons for the return to Kuk

Gorecki (1979) has provided an admirably detailed discussion of Kawelka history and ethnohistory. He poses the question of why the Kawelka came back to Kuk in the 1950s, following 'pacification', noting the decision of Nggoimba, the leader of a section of the Membo clan (Köyambo Elpuklmbo), to leave the general 'Buk' (Mbukl) area and emigrate to a part of 'Kuk' (1979: 99). He goes on: 'Nggoimba's decision to emigrate must have been important and as suggested by Strathern (1972: 156–158, 247–248), was caused by some areas of Buk having nearly reached their maximum carrying capacity' (Gorecki 1979: 99). In Chapter 23, section 'The prelude', Gorecki refers briefly to this matter, which we examine more closely here.

One of the passages Gorecki quotes reads as follows (Strathern 1972: 156–157):

> One account which I have suggests that the moves made by Kawelka men back to the Wahgi were prompted initially by at least a feeling of land-shortage, as well as the aim of finding a better place for pig-keeping. The account was given in 1964 by a big-man Komiti of Membo clan, Kont, who was not one of those that took part in the migration.
>
> 'Councillor Nggoimba forbade anyone to plant on his ground at Tiyapana [a settlement area which is just outside the present accepted boundaries of Kawelka occupation]. The river Piling is a boundary between the Klamakae and the Kawelka, but Nggoimba tried to claim Tiyapana. The Klamakae won the court case, so Nggoimba next tried to live at Rokle, Pat, and then at Öm … but he felt the ground was not good enough. There were too many men and the ground was insufficient for them … so Nggoimba now decided to go back to his father's place.'

There are several things to notice here. First, the text reports the views of Kont, a Kawelka leader from a different and potentially competitive subclan of the Membo clan, the Oyambo subclan, and Kont dissociated himself from the migration. He and some of his friends hung onto the main Membo ceremonial ground in the heart of Membo land at the place Mope. Second, Kont's account makes it clear that Nggoimba's troubles stemmed from a boundary dispute that was settled in court against him. He and his followers were then forced to look elsewhere, intruding on established settlements. These processes are not the same as an overall objective situation of land shortage stemming from gross population densities of the kind that Gorecki computes. Rather, they are the result of intersubjective and competitive processes occurring in a context where outright fighting between groups was banned and courts now decided cases of conflict.

The other passage Gorecki refers to runs as follows (Strathern 1972: 247–248):

> An interesting part of the history of Kawelka re-colonisation in the Wahgi is Nggoimba's aim of establishing himself as a big-man with supporters in his own territory. It is interesting also, and possibly significant, that many of the men of Membo clan who joined him are non-agnates, either themselves incomers or the sons of incomers—men who may not have felt the same bonds with the Mbukl territory as other Kawelka men appear to feel. Perhaps, also, Membo clan took in too many incomers, thus taxing the capacity of its territory; but this I cannot demonstrate.

Gorecki's statements are cautious, hedged about with words like 'possibly' and 'perhaps'. Nggoimba, too, already had status as a leader in his subclan at Tiyapana. The suggestion is that he had greater freedom to expand his influence further in the new territory and that he gathered around him a set of supporters whose ties with the old territory were not very firm. Gorecki (1979: 99) attributes big-man status to Nggoimba, as well as to the well-known leader of Mandembo clan, Ongka, in 1946. So this would have been Nggoimba's basis for pioneering settlement back at Kuk. However, this does not negate the circumstances pointed out, or claimed, in Kont's narrative.

Gorecki goes on to discuss population densities in the two territories, Buk and Kuk, arguing that densities at Buk were much higher than figures given by Strathern. Again, the passage in question reads (Strathern 1972: 32, 34):

> Effective density in the territory of the Kawelka is probably between eighty and a hundred persons per square mile, not very different from the average density for the Central Melpa area (in the early 1960s) of 118.1 persons.

First, it is evident that the figures given for the Kawelka were avowedly approximations, not a definite computation. Second, the figures for the Central Melpa area (which included Kuk) were taken from a council survey/government report. Third, in the same passage it is noted that '[t]he Kawelka do not consider themselves to be *en bloc* short of land' (1972: 34). Fourth, the approximation for the Kawelka overall included Kuk and was not confined to Buk. Fifth and finally, 'Buk' is a simplification of a complex mosaic of situations in different places among different clans and subclans between Mbukl and Tiki.

It is clear from Gorecki's (1979) computations that in November 1958 the Kawelka population living in the Mbukl clan territories ('Buk') was considerably larger than in February 1965 (791 as against 695). This would certainly have meant an overall higher population density at the earlier date (1958), and this in turn supports the notion that land 'shortage' was possibly at work in motivating some of the Kawelka to move back to Kuk. Gorecki further cites a patrol report by Murdock from 1951 in which it was claimed (apparently without details) that the area between the two places Buk and Mala was one of the most heavily populated stretches observed on the patrol (details of the other areas were not given), with a shortage of food around Buk. We may comment here that the area between Buk and Mala includes the large and densely occupied lands of the Tipuka and Welyi tribes in the fertile Möka Valley and only a proportion of the Kawelka land (depending on what is meant by 'Buk', the actual patrol post location on the edges of Kawelka territories or all of the Kawelka locations). The overall point here is that data from Buk and Mala in 1951 do not tell us much about effective population density in a section of the Kawelka in 1960, around the time of the inception of Kawelka initiatives to go back to Kuk and recolonise it. Aims of reclaiming an old territory with fertile land near to the Mount Hagen government centre and with good potential for growing coffee, a new cash crop being gradually introduced by the colonial agricultural officers, were probably to the forefront, in addition to the leadership ambitions of Nggoimba.

We offer these remarks as a set of notes to Gorecki's exposition, in order to make it clear that overall gross population densities need to be recast in more local, experiential and politically motivated terms in accounting for patterns of mobility.

Settlement places and the land

One factor that must be remembered is that immediately before the creation of Kuk Tea (later Agricultural) Research Station in 1969, large sections of land in the area near to where the Kawelka and others lived were uninhabited swampy zones. It is precisely in these, of course, that evidence of earlier prehistoric agriculture has been preserved and discovered. The Kawelka themselves knew the extent to which they could or could not profitably venture into the swamps for productive gardening purposes. During the 1970s, older informants were quite clear that the swamp areas were recognised as intractable and unusable and that they could dig their garden ditches (*pana ru*) only up to the edges of these areas without being able over time to extend their usage or to progressively reclaim land from swamp zones (Strathern, fieldnotes, 1972–78). This evidence indicates that although the Kawelka and others had access to prime land they were also hemmed in, on some sides by hostile neighbours, on others by flooded swamp and in other locales by wooded hillsides. They were able to cultivate the hillsides to some extent—the two settlements Poklök and Ropri mentioned earlier in this chapter are located on the slopes of Ep Ridge at the northern edge of Kawelka territory and were the home settlement areas of Kaepa, the father of a well known Kawelka leader, Ongka-Kaepa (Strathern and Stewart 2000b, 2000c).

When the Kawelka fought with sections of the Mokei, according to Ongka's own 1969 narrative (Strathern 1972: 37):

> 'Kawelka men were chased into a swamp, where some drowned and others were cut with the axe as they waded in it. Some escaped to the top of Ep hill and others to Poklök [Kaepa's place]'

The Kawelka gathered on Ep hill and there Kaepa held a sacrifice of a large pig brought by the son of a woman of Oyambo clan in the Kawelka group (this clan is now a section of the Membo clan). Acting as a big-man and ritual leader, Kaepa held the tethering rope of the pig and spoke the names of all the settlements they would soon be leaving as refugees, saying (Strathern 1972: 38):

> 'Now they are driving us out and we must leave you, our places, only a few of us are left and we are going. I am sorry for you, my land, and I am killing this pig for you.'

The intense attachment of the people to their named settlement places and the fusion of personal and collective identity with the land is seen clearly in this narrative. The land as such included also the remains of Kawelka dead buried there and the spirits of these dead (*kor kui wamb*) might be thought to be attached to these settlements as well. Yet the Kawelka also thought of themselves, as did other Hagen groups, as mobile and migrating. 'Now we are going to Mbakla, our sisters' sons will show us the way', Kaepa said at the conclusion of his speech, referring to their destination near Mbukl at the place Mbakla (Strathern 1972: 38). By the 1960s, this figured as a sacred place of all the Kawelka, a site where the ancient *eimb* cult was practised for the fertility of the land (on this cult see Strauss and Tischner 1962; Strathern and Stewart 2000b: 40–71; Stewart and Strathern 2001b: 89–90). Mbakla is also the name of a Kawelka settlement place at Kuk.

Landscape, identity and history

The Kuk site is recognised by Hageners as one that was, and is, exceptionally fertile and therefore desirable. Groups that reside on the land or near it therefore have historically placed a high value on maintaining their claims. Subgroups within groups have also identified with certain areas and tracts of land, and settlement claims are signalled in knowledge of particular names of places. When the Kawelka were driven out from the Kuk territory, as noted above, and had to seek refuge to the north, they established placenames in their new territory. The knowledge of these is nowadays encapsulated in speeches that are made for public events. This knowledge of names and of the landscapes that go with the names is an important way of self-conceptualisation that Hageners in general practise. It enables the Kawelka to think of themselves as belonging both to Kuk and to the territories round Mbukl, Mope and Nggolke that they established as immigrants from Kuk. Landscape is thus closely tied to historical notions of identity (see Stewart and Strathern 2003). The placenames at Kuk were in general not transposed onto places in Mbukl, nor have the names at Mbukl been brought back to the Kuk area (an exception is Mbakla). Rather, knowledge of the names specific to each area acts as a focus around which memories and historical consciousness can crystallise. Older speechmakers from the Mbukl area who came in the 1990s to take part in public occasions at Kuk referred to the names of rivers and settlement places at Mbukl, evoking images of past residence, events and persons associated with these names. In January 2000, at the funeral of two men from the area, speeches were interlaced with this imagery of past locale and present locale mixed to form contemporary identity.

The Kawelka today are split between their northern areas around Mbukl and their main central location at Kuk. Warfare in the mid-1980s somewhat weakened the position of those still living near Mbukl, although the Kawelka remained undefeated and even increased parts of their territory in fertile low-lying coffee-growing places near to the Tiki plantation. The story of how they undertook their reverse migration and recolonisation of the Kuk area illustrates the 'patchy' processes whereby colonisation and migration take place generally in the highlands. It also illustrates the important roles of particular leaders who were conscious of their own traditions and eager to recapture the fertile resources they or their parents had left behind more than a generation earlier. The different subgroups, whose narratives cluster around the doings of leaders, tend to maintain distinctive overlapping versions of the history of resettlement, each claiming some precedence in relation to specific tracts of land around the old Kuk Agricultural Station.

Individual narratives: Ongka, Nggoimba, Kundi

Ongka's narrative from 1969 clearly relates the vital role of his father Kaepa in signalling the Kawelka's continuing historical claim on the land at Kuk, and especially at Ep and Poklök, through his sacrifice of a pig and his naming of settlement places. Kaepa's ritual act was not merely expressive. It declared an ongoing claim to the land at Kuk through the invocation of the names of places and spirits associated with them. Ongka himself, later in his life, returned to Poklök and made his own settlement there (Strathern and Stewart 2000c). Ongka's narrative highlights the significance of the wealthy major leader Koi, after whose death Kaepa decided to make his sacrifice. Another narrative cycle that is well known credits Koi with setting up a stone stele at Kuk (Fig. 22.2) that is now taken as a fiduciary marker of the Kawelka's real claims to the land there (Stewart and Strathern 1998; see also Chapter 23). The narrative records that Koi had this stone brought over to Kuk from Ropri, where it was discovered. In recent historical times, further stones of this kind were in fact found at Ropri and two were brought out and set up at one of the main settlement places of the Membo clan at Kuk, Mbakla. Thus, in two ways Ongka reinforced the point that he was himself tied in with traditions of leadership and political representation among the Kawelka.

Figure 22.2 The Kuk stone, slab, pillar, stele or obelisk as it has been variously called.

The place of the stone in the story of the Kawelka's departure from Kuk around 1920 and return there from about 1960 is told here, in Chapter 23 and in publications about it that are cited there.

Source: Photograph by Paul Gorecki.

Another set of narratives (see Ketan 1998: 12–16, published after Strathern and Stewart 1998a) focuses on the activities of leaders of the Membo clan, including Nggoimba, in pioneering the Kawelka return to Kuk. In 1964, as discussed earlier in this chapter, Kont, a Membo Oyambo subclan leader who stayed at Mope near Mbukl and did not go to Kuk until later, noted that Nggoimba (who was of Köyambo subclan and the grandfather of Ketan) had left his settlement at Tiyapana (north of Mope) and had gone to Kuk after losing a court dispute over land with Klamakae people, so he 'now decided to go back to his father's place. This was his own ground, and now he is firmly established there, and since then many other Membo men have joined him' (Strathern 1972: 157). Notable here is Kont's conviction that the Membo leader's claims were historically well established at Kuk and that he was returning to his own land, and so went on to draw many supporters around him. As Ketan (1998: 15) notes, Nggoimba was recognised as a leader well before he left for Kuk; but he clearly was able to extend his activities further in a new area along with his followers, including numbers of non-agnatic affiliates of his group (Strathern 1972: 247).

The Kundmbo clan, in turn, maintain a narrative that explains that the overall Kawelka claims on Kuk actually depended on the presence of an old Kundmbo clansman, Kundi, who stayed with some Ndika relatives of his (his mother's people) rather than going to Mbukl, and then opened the way for other Kundmbo men (e.g. Konga and Makla) as well as the Kawelka at large to reoccupy Kuk. According to the narrative, Kundi also played a part in authenticating the overall Kawelka claims to their land when the Australian administration purchased it for a tea research station.

These narrative versions thus make up a patchwork, validating for different parts of the territory the Kawelka's total historical claims to the land at Kuk. The narratives are complementary to one another in the broadest sense, while stressing the singularity of particular claims within the wider framework and emphasising the importance of the claims of particular subgroups. Such divergent narratives are relevant to the land claims of Kawelka groups today in relation to areas designated for World Heritage status.

Conclusion

Our concern here has been to trace the history of migrations among the Kawelka as illustrative of general patterns of group migrations in the Hagen area. These spatial movements combine ideological elements of fixity and fluidity together. The two elements correspond to historically realised patterns of dispersal and consolidation. We suggest further that these two elements inscribe major characteristic sequences of history in other highlands areas also (Merlan and Rumsey 1991; Stewart and

Strathern 2001b). A further mechanism whereby populations asserted their territorial claims and their consubstantiality with the ground was the performance of ritual, as Rappaport (1984) has discussed extensively. While periodic exchange festivals and pig kills among the Hageners also had this function, there is also a close parallel with fertility cults, such as the Female Spirit cult, that were performed at generational intervals. A performance of the Kawelka Kurupmbo clan section in 1983–84, sponsored by the family of Ru-Kundil and held near to Raiorong at Kuk, illustrates this point (Strathern, fieldnotes, 1983–84). Groups tend to move over time but also to fix their connections with the ground at a given time through the medium of ritual.

Nowadays, the Christian churches in the area serve this function and are significant loci for the political and spiritual condensation of group solidarity, while the advent of doctrinally different churches, e.g. Catholics and Assemblies of God, presents challenges and precipitates disjunctures among and between groups (for a set of references on these topics and related ones, see the publications listed at www.pitt.edu/~strather). The juxtaposition of cooperation and conflict appears also in the arena of the reoccupation of land in the old Kuk Agricultural Station, including the section designated for World Heritage status.

Appendix 22.1: A Note on Magic Crystals[2]

Andrew Strathern and Pamela J. Stewart

In the mid-1960s in Mount Hagen, men quite commonly owned small crystals, which they kept in pouches and could pull out for occasional use in the context of pig-rearing. The crystals were called *kng konga ku*, 'pig magic stone'. One story that was told was that they were used magically to make the highly valued layer of fat under the skin of a pig copious. The crystal itself was said to embody this property (Strathern, fieldnotes, 1964).

These crystals were quite small and generally corresponded to those that are illustrated in volume 1 of Vicedom and Tischner's three volume study, *Die Mbowamb* (Vicedom and Tischner 1943–48). This work was published with Herbert Tischner as coauthor, but all of the field materials were collected by Vicedom. On page 126 ff. of volume 1, Vicedom gives a discussion of *Zaubersteine*, magic stones, all of which he says the people find in the earth while digging gardens or nowadays building airstrips. Some of these stones, he notes, are prehistoric artefacts while others are simply natural, such as mountain crystals. These, because of their *gestalt* (their overall shape), are considered to be beyond the terms of everyday experience. Vicedom (page 126 ff.) describes the stones as '*glatte, kugelig, abgeschliffene Steine*' (smooth, rounded and worn-down stones).

Vicedom (1943–48, vol 1: 128) gives an example of such crystals and notes further that people connect them to the supernatural powers because of their unusual form (Fig. A22.1). In his Figure 35, he reproduces a drawing of one crystal at 80 per cent of its actual size. His drawing measures about 25 mm at the widest point and about 44 mm in length. Actual size would thus be about 20 mm wide and 36 mm long. Two similarly sized crystals, bound with plant fibre at their tops, appear in Figures 43 and 44. The crystal in Figure 35 was described to Vicedom as '*kung kopena*' (pig magic). The sizes of these crystals are similar to ones seen in 1964 by Andrew Strathern (fieldnotes, 1964) when they were still in common use (although there is no definitive evidence that they are abandoned nowadays).

2 The authors were asked to write this appendix because of the interest shown by the workmen at Kuk in the discovery of two quartz crystals during the excavation of a house site (see Chapter 20, section 'Phases 4–6, from 2000 years ago to AD 1900').

Vicedom (1943–48, vol 1: 128) goes on to give an interesting description of how the crystals were used, as *Orakelzauber* and perhaps *Fernzauber* (oracle magic and magic to work at a distance). With regard to their use as oracles (divinatory instruments), Vicedom writes that 'with their help a man can determine the number of piglets that can be expected to be born when a sow farrows. To this end the people lay the crystal in the steam coming up from an earth oven, or else they rub it with pork fat and then wipe off the fluid or fat and then enumerate the resulting iridescent lines that appear in the crystal' (Vicedom 1943–48, vol 1: 128, as translated by the authors). The number of striations, it seems, would be the number of the piglets to be born.

Figure A22.1 The quartz crystals shown here are similar in form to the individual crystals illustrated by Vicedom, as cited in the text.

Source: Photograph by Rob Lavinsky, iRocks.com, commons.wikimedia.org/wiki/File:Quartz-153455.jpg, CC-BY-SA-3.0.

As distance magic stones, '*kopena ketitloa*', Vicedom says, 'stones that are simply rounded or egg-shaped, smooth and black are in use' (1943–48, vol 1: 131). He goes on to explain that they were employed to harm an enemy at a distance, by pointing or throwing the stone in the direction of the enemy and speaking the magical spell along with the action. Since these distance magic stones are described as 'black', it is not clear whether they were a kind of crystal.

In volume 2 of *Die Mbowamb* (pp. 331; 368–371), Vicedom discusses magic in general, pointing out the connection of magic with higher powers in the world. Crystals do not appear to have been exclusively possessions of ritual experts, but these latter certainly did carry other magic stones around. Vicedom (1943–48, vol 2: 268) notes that such stones are clearly seen as property and are accordingly passed down from father to son and stay in the family. A ritual expert guards such stones jealously, because they help him to increase his practice. The expert (or medicine man) regards the stones as '*ungeheuer wertvoll'* (extraordinarily valuable) (cf. the general discussion of magic stones in highlands Papua New Guinea (PNG) cultures in Stewart and Strathern 1999).

A comparable use of crystals is found among the Duna people of Hela Province (previously part of Southern Highlands Province) in PNG. Ritual experts who presided over seclusion rituals for boys, intended to help them grow into attractive young men, performed magic for the boys' hair and also gave them small crystals, known as '*ipu rei*', to help make the condition of their skin smooth and healthy. Youths would carry these crystals with them on journeys to other settlements, wrapped inside netbags. On such journeys they might be seeking girls with whom they could establish a possibility of courting for marriage at special dance occasions. One senior informant told us that an *ipu rei* stone might be found inside the stomach of a particular kind of marsupial, and if so it was a gift from the female mountain spirit, the *Payame Ima*. Another narrative told how a man from Yeru, a locality near to the Strickland River, had seen crystal stones falling down to the earth in volcanic ash emerging from an earthquake and a volcanic eruption. The ash came from Oksapmin west of the Duna area, on the other side of the Strickland River. In general, these crystals were seen as possessions of the *Payame Ima*, gifted to youths to help them find wives (Stewart and Strathern 2002: 108).

In Duna folk traditions, then, magic crystals belonged to a specific female spirit, the *Payame Ima* (or her local instantiations, with specific names) and their use was to improve the skin of boys and make them attractive to girls. In Hagen traditions, the stones were carried around by men and were employed in pig magic, including the improvement of the skin quality of pigs. In both cases, the crystals were aids to excellence at different stages of the life cycle. See also Frankel (1986) on sacred underground caves where crystals of the kind discussed here were formed. Such caves were the object of ideas about their numinous power among the Huli. It would be interesting to find out more about the historical diffusion of these esoteric objects from their physical sources in the highlands of PNG.

23

Kuk Phase 7, 1969–1990, the Kuk Research Station: A Colonial Interlude[1]

Paul Gorecki

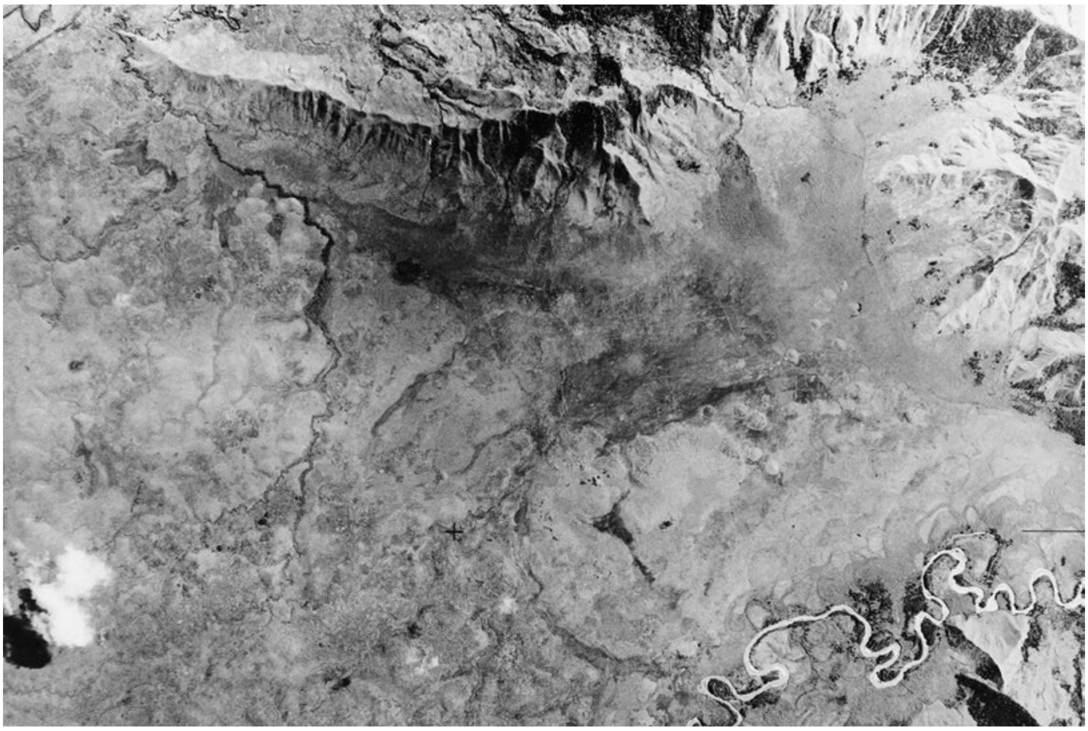


Figure 23.1 Kuk in 1955, a few years before the start of its recolonisation. The photograph essentially depicts the area in Fig. 23.2. The absence of habitation is paralleled by the absence of trees.

Source: Commonwealth of Australia aerial photograph, 25 August 1955, CAJ136, Run 2 5002, reproduced with permission.

Phase 6, the subject of Chapter 16, represents the last phase of agriculture at Kuk Swamp before the appearance of Europeans in the upper Wahgi Valley in 1933: two prospectors, Mick and Dan Leahy, and a government officer, Jim Taylor. Chapter 22 discusses narrative accounts of their own recent history by the Kawelka, the traditional owners of Kuk and those responsible for Kuk Phase 6: their abandonment of Kuk in the early 20th century after their defeat in war;

1 This chapter is substantially based on the first two chapters of my PhD thesis (Gorecki 1982). Where figures in the text for area and population differ from those in the thesis and in my publications of the time (especially Gorecki 1979b), they supersede the earlier ones.

their retreat for the most part to Buk[2] in the hills of the Sepik-Wahgi Divide to the north of the Wahgi Valley; and their recolonisation of Kuk more than a generation later, some years after the arrival of the first Europeans. The present chapter deals with the story of those Kawelka whose gradual move back to Kuk from Buk and elsewhere from about 1960 is part of the documented history of the upper Wahgi Valley under Australian administration, their return made possible by the suppression of tribal warfare and encouraged by developments in the region that followed.

The prelude

Mick Leahy told me (on 26 October 1977) that in 1933 he, his brother Dan and Jim Taylor crossed Kuk Swamp from Ep Ridge in the north and saw the stone pillar that stands on Kawelka land at the southern margin of the swamp (Gorecki 1979a; Stewart and Strathern 1998; see Fig. 22.2 here). But there were no people (Dan Leahy, pers. comm., 30 September 1978). Nobody, it seems, had moved to occupy the Kawelka territory at Kuk after it was abandoned (Fig. 23.1). Indeed, according to the stories recorded from Ru Kundil (Stewart and Strathern 1998: 96) and from Goimba (Ketan 1998: 15), the stone pillar seen by the Leahys and Taylor had been deliberately set up by the Kawelka before they left, as a sign of their ownership of the land, just like the concrete boundary markers later used by surveyors in the period of Australian administration.

The circumstances that led Kawelka back to this essentially vacant land were, as already mentioned, the result of Australian administrative activity following the end of World War II: the suppression of tribal warfare, which allowed for freer movement; and developments in the Wahgi Valley, for which the end of tribal warfare was a precondition. These consisted of the drainage of extensive tracts of unused swampland for coffee and tea plantations and for resettlement blocks to relieve population pressures in the other parts of the highlands; the growth of Mount Hagen township as an administrative and commercial centre; and the introduction of the local population to a market economy through wage labour and cash cropping, especially of coffee.

The traditional Kawelka lands at Kuk, on the valley floor just below 1600 m altitude and less than 20 km from Mount Hagen by road, were in every way better placed to participate in the new economy than the area at Buk at around 1800 m in the mountains north of the Wahgi Valley (see Fig. 22.1). Other factors in the move back may have been the perception of a developing land shortage at Buk, as suggested by Strathern (1972: 156–157; see Chapter 22, section 'Reasons for the return to Kuk'), and government interest in the purchase of swampland in the Wahgi Valley for drainage and development (Gorecki 1979b: 99).

The resettlement of Kuk

The evidence in reports and censuses by government patrol officers allows us to identify the beginning of the Kawelka return to Kuk (Gorecki 1979b: 97–98). A report of 1958 indicates that no movement had yet taken place, though there was a rumour that it would. A population decrease of 7.2 per cent between censuses of 1958 and 1962 at Buk, from 791 to 734, indicates that it had occurred. A census of 1965 by the anthropologist Andrew Strathern (1972: Table 1d) reports a Kawelka population of 161 in the Wahgi settlement area at Kuk (cf. Gorecki 1979b: Table 2).

2 On the spelling of placenames see footnote on Melpa orthography in Chapter 22.

The first Kawelka to return established themselves around the swamp at Kuk, except at its western boundary, where another tribal group, the Jika[3], had claim (Gorecki 1979b: 100 and 1982: Map 2, where the spelling used in both citations is Djiga). From 1964 to 1968, the administration undertook complex negotiations for the purchase of blocks of the larger swamp, of which Kuk was part, with the groups claiming title to them (Gorecki 1982: 3, 7; see Fig. 23.2 here) These began with the block that became Tibi Tea Plantation and ended, on 13 June 1968, with the block on which in 1969 the (then) Department of Agriculture, Stock and Fisheries set up the Kuk Tea Research Station. Although it was common knowledge among surrounding tribes that this block was theirs, the Kawelka did not receive major compensation for the Kuk purchase, since, according to an anonymous and undated patrol report, the sale involved no less than seven groups. Citing the original deed of sale, Andrew Moutu (1998: 20–21) reports the purchase as involving the payment of A$7771 to 63 persons, of whom 11 were chosen as agents. Moutu says that from the list of 63 it is impossible to tell clan or tribal affiliation. Ian Hughes, who saw the deed of sale in the early 1970s, told Golson (pers. comm., 1976) that the A$25 paid per hectare was a considerably higher rate than in other Wahgi Valley transactions with which he was familiar.

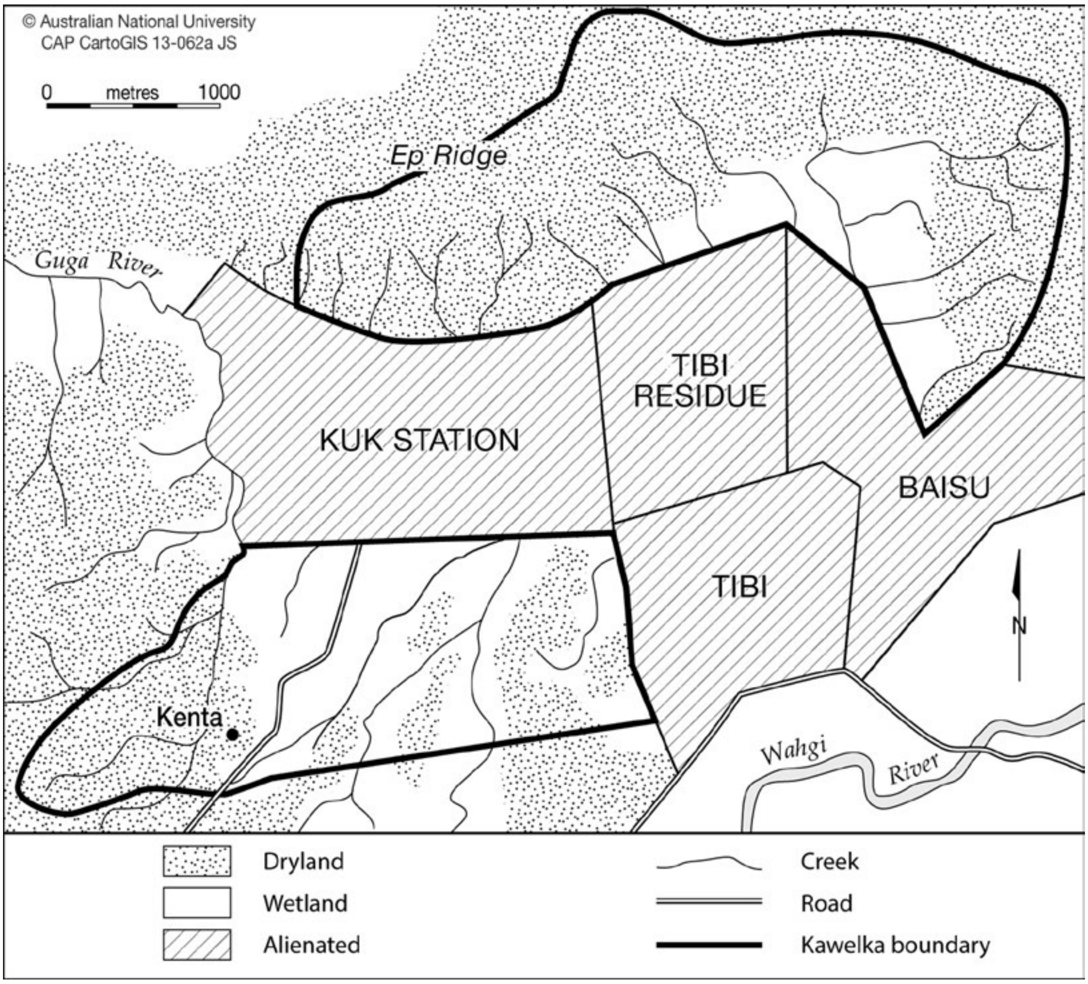


Figure 23.2 Kawelka territory at Kuk after the alienation of the swampland in 1969. Specific mention is made in the text of movement into the swampland west of the Station access road.

Source: Jennifer Sheehan, CartoGIS Services, College of Asia and the Pacific, ANU.

3 On the spelling of tribal names see 'Note on Melpa orthography' in Chapter 22.

From the ownership of a territory estimated at somewhat in excess of 12 km^2, the Kawelka were left with two blocks covering just over 9 km^2 after the sale (Fig. 23.2). These two blocks were separated by Station land, one of some 5.65 km^2 to its north on and below Ep Ridge and the other of some 3.4 km^2 to its south, which I shall call South Kuk. The northern block, dominated by the steep slopes of Ep Ridge rising above the swamp, had only one extensive flat area, a wet tract of land to the east. The southern block, with low hills in swampland and some of this swamp in small patches easy to drain, was the preferred area for Kawelka settlement even before the sale of the intervening swamp, and it became increasingly the focus of activity afterwards.

For the most part, the few available records treat the two blocks together, revealing a marked rise in population over the period following the sale of the swamp. Some of this resulted from continued Kawelka immigration from Buk. Between 1965, when Strathern's census (1972: Table 1d) recorded the presence of 161 Kawelka men and dependents in the Kuk settlements, and 1977/78, their numbers increased by 19.5 per cent, using the figure of 553 from my census (by household) of 1977, and 17.3 per cent, using the lower number of 535 counted in the government census (probably at assembly) of July 1978 (Gorecki 1979b: 99, Table 2). The July 1978 census at Buk (Gorecki 1979b: Table 1) reveals a drop there of 198 from the 698 counted by Strathern (1972: Table 1d) in February 1965, a decrease of 28.4 per cent, or just over 2 per cent annually. By this time, Kuk had overtaken Buk in tribal numbers, 535 to 500, using the figures of the 1978 census.

In addition, my 1977 census recorded 191 'foreigners' at Kuk, people from other tribes who seem to have settled down among the Kawelka, most of them permanently (Gorecki 1979b: 98; cf. Strathern 1979: 110, note 6, 111, note 7). This made a total population of 744. It is evident from Strathern (1972: 65, note to Table 1) that there were 'foreigners' living with the 161 Kawelka clansmen and their families at Kuk in 1965, but their number is unknown and they appear to have been few. Of the total population of 744 at Kuk in 1977, 571 lived at South Kuk (Gorecki 1982: Table 1), and 173 at Ep Ridge. The population density at South Kuk was 168 per km^2 compared to 30–31 at Ep Ridge.

Of the estimated 3.4 km^2, or 340 ha, at South Kuk, 109 ha (32 per cent) can be broadly categorised as dryland, the lower-lying parts of which might become a sort of wetland during long spells of rain, and 231 ha (68 per cent) as swampland that might become wetland during dry spells. The intensive use of South Kuk that supported its growing population was made possible by the drainage work associated with the Kuk Station and its access roads, which affected a large section of the South Kuk area and gave the Kawelka control over all the South Kuk swampland (Figs 6.6, 6.7; cf. Fig. 23.2). Of primary importance was the southern boundary drain of the Station, which diverted the incident water coming in from Kuk Swamp's southern catchment. Added to this were the major ditches along both sides of the two roads that provided access to the Station from the south. One in the east ran along the western boundary of Tibi Plantation, the other in the west ran largely through garden land. Like the southern boundary drain, these ditches not only drained extensive areas themselves, but also allowed Kawelka ditches to be connected with them. Thus, the processes seen at Kuk during Phase 7, the period of the Kuk Research Station, from 1969 to 1990, were substantially allowed or accelerated by infrastructure provided by government for the Station itself.

South Kuk

I did two spells of fieldwork at Kuk in 1977 and 1978 as a PhD student of the University of Sydney, observing the agricultural and domestic activities of the Kuk community. My fieldwork was designed to see what sort of archaeological evidence such activities might leave in the ground over time and how this might help in the interpretation of the archaeological evidence being uncovered in the excavations taking place just across the Station boundary. I concentrated on South Kuk because it was the area that had been most intensively occupied and modified over the previous 20 or so years of Kawelka reoccupation and also the one most relevant to the archaeological work being carried out on Station land. A series of photographs had been taken in connection with the establishment of the Research Station and other development projects in the locality. These proved invaluable for ground survey and mapping of present and past activities, as well as for cross-examining informants.

I was able to draw on aerial photographs of 1969, 1970 and 1973 for my fieldwork in 1977 and 1978. I used them, in association with census information from 1958, 1965, 1977 and 1978 and informant testimony, to estimate the course of population growth through associated change in settlement and landuse. There was an aerial photograph of January 1980, which I could not make use of in my dissertation, but which confirmed the general trends that I had noted for the period between 1960 and 1977/78. Below, I look at South Kuk in greater detail in terms of four periods of activity (cf. Gorecki 1985: 331–337).

Period 1: 1960–1969

Earlier in this chapter, I suggested that the recolonisation of Kuk began between a patrol report of 1958 and a census of 1962; consequently I take 1960 as my starting point. Strathern's census of 1965 (1972: Table 1d) recorded 161 Kawelka clansmen and their families at the Kuk settlements as a whole. If the distribution of the population then in relation to Kuk Swamp was what it was 12 years later when I did my census, that is, 3.3 persons south of the swamp for every one north of it, there would have been 124 people in South Kuk. By 1969, this number might have risen to 170, or 50 people per km^2, in the light of the scale of population growth that took place between Strathern's census of 1965 and mine of 1977, representing continuing recolonisation and the subsequent establishment of families, accompanied by house building, gardening and pig raising.

While the first cultivations were restricted to the drylands, it seems that within three years gardens were being made in swampland as well, indicating both an affirmation of Kawelka ownership and a recognition of this by surrounding tribes (Fig. 23.3). In the case of both drylands and wetlands, there were two kinds of ditching. Major ditches, wide and deep, formed an enclosure, with the spoil from their digging heaped on the inner side and a fence built on top. Within such enclosures was a grid of smaller ditches marking the gardens themselves, narrow and shallow and about 3 or 4 m apart, with the spoil from their digging thrown on to the plot surface to form a raised garden bed. Thus, one might say that for one hectare being opened for gardening, a minimum of 400 m of major ditching and 5000 m of plot ditching was required.

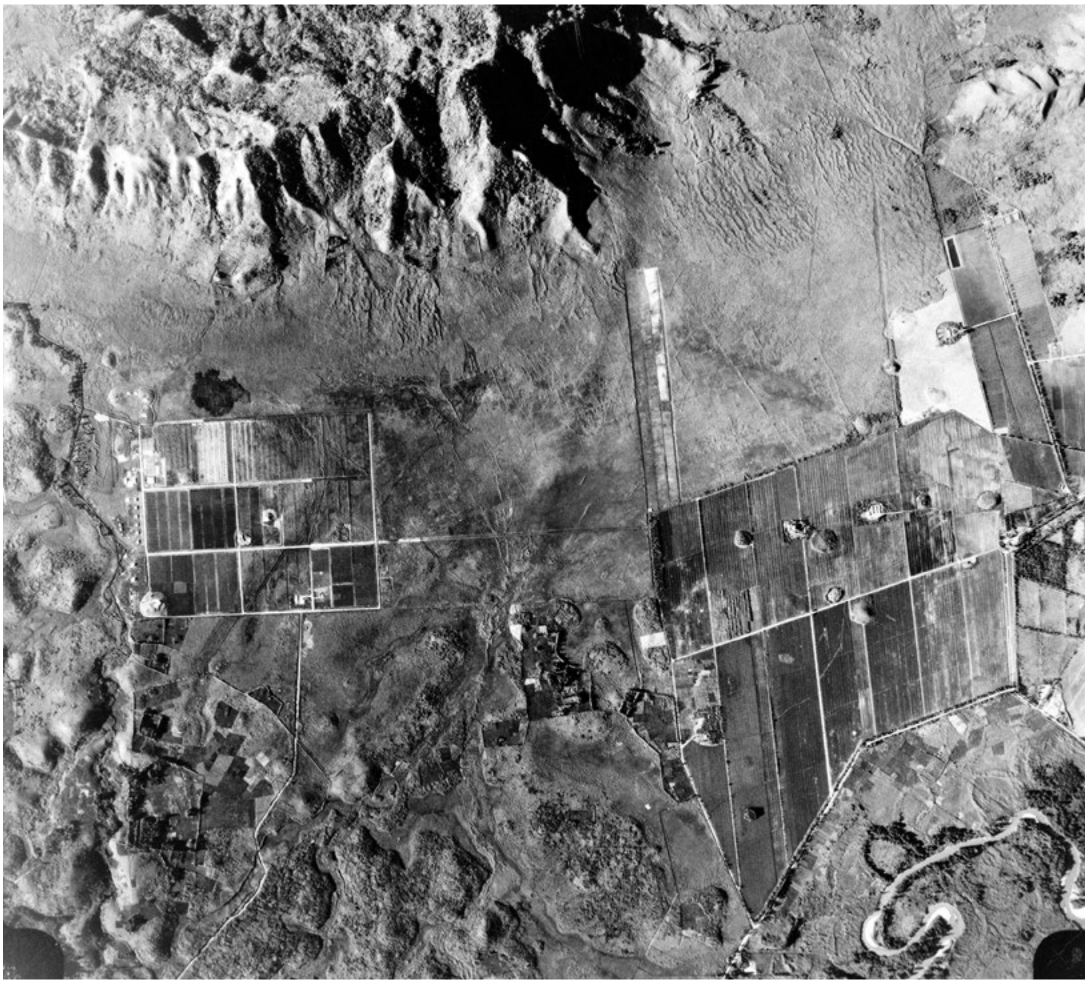


Figure 23.3 Kuk in 1970 after the establishment of the Tea Research Station. Settlement with gardening south of the Station boundary and west of Tibi plantation is obvious.

Source: Qasco aerial photograph, 5 October 1970, Film NG127, Run 4 8112-8125, reproduced with permission.

Overall, looking at the relationship between garden enclosures, represented by major ditching, and gardens, represented by plot ditching, larger areas were enclosed than necessary, while areas gardened were the minimum required to sustain the economy. This would be consistent with the point already made about the Kawelka aiming to put their mark of ownership on the land, especially if it was anticipated that immigration from Buk would continue. By July 1969, 17 km of major ditches had been dug at South Kuk, or about 100 m per head. In terms of gardened land, some 50 ha were under cultivation, about 0.29 ha per head, representing some 25 km of plot ditching or close on 150 m for every inhabitant. Of the 50 ha of gardened land, 40 ha (80 per cent) were located in dryland and only 10 ha (20 per cent) in wetland.

Period 2: 1969–1970

Within a period of only 15 months, the Kuk Tea Research Station was established, the basic drainage works completed and the first tea plantings done. In November 1969, Jim Allen, a lecturer in prehistory at the University of Papua New Guinea, was in Mount Hagen in the course of a familiarisation trip to the highlands. He heard about the discovery of stone and wooden artefacts during drain digging at the Station and paid a visit there. On the basis of what he saw, he made arrangements to return in December to undertake investigations.

Allen (1970: 177–178) reported that 25 miles (just over 40 km) of drains had been dug on the Station by late 1969 and that the profiles of prehistoric ditches could be seen in the walls of these drains across the whole of the drained area. Fifteen blocks had been drained, each 265 m north–south and 180 m east–west (A2–6, B2–6 and C2–6 in the Station code; see Figure 25.T2.1). Allen investigated in detail 17 drain walls within two blocks in the northwest, C2 and C3.

He also wrote to Jack Golson about his findings, because Golson had been a member of a small Australian National University team that had investigated a similar situation in the upper Wahgi swamplands, at Warrawau Tea Estate, in 1966. As a result, Golson and another member of the 1966 team, Ron Lampert, paid a visit to Kuk in mid-1970 (see Chapter 1). Station workmen were at this stage digging the drains along either side of the line of the future E–W Rd 1 in the stretch between N–S Rd 3 at the west and the eastern boundary of the Station at Tibi Tea Estate. Encouraged by their work on the old ditches visible in the walls of these newly dug drains, they sought the agreement of the Station management to begin planning for a longer-term project at Kuk.

Meanwhile in South Kuk, the Kawelka had dug more major ditches than were required for planting, just as in Period 1, but more areas were now gardened within the enclosures. There is evidence of a shift in emphasis from dryland to swampland, made possible by the drainage work undertaken by the Research Station. This was particularly the case for Kawelka Membo clan, which moved right into the swamplands bordering the Guga River to the west of the western access road to the Station (Gorecki 1985: Fig. 4; for location see Fig. 23.2 here).

I estimate the Kawelka population in the Kuk vicinity to have been around 190 persons by the end of the period, a density of 56 per km^2. Nine kilometres of major ditching were dug (450 m for every new arrival), making a total of 26 km. New gardens occupied 21 ha (1.05 ha for every new arrival), making a total of 71 ha (0.37 ha per head). Of the new 21 ha, 14 ha (66.7 per cent) were in wetland and 7 ha (33.3 per cent) in dryland, while of the total of 71 ha the respective areas were 24 ha (33.8 per cent) and 47 ha (66.2 per cent).

These figures, particularly the 450 m of major ditching for every new arrival, point to a planned extension of activities into the swamp, rather than a stabilised agricultural system. Two-thirds of the new land brought into cultivation was in wetland, so it would appear that most of the 9 km of new major ditching would have been for the drainage of swamp. This coincides with the establishment of the Research Station, whose own drainage, as we have seen, helped the drainage effort of the local population in South Kuk (see Fig. 6.6). In the light of this evidence, I suggest that the planned extension of activities into the swamp was because of an increasing demand for land to plant coffee, which was becoming an increasingly important cash crop. In these circumstances, new arrivals would have tended to be allocated the more difficult wetlands to drain and cultivate.

Period 3: 1970–1973

The archaeological project (the Project) discussed with the Station management in 1970 was authorised by the Department of Agriculture, Stock and Fisheries and began in July 1972. By agreement, work was to take place in the eastern half of the Station, which was unused and where there were no immediate plans for development. Management undertook to provide the major drainage lines to make this possible, and during the dry season of 1972 labour was hired. It involved digging a drain along the eastern boundary of the Station from its northern boundary to the drainage easement at the northwest corner of Tibi Tea Estate, as well as flanking ditches to articulate with this boundary drain along the line of E–W Rds 2–4 eastwards from N–S Rd 3. Project members took advantage of the lengthy exposures provided to record the swamp stratigraphy and the evidence of former ditches.

The Project itself undertook the digging of the N–S ditches that were necessary for the archaeological investigations. These were dug in conformity with the Station drainage plan. Initially the Project focused on block A9, where hired workmen, most of them initially not Kawelka, dug minor N–S drains that subdivided the block at 22.5 m intervals. In South Kuk, the trends noted in the previous two periods continued. There were decisive moves into swampland, but also substantial new activity on dryland.

The population had risen to an estimated 310 by the end of the period, representing a density of 91 per km^2. There was an increase of 16 km of major ditching (to a total of 42 km), or 133 m per new arrival, a marked decrease when compared with the previous period. This might indicate an increase in the relative importance of actual gardening as against the preparation of new garden areas by major ditching. Reasons for this may have been that new gardens could be established using existing major drains as a boundary or that population had caught up with the planning of the previous period, or a combination of the two.

Some 65 ha of new gardens were made, divided between 37 ha (57 per cent) in wetland and 28 ha (43 per cent) on dryland, bringing the total of gardened land to 136 ha, 61 ha (45 per cent) wetland and 75 ha (55 per cent) dryland. The areas of wetland and dryland cultivation per head of population for the total gardened land were 0.20 ha and 0.24 ha, respectively.

Period 4: 1973–1977/78

This period saw Papua New Guinea's transition to independence on 16 September 1975. Over the years 1973 to 1975, the Project extended its investigations on Station land northwards by the digging of selective drains, always according to the Station plan, in some B blocks and a few C, D and E blocks. These investigations provided archaeological and stratigraphic information on the deeper parts of the swamp and its northern margins. From 1975 to 1977, the focus was on the excavation of prehistoric agricultural systems in the southeast part of the Station, blocks A11 and A12. Over these years, the workforce was almost exclusively Kawelka. In 1977, due to the sheer accumulation of data, as well as other commitments of Project personnel, a halt, though not necessarily an end, was called to fieldwork at Kuk, which had gone on longer than originally anticipated. The first spell of my own fieldwork took place during the final season of the Project, my second spell followed in the course of 1978.

By this time, the Station's own agronomic research was no longer restricted to tea. The expanded range of its activities had been accompanied by a change of name to Kuk Agricultural Research Station and by the use of land in its hitherto barely exploited eastern half, where the Project had done all its work up to date and would focus in the future. In these circumstances Jack Golson, who visited me at Kuk late in my second season, had a discussion with Batley Rowson, then Officer-in-Charge of the Station, about future prospects for archaeological research there. Golson indicated 19 Station blocks as being of archaeological interest (see Fig. 25.T2.1), the seven most important of these being in the southeastern part of the property (A8–12, B11–12), three of lesser importance being on the margin of these (A7, B8, C9) and the remaining nine lying to the north (C, D and E10–12). These three categories were marked on a Station plan and the plan filed in the Station office (cf. Mandui 1998: Figs 1A and B). The understanding was that efforts would be made to safeguard the more important blocks and give notice if future developments at the Station were to affect any of the indicated areas. All 19 blocks were included among the 24 that constituted the core area of the site nominated to UNESCO for World Heritage status in early 2007 (see Fig. 25.T2.1).

In the meantime, at South Kuk the population increased to 571 by the end of Period 4, at a density of 168 per km^2. The indications are that local needs were now determining developments, not provision for further immigration. While only 13 km of new major ditching were added to the existing 42 km (or 50 m for each new arrival), an impressive 71 ha of new land was opened up to cultivation, divided between as much as 57 ha (80 per cent) in wetland and as little as 14 ha (20 per cent) on dryland. This brought the total area under garden to 207 ha, 118 ha (57 per cent) in wetland and 89 ha (43 per cent) in dryland (Fig. 23.4). The areas of wetland and dryland cultivation per head of population for the total gardened land were 0.21 ha and 0.16 ha, respectively. These figures reveal the dependence of the South Kuk community on wetland gardens.

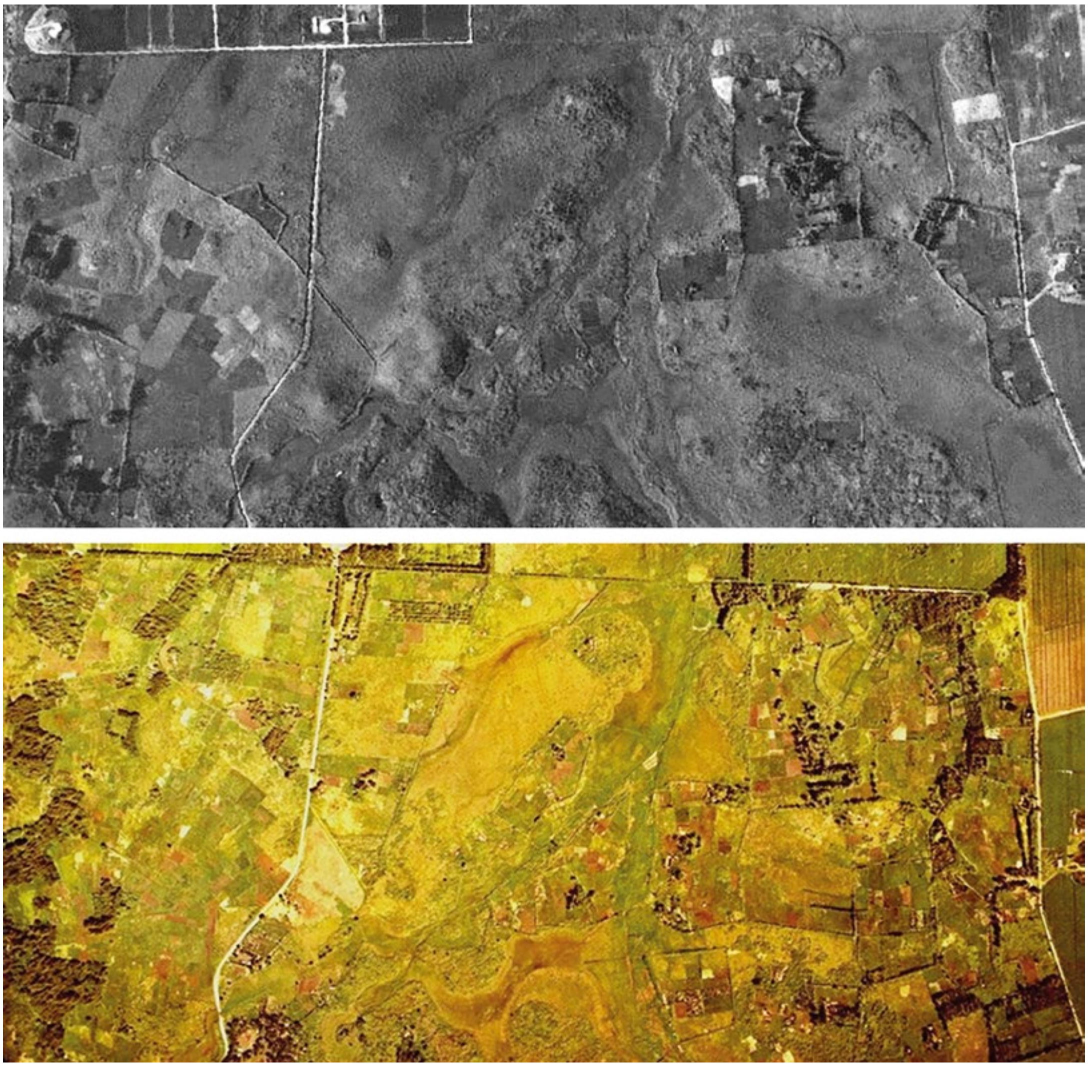


Figure 23.4 South Kuk in 1970 (top) and 1980 (bottom), showing the expansion in gardening and settlement that had occurred in the 10 years between the beginning of Period 3 and shortly after the end of Period 4.

Sources: Qasco aerial photograph, 5 October 1970, Film NG127, Run 4 8112-8125 (top image); and Qasco aerial photograph, 19 January 1980, Film Wahgi Valley AM 259, Run 5 (bottom image), both reproduced with permission.

Discussion

The recolonisation of Kuk from about 1960 represented the movement of Kawelka back to their traditional land in the Wahgi Valley from their settlements in the mountains north of the Wahgi, and in some cases from elsewhere, where they had retreated after their defeat in war a couple of generations before. It was made possible by the suppression of tribal warfare by the Australian administration and subsequently influenced by the proximity of Mount Hagen township and the ability to market cash crops there. I tried to quantify the extent of cash cropping at Kuk in terms of the area of arable land occupied by it, but reached only approximate figures because it promised to be a time-consuming investigation and one that fell outside my primary research project.

The data that I collected suggest that at the time of my work at South Kuk in 1977/78 there was a minimum of 40 ha and possibly up to 70 ha of cultivated land reserved for the market-oriented economy. This indicates that 20–34 per cent of cultivated land was being used for cash crops, primarily coffee. Other crops for market included sweet potatoes, corn, peanuts and beans. Cash cropping competed with subsistence plantings for fertile land. The money earned from cash cropping was not spent on food so much as on consumer goods like clothing, cooking pots, radios, tape recorders and especially beer. Under a more traditional economy, South Kuk could easily have sustained a more populous community than existed in the late 1970s and without the stresses apparent then, which arose directly from decisions about landuse. Two of the three Kawelka clans were running short of land, with little of it in fallow, while pigs were agisted where possible outside the territory.

Such stresses in South Kuk are likely to have continued and increased in the years following my work at Kuk. Stewart and Strathern (1998) point to the growing need for money, with a marked increase in the consumption of store-bought food since the 1970s and regular calls for contributions to ever larger compensation and bridewealth payments that strained individual means and fuelled tensions over inequalities, real or perceived, in land resources. Strathern and Stewart (1998: 95) observe that '[b]y 1994, the Tok Pisin term *jelas* ("jealous") had entered into local discourse as a way of describing the ordinary tenor of *intra-clan* as well as *inter-clan* relationships'.

The context for these developments was the growth of population beyond the rate of natural increase. This was now less the result of immigration from Buk, which is likely to have virtually ceased, than the sponsorship of incomers by big-men as a source of labour in production, support in ceremonial exchange and strength in fighting (Strathern 1979: 100; Ketan 1998: 20; 2004: 133–134, 164–165). Such recruitment continued despite the pressure it exerted on available land, leading to unsuccessful efforts to negotiate access to Station land for sharecropping in the largely undeveloped eastern half of the property (Strathern and Stewart 1998: 91) and equally unsuccessful applications to the Land Board for adjacent land for cash cropping and resettlement (Ketan 1998: 21–22).

For a number of reasons it is not possible to give population numbers to support these statements. Up to 1978 there are figures for the number of Kawelka living at Kuk and the number living at Buk, while after that date the figures tend to be for the Kawelka as a whole. In the census of 1979, they were numbered at 1631 (Ketan 2004: Table 3.3), 578 or 596 more than in 1977/78, depending on the slightly different counts in those years produced by myself and the local administration. However, I counted 191 'foreigners' at Kuk in 1977, bringing my population total for Kuk that year to 744. Ketan (2004: Appendix II, Table 2.2) reports that there were no returns from Kawelka census units at Kuk in the 1979 census. In the national census of 1990, the Kawelka are numbered at 4168, an apparent increase of 156 per cent in 11 years

(Ketan 2004: Table 3.3), leading Ketan (2004: 109) to comment that the tribe may have been enumerated twice, at both Kuk and Buk, in addition to the 500 or more migrants who were counted at the Kuk census point.

There are some relevant figures in the document produced for the nomination of Kuk for World Heritage listing (PNG Government 2007: 60; see Chapter 25 here). The document says that in 2000 an estimated 150 people were living in the core area of the nominated property, which consists of 116 ha in the southeastern part of the old Agricultural Research Station, with an estimated 350 people in the buffer zone, which consists of 195 ha to the north and west of the core area (Fig. 25.T2.1). The nomination document goes on to cite the national census of 2000 as recording 1928 Kawelka and 186 Jika Kilampi as living on or in the immediate vicinity of Kuk Swamp. National Statistical Office sources conceded prior to the 2000 census that the 1990 figures were unusable (John Burton, pers. comm., 2007).

The last paragraph has brought me well beyond the end of my brief. This was to tell the story of the Kawelka community and its relationship with the government Research Station set up on traditional Kawelka land at Kuk, in the course of which the Kuk archaeological project began and developed. At the beginning of the 1990s, as we shall see in the next chapter, Kuk Agricultural Research Station ceased to exist and the Kuk community, and especially its leaders, was faced with a new and uncertain situation. The same was true for the Project and its personnel, a few of whom had done limited investigations of short duration every year between the end of major fieldwork in 1978 and 1990.

Acknowledgements

The 1980 aerial photographs of Kuk, held in the Ken Logan collection (Accession 110822), Fryer Library, University of Queensland Library, were located by John Burton. Permission to use some of these by was kindly given by Lois Logan and Qasco. Laurie McNeice and Darren Williams of the Fryer Library made high-quality prints of them. I am grateful to these institutions and individuals for their assistance. I am indebted to Paul Brugman, then GIS manager, College of Asia and the Pacific, ANU, for checking the areas of the three blocks of Kawelka land that I am dealing with at Kuk—Ep Ridge, the former Research Station and what I have called South Kuk—and for the illustrations that he prepared in the process. I am also indebted to Martin Gunther, the last and longest-serving Officer-in-Charge of the Research Station at Kuk, for commenting on my text in the light of the knowledge and experience that he acquired there. It has been improved as a result.

24

Kuk 1991 to 1998, the Station Abandoned and the Land Resumed: Archaeological Implications

Jack Golson and John Muke

Introduction

Chapter 23 has told how major fieldwork at Kuk Station stopped in 1977 to give time for members of the Kuk Project to catch up with the data they had collected and see to other commitments. It was clear that the site had much more to give than it had already given. In these circumstances, Jack Golson, sometimes with others, paid short annual visits to Kuk to undertake specific pieces of work and keep in touch with Station developments and with the local community. No firm plans for renewing the Project had been made when the Agricultural Research Station was unexpectedly earmarked for closure at the end of 1990. This chapter discusses the uncertain situation that now followed for both the local community and the Project, given that the Papua New Guinea (PNG) Government still held legal possession of the land. In late 1995, however, its traditional owners began to move across the old Station boundaries, radically changing relationship between the Kuk community, the Kuk site and the archaeologists who wished to continue work there.

Prelude: 1991–1995

Jack Golson was at Kuk in August 1990 when Martin Gunther, the Officer-in-Charge over the previous 10 years, told him of the impending closure of some of the research stations of the Department of Agriculture and Livestock, as the Department of Primary Industry was now called. The reason for this was the suspension of operations the previous year at the Panguna mine on Bougainville, which had become a target of the secessionist Bougainville Revolutionary Army. By the time of its closure and after 15 years of operation, Bougainville Copper managing director reckoned that the mine had provided 40–50 per cent of PNG's foreign earnings and 15–20 per cent of revenue (cited by Denoon 2000: 192–193). Of the two highlands research stations, Aiyura, near Kainantu, and Kuk, it was anticipated that Kuk would continue because of recent investment in housing and facilities there.

In the event it was Aiyura that survived, on the grounds of perceived security problems for staff at Kuk. However, the Western Highlands Provincial Government was interested in the housing and the land. Consequently, before his departure, OIC Gunther (pers. comm., 2006) negotiated the transfer of the Station to the provincial administration for 'mothballing' for three years from

January 1991, after which the Department of Agriculture and Livestock would decide what to do with it. The mothballing consisted of renting Station houses to staff from a variety of government departments in Mount Hagen and district, with some of the money going to the local community (cf. Muke 1998: 73; 2000: 99). However, trouble resulted from this arrangement, so the public servants were withdrawn, with the result that locals moved illegally into the houses to replace them. There was no intervention by government authorities in Mount Hagen, so essentially the Kuk Research Station was abandoned. Continued official inaction led in time to the traditional owners challenging the State by taking back the land that had originally been purchased from them (Ketan 1998: 20–21; Muke 1998: 76–79; 2000: 111).

The events leading to the abandonment of the Station took place in 1991 and 1992, when John Muke was doing graduate studies in the United Kingdom. In both years Golson, passing through Mount Hagen on his way to Southern Highlands Province, was dissuaded from visiting Kuk on the grounds that safety could not be guaranteed. In 1993 Muke was back in PNG, planning work for November with students of the University of Papua New Guinea at archaeological sites in his home district of Minj in the middle Wahgi Valley, including the Kana site (Muke and Mandui 2003). He invited Golson to join him. The plan was to try to pay a visit to Kuk at the same time, to see what the situation was and assess the prospects for future scientific work there. In October 1993 Muke, with Nick Araho from the PNG National Museum, visited Kuk to prepare the way.

The first thing Golson needed to do on arriving at Kuk after an absence of three years was to make contact with the people with whom he had developed close relations during the work of the Kuk Project in the 1970s and 1980s. Because most of this work had taken place in the eastern part of the Station, his closest relations were with the Kawelka Mandembo clan, which had land north and south of the easternmost Station blocks. There were two men of the clan who had been particular friends of the Project, the established big-man Ongka and a younger man Ru, both of whom were long-time friends and informants of the anthropologist Andrew Strathern (Strathern and Stewart 2000a for Ongka and 2000b: Part III for Ru).

Walking through the old Station the first day of their visit, Muke and Golson found the Station houses in the southwestern part occupied by locals, as they had been told. But they were surprised to see Ongka's lineage working gardens in blocks E8 and E9 in the northeast part of the Station on the lower slopes of Ep Ridge. At this stage, these were the only people to have crossed the boundary to occupy Station land, as distinct from buildings. They had not built houses there, only a small bush-materials church, from memory some 20 m x 8 m, in block E9. Ongka offered this as a venue for the public meeting about the future of Project work at Kuk that they had come to discuss with him and others.

Having had a favourable reception at Kuk, they went on to Mount Hagen to tell relevant people in the Western Highlands provincial administration about the forthcoming meeting. There they were informed that the head office of the Department of Agriculture and Livestock in Port Moresby had decided to reopen the Kuk Station the following year. If this were indeed the case, it meant that their planned meeting with Kuk people would be taking place at just the right time. The provincial administration agreed that two of its agricultural officers would come with them to the meeting in Ongka's church, as well as one officer from Cultural Affairs and Tourism.

On the day of the meeting, the little building was full to overflowing, though things were so busy for us inside and outside it that neither of us made a count. Proceedings lasted several hours, with many expressions of anger against the government directed at the three local officials who were present. The Station land, people said, had been Kawelka land before it had been sold to the government, which had not only paid too little for it, but had now abandoned it. As a result, the community had to take on the responsibility of looking after it, because the government had failed in its duty to do so. When the agricultural officers announced to the meeting that it had been decided to reopen the Station the following year, people declared that this would only happen if the community were compensated for having looked after the land following the government's abandonment of it.

These were the matters of major concern to people at the meeting, but Golson and Muke were able to say something about the Kuk Project, the widespread interest that there was in it and their hope that the work could continue, with the possibility of benefits flowing to the local community from its continuation. People were curious about what these benefits might be and the tourism officer said that the provincial administration might be ready to help from the tourism point of view. In general, the meeting left them confident that there was community support for the Project and its continuation.

In June 1994, Golson was again in the highlands working with Muke near Minj and they paid another visit to Kuk. There was no sign of Kuk Agricultural Research Station being reestablished. A government plan to set up a police post at Kuk and hand over the Station land to the Department of Forestry had come and gone. By contrast, there was a lot of non-governmental activity. A Jika[1] big-man, who had taken over Martin Gunther's former house in the very southwest corner of the property, had set up a vehicle workshop there. The playing field near the old workmen's compound a few hundred metres to the north was totally covered with plastic sheeting on which coffee beans were ripening. Two young men were operating a portable sawmill on the eucalypts that the Station management had planted, along its grid of road drains, for their capacity to soak up water from the swamp (cf. Mandui 1998: 47). People were cutting the cane grass growing widely across the eastern blocks for building purposes. Ongka's gardens in blocks E8 and E9 were well advanced.

A year later, in June 1995, Andrew Strathern, who by this time had joined the University of Pittsburgh, was at Kuk with a BBC team led by Charlie Nairn making a film, *A Death to Pay For* (Nairn 1996), about a compensation case involving the Kawelka. He reported to Golson, when they met in Sydney three months later, that no government official ever visited the old Station. Pigs were regularly invading the property along the drains leading from the boundaries, breaking down drain walls and blocking drainage. The felling of trees along the Station roads was now a commercial operation, with trucks coming in to carry the timber away, damaging roads and bridges on the old Station and the access routes to it. Andrew Strathern and Pamela J. Stewart, also of the University of Pittsburgh, saw further stages in this process while on periodic anthropological fieldwork in the Kuk area from 1996 to 1999, based at Ru Kundil's settlement. They kept in touch with Golson and his PNG colleagues.

Though the locals still recognised the Station as government land, they now considered it truly abandoned and were considering their options. In preparation for staking future claims, Kawelka clans on the southern side, Gorecki's South Kuk (Chapter 23), had put up fences north into Station land from its southern boundary and some of them were talking about consolidating this by moving residences across the boundary. Strathern said that there was an air of urgency about this activity because of possible preemption by rival claimants. Thus, recently, the Kawelka had refused to meet compensation claims for the killing of a Mokei man by giving rights to land at Kuk, as the Mokei had requested, and insisted on paying in money and pigs instead (Strathern and Stewart 1998a: 91). In addition, there were increasing stresses in the Kuk community (Chapter 23, section 'Discussion'). Among these were the competing requirements of land for subsistence and cash cropping, which would make a move into vacant Station land an attractive proposition (cf. Moutu 1998: 32–34).

1 On the spelling of tribal names see 'Note on Melpa orthography' in Chapter 22.

The anthropologist Marilyn Strathern, who was on a visit to Kuk at the end of 1995, confirmed to Golson the information about the repossession of Station land beginning around that time, when they met at Cambridge University in mid-1996. When Muke was at Kuk with a Japanese film crew in November 1996, the repossession of the land was being consolidated through house building and gardening. This was a new phase in the Kuk story (Muke 1998: 81–82), which the authors call Phase 8.

Phase 8 at Kuk

In the light of these decisive developments, there was the need for another visit to Kuk to assess the prospects for renewed research in the newly changed conditions of landuse and landholding. Golson and Muke made that visit on 3–4 May 1997. Golson flew to Port Moresby on 2 May, staying overnight with Pamela Swadling, Chief Curator of Prehistory at the National Museum, to whom he promised to report on the Kuk visit. Muke and Golson flew to Mount Hagen the next morning, holding preliminary discussions at Kuk on the first day and making a site inspection on the second. This inspection took place on land allocated to Ru and his family and was carried out with Ru accompanied by two or three former Project workmen. Golson wrote a short report on the operation when he got back to Canberra, sending a copy to Swadling, as promised, and one to Muke (1998: 75).

The Golson report

Golson's report (Muke 1998) noted that the reoccupation of the old Station land had been most systematically carried out by its traditional owners, using the grid of Station roads and drains to arrange land allocation down to family level (cf. Moutu 1998: Fig. 1). A good proportion of the land resumed was under cultivation. In the time available, detailed inspection was limited to the southeastern blocks A8–12, where most of the archaeological work of the 1970s had been done and on which any future work was likely to concentrate. The food gardens in this area, as indeed elsewhere, could be expected to have destroyed the surface and near-surface evidence of houses and cultivations belonging to the two most recent agricultural phases at the site, Phases 5 and 6. As well as more deeply buried evidence from these two phases, that of the earlier Phases 1–4 should on the whole not have been disturbed, except by the roots of coffee and other planted woody species. Moreover, not all of the ground in the A8–12 blocks had been fully cleared of its swamp grass cover, and some of these uncleared areas were archaeologically important locations for future excavations, if they could remain uncleared or at least uncultivated for long enough. The document then went on to propose a plan for fieldwork in these circumstances, noting Ru's point that this would require the agreement of every individual to whom any ground requested for excavation had been allocated in the process of repossession. Muke (2000: 112) subsequently reckoned that there were more than 50 landholders on the blocks of particular interest to the archaeologists.

Golson's report arrived at the museum at a time when its director, Soroi Eoe, was preparing for a UNESCO meeting in July 1997 at the Fiji Museum in Suva, at which he was planning to make two nominations for World Heritage listing on behalf of PNG: the coral terraces of the Huon Peninsula at Bobongara (illustrated in Swadling 1981: 2–3), and the Kuk site. To be eligible to make the nominations, PNG registered its acceptance of the World Heritage Convention the same month. The context of these nominations is considered in Chapter 25. Here we are concerned with the implications of the new situation at Kuk, as described in Golson's report, for the Kuk nomination itself.

To investigate the new situation in detail, the museum sent a team to Kuk from 23–30 May 1997 to make an on-site assessment of the extent of the impact that repossession of the Kuk Station would have on the archaeological features of the site. This assessment was to take into account views about the heritage aspects of the site on the part of the Kawelka who had repossessed it.

The National Museum report

The PNG National Museum team consisted of Nick Araho and Herman Mandui of the Department of Prehistory at the museum and Andrew Moutu of the Department of Anthropology there, together with Muke from the university. Reports by Moutu (1988) on 'The Kuk archaeological heritage and the Kawelka landowners: An anthropological view of some pertinent issues' and by Mandui (1988) on 'Kuk Swamp at present – technical considerations' were submitted by Director Eoe at the Suva meeting, together with a nomination document drawn up by Golson and Pamela Swadling, Chief Curator of Prehistory at the museum. In Chapter 25, the section 'World Heritage listing' will show how all these documents came to be published in a volume headed by Andrew Strathern and Pamela J. Stewart (1998a), with additional chapters by Araho (1998), Muke (1998), Stewart and Strathern (1998) and Strathern and Stewart (1998b). The volume was intended to show 'some elements of the complexities that surround issues to do with cultural heritage generally, in cases where a delicate balance has to be sought between international, national, provincial, and local interests' (Strathern and Stewart 1998b: Preface and Acknowledgments).

The local context

At Kuk, the complexities referred to by Strathern and Stewart began with Kawelka repossession of the Station land. As Muke explains (1998: 71; cf. Moutu 1998: 22–23), the Kuk Project had started on government land in the colonial period in the early 1970s; even after PNG independence in 1975 the Station was run by expatriate Officers-in-Charge, under whom things continued as before. Over the years, the Project team won respect and friendship in the Kuk community and so proceeded without local hostility. At no time did Project members have to confront the original landowners over access because the State was owner of the land. This situation changed with its repossession. It was now the traditional owners who had the power to say yes or no.

Ru summarised the situation in a conversation with Muke, which Muke (1998: 83–84) translated from the original *tok pisin* as follows:

> You want us to look after these things of the ancestors, and this is an issue to discuss in future. Now the Kawelka are short of land and have divided the blocks among themselves. It is hard for me to try and stop them from destroying the prehistoric sites. You know when they have already made their gardens, they will ask you for money if you want to excavate on their land.

Moutu (1998: 34) has pointed to intergenerational conflict on the question of the use of land containing prehistoric remains, the younger generation being much less sympathetic to the preservation of such evidence. He saw two reasons for this: first, because the main research at Kuk had taken place when the present young people were children; and second, because they 'were not educated about the history of their own place and people'. This made him pessimistic about the prospects for 'a mutual compromise' (1998: 36) to save the archaeological heritage at Kuk without a concerted effort of dialogue and education in the local and wider context (1998: 36–38). Muke too (2000: 112) reported that 'only a significant effort at public education [would] change the attitude of the people' in a situation where the possession of the cultural resource was weighed against the economic value of the swamp by way of the cash crops that could be grown there.

There are many factors to take into account when considering these questions, some specific to Kuk, others general to highlands populations. Though the Kuk Research Station was established on Kawelka land in 1969, Kawelka men were not given preference in employment during the development phase of the next few years, when it was provided with its grid of drains and roads (as described in Textbox 6.1). The policy was that the labour force should not be dominated by any one group, though at least one early Officer-in-Charge saw advantages in hiring and housing men with no local ties and obligations that might interfere with their regular and full-time attendance at work.

Beginning in 1972, the Kuk Project overlapped this developmental stage and so initially required labour for removing swamp vegetation and digging drainage ditches in the eastern half of the Station where it was to operate. Golson's labour force for this work was haphazardly recruited. It began with three young Hageners, two of them English-speaking, who had worked with Australia-based academics in the recent past. They brought men from their own groups with them when taken on by Golson, while other men were attracted to the Station by the prospect of work and presented themselves for employment on the spot. Again, Kawelka were underrepresented in the Project as in the Station workforce, though for different reasons, and Golson was quickly made aware of this by the Kawelka whom he had hired. He moved to correct the situation when, after a few weeks during which the workforce spiralled to around 40, the preparatory work of grass cutting and drain digging was finished on block A9 and there was need for less labour. From this point on, Kawelka came more and more to provide labour, in the first season and in subsequent years.

In these circumstances, and with men who were increasingly likely to be working directly with archaeologists or other Project specialists, it was possible to sit down and talk about what the Kuk Project was all about. The men identified many of the archaeological features that were being exposed both in plan in excavation trenches and in profile in drain walls, because they were familiar with them in their everyday life: garden ditches, house floors and the stakeholes, postholes and cooking pits associated with the two areas of activity. Both drain diggers and excavators would from time to time encounter agricultural tools of wood preserved by the swamp waters, some of them of types no longer in use, as well as stone axe blades and fragments of them. Everyone recognised what such things were and the older men knew how to use them (cf. Steensberg 1980: Chapters 1 and 2; cf. Chapters 19–21 here).

The Project benefited greatly from conversations about these and other matters that came up in the course of investigations, but what team members were unable to convey was a sense of the chronology of the site and their interest in the relationship of gardening systems of different ages. This was in great contrast to their experience with the literate and numerate students who came to visit in groups from Mount Hagen High School and the Highlands Agricultural Training Institute at Korn Farm just out of town. Nevertheless, Project workmen and the Kuk community at large were in agreement that the Kuk Project had to do with the work of the ancestors, *samting bilong tumbuna*, and in that we had a common cause. There was quiet satisfaction locally that the name of Kuk was becoming widely known (*Kuk i gat bik nem*). As regards the workmen specifically, they said that they were also happy to work for the Project because they were not shouted at as they were on plantations. In November 1972, towards the end of the first season, on their own initiative, some of them gave a broadcast in Melpa on Radio Hagen about their work.

With this background, the various visits and discussions of the 1990s that have been described helped to 'open the road' for a new phase of archaeological research in 1998 and 1999 (cf. Strathern and Stewart 1998a: 93). The direction of this research was in the hands of ANU doctoral student Tim Denham, and it formed the basis of his dissertation (Denham 2003a).

Denham had no difficulty in recruiting labour for his excavations, mainly men who had worked for the Kuk Project in the past. Predictions in Golson's 1997 report that the earlier layers at the site would not be affected by the subsistence gardening of the new inhabitants of former Station land proved accurate. The location of excavations and compensation for such use of land were harmoniously negotiated by Denham with the new landholders. However, the PNG National Museum's 1997 decision to nominate Kuk for World Heritage listing had already put the matter in an arena where wider issues were at play. This had serious implications at the local level, as discussed in Chapter 25.

Acknowledgements

Thanks are due to Martin Gunther for information about the circumstances, general and local, in which the Kuk Agricultural Research Station, of which he was the last and longest-serving Office-in-Charge, came to an end.

25

Kuk Phase 8: Heritage Issues to 2008

John Muke and Tim Denham

Introduction

The subject of this chapter is the nomination of Kuk for World Heritage listing by UNESCO. It deals with the story up to the point of the site's acceptance in July 2008. The nomination was not the first time that consideration had been given to the question of long-term conservation at Kuk in the interests of cultural heritage, as distinct from short-term protection in the interests of archaeological research, as discussed in Chapter 24. Previous cases had relied on the possibility of proclaiming a reserve under existing legislation. There were two unsuccessful attempts in the middle of the 1970s, of which Muke (1998: 72) gives some details based on Golson's files. We discuss a third case of the early 1980s, which is notable because of the circumstances in which it arose and the ways in which it was taken up.

The catalyst for this third nomination seems to have been the 1981 publication by the Papua New Guinea (PNG) National Museum of Pamela Swadling's booklet, *Papua New Guinea's Prehistory*. This had on its front cover a dramatic colour picture of the cross-section of a large drainage channel of early Phase 2 at Kuk, with the figure of Korowa, the Kawelka workman who had helped to dig it out (see Fig. 12.6). In the chapter on the Kuk archaeological heritage and the Kawelka landowners that he wrote for the National Museum's report on Kuk discussed in Chapter 24, Andrew Moutu says (1998: 22) that the picture of Korowa and the huge channel behind him 'sparked a stunning sensation among the Kawelka'. The director of the museum, Geoffrey Mosuwadoga, wrote to Golson on 3 June 1982 to say that Andrew Strathern, at the time director of the Institute of Papua New Guinea Studies in Port Moresby, had sent copies of the booklet on behalf of the museum to the Premier and other members of the Western Highlands Provincial Government. Mosuwadoga reported that the 'information about Kuk generated considerable interest and as we hoped some desire to see these deposits preserved'. Golson received a copy of a letter of 26 May 1982 from the Provincial Secretary, John Pun Elipa, to the Secretary of the Department of Primary Industry to this effect. The department was asked to give its approval for the unused part of the site, namely the eastern half of the Station, to be declared a 'national cultural property' (in accordance with the *National Cultural Property (Preservation) Act 1965* and associated *Regulations*), so that the site could be properly conserved and worked on, including for tourism.

National Museum Director Mosuwadoga's letter of 3 June 1982 asked Golson about areas of Kuk that should be preserved, in order of priority, as well as about drainage restrictions that might have to be imposed to prevent the preserved area from deteriorating. In addition, Golson was invited to make suggestions about a visitors' centre that would give information about the site. In response, Golson over the next year developed a proposal to proclaim a historic site at

Kuk Agricultural Research Station. This involved discussion with the Station's management in the person of Martin Gunther, who, while as sympathetic and flexible as ever, had to bear in mind the long-term implications for the development of the Station within its current boundaries. As reported in Chapter 23, section 'Period 4: 1973–1977/78', only a few years previously, Kuk's agronomic research had ceased to be restricted to tea and its activities had ceased to be confined to the western half of the Station. As a result of this, Golson had talked with the then Officer-in-Charge, Batley Rowson, about mitigating the effects of the new policy on future archaeological work in the eastern half, where all such work had been done. With the new policy now well under way and a new Officer-in-Charge, Golson selected three blocks from the seven that had originally formed the most important category, specifically A8, B8 and a block including parts of A11 and A12 (see Fig. 25.T2.1 for location). In mid-1984, the proposal was sent to the Department of Primary Industry, the Western Highlands Provincial Government and the Officer-In-Charge at Kuk, as well as to the PNG National Museum and the Institute of Papua New Guinea Studies. There, for the time being, the matter ended.

National cultural property

Mark Busse, who spent several years in the 1990s as an anthropologist at the PNG National Museum, says that the concept of national cultural property had been introduced in an Ordinance passed by the House of Assembly of the Territory of Papua and New Guinea in 1965 to revise and update the *Antiquities Ordinances* of previous years. In his opinion (Busse 2000: 87–88), the *National Cultural Property (Preservation) Ordinance* marked 'an important turning point' in policy 'by defining national cultural property in terms of cultural heritage' and vesting administrative responsibility for it in the Trustees of the Papua and New Guinea Public Museum and Art Gallery, which had been established in 1954.

On PNG independence in 1975, the Ordinance of 1965 became an Act that defined national cultural property as 'any property, movable or immovable, of particular importance to the heritage of the country' (Busse 2000: 88) and gave wide powers to the Trustees of what was now the National Museum in the administration of the legislation (Busse 2000: 90). Ketan and Muke (2001: 93) believed that the Act dealt almost exclusively with cultural objects, and the description that Busse (2000: 91–92) gives of the implementation and enforcement of the legislation supports this view. Nevertheless, the Act was there to offer some protection to cultural heritage sites. The same was true of another piece of legislation, the *Conservation Areas Act 1978*. Provisions in this Act comprise 'the primary legislation that provides for the protection, preservation and management of sites and areas having particular biological, topographical, geological, historic, scientific or social importance' (cited by Ketan and Muke 2001: 93).

Despite these pieces of legislation, Ketan and Muke (2001: 92) were able to say that '[t]he legislative and administrative frameworks covering the cultural landscapes and heritage sites in PNG are deficient, ineffective, [and] lack administrative, financial and technical support'. Three years earlier, Muke (1998: 65–67) had discussed how rural development schemes in PNG had been financed by grants or loans with no provision for the archaeological impact studies that the good practice promoted by development agencies like the World Bank specifies. Under other circumstances, Kuk might have ended up the same way. As it was, however, the site became one of two PNG cases to be considered for protection under UNESCO auspices.

World Heritage listing

As mentioned in Chapter 24, section 'The Golson report', there was a UNESCO meeting planned for July 1997 at the Fiji Museum in Suva at which the Director of the PNG National Museum was to propose Kuk and the Bobongara coral terraces of the Huon Peninsula (the latter pictured in Swadling 1981: 2–3) for World Heritage listing. The occasion was a Global Strategy meeting organised by UNESCO's World Heritage Centre—the Secretariat of the World Heritage Convention—to identify World Heritage sites in the Pacific.

Such meetings address significant geographical and thematic gaps that exist in the World Heritage List. At the Suva meeting, there were representatives of key Pacific Islands states: Fiji, the Federated States of Micronesia, Palau, Papua New Guinea, the Solomon Islands, Tonga and Vanuatu, as well as of USA, Australia and New Zealand. They found that 'despite the Pacific's archaeological, architectural, technical and spiritual treasures, its remarkable modes of occupying and using land and space and its networks for trade and the exchange of ideas, it was significantly underrepresented on the World Heritage List' (as reported to us, pers. comm. 2006, by Elizabeth Williams, who was the Australian representative at the meeting as a member of the Commonwealth Government's World Heritage Unit).

At the time, there were only three Pacific islands sites on the World Heritage List, none of them in Pacific Islands states—Hawaii Volanoes National Park (USA), listed in 1987, Henderson Island (UK), listed in 1988, and Rapa Nui [Easter Island] (Chile), listed in 1995, all three of them for natural World Heritage values. The first listing from an independent Pacific Islands state was the East Rennell natural area, nominated by the Solomon Islands in 1997, the year of the Suva conference, and inscribed on the World Heritage List in 1998.

The underrepresentation of independent Pacific Islands states resulted in part from the requirement that to make a formal nomination for the World Heritage List a country must have signed the Convention concerning the Protection of the World Cultural and Natural Heritage (the World Heritage Convention). In July 1997, PNG was the 148th State Party to become a signatory, thus entitling it to nominate Kuk and the Huon terraces at the Suva meeting. As the *World Heritage Review* noted (1997: 79):

> Papua New Guinea is only the third Pacific island nation to join the World Heritage Convention, after Fiji, which became a State Party in 1990, and the Solomon Islands in 1992.
>
> Papua New Guinea is likely to offer challenging opportunities for the application of the concept of World Heritage cultural landscapes, linking nature and the centuries-old interactions of local people with the environment.

In preparation for the Suva meeting, the PNG National Museum sent a team of three, Nick Araho, Herman Mandui and Andrew Moutu, together with John Muke of the University of Papua New Guinea (UPNG), to report on the impact on the archaeological site of the repossession of the Kuk Station by its traditional owners (see Strathern and Stewart 1998b). The resulting reports by Moutu (1998) and Mandui (1998) were attached as supporting documents to a draft nomination of Kuk for inclusion in the World Heritage listing, which was drawn up by Jack Golson and Pamela Swadling (1998) and presented by the Director of the PNG National Museum, Soroi Eoe, at the Suva meeting. In addition, the National Museum produced a poster of each of the two nominated sites for the meeting.

After the meeting, these posters became a means of advertising the nominations that had been made, within PNG and elsewhere. At the same time, Pamela Swadling set to work on the organisation of a museum booklet to support the Kuk case for World Heritage listing and to help with the local negotiations that this would involve. The booklet was to follow the lines of her earlier one on PNG prehistory, which, as already noted, had made such an impression at Kuk some 15 years before (Swadling 1981: 32, 34, 36–39). The new proposal was important in the context of the Operational Guidelines for the Implementation of the World Heritage Convention, which emphasised that participation of the local community in the nomination process was essential, to make them feel a shared responsibility with the State Party in the protection and preservation of the nominated site (Ketan and Muke 2001: 51).

The nomination process: The first phase

Following PNG's accession to the World Heritage Convention, the National Commission for UNESCO in Port Moresby began to replace the PNG National Museum in the promotion of Kuk as a potential World Heritage site (Ketan and Muke 2001: 51). Activity at the national level encouraged the Western Highlands Provincial Government to take a proactive approach.

In early 1999, the Western Highlands Provincial Executive Council met with representatives from the PNG National Museum and UPNG in Port Moresby. This was followed by the establishment of a Kuk Heritage Management Committee at the provincial level under the chairmanship of the Provincial Secretary, Dr Thomas Webster, with a membership representative of local, provincial and national interests (Ketan and Muke 2001: Table 3). Tim Denham and Jack Golson, of the Kuk Archaeological Project of The Australian National University, were also appointed and able to attend the first meeting of the committee in Mount Hagen in July 1999, which coincided with the second season of Denham's fieldwork at Kuk (see the last three paragraphs above 'Acknowledgements' in Chapter 24). At this time, the Provincial Governor, Father Lak, visited the excavations and Dr Webster addressed a public meeting at the site, attended by several hundred Kawelka and others from neighbouring groups, when he endorsed the nomination of Kuk for World Heritage listing. At the community level, two local councillors appointed to the Provincial Heritage Management Committee set up a Local Management Committee (Ketan and Muke 2001: Table 4). The provincial government made material contributions to the nomination process (Ketan and Muke 2001: 52).

Responsibility for the nomination process was delegated to a study team (or 'technical team', Ketan and Muke 2001: 54–55, Table 5), set up by the Kuk Heritage Management Committee at a meeting in Port Moresby. The team leader was John Muke and the deputy Joseph Ketan, both from UPNG. There were two archaeologists from the PNG National Museum, Nick Araho and Herman Mandui, and three consultants from The Australian National University, Denham, Golson and Swadling, who had only recently left the National Museum.

In their interim report on the Kuk nomination project, Ketan and Muke (2001: 55) were critical of the narrow focus of expertise on the team and argued for its widening, as well as for a freer hand for the team leaders within more clearly defined terms of reference. They also complained of under resourcing and poor administration of the funding that was on offer (2001: 54, 97–99). Finally, and perhaps as a result of these problems, divergent and conflicting interests emerged among national institutions sharing responsibility for heritage matters as well as access to funds (cf. Ketan in Ketan and Muke 2001: 146–147). The Western Highlands Provincial Government discontinued its funding at the end of 2001 because of uncertainties over the completion of the nomination process. By mid-2004, despite the fact that a number of drafts of a nomination document had been completed, the National Commission for UNESCO was ready to close the project. However, salvation was at hand.

The nomination process: The second phase

Until 2003, many of the principal participants in the Kuk nomination process were unaware of the existence of a decision in 1994 (NG 45/94) by the National Executive Council, an advisory body to government, which identified the Department of Environment and Conservation (DEC) as the focal point for World Heritage matters in PNG, charged with responsibility for the implementation of the World Heritage Convention in PNG, its protocols, directives and guidelines. However, the 1994 decision did not come into effect until after PNG became a State Party to the World Heritage Convention in 1997—and by this time, matters were proceeding under different auspices. In 2003, the Secretary of DEC held a meeting with the main agencies involved in heritage matters to brief them that the 1994 decision was yet to be implemented.

In 2004, when it became known that the National Commission for UNESCO was seeking to abort the Kuk nomination process because of dissatisfaction with the performance of the study team, an informal working committee was set up on the initiative of Vagi Genorupa, Assistant Secretary of the Protected Areas Branch of DEC. Relying on a team of committed individuals, Genuropa prepared the way for the implementation of the 1994 decision. In 2005, all the key PNG institutions—the National Commission for UNESCO, the National Museum, the National Cultural Commission and the Tourist Promotion Authority—were in agreement and supported DEC as the agency to implement the necessary directives, including the establishment of a National Heritage Secretariat. The increasing national significance of Kuk was reflected in two exhibitions on Kuk at the J.K. McCarthy Museum in Goroka in 2004 and 2005 (see Textbox 25.1).

Textbox 25.1 The Kuk Exhibitions, 2004 and 2005, at the J.K. McCarthy Museum, Goroka

Martha Tokuyawa and Vincent Pou

The J.K. McCarthy Museum is an ethnographic museum based in Goroka, the capital of Eastern Highlands Province. It is named for John Keith McCarthy, a distinguished pioneer administrator in the Territories of Papua and New Guinea before independence, who began as a patrol officer in the late 1920s and became Director of District Administration and an official member of the first elected House of Assembly in the mid-1960s. The museum was established in 1964 through the initiative of the Goroka Rotary Club, with support from the Goroka Show Society, the Goroka Local Level Government and the National Museum authorities. Today, the J.K. McCarthy Museum is a department of the PNG National Museum and Art Gallery in Port Moresby.

In 2004 and 2005, exhibitions on Kuk were initiated and hosted at the J.K. McCarthy Museum in conjunction with the Cultural Studies program at the University of Goroka. Each exhibition ran from August to October. The objectives of these exhibitions were to encourage student teachers and equip them with information and materials for them to go out to their respective schools to teach children in PNG about the importance of Kuk and other archaeological, cultural and historical sites of significance.

The 2004 exhibition was based around the theme 'The illusion, the reality and the beauty of Kuk'. The theme arose from discussions among staff members at the museum during which the authors heard someone say 'Everybody hears and reads about Kuk and they are amazed by the scientific findings, but if you go up to the site and ask where exactly are the ancient drains, all you see are stretches of bush and the drains lie below murky mud'. The message of the exhibition was simple: Kuk is an important site for us all and here is the scientific evidence.

Visitors were asked to assess the importance of the Kuk site and to wonder at its age and at the things made by people using only simple tools. But there is also a sadness that comes with an awareness of Kuk, which is where teachers can make a difference. Teachers can educate people to learn about Kuk and to promote other sites of significance that could become equally as important for educational and heritage purposes.

The 2004 exhibition contained information compiled from the scientific evidence, which was based on the research at Kuk by Professor Golson and colleagues. Information about the site was supplemented by visual material, including maps and plans of the archaeological features, illustrations of the ditches, paintings, a clay model of the site and photographs. The exhibition included three paintings by Mr Taguba Gambu, a self-taught artist, comprising the stone pillar at Kuk, also known as the 'Kuk stone' (see Fig. 22.2), and two of researchers at work on the prehistoric ditches. The floor exhibit consisted of stone axes and wooden spades similar to those found at Kuk.

The late Regina Kati, former head of the UNESCO National Commission, opened the exhibition on 19 August 2004. During the launch, Ms Kati expressed her concerns about the future of the site and supported the proposed nomination of Kuk to the UNESCO World Heritage List because of its contribution to the story of humankind.

The 2005 exhibition was based around the theme 'Ten thousand years of gardening' and drew upon the renewed investigations at Kuk by Dr Tim Denham and colleagues in the late 1990s. The exhibition broadened its perspective to incorporate the story of the Kawelka, the traditional landowners of Kuk, as well as the impressions of the pioneer gold miners and missionaries who first entered the Mt Hagen area in the 1930s. These first European explorers noted how the intensive agricultural activities in the Kuk vicinity were different from other parts of the country.

The overall objective of the 2005 exhibition was the same as in the previous year. Most of the same materials as in the previous exhibition were used and supplemented by new paintings by Mr Taguba Gambu of early gardening activities and a Kawelka leader going to a *moka* festival. This time, more effort was put into getting schools to visit the exhibition, although there was no press release and no publicity, as had occurred in 2004. A lot of schoolteachers were invited and they were encouraged to bring their students.

The highlight of the exhibition was the arrival of Mr Ru Kundil (Fig. 25.T1.1), one of the principal Kawelka landowners at Kuk and a leading advocate for the preservation of the site. By chance, he visited the museum at the same time as three history classes and he had an audience with the students. He had come to see the Chief Curator of the museum, Mr Pou, in order to discuss with him the possibility of preserving his portion of the land at Kuk where significant archaeological remains were preserved.

One of the student teachers stated that Kuk was important for the development of the human resources of PNG through the training of teachers and eventually their students. The student teacher added that if the government was serious, it would make efforts to preserve such significant sites. The visitors thanked and encouraged Mr Ru for his initiative in attempting to preserve his portion of the land. As in previous years, teachers wanted more information to be available on Kuk.

In conclusion, the Kuk exhibitions were highly successful. In 2004, approximately 2400 people came to view the exhibition, including organised tours for students from Goroka Secondary School, Goroka International School and the University of Goroka. In 2005, despite the lack of publicity at its launch, students of a wide range of ages and abilities came in large numbers. They included three classes of grades six, seven and eight from Faniufa Primary School; three classes of grades 11 and 12 students from Goroka Secondary School; students from Sunrise Elementary School; history and social science students from the University of Goroka; and other classes of agriculture and geography students.

The exhibitions on Kuk at the J.K. McCarthy Museum fulfilled the original aims and objectives, namely to highlight the significance of the site, and cultural heritage management more generally, for student teachers in PNG. Furthermore, the exhibition attracted much interest from others across a wide age range, showing the innate interest of many Papua New Guineans in their history, including Kuk and other sites. Up until these exhibitions there had been limited material available for people to see and read about Kuk and its global significance.

Figure 25.T1.1 Ru Kundil, Kawelka Kurupmbo, is one of the 'fathers' (or champions) of the World Heritage nomination process at the community level.

Source: Photograph by Jo Mangi 2006 (Muke, Denham and Genorupa 2007: Plate 3), reproduced with permission.

From 20–23 March 2006, with UNESCO support, DEC conducted a successful National World Heritage Action Planning Workshop in Port Moresby. This developed a Tentative List of intended World Heritage sites for PNG and clarified institutional arrangements for the nomination and management of World Heritage sites in the country. Following the workshop, a National World Heritage Secretariat was established within the Protected Areas Branch of DEC. The secretary of the department chairs the National World Heritage Committee, an advisory body comprising representatives from various government agencies, non-government organisations, provinces and communities with nominated sites, together with other interested parties.

As regards Kuk itself, discussion of how best to complete the nomination process took place at the Planning Workshop in March 2006. At the workshop, Tim Denham and John Muke were asked by the department to coordinate the remaining tasks and submit a revised nomination document. Muke and Jo Mangi, both of the Social Research Institute, a Port Moresby consultancy, completed the field component, comprising community meetings and mapping of landuse on the nominated site, over a total period of about a month in mid-2006. Denham, then at Monash University, was largely responsible for coordination, designing, writing and production of the final nomination document.

The nomination was submitted at the end of January 2007 (PNG Government 2007). The Kuk Early Agricultural Site was formally accepted onto the World Heritage List at the 32nd Session of the World Heritage Committee in Quebec during early July 2008. Denham was present at the Quebec meeting and served as the PNG representative for Kuk Swamp. Regina Kati, the Secretary-General of the PNG National Commission for UNESCO over the years that the Kuk nomination was developed, died between the submission and its acceptance.

Proposed management at Kuk

The Kuk Early Agricultural Site was nominated to the World Heritage list as an organically evolved cultural landscape (Muke, Denham and Genorupa 2007; Denham 2012, 2013b; see Textbox 25.2 here). The organically evolved landscape at Kuk comprises two components: relict (i.e. associated with past activities) and continuing (i.e. past activities continuing into the present). The proposed management plan for Kuk as a World Heritage site is community-based and incorporates several elements of traditional land management practices, primarily to recognise the nature of community/land relations in PNG and to reduce the extent of external intervention and cost.

The foremost consideration has been the need to formalise existing landholding and landuse arrangements for the site (Muke and Mangi 2006). Kuk is currently alienated land, under a negotiated purchase by the Australian administration in 1968 for the establishment of a Tea Research Station (see Chapter 23, section 'The resettlement of Kuk'). However, since the abandonment of the Station by government agencies, the Kawelka and other groups have increasingly reoccupied the site, so that today the entire area has been allocated to individuals for their use. The bulk of the land is currently occupied and under cultivation, primarily subsistence agriculture with some cash-cropping of coffee and bananas.

The management plan formalises existing arrangements in that the Kawelka acknowledge the government's legal title over the land and, simultaneously, the government acknowledges the Kawelka as its traditional owners (see Textbox 25.3) and grants them usufruct rights over it. Kawelka use of the land constitutes site management under traditional, essentially continuing, land management practices. In terms of the relationship between the provincial administration and the Kawelka, the Western Highlands Provincial Government had indicated they would provide services, including road grading, piped water and an aid post, in return for the effective management of the site by the local community.

Textbox 25.2 The Kuk Early Agricultural Site: Nomination specifics

Tim Denham

Criteria for nomination

Kuk has been accepted for inclusion on the World Heritage List as a cultural landscape. The criteria for nomination are all cultural (UNESCO 2005: 52) and are indicated in italics below. A site must:

> (iii) bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared.
>
> The archaeology of Kuk bears an exceptional testimony to the origins and development of New Guinean and Pacific agriculture. The site preserves the remains of traditional New Guinean plant exploitation and cultivation, including the changing nature of practices and human-environment interactions through time. New Guinean agriculture, based on the vegetative propagation of plants—especially starch-rich staples, e.g. root crops and bananas—was fundamental to the development of Pacific agriculture as documented in the recent past and as it continues today.
>
> (iv) be an oustanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history.
>
> Kuk is an oustanding example of an ancient and continuing agricultural site and is representative of one of the most significant developments in the history of humanity, namely the development of agriculture. The site preserves:
>
> - the oldest remains of plant exploitation and agriculture in the Pacific region;
> - successive phases of drainage, manipulation and cultivation from 10,000 years ago to the present; and,
> - sequential technological developments and innovations, including mounding, ditched drainage and *Casuarina* tree-fallowing.

The organically evolved landscape at Kuk contains relict (i.e. archaeological remains of past plant exploitation and cultivation) and continuing (i.e. ongoing cultivation) components.

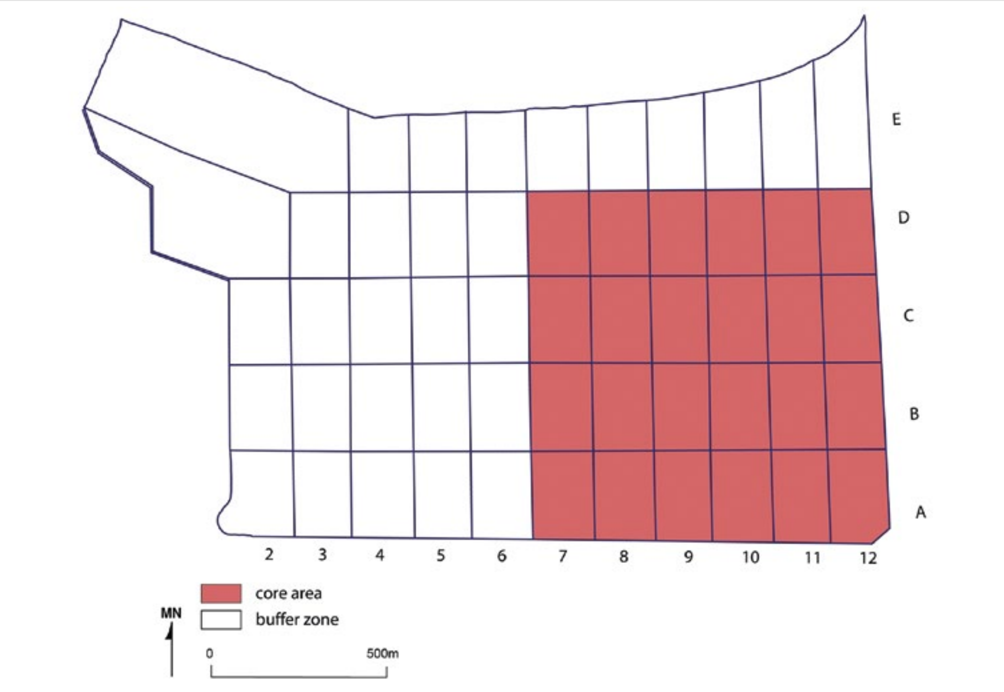


Figure 25.T2.1 Map showing the core area and buffer zone of the Kuk Early Agricultural Site.

Source: Drawing by Kara Rasmanis.

Core area and buffer zone

The site nominated for management includes a core area and a buffer zone, both of which have been defined based on the Station layout. The core area comprises 116 hectares in the eastern and southeastern portion of the Station. The core area includes the areas of greatest archaeological, geomorphological and palaeoenvironmental significance with respect to the evidence of early plant exploitation and agriculture at Kuk. The core area requires the most active management to ensure the preservation of buried archaeological materials, features and associated deposits.

The buffer zone comprises the remaining 195 hectares of the Station and includes areas of considerable heritage significance. Activities within the buffer zone have the potential to adversely affect the core area, principally in terms of drainage and hydrology. Consequently, the buffer zone requires active, albeit limited, management.

Textbox 25.3 *Mae Pukl Wua*: The Traditional Owners of Kuk

John Muke

The acknowledged traditional owners of Kuk are the Kawelka, a Melpa-speaking group. The Kawelka are recognised as the *mae pukl wua*, or 'ground root man', and the *mae ombil amborom*, or the one who 'holds onto the ground bone' (Strathern and Stewart 1998b: 87–88). In Melpa societies, *mae pukl wua* have overriding authority in 'matters to do with custodial rights over clan land, in granting gardening rights to group members, and in the protection of clan land' (Ketan and Muke 2001: 125). Although other groups reside at Kuk, they all recognise the Kawelka as the traditional owners.

The use of 'root' is a form of social evidence that demonstrates a direct link to land and corresponds to its botanical and, primarily, agricultural meaning (detailed in Muke and Mangi 2006: 42–62). Just as a physical root anchors a plant into the ground, so too the concept anchors people to their land. Further analogies with plants and vegetative propagation are used in Wahgi societies to refer to social reproduction. Terms such as 'shoot', 'stem', 'stock' and 'vine' refer to various levels of lineage-based social structure that effectively rise from the primary root and are fixed within corresponding territories. For instance, root may signify a clan or tribe; shoot, stem or stock represent clan sections within that clan or tribe; and vines indicate subclans. Terms such as 'cutting' and 'transplant' refer to social transplanting of people through marriage from one exogamous group to another; they effectively infer movement between territorial, putatively lineage-based groups. These social processes have a spatiality, in the ways that people are fixed in and distributed across space, and a temporality, in the ways that interactions are remembered and understood through time.

The social relationships embodied in the root ideology provide insights into the Kawelka's relation with the PNG Government. From a traditional standpoint, the Kawelka are the root people, namely, primary landholders with a deep and permanent association to the land, whereas the State is a transplant, namely, a secondary tenant with a shallow and transient association. From a traditional standpoint on all transplants, and despite a legally binding purchase agreement, the State is in perpetual debt to the ground root man for its use of Kuk while the Station was in operation.

The recognition of the Kawelka's deep and long association as *mae pukl wua* and the continuation of traditional landuse practices within the framework of a community-based management plan were essential to the successful nomination of Kuk as a World Heritage site and will be for its successful management. Without them, management would be perceived as something imposed from the outside; it would be unsustainable because of the constant burden of expectation placed upon a transplant.

Traditional land management as proposed in the nomination of Kuk incorporates ongoing settlement and cultivation practices. Prohibited activities are limited to deep drainage of the wetland, deep digging and the planting of deep-rooting trees. Ongoing practices are considered to contribute to, and augment, the cultural values of the site; they represent the latest phase, Phase 8, of drainage, manipulation and cultivation practices that have occurred intermittently for 10,000 years. In this light, current land usage at Kuk exhibits continuity with the past; modern cultivation techniques and crops are merely the latest innovations and introductions to be adopted by people living in this area.

The Kawelka have already signed a Consent Agreement that inscribes their voluntary acknowledgement of and adherence to the site management plan. The Consent Agreement and management plan are, further, to be incorporated in an Organic Law to be proposed by the Kawelka at Kuk. The *Organic Law on Provincial and Local Level Government (1995/1997)* enables local communities to generate laws regarding the management of their natural and cultural resources. Once generated and validated at the local, provincial and national levels, Organic Laws are legally binding and enforceable. Thus, not only is site management based on ongoing landuse practices but the management plan will be enshrined in legislation proposed by the local community at Kuk. These management initiatives are essential in a country where land is usually an inalienable right of every community and where provincial and national governments have only limited influence over local community affairs. These initiatives also ensure that site management does not require large inputs of time and resources.

The principal managers at Kuk should be three local heritage officers to be drawn from the three main Kawelka clans: Membo, Mandembo and Kundmbo (see Strathern 1972: 35, Fig. 2). They will ensure the daily monitoring of land usage and site preservation, most of which will be undertaken incidentally during their own daily activities at Kuk. Periodic and more systematic monitoring will also occur, either by the local heritage officers alone or in conjunction with visits by provincial and national representatives or contracted teams. Consequently, the management of Kuk will be community-based in terms of management practices founded on traditional landuses, an Organic Law proposed by the local community and monitoring conducted largely by local heritage officers drawn from the community. National and provincial agencies will oversee and regulate these local-level activities in accordance with their own requirements and responsibilities.

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