THE ANTHROPOLOGICAL PAPERS OF THE UNIVERSITY OF ARIZONA

THE GEOARCHAEOLOGY OF WHITEWATER DRAW, ARIZONA

Michael R. Waters

THE UNIVERSITY OF
ARIZONA PRESS
TUCSON
1986

Number 45

The Geoarchaeology of Whitewater Draw, Arizona

ANTHROPOLOGICAL PAPERS OF
THE UNIVERSITY OF ARIZONA
NUMBER 45

The Geoarchaeology of Whitewater Draw, Arizona

Michael R. Waters

THE UNIVERSITY OF ARIZONA PRESS
TUCSON, ARIZONA
1986

About the author

MICHAEL R. WATERS has conducted research on numerous geological and archaeological projects in the western United States and has published articles on the late Quaternary geology and archaeology of ancient Lake Cahuilla, California; the structural geology of the Sapphire Thrust Plate, Montana; and the Lowland Patayan ceramic tradition of southern California and southwestern Arizona. His research interests include the geological and archaeological problems involved with the peopling of the Americas, late Quaternary geology, paleopedology, geomorphology, and archaeological geology. Dr. Waters received his doctoral degree from the Department of Geosciences at the University of Arizona in 1983.

Cover: Excavation of site Arizona FF:6:8 by E. B. Sayles and E. Antevs in 1939. (Photograph courtesy of the Arizona State Museum, University of Arizona.)

THE UNIVERSITY OF ARIZONA PRESS

Copyright © 1986
The Arizona Board of Regents
All Rights Reserved

This book was set in V-I-P 10/12 Times Roman
Manufactured in the U.S.A.

Library of Congress Cataloging in Publication Data

Waters, Michael R.
The geoarchaeology of Whitewater Draw, Arizona.
(Anthropological papers of the University of Arizona; no. 45)
Bibliography: p.
Includes index.
1. Geology, Stratigraphic—Quaternary. 2. Geology—Arizona—Whitewater Draw. 3. Cochise culture. 4. Indians of North America—Arizona—Whitewater Draw—Antiquities. I. Title. II. Series.
QE696.W27 1986 551.7'9'0979153 85-24616

ISBN 0-8165-0955-7 (alk. paper)

For Susan

Contents

FIGURES

TABLES

Preface

A complex sequence of late Quaternary alluvial strata laid down over the last 15,000 years is exposed in the steep walls of Whitewater Draw in southeastern Arizona. Preserved in these deposits is an archaeological record extending back in excess of 10,000 years. This area has drawn the attention of archaeologists ever since 1926, when Byron Cummings discovered mammoth remains overlying and associated with ground stone artifacts. The arroyo was later examined in detail by archaeologist Edwin Sayles and geologist Ernst Antevs in the late 1930s, resulting in a 1941 monograph entitled "The Cochise Culture," published by Gila Pueblo, an archaeological research foundation in Globe, Arizona. In that book the late Quaternary geology of the area was outlined and the Cochise culture was defined. Sayles and Antevs started additional studies in the area in 1953, but unfortunately both died before finishing a final manuscript. The preliminary results of that research were posthumously published in 1983, representing the final thoughts we have of Sayles and Antevs concerning the geology and archaeology of Whitewater Draw ("The Cochise Cultural Sequence in Southeastern Arizona," *Anthropological Papers of the University of Arizona* 42). The research described herein was undertaken to clarify unresolved geological and archaeological questions in Whitewater Draw. These results serve to supplement and complement the pioneering work by Sayles and Antevs.

ACKNOWLEDGMENTS

Thanks are due to a number of people and institutions who contributed to this research in Whitewater Draw. Financial support was received from the Wenner-Gren Foundation for Anthropological Research (Grant-in-Aid No. 4335), from Sigma Xi, and from the Department of Geosciences, the Department of Anthropology Education Fund for Archaeology, and the Graduate College Program Development fund of the University of Arizona.

I thank V. R. Baker, T. L. Péwé, A. J. Jelinek, and D. M. Hendricks for their comments during the course of this project. I especially appreciate the aid of C.V. Haynes, who provided many helpful comments and suggestions, supplied chemicals and facilities for the pretreatment of radiocarbon samples, made his files and data freely available to me, assisted in obtaining funding from the Wenner-Gren Foundation, and secured funding for two radiocarbon dates. I have also benefited from discussions with E. W. Haury regarding many aspects of this project.

Scientists who visited Whitewater Draw and offered useful comments include: V. R. Baker, Bryant Bannister, O. K. Davis, G. C. Frison, E. W. Haury, J. D. Hayden, C. V. Haynes, B. B. Huckell, L. L. Huckell, A. J. Jelinek, Austin Long, P. S. Martin, and T. W. Stafford. A number of individuals kindly provided their expertise to this project. O. K. Davis collected pollen samples; W. H. Birkby is studying the human skeletal remains; and Everet Lindsay and Kevin Moody identified the vertebrate remains. Austin Long, of the Laboratory of Isotope Geochemistry, University of Arizona, dated my radiocarbon samples at reduced cost and gave them priority status. D. J. Donahue and Timothy Jull of the Arizona-NSF Regional Accelerator Dating Facility dated two samples on the tandem accelerator, one at no charge. Mike Jacobs, Ellen Horn, and Sharon Urban made the Arizona State Museum collections and files freely available to me, and Keith Anderson of the Western Archeological Center, National Park Service, provided space for analysis.

Several additional people were involved with the completion of this monograph. R. H. Thompson, Director of the Arizona State Museum, provided funds for the photographic illustrations in this report. R. G. Vivian, Assistant Director of the Arizona State Museum, authorized photography of figures 4.2–4.5 and Helga Teiwes is responsible for the actual photography. E. W. Haury and H. M. Wormington reviewed an earlier draft of this manuscript. Carol Gifford provided editorial and technical assistance. Finally, I express appreciation to the University of Arizona Press and its staff, directed by Stephen Cox, for the production of this volume.

The people in the Douglas basin were especially helpful, which made my field investigations very pleasant. I am grateful to the ranchers who allowed me to examine their property and excavate trenches. Special thanks go to Mr. and Mrs. M. A. Fairchild and Mr. Hugh Pendergrass, who made the stay in Double Adobe very enjoyable.

Michael R. Waters

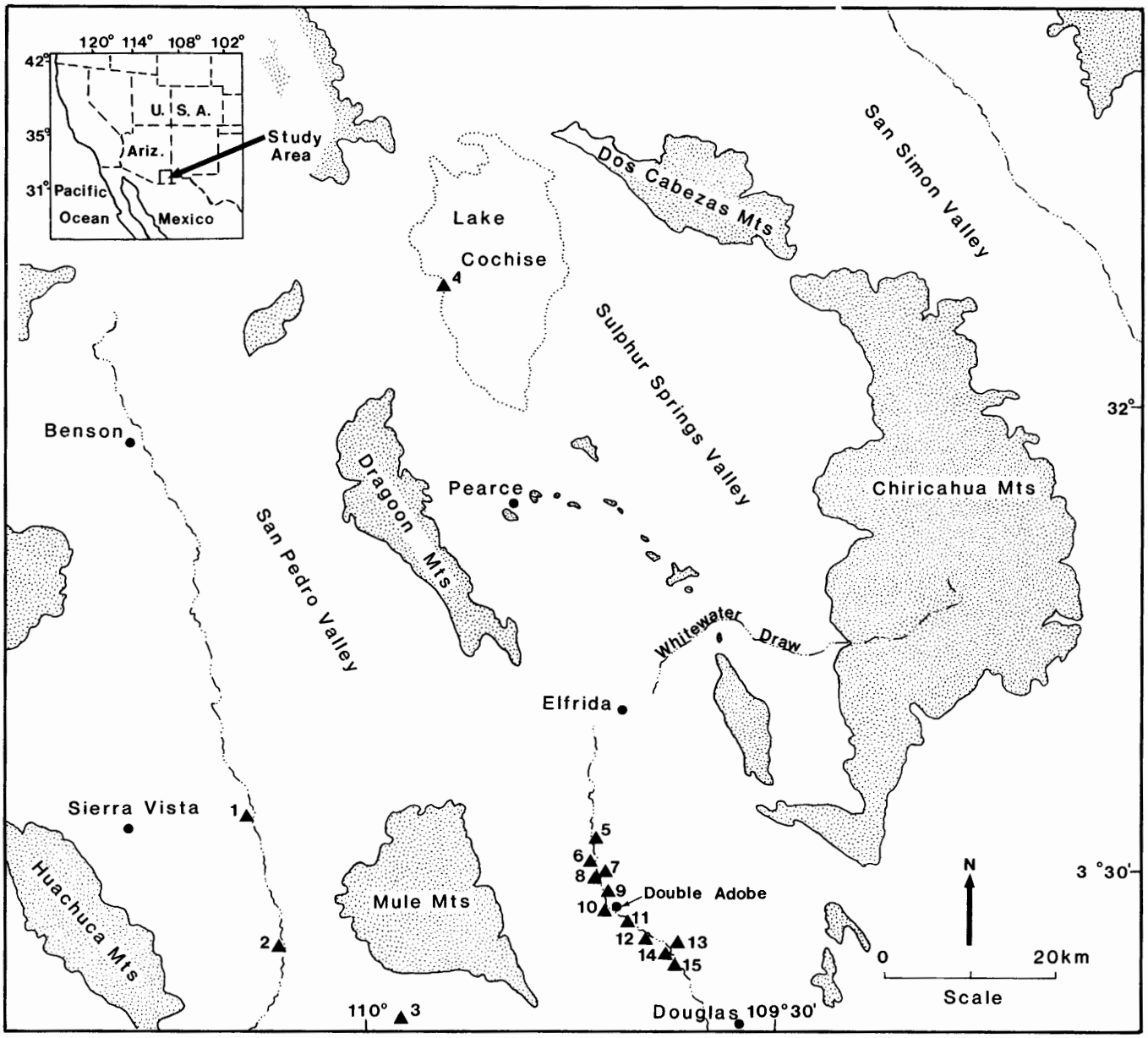


Figure 1.1. Location of towns, archaeological and geological sites, and physiographic features in southeastern Arizona that are mentioned in the text. The maximum extent of ancient Lake Cochise is shown by a dotted line. Mountain areas are shaded. Sites are indicated by solid triangles: 1, Murray Springs; 2, Lehner; 3, Naco; 4, Arizona CC:13:3; 5, Arizona FF:6:2; 6, Arizona FF:6:9; 7, Arizona FF:6:8; 8, Arizona FF:6:10; 9, Arizona FF:10:4; 10, Arizona FF:10:1, Arizona FF:10:13; 11, Arizona FF:10:16; 12, Arizona FF:10:14; 13, terrace cross section, Kings Highway; 14, Arizona FF:10:15; 15, Crystal locality.

CHAPTER ONE

The Whitewater Draw Region

Whitewater Draw, a deep arroyo in Cochise County, southeastern Arizona, exposes a long sequence of deposits of late Quaternary age that presents an archaeological record extending back 10,400 years. Geologist Ernst Antevs and archaeologist Edwin Sayles proposed the first geological and archaeological chronology of Whitewater Draw (Sayles and Antevs 1941). Since their pioneering interdisciplinary research, many questions have arisen about their findings as both the geological and archaeological data bases have increased, necessitating this reinvestigation of the geology and archaeology of Whitewater Draw.

PHYSIOGRAPHIC SETTING

Whitewater Draw is located in the southern part of the Sulphur Springs Valley, Arizona (Fig. 1.1). The Sulphur Springs Valley is part of a northeast-trending structural trough within the Basin and Range physiographic province. A surface drainage divide, formed by low volcanic hills near Pearce, separates the Sulphur Springs Valley into two basins: the northern Willcox basin and the southern Douglas basin. The former is a closed basin in which ancient Lake Cochise formed during the late Pleistocene (Meinzer and Kelton 1913; Schreiber 1978).

The Douglas basin, encompassing 3,100 square kilometers, is that portion of the Whitewater Draw drainage basin that is north of the international border, although it extends into Mexico (Coates and Cushman 1955; White and Childers 1967). It is characterized by a broad alluvial valley about 65 km long and 40 km wide, bounded on the east by the Chiricahua, Swisshelm, Pedregosa, and Perilla mountains and on the west by the Dragoon and Mule mountains, which rise 900 m to 1,200 m above the valley floor (Fig. 1.2). The bedrock lithologies of the surrounding mountains consist of igneous, metamorphic, and sedimentary rocks, ranging in age from Precambrian to Tertiary. The basin axis slopes gently southward at approximately 1.9 meters per kilometer from the surface drainage divide (altitude 1,310 m) to the international border (altitude 1,190 m). The climate of the Douglas basin is arid to semiarid, characterized by low precipitation and high evaporation (White and Childers 1967).

WHITEWATER DRAW

Whitewater Draw, named for the outcrops of white caliche along its banks, is an ephemeral stream that drains the Douglas basin. It is divided into two segments: north and south of Elfrida. Whitewater Draw occupies a continuous channel from its source in the Chiricahua Mountains, around the north end of the Swisshelm Mountains, to a point northeast of Elfrida where the channel loses its identity. This channel, according to Cooke and Reeves (1976), is similar to channels developed at the heads of many arid alluvial fans. There is no evidence that this channel was developed in historic times.

South of Elfrida, however, Whitewater Draw is an arroyo that developed during the late nineteenth century. It now extends southward from an area approximately 3 km southwest of Elfrida to its juncture with the Rio Yaqui, which flows south to the Gulf of California. The arroyo channel meanders and is at an average 30 m wide and 4 m deep, with a width-depth ratio of 10 or less (Cooke and Reeves 1976).

PREVIOUS RESEARCH

In 1926, Byron Cummings and a group of students recovered a mammoth skull from laminated sediments overlying a rusty sand containing artifacts associated with the remains of bison and horse near Double Adobe, Arizona (Fig. 1.3). These artifacts, unlike the Folsom projectile points discovered that same year with extinct bison, were milling stones and handstones with no projectile points.

These finds went relatively unnoticed until 1936, when Sayles and Antevs began an intensive survey of Whitewater Draw under the auspices of the Gila Pueblo Foundation. This research continued for a number of years and resulted in a monograph that outlined the late Quaternary geology of Whitewater Draw and defined the Cochise culture (Sayles and Antevs 1941). On the basis of stratigraphic occurrence, associated fauna, and material culture, three stages of the Cochise culture were distinguished: from early to late, they are the Sulphur Spring, Chiricahua, and San Pedro. Little further work was conducted until 1953 when Sayles and Antevs returned to Whitewater Draw to collect samples to radiocarbon date the stages of the Cochise culture. This same

Figure 1.2. The Douglas basin, looking east. Double Adobe is located in the central part of the photograph.

year, Sayles defined a fourth stage, the Cazador, which he placed chronologically between the Sulphur Spring and Chiricahua stages. Sayles described this new stage in a 1958 manuscript, which was posthumously published in 1983 (Sayles 1983).

Research in Whitewater Draw has remained dormant since 1953 except for Paul Martin's palynological work in 1959, a 1970 highway salvage excavation, and miscellaneous field trips by personnel of the University of Arizona to collect fossils or artifacts.

As the archaeological data base has expanded through the years, especially the recognition of the Clovis culture and the establishment of a timetable of late Pleistocene extinctions, many questions have arisen concerning the Sulphur Spring and Cazador stages. Willey and Phillips (1958), Whalen (1971), and Irwin-Williams (1979) have all questioned the validity of the association of extinct fauna with the Sulphur Spring stage. Haury (1960) has defended these associations. Some researchers (Haury, Sayles, and Wasley 1959; Martin and Plog 1973; Haury 1983) have suggested that the Sulphur Spring sites may represent specialized plant processing stations of the Clovis culture. Whalen (1971) and Irwin-Williams (1979) have questioned the validity of the Cazador stage. Questions have also arisen about the alluvial chronology of Whitewater Draw and the timing of late Pleistocene extinctions in the Douglas basin.

PURPOSE AND METHODOLOGY

The geological and archaeological investigations of Whitewater Draw described herein had five major objectives: (1) definition of the late Quaternary geologic history of Whitewater Draw, providing a stratigraphic framework on which to reference all other data; (2) interpretation of the

Figure 1.3. Excavation of a mammoth skull from laminated marl (unit F1) by Byron Cummings and students in 1926. (Photograph courtesy of the Arizona State Museum, University of Arizona.)

geologic sequence in an effort to gain insight into the problem of regional synchronous degradation and aggradation in the Southwest; (3) evaluation of the evidence for the timing of late Pleistocene extinctions in Whitewater Draw; (4) determination of the age of the Sulphur Spring stage of the Cochise culture and of the validity of the extinct faunal associations, description of its material culture, and assessment of its relationship with other cultures of similar age; and (5) determination of the validity of the Cazador stage of the Cochise culture.

Field investigations of Whitewater Draw were conducted from September of 1982 to May of 1983. The arroyo exposures were examined from Douglas to Elfrida and a backhoe was used to expose the older geological deposits at five sites of archaeological and geological interest. Artifacts, faunal remains, and radiocarbon, sediment, shell, and pollen samples were carefully recorded and collected at selected exposures. Radiocarbon samples were submitted to the University of Arizona Laboratory of Isotope Geochemistry and the Arizona-NSF Regional Accelerator Dating Facility for analysis. Artifacts collected during my field investigations and those from Double Adobe in the collections at the Arizona State Museum were studied.

The sites described in this report are assigned Arizona State Museum site designations (Wasley 1957). Where applicable, a second number follows in parentheses; it is the Gila Pueblo Foundation designation assigned to the site by Sayles and Antevs (1941) and is no longer used. Official site records are on file with the Arizona State Museum, University of Arizona, Tucson.

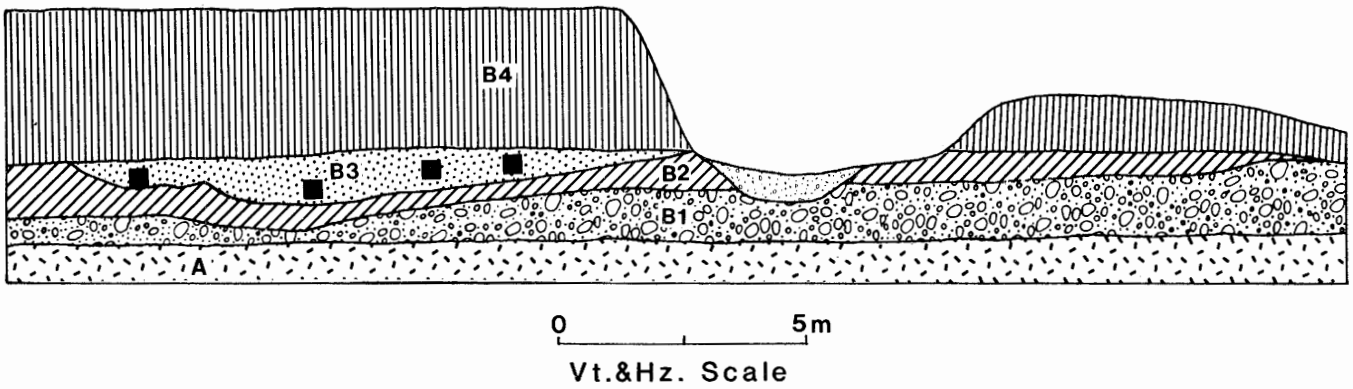


Figure 2.1. Geologic cross section of terrace deposits south of Kings Highway. Unit A, clay; Unit B1, coarse gravel and sand; Unit B2, clayey sand and gravel; Unit B3, sand; Unit B4, calcareous sandy clay and clayey sand. Solid squares represent megafaunal remains.

CHAPTER TWO

Quaternary Geology of Whitewater Draw

LOWER QUATERNARY STRATIGRAPHY

The oldest known valley fill in the Douglas basin is randomly exposed in the arroyo walls of Whitewater Draw and was exposed in all excavated trenches. It is generally a red to greenish red mottled calcareous clay, probably lacustrine in origin, interbedded with clayey clastic alluvium. The age of the fill is unknown because no fossils have been recovered from it and no other evidence (radiometric or paleomagnetic) bearing on its age is available. This fill may be the equivalent of the St. David Formation in the San Pedro Valley, which dates to the late Tertiary and early Pleistocene. Antevs (Sayles and Antevs 1941; Antevs 1983) referred to this unit as the "pink clay"; this designation is retained and, in addition, the unit is referred to as unit A herein.

A paired terrace occurs 5 to 6 m above the modern floodplain of Whitewater Draw. The terrace surface is typically characterized by a loose desert pavement (lag gravel) and development of Haplargids. The terrace deposits are well exposed south of Double Adobe (especially south of Kings Highway), where the arroyo has cut into them. These deposits of gravel, sand, silt, clay, and combinations thereof rest unconformably on the old valley fill. The recovery of mammoth, horse, sloth, and turtle remains from the terrace deposits indicates they are Pleistocene in age. This sequence of deposits is designated unit B.

Typical terrace deposits were exposed in a trench excavated south of Kings Highway (Figs. 1.1, 2.1). Overlying the pink clay (unit A) at this site is a coarse alluvial gravel and sand, which, in turn, is overlain by a clayey sand and gravel. A shallow channel is incised into this unit and is filled with sand containing the remains of mammoth, horse, and turtle. Above this are calcareous sandy clays and clayey sands. Four hundred meters downstream from this site, Sayles and Antevs (1941) recovered sloth remains from similar terrace deposits.

One kilometer south of Douglas, Arizona, a tributary arroyo has trenched through terrace deposits. Exposed in the arroyo at a site 2.4 km east of Whitewater Draw, according to C. Vance Haynes, is a sandy channel containing mammoth bones that is cut directly onto what is probably the pink clay (unit A). The channel is overlain by sandy silts and clays. Sayles and Antevs (1941) also recovered megafaunal remains from gravel and sand in the "barrier area" where the arroyo cuts through the terrace sediments.

UPPER QUATERNARY STRATIGRAPHY

No single exposure in Whitewater Draw shows a complete section of the upper Quaternary stratigraphy. Instead, an ordering of geologic events has been achieved by correlation from one radiocarbon-dated site to another, thereby establishing a geologic record for the last 15,000 years. Sixteen major geologic units are defined and labeled C through P, from oldest to youngest. Further internal stratigraphic subdivisions within a geologic unit are indicated by numbers, with 1 the oldest, 2 younger, and so on, and facies are designated with lower-case letters.

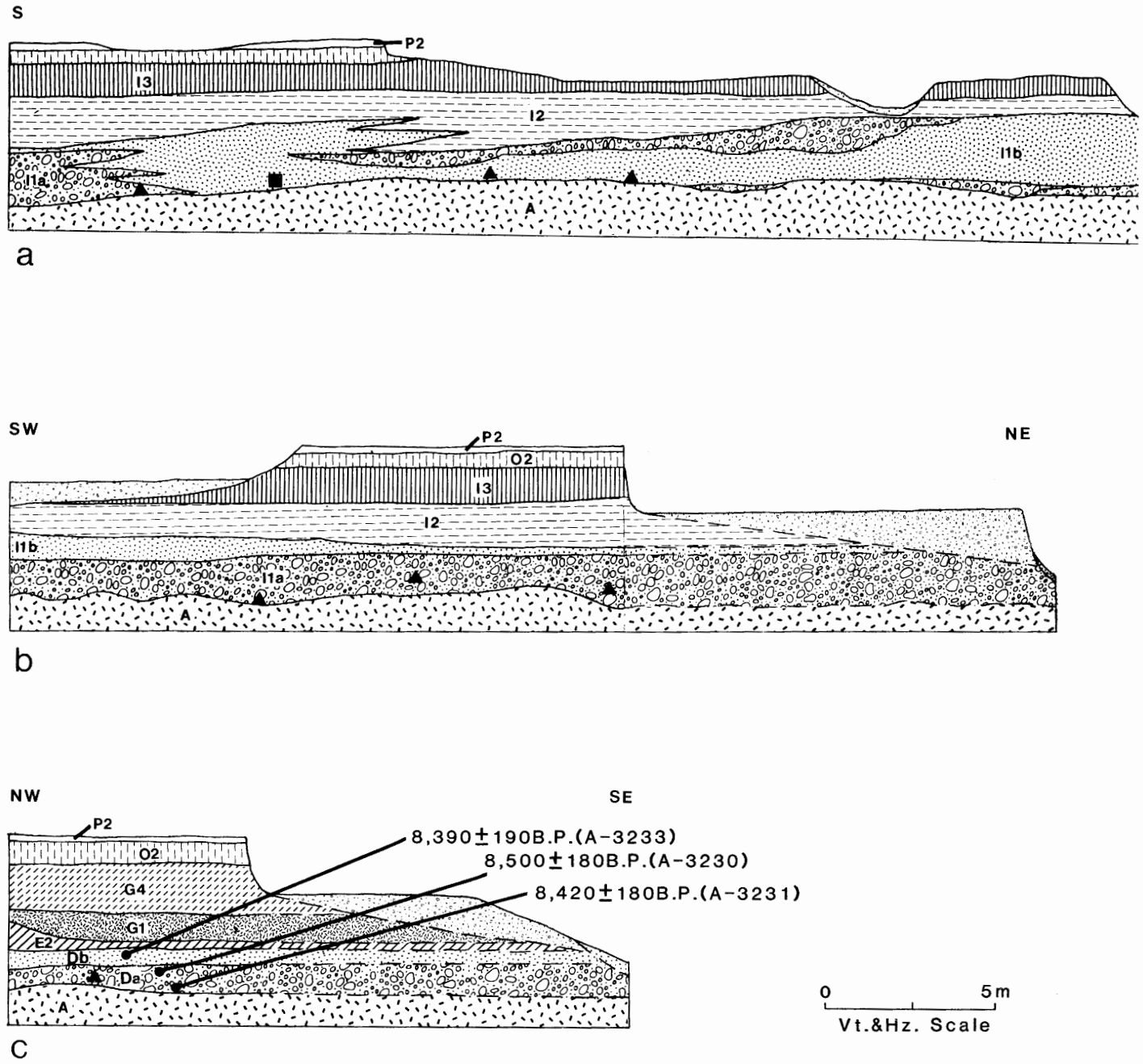
The stratigraphy of six geological and archaeological sites are described, followed by a discussion of the depositional systems operating in Whitewater Draw over the last 15,000 years. After reviewing the late Quaternary history of this fluvial system, I present the significance and implications of this alluvial sequence to the broader issue of regional synchronous degradation and aggradation in the Southwest.

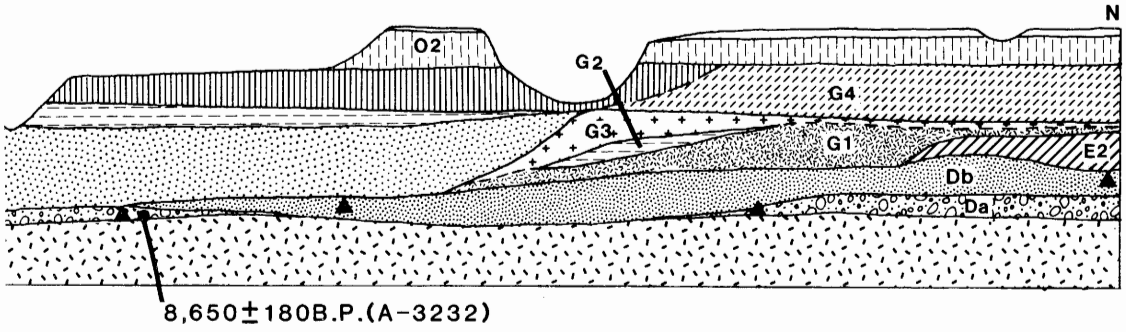
Site Arizona FF:6:9 (GP Pearce 8:21)

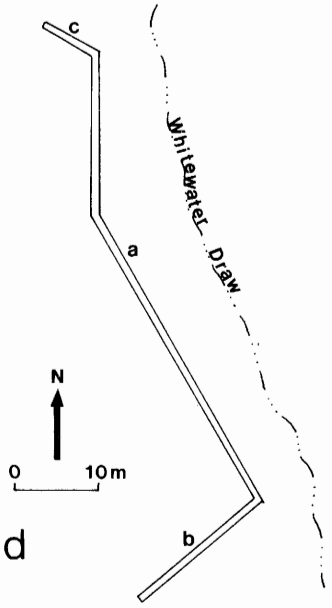
Arizona FF:6:9 is located on the west side of Whitewater Draw approximately 6 km northwest of Double Adobe (Fig. 1.1). It was excavated originally in 1937 and 1938 and identified by Sayles and Antevs (1941) as a two-component site, with Chiricahua or San Pedro stage material overlying Sulphur Spring stage artifacts. The upper artifact-bearing stratum was reassigned to the Cazador stage by Sayles (1983) and Antevs (1983), and artifacts from the lower strata are still considered to be Sulphur Spring (Sayles 1983; Antevs 1983).

I reinvestigated this site in January 1983, excavating a 60-m-long trench parallel to the arroyo bank and two trenches perpendicular to the main trench. Fourteen geologic units are defined and described in the Appendix, and the stratigraphic relations are shown in Figure 2.2. The correlation of my units with those described by Antevs (1983) is also in the Appendix.

The oldest deposit at the site is a calcareous reddish brown clay, the old valley fill (pink clay, unit A), which is unconformably overlain by fluvial stream gravel (unit Da) and sand (unit Db). Interbedded thin lenticular silt and clay lenses occur in the sand and represent deposition in charcos (small natural depressions in a streambed where water collects) during periods of reduced flow. Both of the units contain


S
P2
I3
I2
I1b
I1a
A
a
SW
NE
P2
O2
I3
I2
I1b
I1a
A
b
NW
SE
P2
O2
G4
G1
E2
Db
Da
A
8,390±190B.P.(A-3233)
8,500±180B.P.(A-3230)
8,420±180B.P.(A-3231)
0
5m
Vt.&Hz. Scale
C





▲ Artifacts ■ Megafauna ● Radiocarbon-dated samples

Figure 2.2. Geologic cross sections of site Arizona FF:6:9: *a,* stratigraphy of main trench; *b,* stratigraphy of south trench; *c,* stratigraphy of north trench; *d,* trench layout. Explanation: gravel, units Da and I1a; sand, units Db and I1b; silt, units G2 and P2; clayey silt, units E2 and O2; sand, silt, and clay, unit I2; clay, units A, G1, G3, G4, I3.

Sulphur Spring stage artifacts and abundant dispersed charcoal, some of which has been identified as cottonwood (*Populus*). A freshwater fish vertebra and freshwater pelecypods and gastropods occur in the sand. Two radiocarbon dates on charcoal from the basal gravel (unit Da) are 8,650 ± 180 yr B.P. (A−3232) and 8,420 ± 180 yr B.P. (A−3231), and two charcoal samples from the sand (unit Db) yielded dates of 8,500 ± 180 yr B.P. (A−3230) and 8,390 ± 190 yr B.P. (A−3233). A date of 8,860 ± 160 yr B.P. (A−3314) was obtained on the soluble humate fraction of charcoal sample A−3231. A sandy clayey silt (unit E2) with coarse prismatic structure overlies the fluvial sand.

A channel cuts through units Db and E2 to within 0.5 m of the pink clay (unit A). The channel is filled with a blue-gray clay (unit G1) with weak prismatic structure, a massive silt (unit G2), and a bluish gray clay (unit G3), which is transitional into a gleyed cienega soil (unit G4) with strong prismatic structure and abundant calcium carbonate nodules. Artifacts, attributed to the Cazador stage, were recovered from unit G1 along with freshwater molluscs, 17 species of diatoms, and fine charcoal (Sayles and Antevs 1941; Antevs 1983; Sayles 1983). The diatoms and molluscs indicate that the clay was deposited in slightly alkaline, brackish water (Sayles and Antevs 1941; Antevs 1983).

A prominent channel cuts through the older units to the pink clay (unit A) and is filled with gravel (unit I1a) and cross-bedded sand (unit I1b) deposited in a high-energy fluvial environment. The cross-bedded sand (unit I1b) is conformably overlain by a fining-upward sequence of horizontally laminated, very fine sand, silt, and clay (unit I2), which, in turn, is transitional into a cienega soil (unit I3) with strong blocky structure and abundant calcium carbonate nodules. Units I1a and I1b contained artifacts, probably reworked from the older gravel (unit Da) and clay (unit G1), shells of the genus *Anodonta*, and bones of bison, mud turtle (*Kinosternon*), and *Homo sapiens*.

A clay to silty clay (unit O2) with weak soil development overlies units I3 and G4. This deposit, in turn, is overlain by a yellow silt to very fine sand (unit P2), an overbank flood deposit.

Site Arizona FF:6:8 (GP Pearce 8:10)

Arizona FF:6:8 is located on the east side of Whitewater Draw, approximately 3.8 km northwest of Double Adobe (Fig. 1.1). It was originally identified as a Sulphur Spring stage site by Sayles and Antevs (1941), with Sulphur Spring artifacts occurring in five geologic deposits. They conducted excavations at this site in 1939 (Fig. 2.3). The upper two artifact-bearing strata were reassigned to the Cazador stage in 1953 by Sayles and Antevs, and artifacts from the lower units were still considered to be Sulphur Spring (Sayles 1983; Antevs 1983).

I reinvestigated the site in January 1983, excavating a 45-m-long trench parallel to the arroyo bank and one trench perpendicular to it (Fig. 2.4). Fifteen geologic units are defined and described in the Appendix, and the stratigraphic relations are shown in Figure 2.5. The correlation of my units with those described by Antevs (Sayles and Antevs 1941; Antevs 1983) is in the Appendix.

Fluvial stream gravel (unit Da) and sand (unit Db) unconformably rest on an eroded surface of calcareous reddish brown clay (pink clay, unit A). Thin lenticular discontinuous silt and clay interbeds occur in the sand. Both units contain Sulphur Spring stage artifacts (Figs. 2.6, 2.7), and unit Db contains abundant charcoal. A date of 6,210 ± 550 yr B.P. (C−511) was derived by the solid radiocarbon method on charcoal collected from the basal portion of the unit Db sand (Antevs 1983). Two other charcoal samples from the unit Db sand separated by an unconformity date 9,340 ± 180 yr B.P. (A−3238) and 8,140 ± 220 yr B.P. (A−3237). The solid radiocarbon date is too young compared with the other more reliable dates from the sand, and it is rejected.

Shallow channels cut unit Db and are filled with a brown clayey sand (unit E1) containing charcoal and freshwater gastropods and pelecypods. This unit is overlain by a clay to sandy clay with coarse prismatic structure (unit E2) containing freshwater molluscs. Organic material from unit E2, soluble in sodium hydroxide, yielded a radiocarbon date of 7,630 ± 280 yr B.P. (A−3382).

A shallow narrow channel is incised into the older units and is filled with bluish gray clay (unit G1) with coarse prismatic structure, a massive silt (unit G2), and a gray gleyed cienega soil (unit G4), with strong prismatic structure and abundant calcium carbonate nodules (Fig. 2.8). Artifacts attributed to the Cazador stage occur along the base of unit G1 in contact with units E2 and Db (Antevs 1983; Sayles 1983). Abundant charcoal, bones of mud turtle (*Kinosternon*) and fish, and molluscs occur in unit G1. A radiocarbon date on charcoal at the base of unit G1 is 6,940 ± 190 yr B.P. (A−3235), and another date near the top is 6,950 ± 170 yr B.P. (A−3236). These dates suggest a rapid filling of the channel with clay.

A shallow channel cuts unit G4 and is filled with a clayey sand (unit H). This unit contains freshwater gastropods and pelecypods, charcoal, abundant bones of freshwater fish and mud turtle (*Kinosternon*), and artifacts attributed by Sayles (1983) and Antevs (1983) to the Cazador stage. A radiocarbon date on charcoal and humates is 6,750 ± 180 yr B.P. (A−3234).

A prominent channel cuts through the older deposits nearly to the pink clay (unit A) on both the north and south ends of the main trench. The channel is filled with gravel and sand (units I1a and I1b) and a fining-upward sequence of horizontally laminated, very fine sand, silt, and clay (unit I2), which is transitional into a brown cienega soil (unit I3) with strong blocky structure and abundant calcium carbonate nodules.

This is overlain by a cienega clay (unit N2), with blocky structure, containing shallow channels filled with clayey sand. Overlying the eroded surface of unit N2 is a silty clay

Figure 2.3. Excavation of site Arizona FF:6:8 by E. B. Sayles and E. Antevs in 1939. (Photograph courtesy of the Arizona State Museum, University of Arizona.)

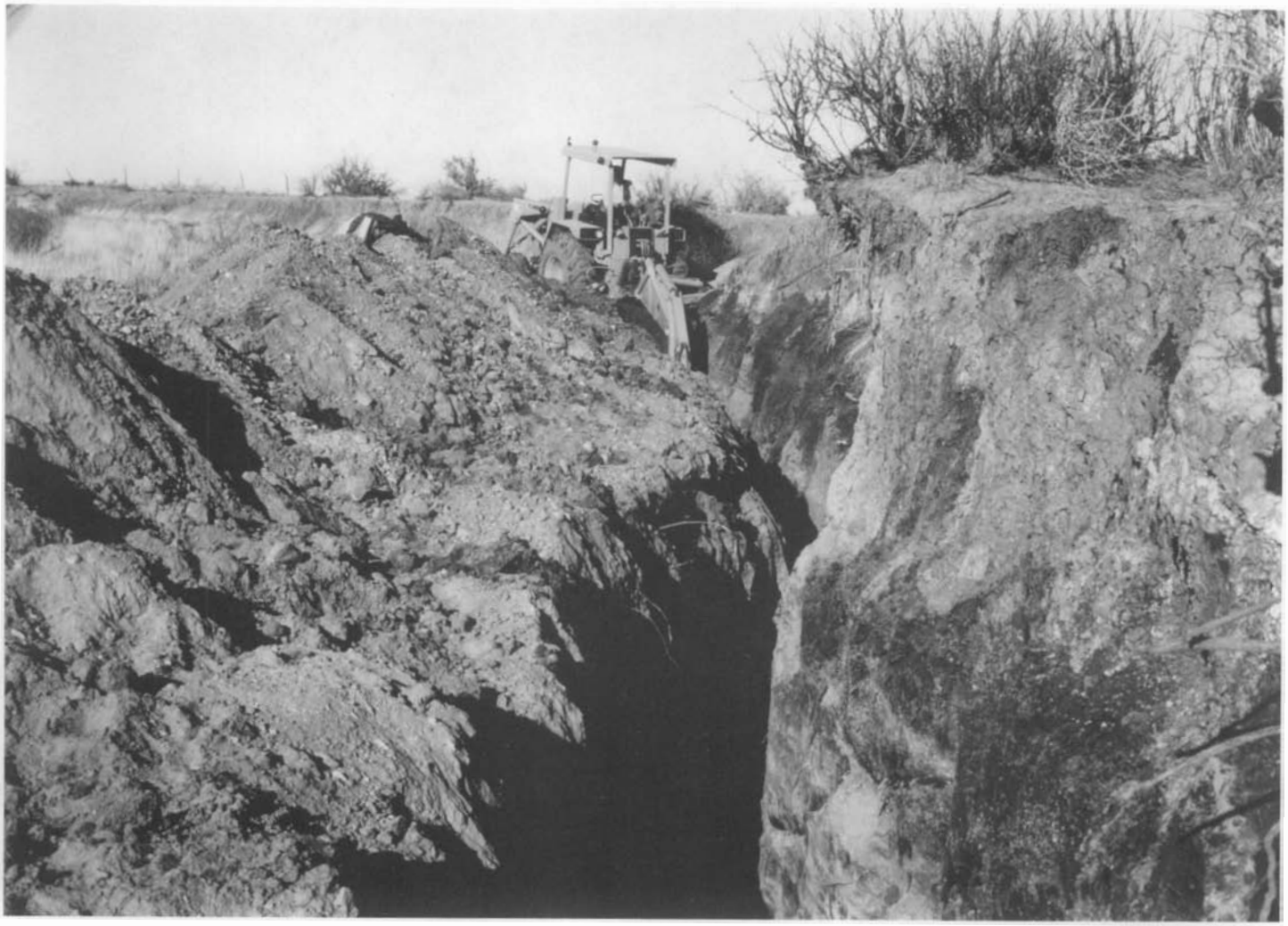


Figure 2.4. Excavation of site Arizona FF:6:8 with a backhoe in 1983.

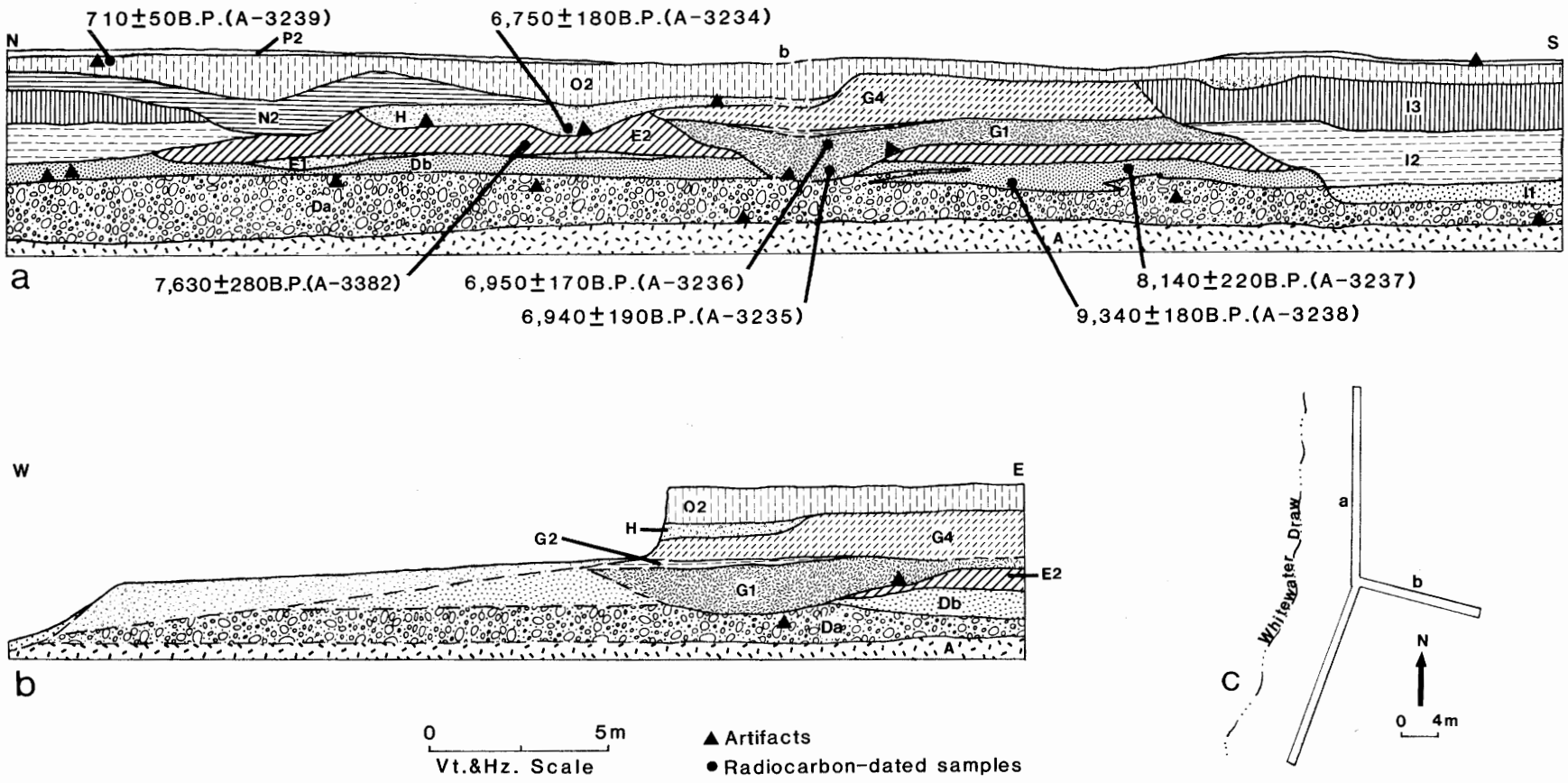


Figure 2.5. Geologic cross sections of site Arizona FF:6:8: *a,* stratigraphy of main trench; *b,* stratigraphy of side trench; *c,* trench layout. Explanation: gravel, unit Da; sand, unit Db; gravel and sand, unit I1; clayey sand, units El and H; silt, units G2 and P2; silty clay, units E2 and O2; sand, silt, and clay, unit I2; clay, units A, G1, G4, I3, and N2.

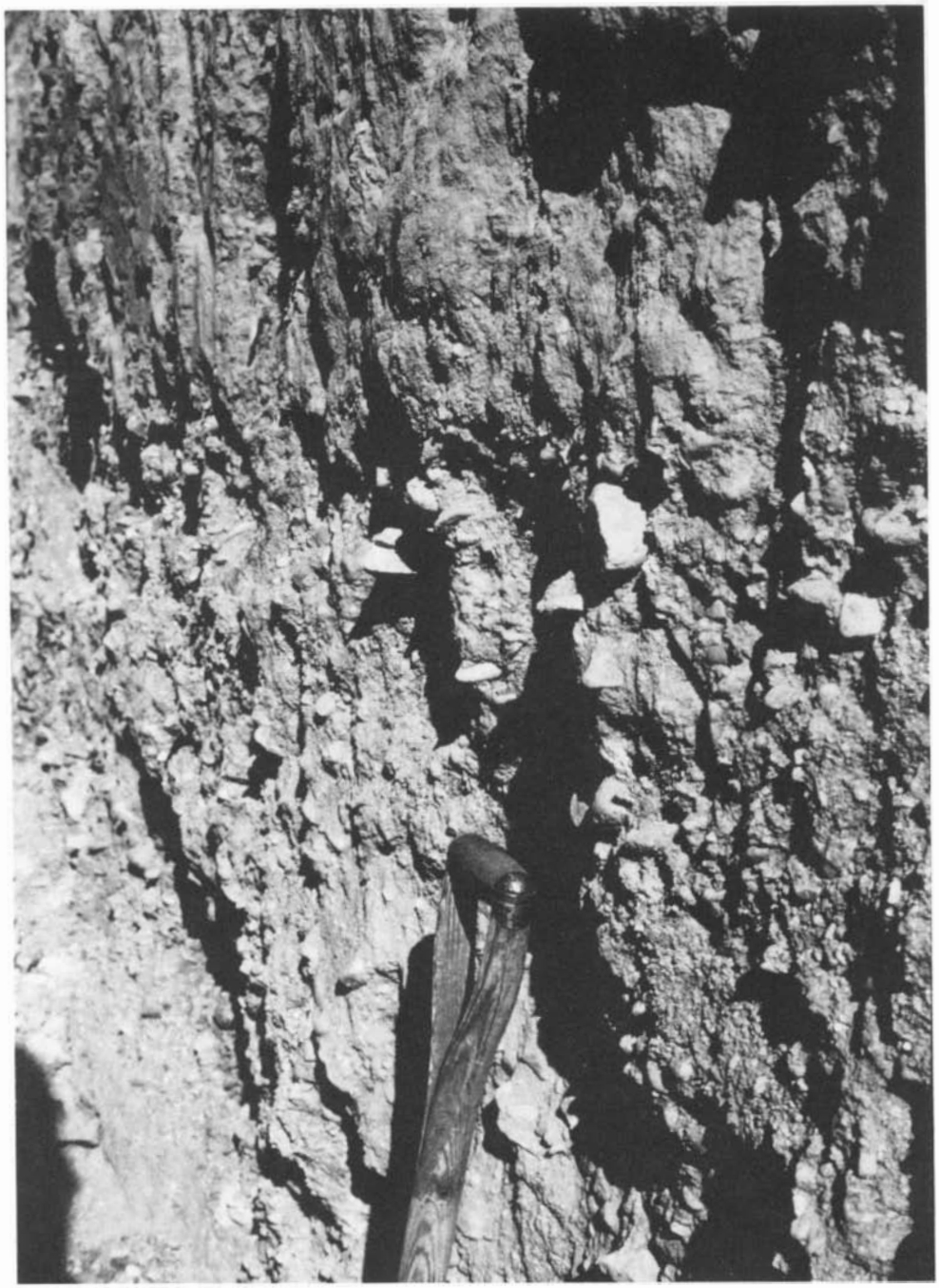


Figure 2.6. Handstone and milling stone (*center*) in situ within basal gravel unit Da at site Arizona FF:6:8.

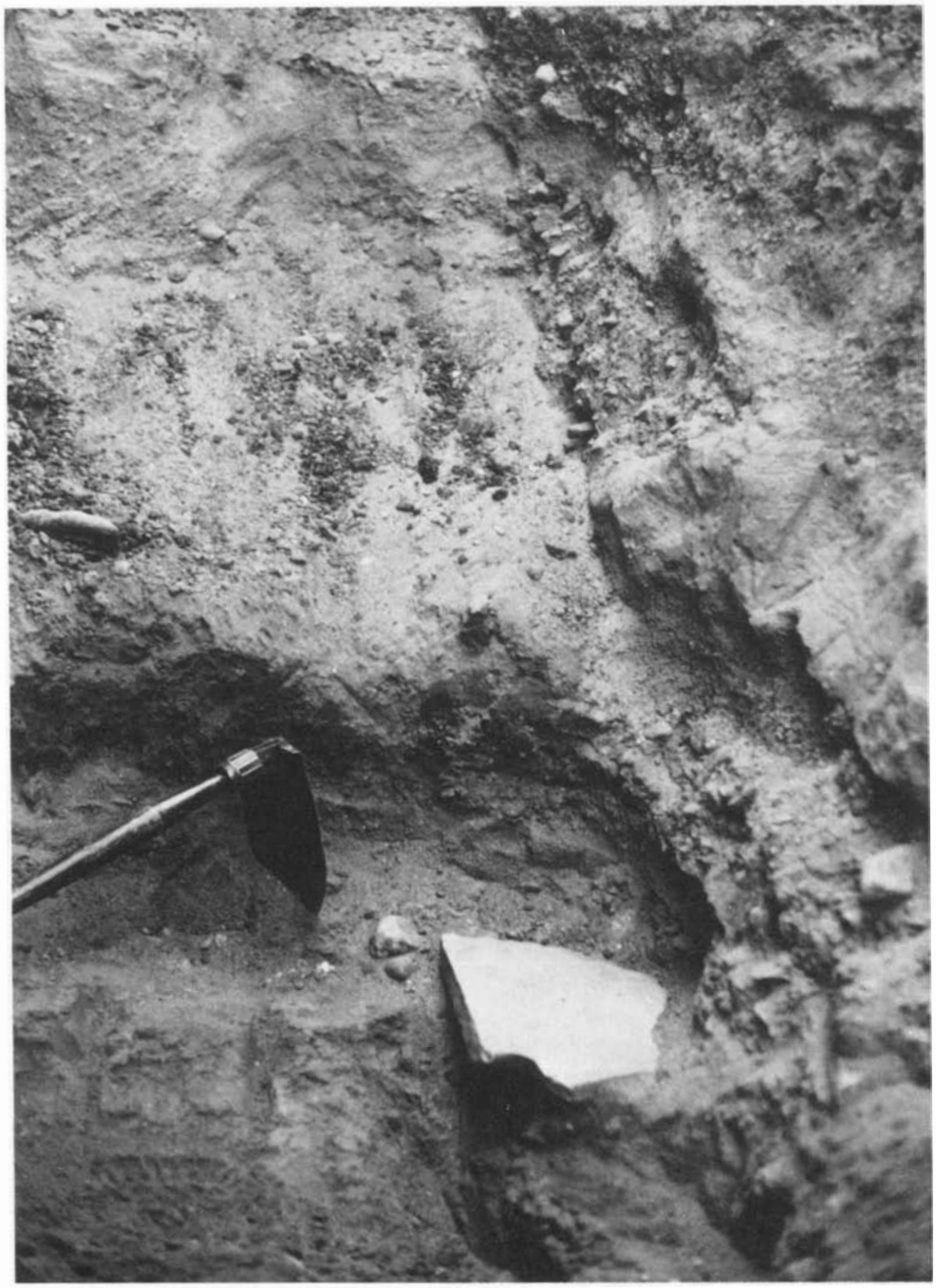


Figure 2.7. Milling stone in situ within basal gravel unit Da at site Arizona FF:6:8.

Figure 2.8. Main trench at site Arizona FF:6:8, looking south. Pick rests on channel filled with clay unit G1. Sand unit Db and gravel unit Da below.

with blocky structure (unit O2). A hearth at the top of this unit provided charcoal that dated 710 ± 50 yr B.P. (A−3239). Very fine sand and silt (unit P2), an overbank flood deposit containing potsherds, overlies unit O2.

Double Adobe Site Area
Arizona FF:10:1 and Arizona FF:10:13

The Double Adobe site area (Figs. 1.1, 2.9, 2.10, 2.11) was first investigated by Cummings in 1926 and later examined in detail by Sayles and Antevs in the late 1930s. This area became the type site of the Sulphur Spring and Cazador stages of the Cochise culture. Further investigations of the area were conducted by Paul Martin in 1959 and Ric Windmiller in 1970. I excavated several test trenches near the site and two trenches north of the original site area in April 1983. Eighteen stratigraphic units are defined and described in the Appendix, and their stratigraphic relations are shown in Figure 2.12. The correlation of my units with those described by Antevs (Sayles and Antevs 1941; Antevs 1983) is in the Appendix.

The oldest deposit at Arizona FF:10:1 (GP Sonora F:10:1), localities 3, 4, and 5 (Figs. 2.9 and 2.12*b*), is a calcareous red-brown clay (pink clay, unit A), which, in turn, is overlain by a calcareous marl (unit C) with interbedded tufa and alluvium containing the remains of horse and mammoth. Unit C was not recognized by Antevs (Sayles and Antevs 1941; Antevs 1983) or Sayles (1983) and was included as part of the pink clay (unit A). Stream gravel (unit Da) and sand (unit Db) unconformably cut units A and C. Sulphur Spring artifacts, cottonwood (*Populus*) and hickory (*Carya*) charcoal, and the remains of mammoth, camel, horse, dire wolf, bison, pronghorn antelope, and coyote were recovered from the alluvium (units Da and Db; Sayles and Antevs 1941; Sayles 1983; Antevs 1983). Haury (1960) reported that he collected articulated leg bones of a camel from these deposits.

The fluvial deposits are cut by a shallow channel and filled with a laminated marl (unit F1) from which the skull, ribs, and leg bone of a mammoth and remains of freshwater molluscs were removed (Fig. 2.13; Cummings 1927, 1928; Sayles and Antevs 1941; Antevs 1983). This unit is overlain by a massive marl (unit F2), which, in turn, is overlain by a massive to faintly laminated calcareous brownish gray clay and a clay with strong prismatic structure and abundant calcium carbonate nodules (unit L). A silt (unit P2) containing potsherds (Sayles and Antevs 1941; Antevs 1983) overlies this unit.

Martin (1963b) investigated locality 5 in 1959 and designated it the Double Adobe I pollen profile (Fig. 2.9). Through previous erosion and his use of mechanical equipment some of the original deposits described by Antevs (Sayles and Antevs 1941) were removed, leaving the following sequence of units from oldest to youngest (Fig. 2.12*c*): pink clay (unit A), gravel (unit Da), sand (unit Db), blue-gray clay (unit Dd), white silt and clay (unit Ola),

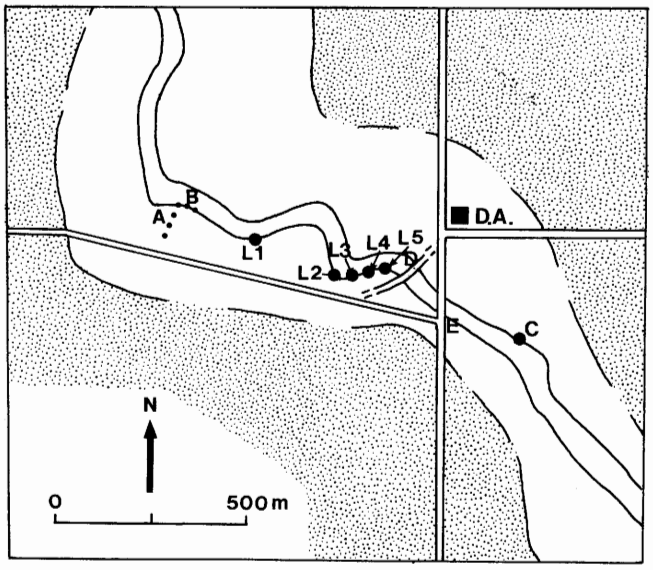


Figure 2.9. Double Adobe site area: A, location of trench shown in Figure 2:12*a*; B, location of trench shown in Figure 2.12*e*; C, site Arizona FF:10:13; D, location of 1983 test trenches; E, location of 1970 highway salvage excavations; L1, Arizona FF:10:1, locality 1; L2, Arizona FF:10:1, locality 2 (Double Adobe II); L3, Arizona FF:10:1, locality 3; L4, Arizona FF:10:1, locality 4; L5, Arizona FF:10:1, locality 5 (Double Adobe I); DA, Double Adobe schoolhouse. Shaded area indicates position of terraces.

indurated silt (unit O2), sandy silt (unit P1), and silt (unit P2). Five radiocarbon dates, ranging from 8,960 ± 100 yr B.P. (A−189) to 8,000 ± 60 yr B.P. (A−191), were obtained on charcoal, carbonaceous alluvium, and disseminated charcoal and organic matter collected from the unit Db sand (Martin 1963b). A sample of carbonaceous alluvium from clay unit Dd, overlying the unit Db sand, dated 7,910 ± 200 yr B.P. (A−190; Martin 1963b). A horse tooth was found in the basal gravel (unit Da) by Rogers (1958).

I excavated two test trenches near locality 5 (Figs. 2.9 and 2.12*c*), which duplicated the stratigraphy described by Martin (1963b) and dated two charcoal samples from the sand (unit Db). These dates are 9,050 ± 260 yr B.P. (A−3386) and 8,680 ± 240 yr B.P. (A−3387). A tumbled mammoth bone was associated with the latter date.

At Arizona FF:10:1, locality 1 (Fig. 2.9), Antevs (1983) and Sayles (1983) found Sulphur Spring artifacts and the remains of mammoth, camel, dire wolf, and birds in a stream-deposited gravel (unit Da) and sand (unit Db). Overlying unit Db is a massive marl (unit F2) containing the remains of a camel. This unit is overlain by a brown cienega clay (unit N2) and a silt (unit P2). Locality 1 has been destroyed by erosion.

Arizona FF:10:1, locality 2, located on the west side of Whitewater Draw, is the type site of the Cazador stage (Fig. 2.9; Sayles 1983; Antevs 1983). The stratigraphy at this site consists of fluvial gravel (unit Da) and sand (unit Db) resting

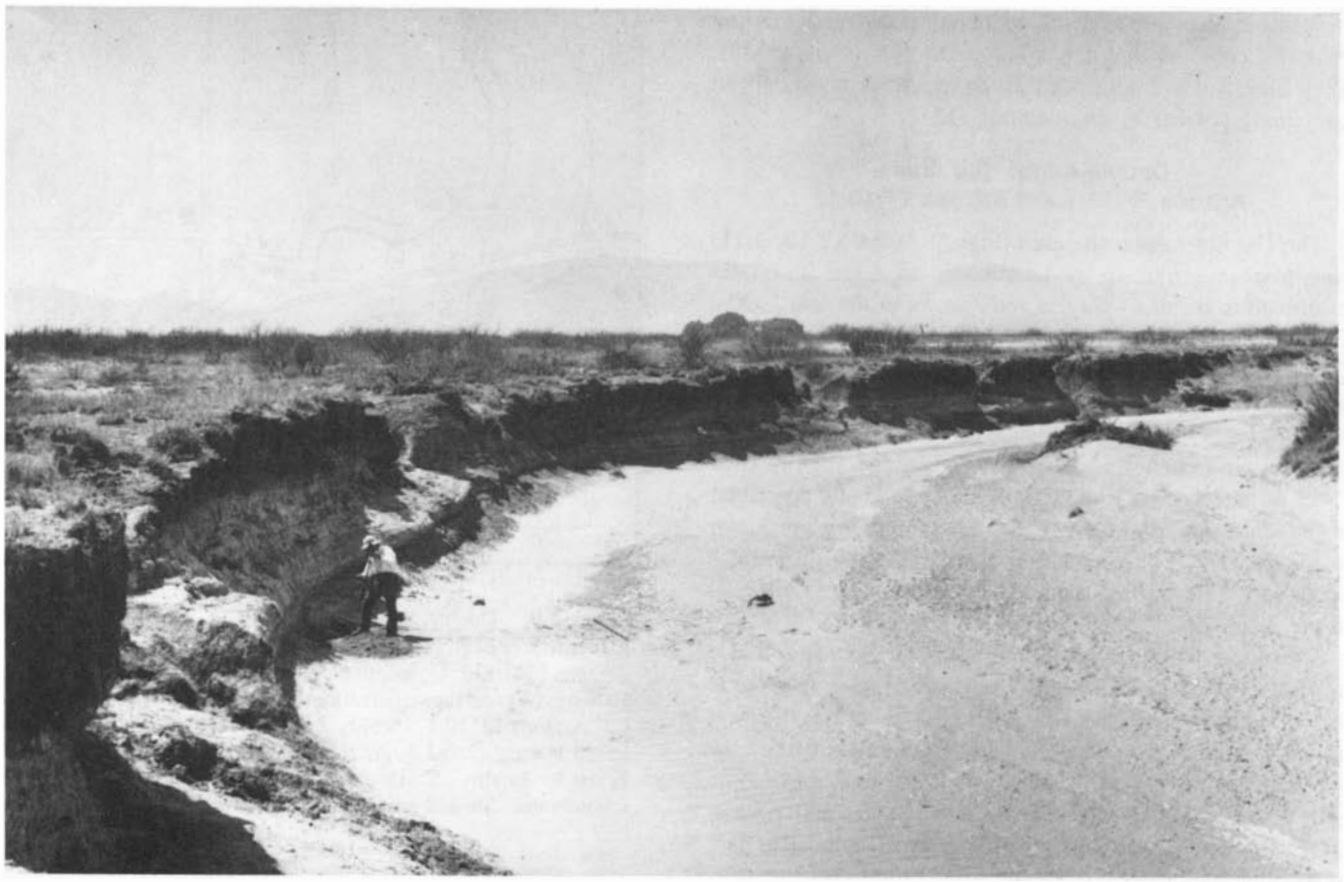


Figure 2.10. Double Adobe site area in 1936, looking west. (Photograph courtesy of the Arizona State Museum, University of Arizona.)

on an eroded surface of the pink clay (unit A; Fig. 2.12*b*). These units are overlain by a massive blue-gray clay (unit Dd), which, in turn, is overlain by a series of massive calcareous sandy silts (unit Ola), a brown silty clay (unit O2), and a yellow silt (unit P2). Cazador artifacts occur in the basal gravel (unit Da) and sand (unit Db; Sayles 1983; Antevs 1983). Two dates derived by the solid radiocarbon method reported from the alluvium (units Da and Db) are 7,756 ± 370 yr B.P. (C−216) and 8,200 ± 260 yr B.P. (A−67). The carbon residue from the latter sample was reanalyzed using the carbon dioxide method, resulting in a date of 9,350 ± 160 yr B.P. (A−67bis; Damon and Long 1972). The solid radiocarbon dates appear to be too young when compared with the more reliable gas date and are rejected.

Martin (1963b) reinvestigated locality 2 in 1959 and designated it the Double Adobe II pollen profile (Fig. 2.9). He found that the stratigraphy at the Double Adobe I profile was duplicated here (Fig. 2.12) and he obtained radiocarbon dates on charcoal and carbonaceous alluvium from the sand (unit Db) of 8,240 ± 960 yr B.P. (A−184c) and 7,030 ± 260 yr B.P. (A−184e), respectively. The second date is too young compared to other dates from this unit and it is rejected. I investigated this site in April 1983, found the stratigraphy as described by Antevs (1983) correct, and obtained two radiocarbon dates on charcoal of 8,840 ± 310 yr B.P. (A−3377) and 8,760 ± 210 yr B.P. (A−3379) from the unit Db sand. The humates from sample A−3377 dated 8, 970 ± 220 yr B.P. (A−3378).

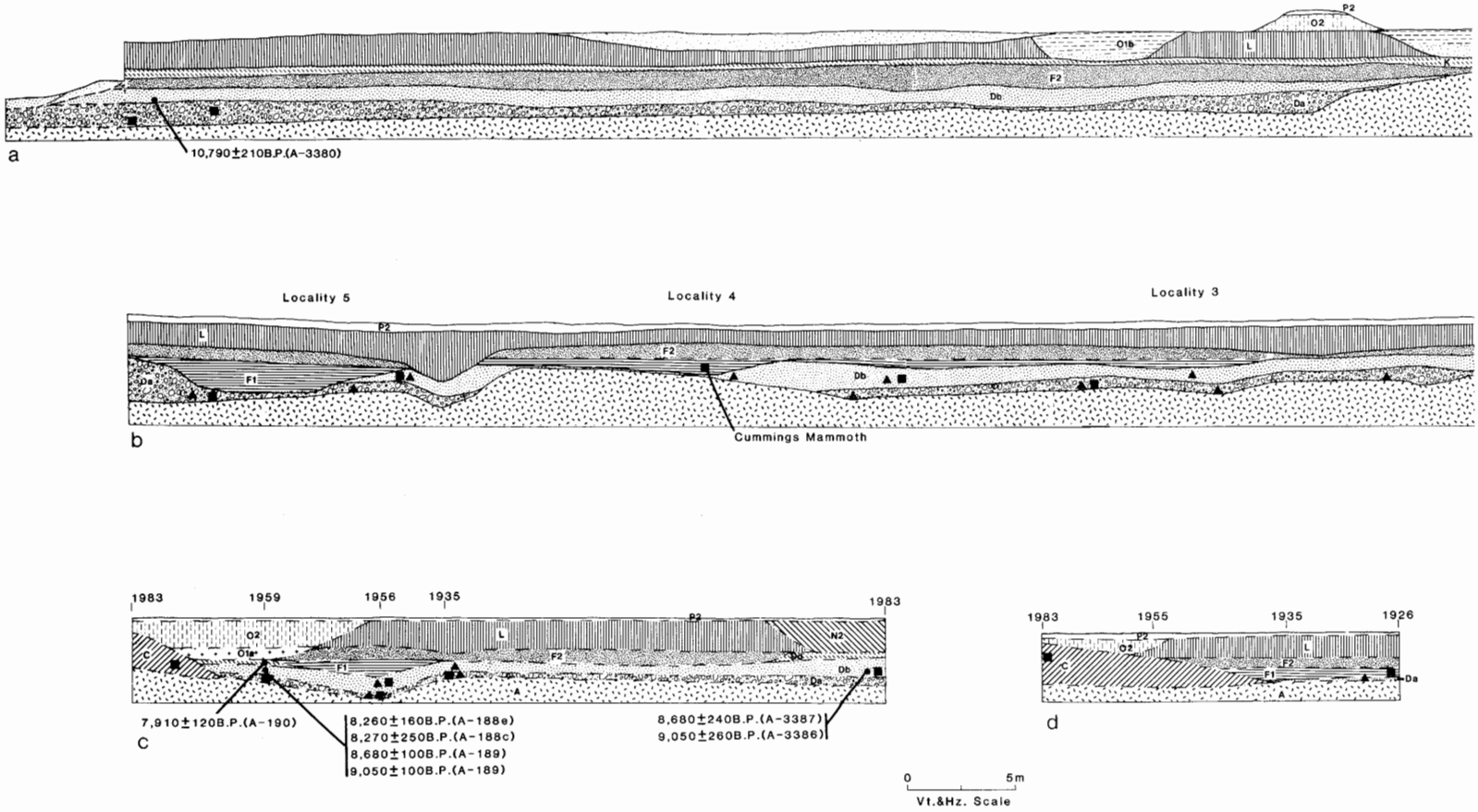
Several trenches (Fig. 2.9) were excavated about 240 m downstream from Arizona FF:10:1 (locality 5) during a highway salvage excavation in 1970 (Windmiller 1970). Haynes (1971) recorded the stratigraphy exposed in the trenches and obtained four radiocarbon dates. The stratigraphy in the trenches is similar to that found elsewhere in the Double Adobe area. A stream-deposited gravel (unit Da) and sand (unit Db) rests unconformably on an eroded surface of the pink clay (unit A). This, in turn, is overlain by a brown clay (unit E2) with coarse prismatic structure. Cut into this unit is a channel filled with a laminated marl (unit F1), which is overlain by a gleyed cienega soil (unit L) with strong prismatic structure, a brown clay (unit N2), and a yellow flood silt (unit P2).

Sulphur Spring artifacts were found in the unit Db sand, and the remains of a mammoth were recovered from the unit Da gravel. Most of the mammoth bones were unarticulated and scattered across a 60-square-meter area. However, a pair

Figure 2.11. Double Adobe site area in 1983, looking west. Photograph taken from Arizona FF:10:1, locality 5; localities 4, 3, and 2 are shown. Note filling of arroyo channel on right.

of lumbar vertebrae was found in normal articulated relationship (Huckell 1972). No association between the mammoth bones and artifacts could be demonstrated. Two radiocarbon dates, 10,420 ± 100 yr B.P. (A−1152) and 8,920 ± 1150 yr B.P. (Tx−1199) were obtained on charcoal from the unit Da gravel near the mammoth bones. Two radiocarbon dates on calcium carbonate laminations from the laminated marl (unit F1) are 9,730 ± 100 yr B.P. (SMU−129) and 10,980 ± 90 yr B.P. (SMU−128). The marl dates are rejected as too old because the laminated marl (unit F1) overlies the unit Db sand, which dates between about 9,500 and 8,000 yr B.P. The calcium carbonate was probably contaminated by radiometrically inactive carbon.

North of Arizona FF:10:1, I excavated two trenches: one parallel and one perpendicular to the arroyo bank (Figs. 2.9, 2.12*a*, 2.12*e*). The oldest exposed deposit is the calcareous pink clay (unit A). This is overlain by a calcareous clay (unit C), probably a marl, containing the bones of horse and mammoth. Inset against units A and C are stream-deposited gravel (unit Da) and sand (unit Db) with interbedded silt and clay lenses. In one trench, a conspicuous channel filled with clay (unit Dd) is underlain and overlain by gravel (unit Da). Within the gravel are freshwater molluscs and mammoth bones. Charcoal from the base of the unit Db sand near the mammoth bones dated 10,790 ± 210 yr B.P. (A−3380). The humates from this charcoal sample dated 11,320 ± 280 yr B.P. (A−3381). The gravel is overlain by a massive marl (unit F2) with prismatic structure, which, in turn, is overlain by a laminated gray clay that fills a shallow depression and a massive gray clay with a prominent silt interbed (unit K?). This unit is overlain by a gleyed cienega soil (unit L) with strong prismatic structure and abundant calcium carbonate nodules. Several small channels are incised into the soil (unit L) and filled with silty sand and silt (unit Olb). These shallow channel fills are overlain by silty clay (unit O2) and overbank flood silts (unit P2).



Arizona FF:10:13 is located 400 m downstream from locality 5 (Fig. 2.9). Here a shallow channel is incised into a sequence of older sediments (units Db, Jl, and L) and filled with an olive blue-gray clay (unit M; Figs. 2.12*f*, 2.14). Artifacts, freshwater molluscs, and mud turtle (*Kinosternon*) and bird bones occur along the contact of the channel with the older units (Fig. 2.15). Charcoal is abundant, and a date of 3,500 ± 110 yr B.P. (A−3183) was obtained on cottonwood (*Populus*) charcoal from the base of the clay (unit M). This deposit is overlain by a sequence of brown clays (unit N2) and a flood silt (unit P2).

Site Arizona FF:10:14 (GP Sonora F:10:17)

Arizona FF:10:14, a Sulphur Spring stage site identified by Sayles and Antevs (1941), is located on the west side of Whitewater Draw approximately 2 km southeast of Double Adobe (Fig. 1.1). I reinvestigated this site in February 1983, excavating a 70-m-long trench parallel to the arroyo wall and two trenches perpendicular to it. Two additional trenches were excavated 150 m downstream and 300 m upstream from the site and are designated the Bull and Tortoise localities, respectively. Twelve stratigraphic units are defined and described in the Appendix, and their stratigraphic relations are shown in Figure 2.16. The correlation of my units with those described by Antevs (Sayles and Antevs 1941) is in the Appendix.

The oldest unit at the site is a reddish brown calcareous clay (pink clay, unit A). On the eroded surface of the clay rests a fluvial stream-deposited gravel (unit Da) and sand (unit Db) containing disarticulated mammoth and camel bones and freshwater molluscs. A radiocarbon date of 15,100 ± 400 yr B.P. (AA−233) on dispersed charcoal was obtained from the base of unit Da, and a charcoal sample from the base of the unit Db sand dated 12,850 ± 890 yr B.P. (AA−269). Overlying unit Db is a silty sand (unit Dc) with dispersed pebble gravel, which probably represents deposition in a splay bar or levee. This unit contained Sulphur Spring stage artifacts, human skeletal remains, bison, and very fine dispersed charcoal (Fig. 2.17).

The older deposits are cut by a channel that is filled with a laminated brown clay-silt (unit Jl). Charcoal from this unit yielded a date of 5,350 ± 230 yr B.P. (A−3308) and the humates derived from this charcoal sample dated 4,900 ± 110 yr B.P. (A−3309). A channel, filled with laminated gray clay (unit K), overlies unit Jl and contains freshwater molluscs and abundant charcoal and carbonized plant remains along laminations. A shallow channel cuts unit Dc on the north end of the site and is filled with a faintly laminated clay, which is probably the equivalent of unit K. These units are

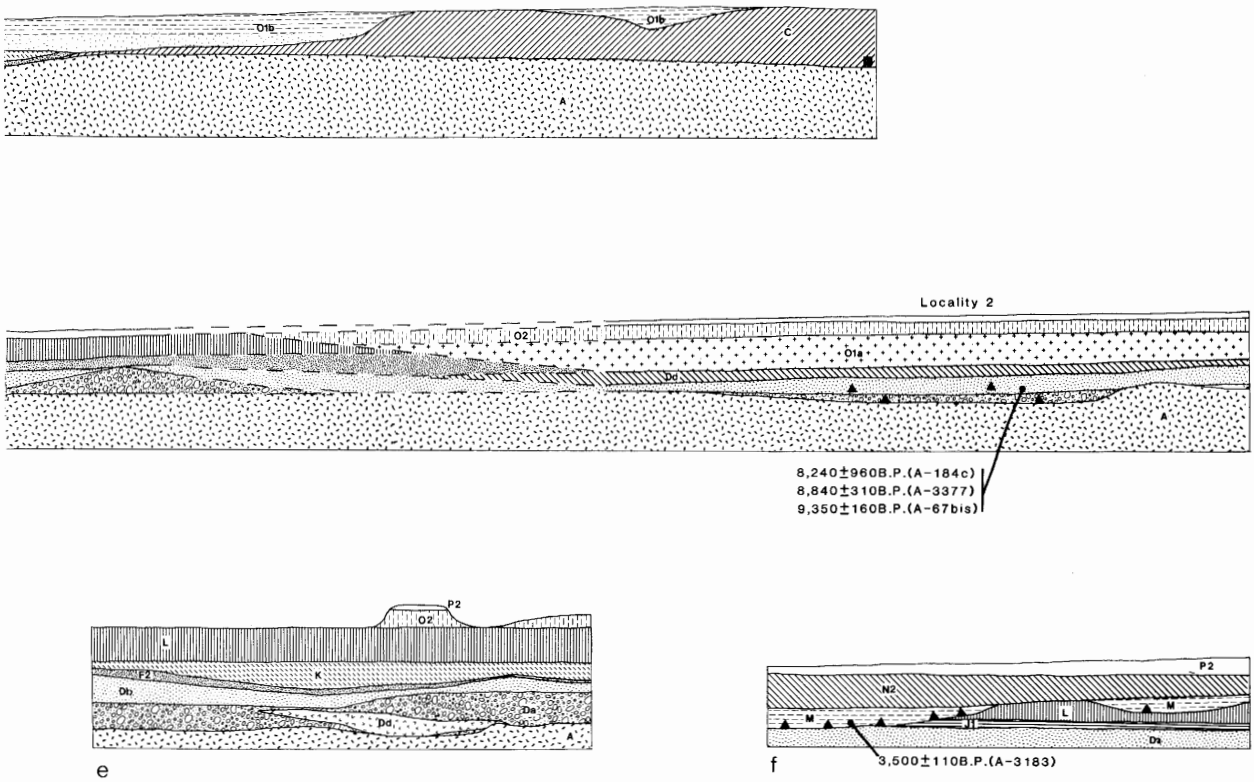


Figure 2.12. Geologic cross sections of the Double Adobe area. *a,* Stratigraphy at northernmost trench, shown as A in Figure 2.9. *b,* Stratigraphy of Arizona FF:10:1, localities 5, 4, 3, and 2, from an unpublished geologic cross section by Antevs and Sayles (1937). *c,* Interpolated stratigraphy of Arizona FF:10:1, locality 5, based on stratigraphic information recorded in years indicated; cross section is perpendicular to arroyo. *d,* Interpolated stratigraphy of Arizona FF:10:1, locality 4, based on stratigraphic information recorded in years indicated; cross section is perpendicular to arroyo. *e,* Stratigraphy of northern trench, shown as B in Figure 2.9. *f,* Stratigraphy of Arizona FF:10:13. Explanation: gravel, unit Da; sand, unit Db; silty sand, units 01a and 01b; silt, unit P2; clay-silt, unit J1; silty clay, unit 02; clay, units A, Dd, K, L, M, and N2; marl, units C, F1, and F2. Solid triangles represent artifacts, solid squares represent megafauna, and solid dots indicate position of radiocarbon-dated samples.

overlain by a gleyed cienega soil (unit L) with strong prismatic structure and abundant calcium carbonate nodules and freshwater shells, which fills very gentle depressions in the paleotopography. Unit L is overlain by a silty clay and clay (unit N2) with blocky structure, which, in turn, is overlain by a very fine sand and silt (unit P2).

At the Bull and Tortoise localities, the erosional channels filled with units J1, K, and L at Arizona FF:10:14 were exposed (Figs. 2.18, 2.19) to obtain data on the size of the channels, the cut-and-fill sequence, and the age of the deposits. The deposits are best exposed at the Bull locality where the oldest channel cuts into sand and gravel (probably unit Db) and a sandy clay with coarse prismatic structure (unit E2). The base of the shallow channel is filled with a thin lens of sand and pebble gravel, which is overlain by a brown laminated clay-silt (unit J1). This deposit is eroded by a channel approximately 3 m deep and a maximum of 7 m wide. This channel is filled with a blue-gray laminated clay (unit K), which is slightly sandy at the base and contains abundant charcoal and remains of mud turtle (*Kinosternon*) and freshwater molluscs. Unit K is cut by another channel and filled by a massive blue clay with calcium carbonate nodules, which is transitional into a gleyed soil (unit L) with strong prismatic structure and abundant calcium carbonate nodules. Freshwater gastropods are abundant in this unit. Unit L is overlain, as at Arizona FF:10:14, by units N1, N2, and P2.

A similar sequence of beds and cut-and-fill relations occur at the Tortoise locality but they differ in that the channel is cut into a sand and gravel that is probably unit I1b. A milling

Table 2.1 Radiocarbon Dates from Whitewater Draw, Arizona

Unit	Date[1] (yr B.P.)	Lab. No.	Material Dated	Site	Remarks
O2	710 ± 50	A−3239	Charcoal	Arizona FF:6:8	Hearth
N2	1,430 ± 250	A−3182	Charcoal	Arizona FF:10:16	Hearth (N2b)
	1,762 ± 430*	C−518	Charcoal	Arizona FF:6:2	Solid date; rejected
	2,290 ± 190	A−3181	Charcoal	Arizona FF:10:16	Dispersed (N2a)
	2,860 ± 440*	A−194	Carbonaceous alluvium	Arizona FF:6:2	Double Adobe IV, below A−193
	3,860 ± 200*	A−193	Carbonaceous alluvium	Arizona FF:6:2	Double Adobe IV, from floor of pit house; rejected
M	3,500 ± 110	A−3183	Charcoal	Arizona FF:10:13	Dispersed
	4,006 ± 270*	C−515	Charcoal	Arizona FF:10:4	Solid date; rejected
	4,960 ± 300*	A−192b	Carbonaceous alluvium	Arizona FF:10:4	Double Adobe III; rejected
	7,560 ± 260*	A−192a	Inorganic carbonate	Arizona FF:10:4	Double Adobe III; rejected
K	4,400 ± 190	A−3313	Charcoal	Tortoise locality	Dispersed
	4,770 ± 70	A−3312	Charcoal	Tortoise locality	Dispersed
	4,840 ± 80	A−3311	Charcoal	Bull locality	Dispersed
J1	5,120 ± 130	A−3310	Charcoal	Bull locality	Dispersed
	5,200 ± 120	A−3384	Charcoal	Crystal locality	Dispersed
	5,350 ± 230	A−3308	Charcoal	Arizona FF:10:14	Dispersed along laminations
	4,900 ± 110	A−3309	Humates	Arizona FF:10:14	Humates of A−3308
H	6,750 ± 180	A−3234	Charcoal and humates	Arizona FF:6:8	Cazador level
G1	6,940 ± 190	A−3235	Charcoal	Arizona FF:6:8	Dispersed
	6,950 ± 170	A−3236	Charcoal	Arizona FF:6:8	Dispersed
F1	9,730 ± 100*	SMU−129	Calcium carbonate	Arizona FF:10:1	$CaCO^3$ lamination; rejected
	10,980 ± 90*	SMU−128	Calcium carbonate	Arizona FF:10:1	$CaCO^3$ lamination; rejected
E	7,630 ± 280	A−3382	Charcoal and humates	Arizona FF:6:8	Dispersed
Dd (upper)	7,910 ± 200*	A−190	Carbonaceous alluvium	Arizona FF:10:1	Double Adobe I
Db	6,210 ± 450*	C−511	Charcoal	Arizona FF:6:8	Solid date; rejected
	7,030 ± 260*	A−184e	Carbonaceous alluvium	Arizona FF:10:1 (locality 2)	Double Adobe II; rejected
	7,756 ± 370*	C−216	Charcoal	Arizona FF:10:1 (locality 2)	Solid date; rejected
	8,000 ± 60*	A−191	Carbonaceous alluvium	Arizona FF:10:1 (locality 5)	Double Adobe I; rejected
	8,140 ± 220	A−3237	Charcoal	Arizona FF:6:8	Sulphur Spring artifacts
	8,200 ± 260*	A−67	Charcoal	Arizona FF:10:1 (locality 2)	Solid date; rejected

stone fragment was recovered from the gray laminated clay (unit K) at the Bull locality.

Four radiocarbon dates were obtained on charcoal samples collected from these localities. One sample from the basal portion of the brown laminated clay-silt (unit J1) at the Bull locality dated 5,120 ± 130 yr B.P. (A−3310). One sample from the base of the blue-gray laminated clay (unit K) at the Bull locality dated 4,840 ± 80 yr B.P. (A−3311), and two samples from the base and top of the same unit at the Tortoise locality dated 4,770 ± 70 yr B.P. (A−3312) and 4,400 ± 190 yr B.P. (A−3313), respectively.

Site Arizona FF:10:16

Arizona FF:10:16 is located 2.8 km southeast of Double Adobe on the west side of Whitewater Draw (Fig. 1.1). Exposed in the arroyo wall is a sequence of four geologic units. The stratigraphic relations are shown in Figure 2.20*b*, and the units are described in the Appendix.

The oldest deposit at the site is a gray to grayish olive clay (unit M), which contains freshwater gastropods and the remains of antelope. This deposit is unconformably overlain by brown clays (units N2a and N2b) with soil structure. Minor erosion surfaces occur in the clay and are marked by small

Table 2.1 (*continued*)

Unit	Date[1] (yr B.P.)	Lab. No.	Material Dated	Site	Remarks
Db (cont.)	8,240 ± 960*	A−184c	Charcoal	Arizona FF:10:1 (locality 2)	Double Adobe II
	8,260 ± 160*	A−188e	Carbonaceous alluvium	Arizona FF:10:1 (locality 5)	Double Adobe I
	8,270 ± 250*	A−188c	Charcoal	Arizona FF:10:1 (locality 5)	Double Adobe I
	8,390 ± 190	A−3233	Charcoal	Arizona FF:6:9	Sulphur Spring artifacts
	8,500 ± 180	A−3230	Charcoal	Arizona FF:6:9	Sulphur Spring artifacts
	8,670 ± 340	A−3385	Charcoal	Crystal locality	Black clay (Dd) below
	8,680 ± 100*	A−189	Carbonaceous alluvium	Arizona FF:10:1 (locality 5)	Double Adobe I
	8,680 ± 240	A−3387	Charcoal	Arizona FF:10:1 (locality 5)	Dispersed
	8,760 ± 210	A−3379	Charcoal	Arizona FF:10:1 (locality 2)	Cazador type site
	8,840 ± 310	A−3377	Charcoal	Arizona FF:10:1 (locality 2)	Cazador type site
	8,970 ± 220	A−3378	Humates	Arizona FF:10:1 (locality 2)	Humates of A−3377
	8,960 ± 100*	A−189	Charcoal	Arizona FF:10:1 (locality 5)	Double Adobe I
	9,050 ± 260	A−3386	Charcoal	Arizona FF:10:1 (locality 5)	Tumbled mammoth bone
	9,120 ± 270	A−2235	Charcoal	Arizona FF:10:1	Downstream from locality 5
	9,340 ± 180	A−3238	Charcoal	Arizona FF:6:8	Sulphur Spring artifacts in this unit and below in the Da gravel
	9,350 ± 160*	A−67bis	Charcoal	Arizona FF:10:1 (locality 2)	CO_2 rerun of A−67
	10,790 ± 210	A−3380	Charcoal	Double Adobe Area	Mammoth bones
	11,320 ± 280	A−3381	Humates	Double Adobe Area	Humates of A−3380
	12,850 ± 890*	AA−269	Charcoal	Arizona FF:10:14	Underlies Sulphur Spring artifacts
Da	8,420 ± 180	A−3231	Charcoal	Arizona FF:6:9	Upper gravel—Sulphur Spring artifacts
	8,860 ± 160	A−3314	Humates	Arizona FF:6:9	Humates of A−3231
	8,650 ± 180	A−3232	Charcoal	Arizona FF:6:9	Upper gravel—Sulphur Spring artifacts
	8,920 ± 1150	Tx−1199	Charcoal	Arizona FF:10:1	Lower gravel, downstream from locality 5, associated with articulated mammoth—Sulphur Spring artifacts?
	10,420 ± 100	A−1152	Charcoal and humates	Arizona FF:10:1	Lower gravel, downstream from locality 5, associated with articulated mammoth—Sulphur Spring artifacts?
	15,100 ± 400*	AA−233	Charcoal	Arizona FF:10:14	Camel and mammoth bones

1. All dates are $\delta^{13}C$ corrected except those with *.

shallow channels filled with clayey sand. A radiocarbon date on dispersed charcoal from the base of unit N2a is 2,290 ± 190 yr B.P. (A−3181). A date of 1,430 ± 250 yr B.P. (A−3182) was obtained on charcoal from a hearth along an erosion surface separating unit N2a from unit N2b. Artifacts occurred along this surface. The clays are overlain by a brown silt to very fine sand (unit P2).

Crystal Locality

The Crystal locality is located 8.5 km southeast of Double Adobe on the west side of Whitewater Draw (Fig. 1.1). Exposed in the arroyo wall is a sequence of four geologic deposits. The stratigraphic relations are shown in Figure 2.20*a*, and the units are described in the Appendix.

The oldest deposit exposed at this locality is a bluish black clayey gleyed soil (unit Dd) with very coarse prismatic structure. This unit is very organic and characterized by large gypsum crystals. Fluvial sand and silt (unit Db) overlie and underlie unit Dd. Dispersed charcoal from the unit Db sand overlying the unit Dd clay dated 8,670 ± 340 yr B.P. (A−3385). This unit is, in turn, overlain by a brown laminated clay-silt (unit J1) of which the upper 70 cm are charac-

terized by soil development (unit J2). Charcoal from the middle of unit J1 dated 5,200 ± 120 yr B.P. (A−3384).

RADIOCARBON DATING

Fifty-five radiocarbon dates have been obtained from the late Quaternary deposits of Whitewater Draw. The dated materials include charcoal (37 samples), carbonaceous alluvium (8 samples), humates (7 samples), and calcium carbonate (3 samples).

Twelve dates are considered to be in error and are rejected. All dates derived by the solid radiocarbon method are considered unreliable. These dates (C−216, C−511, C−515, C−518, and A−67) are either too young or too old when compared with other dates obtained from the same deposits and derived by the more reliable carbon dioxide method. The three dates (SMU−128, SMU−129, and A−192a) obtained on calcium carbonate are disregarded because they consistently date older than associated dates on charcoal. This inconsistency probably resulted from the partial precipitation and exchange of dead carbon with the samples during ground-water circulation. Four dates (A−184e, A−191, A−192b, and A−193) on carbonaceous alluvium are also rejected because they are inconsistent with associated dates on charcoal.

This leaves 43 dates to provide the foundation for the absolute chronology of Whitewater Draw. Thirty-one of the 43 samples were collected by me and submitted to the University of Arizona Laboratory of Isotope Geochemistry and the Arizona-NSF Regional Accelerator Dating Facility for analysis. These samples were pretreated with hydrochloric acid to remove calcium carbonate and with sodium hydroxide to remove soluble organic contaminants. Twenty-nine samples recieved a $\delta^{13}C$ analysis to correct for carbon isotope fractionation.

Four humate samples derived from the pretreatment of charcoal were dated for comparison with the dates obtained from the charcoal. The humates from the gravel and sand (unit D) yielded dates with means that were 130 to 530 years older than their charcoal counterparts, but that were within one to two standard deviations of each other. A humate sample from the cienega clays (unit J1) yielded a date with a mean that was 450 years younger than its charcoal counterpart and that was within one standard deviation of the charcoal sample. Usually humates yield radiocarbon dates that are younger than their charcoal counterparts and older humate dates are unusual. The older humate dates indicate that older mobile organic contaminants occur in the geochemical environment of Whitewater Draw. These older organic contaminants probably made their way into the charcoal samples via the ground water that flowed through the highly permeable gravels and sand. This contamination is not a problem with the charcoal samples from Whitewater Draw that were obtained by me, because these samples received exhaustive pretreatment that removed all organic contaminants soluble in sodium hydroxide.

Table 2.1 lists all radiocarbon dates from the late Quaternary alluvial sediments of Whitewater Draw. They are grouped according to stratigraphic units and presented in order. Most of these dates have been discussed in the previous sections.

LATE QUATERNARY ALLUVIAL STRATIGRAPHY OF WHITEWATER DRAW

Based on the data previously presented, the late Quaternary stratigraphy of Whitewater Draw is outlined. Figure 2.21 is a generalized geologic cross section of Whitewater Draw showing the stratigraphic relationships of the alluvial units. Figure 2.22 shows the geologic units arranged according to stratigraphic succession and the associated radiocarbon dates.

The oldest dated upper Quaternary alluvium (unit D) in Whitewater Draw unconformably overlies a late Tertiary or early Pleistocene age basin fill (unit A) and is inset against terrace sediments (unit B) and marl (unit C) of Pleistocene age. Unit D is a massive gravel overlain by sand with interbedded silt and clay lenses. Eighteen radiocarbon dates place these deposits between 15,000 and 8,000 yr B.P.

A sandy clay (unit E) with coarse prismatic structure overlies the unit D alluvium and is dated to approximately 7,600 yr B.P. A shallow channel was incised into unit E after 7,600 yr B.P., and before 7,000 yr B.P. it became filled with a laminated and massive marl (unit F). Degradation and aggradation again occurred between 7,000 and 6,800 yr B.P., when a narrow channel was incised into the older units. This channel became filled with clay and overlain by a thick laterally extensive deposit of clay with strong soil structure (unit G). A shallow channel cut into unit G around 6,750 yr B.P. and was filled with a clayey sand (unit H).

Sometime after 6,750 yr B.P. and before 5,500 yr B.P., a large channel was incised to a depth of 4.3 m into the older deposits. It became filled with a gravel, cross-bedded sand, a fining-upward sequence of horizontally laminated very fine sand and silt, which, in turn, was overlain by a clay deposit with strong soil structure (unit I).

Four distinct periods of shallow channel incising, filling, and pedogenesis occurred between 5,500 and 3,500 yr B.P. and produced deposits J, K, L, and M. From 3,500 to 750 yr B.P. the fluvial system was characterized by continued clay and silty clay deposition and soil formation (units N and O). The period after 750 yr B.P. is characterized by the cutting and filling of small draws and the deposition of a large sheet of flood silt (unit P). The modern arroyo formed between A.D. 1885 and 1910, and an inset terrace within the channel has formed since A.D. 1953.

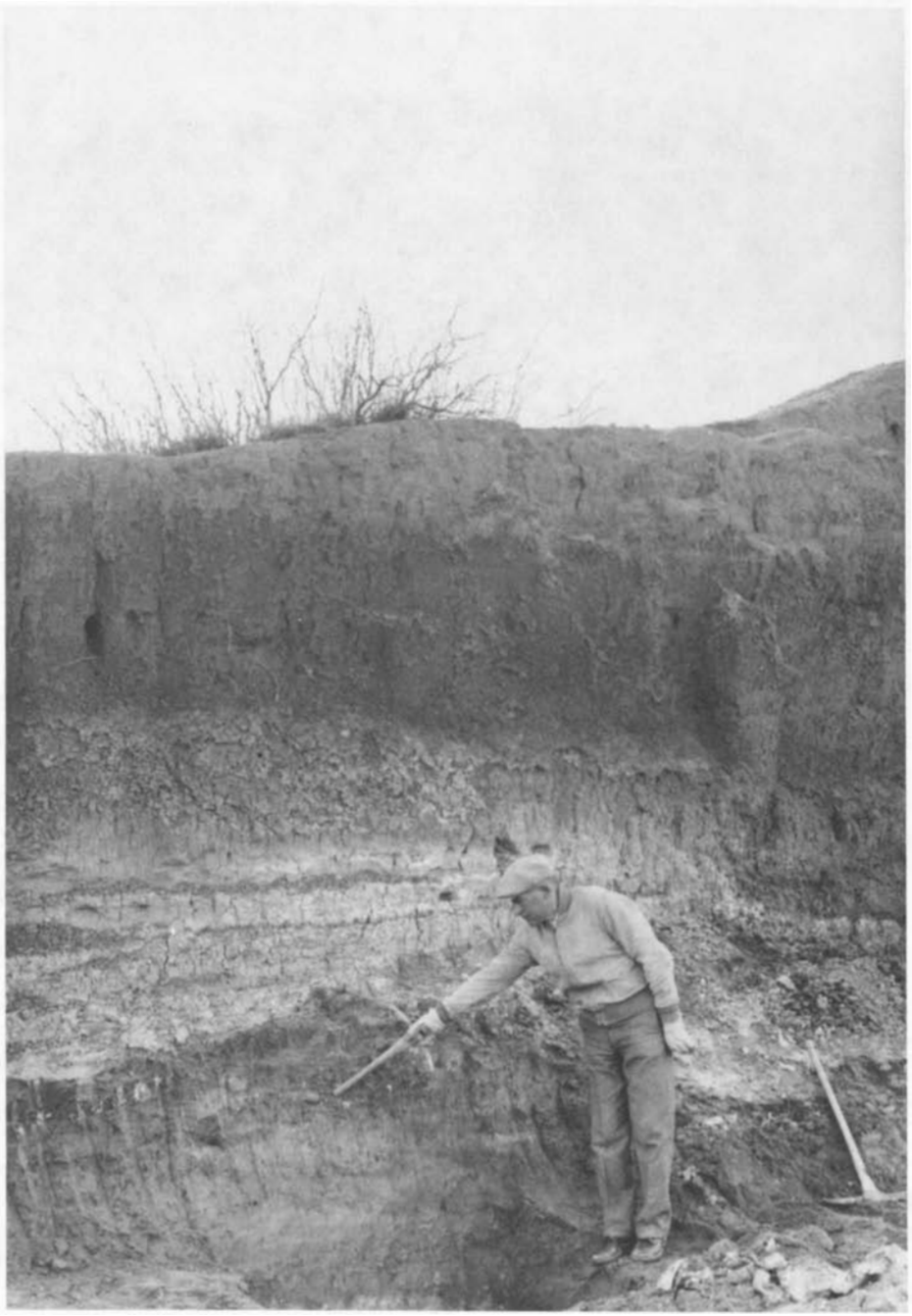


Figure 2.13. Geologist Ernst Antevs pointing to handstone in sand unit Db overlain by laminated marl unit F1 at Double Adobe. (Photograph courtesy of the Arizona State Museum, University of Arizona.)

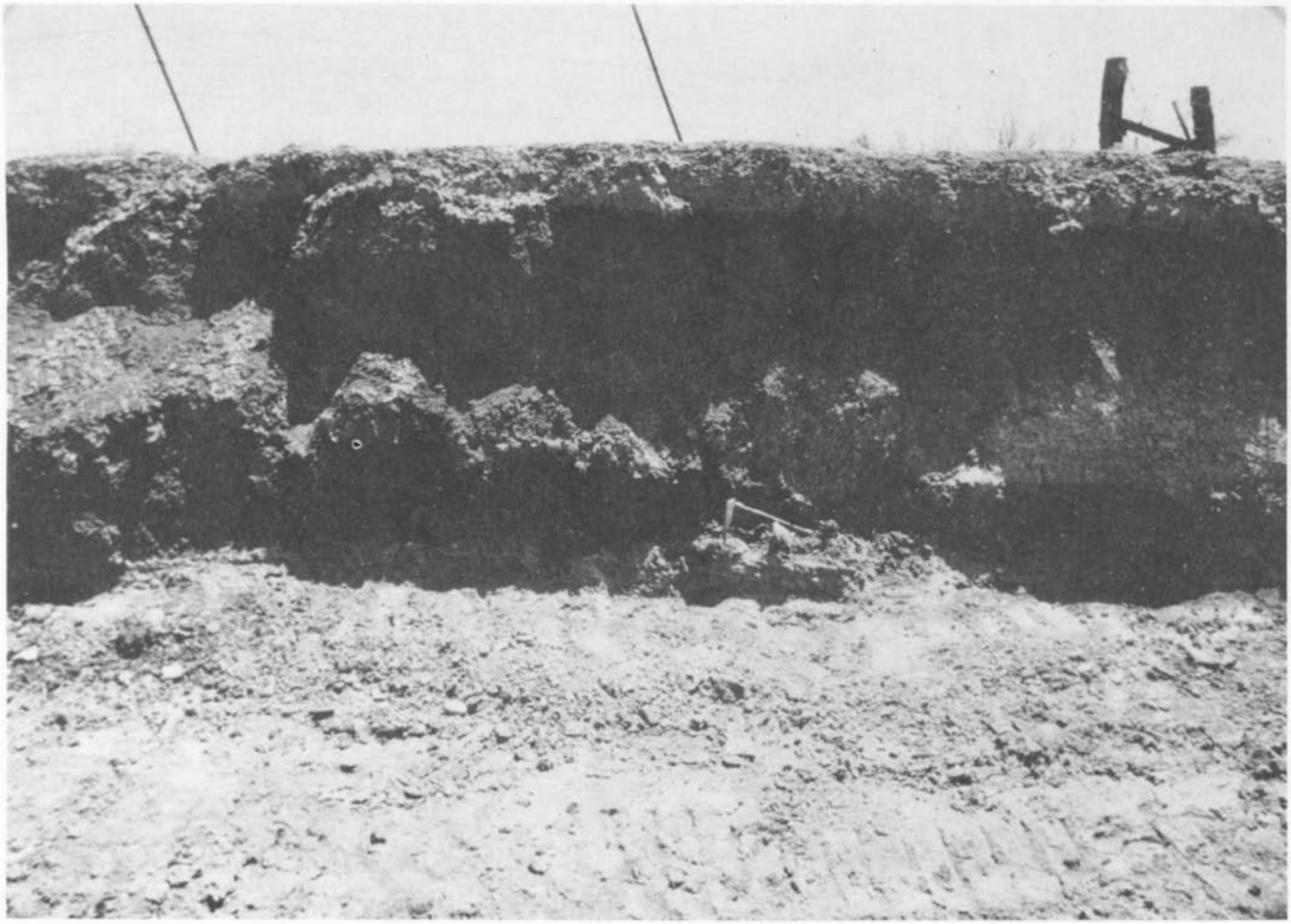


Figure 2.14. Site Arizona FF:10:13. Pick rests on base of channel filled with clay unit M.

LATE QUATERNARY ALLUVIAL DEPOSITIONAL ENVIRONMENTS OF WHITEWATER DRAW

The Late Quaternary sediments of Whitewater Draw were deposited in three different fluvial environments. Each of these fluvial environments is distinguished by a different channel morphology and deposit. The first type is characterized by massive gravel and sand deposits with no distinct channels, the second by fine-grained sediments deposited in shallow channels, and the third by gravel and sand deposition in a deep channel.

The first type of fluvial deposit consists of a massive gravel overlain by sand with interbedded silt and clay lenses. The sand and gravel intertongue along their contact and distinct channels are absent. Massive clay deposits fill abandoned shallow channels within the highly permiable gravels. These deposits are designated unit D and radiocarbon analyses place these deposits between 15,000 and 8,000 yr B.P.

These sediments were deposited in a braided stream that shifted position over a 0.65 km-wide floodplain (Fig. 2.23). The presence of massive clay deposits in the permeable gravels and the occurrence of cottonwood and hickory charcoal in the sand and gravel deposits indicate an associated high water table. Periods of reduced flow are documented by the deposition of silt and clay in charcos or small ponds in the sandy channel. This stream appears to have been relatively stable vertically and it maintained a constant base level as indicated by the absence of channeling and gravel overlying sand.

The second type of fluvial environment is distinguished by the deposition of fine-grained sediments (silts and clays) in narrow shallow channels. Typically, laminated to massive deposits of clay and silt, commonly with carbonized plant remains along laminations, fill the channels. These are overlain by massive, more laterally extensive clay and silty clay deposits with soil structure. These deposits dominate the Whitewater Draw alluvial sequence and are typified by units E, F, G, H, J, K, L, M, N, and O, ranging in age from 7,630 ± 280 yr B.P. (A−3382) to 1,430 ± 250 yr B.P. (A−3182). These sediments appear to have formed in the thalweg plunge

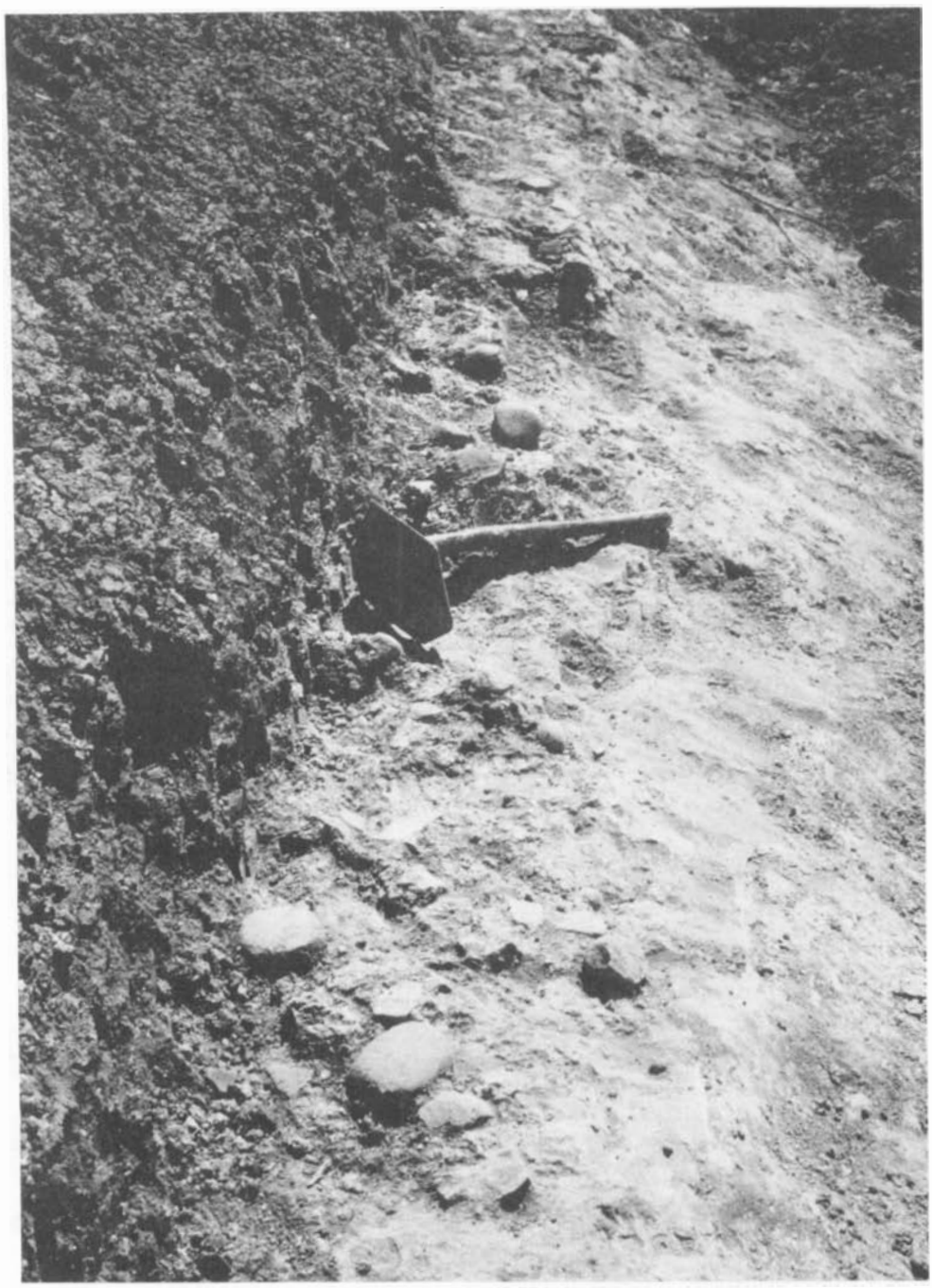
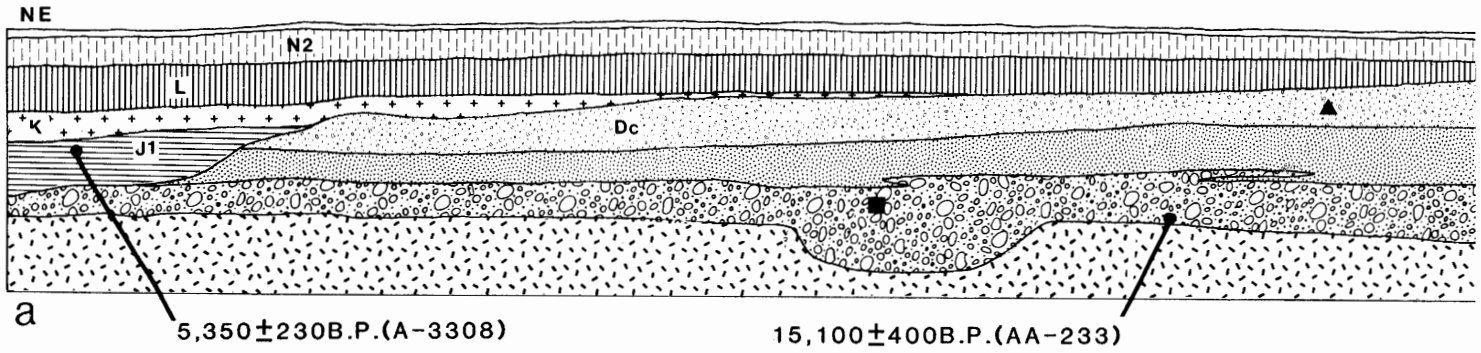
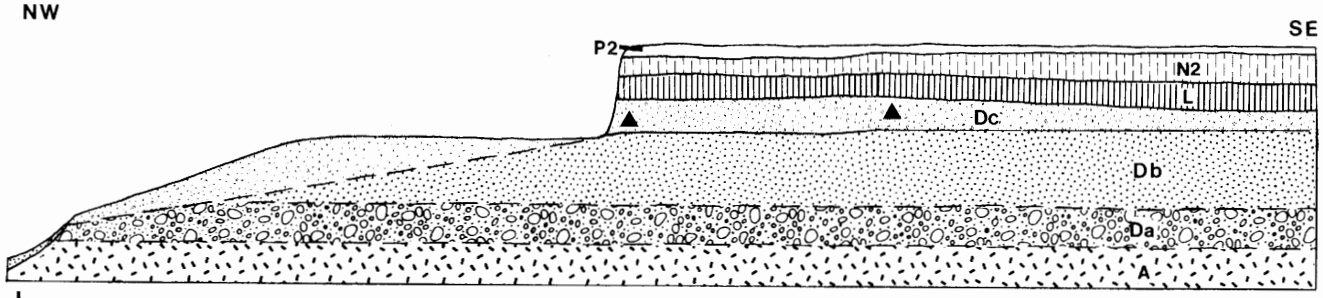


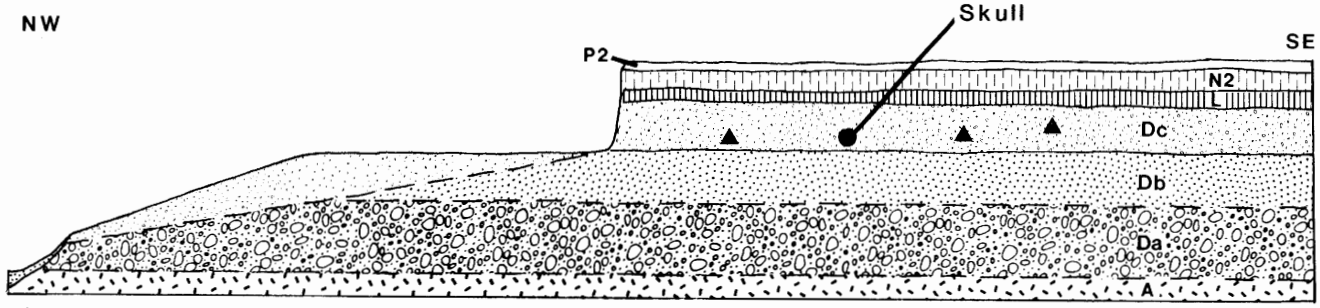
Figure 2.15. Artifacts within clay unit M on contact with sand unit Db at site Arizona FF:10:13.


NE
N2
L
K
J1
Dc
5,350±230B.P.(A-3308)
15,100±400B.P.(AA-233)

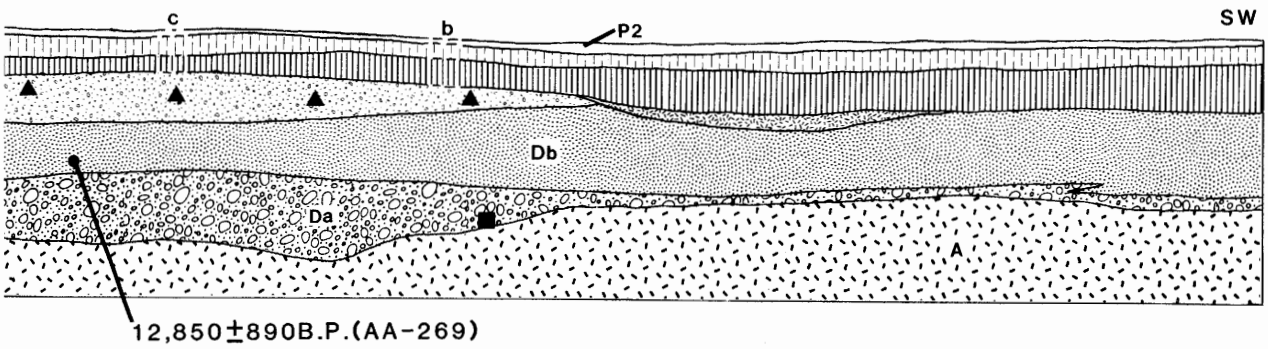
a

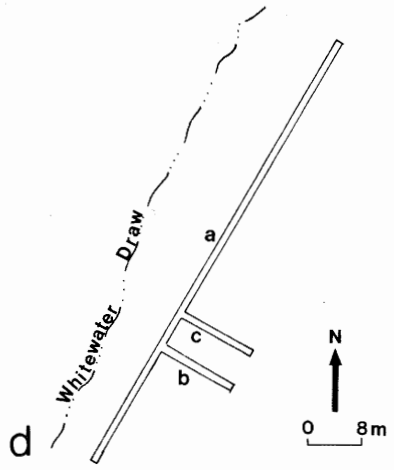

NW
SE
P2
N2
L
Dc
Db
Da
A

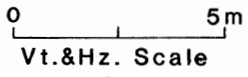
b


NW
Skull
SE
P2
N2
L
Dc
Db
Da
A

c







▲ Artifacts

■ Megafauna

● Radiocarbon-dated samples

Figure 2.16. Geologic cross sections of site Arizona FF:10:14: *a,* stratigraphy of main trench; *b, c,* stratigraphy of side trenches; *d,* trench layout. Explanation: gravel, unit Da; sand, unit Db; silty sand, unit Dc; silt, unit P2; clay-silt, unit J1; clay, units A, K, L, and N2.

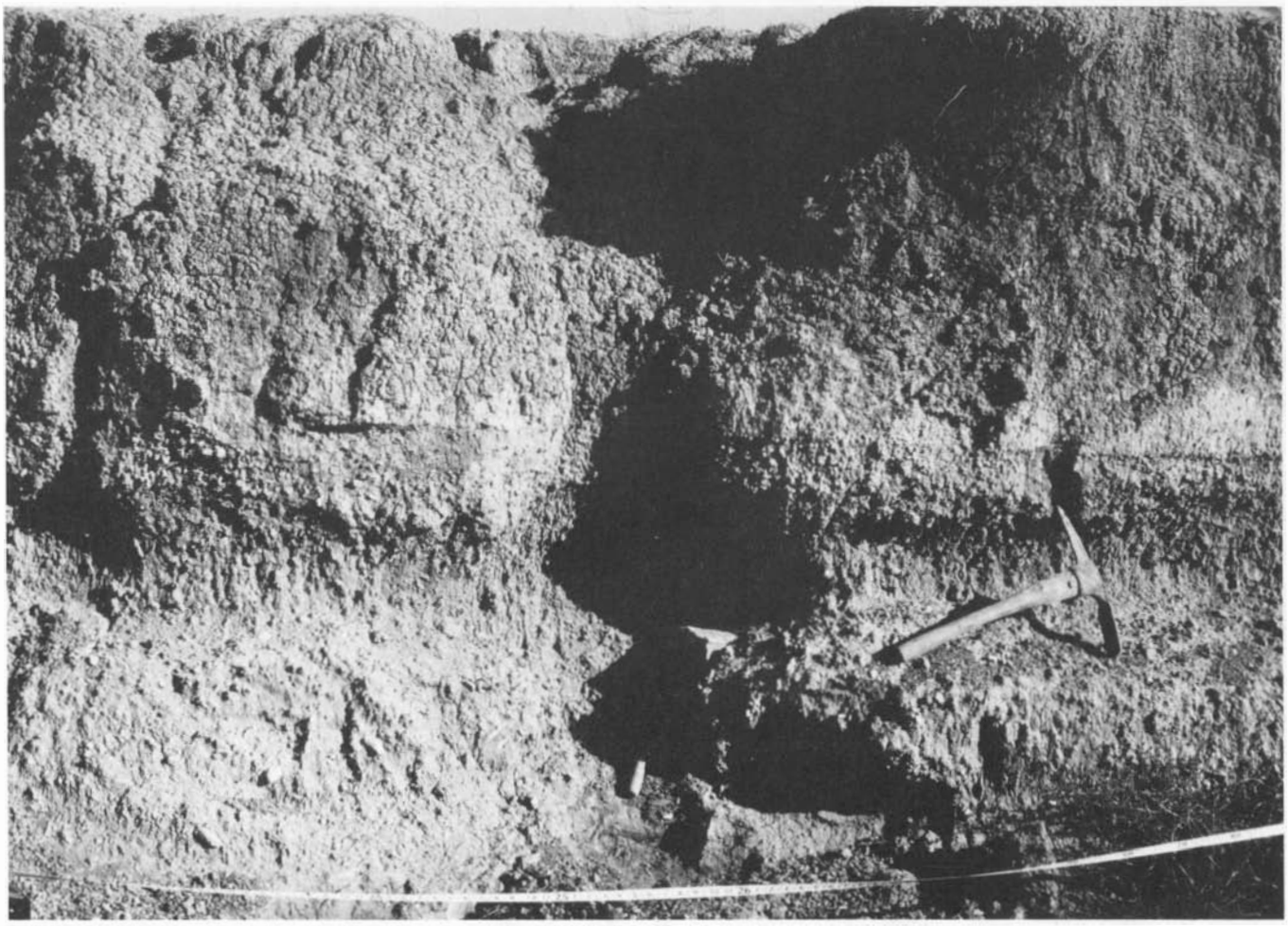


Figure 2.17. Milling stone (*center*, left of pick handle) in situ within the calcareous silty sand unit Dc.

pools or highly vegetated shallow channels flowing within a cienega.

A cienega is a heavily vegetated marsh formed in a shallow basin (Fig. 2.24; Melton 1965; Hendrickson and Minckley 1984). Modern cienegas, for example the San Simon cienega on the Arizona–New Mexico border, extend over 8 km in length and 1 km in width (Wasley 1983; Antevs 1983). Water is supplied to the cienega by springs and seeps and it travels sluggishly through shallow vegetated channels (Fig. 2.25). Only fine-grained sediments are deposited in a cienega because vegetation on the cienega margin filters the sediments derived from the adjacent slopes and removes the coarse fractions. Therefore, the laminated sediments are the pool-channel facies and the overlying massive clays with soil structure are the broad wet meadow facies of a cienega. Pedogenesis occurred under saturated conditions and resulted in gleyed soils.

The extent of these former cienegas is poorly known because of the lack of exposure and the numerous periods of erosion during which older deposits could have been destroyed. The cienegas appear to have been confined to the northern portion of Whitewater Draw, based on the distribution of the fine-grained sediments. Beyond a point 11 km southeast of Double Adobe, few cienega deposits are exposed in the modern arroyo channel. On a finer scale, the former extent of the Holocene cienegas can be estimated from the distribution of the distinctive unit J clay-silt deposit. This unit is found intermittently along an 11-km length of the arroyo and has provided similar dates at either end. Most of the other cienega deposits can be traced over distances of at least 3 km to 4 km. The distribution of the alluvial deposits indicates that former Holocene cienegas were larger than or at least as large as modern cienegas.

Antevs (Sayles and Antevs 1941; Antevs 1952, 1983)

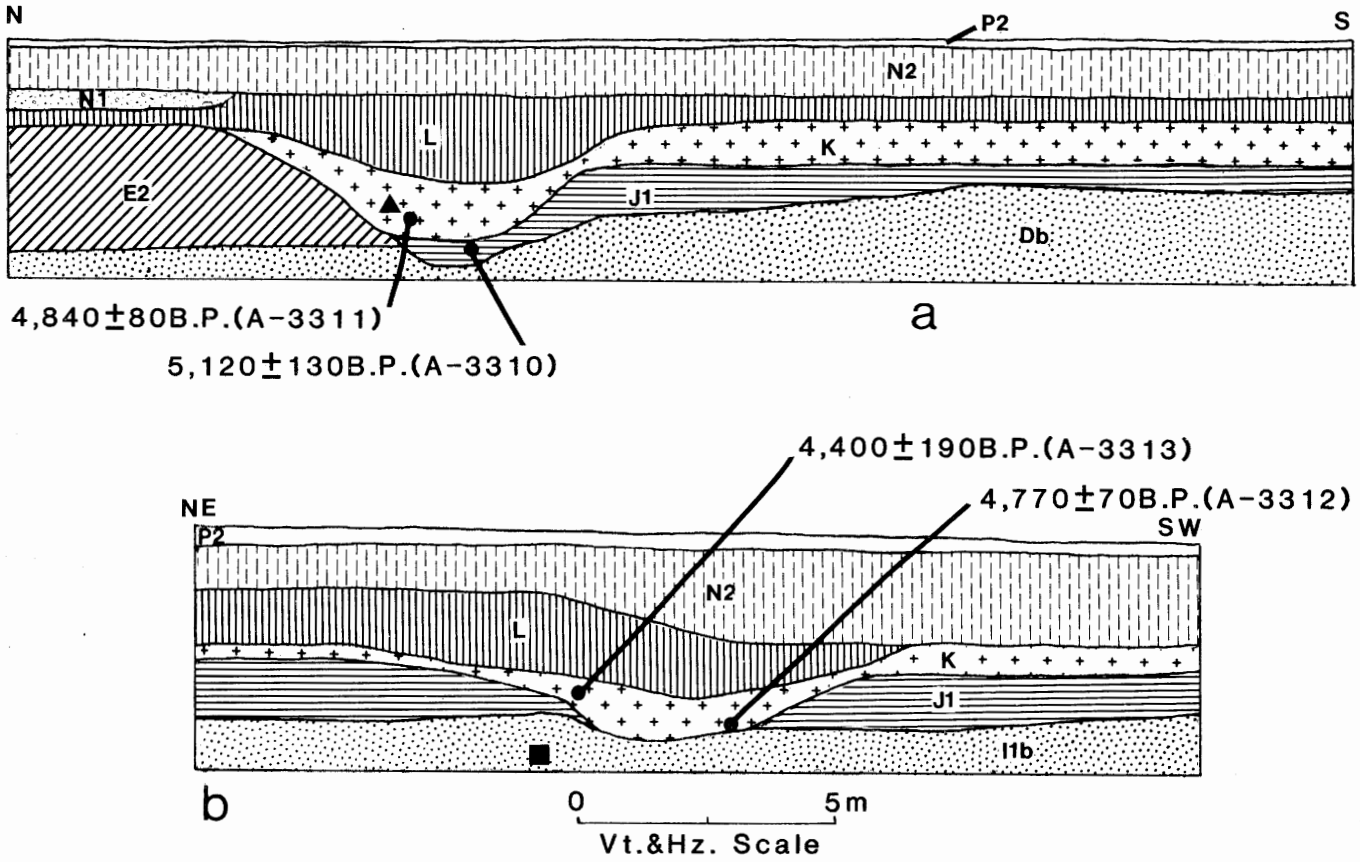


Figure 2.18. Geologic cross section of Bull locality (*a*) and Tortoise locality (*b*). Explanation: sand, units Db and I1b; silty sand, unit N1; silt, unit P2; clay-silt, unit J1; sandy clay, unit E2; clay, units K, L, and N2. Solid triangles represent artifacts, solid square represents megafaunal remains.

suggested an alternative hypothesis for the deposition of fine-grained sediments in these shallow channels. He noted that sedimentation could have occurred in discontinuous ponds formed behind beaver dams that were built across a through-flowing stream. This suggestion is based on the fact that there were probably no natural obstructions along the course of the stream, that the area would have been ideal beaver habitat, and that beaver were trapped historically from the San Pedro River. This idea, however, remains an unsupported hypothesis because no beaver skeletal remains have been found in the sediments of Whitewater Draw.

The third type of fluvial environment is characterized by the deposition of gravel and cross-bedded sand in a deep channel cut to a depth of 4.35 m. The major portion of the deposition in the channel appears to have occurred rapidly during large floods. These deposits became capped by laminated clastic sediments and a clay cienega deposit. These deposits are designated unit I and cutting and filling occurred sometime between 6,750 and 5,500 yr B.P. The extent of this deposit is poorly known but it has been found at three localities over a distance of 1.5 km. This deposit probably represents deposition in an ephemeral discontinuous arroyo.

Whitewater Draw is now an arroyo that was cut during the late nineteenth century. The modern streambed alluvium consists of gravel and sand.

DEGRADATION AND AGGRADATION IN WHITEWATER DRAW

The alluvial record of Whitewater Draw contains numerous cutting and filling events. The major shifts in depositional environments recognized in Whitewater Draw—changes from a braided stream, to a cienega environment, to an arroyo, and back to a cienega environment—appear to

Figure 2.19. Tortoise locality. Shovel rests on clay unit L, filling shallow channel. Dark unit below is clay unit K. Clay-silt unit J1 is shown in the corners below unit K. Units N2 and P2 overlie these units.

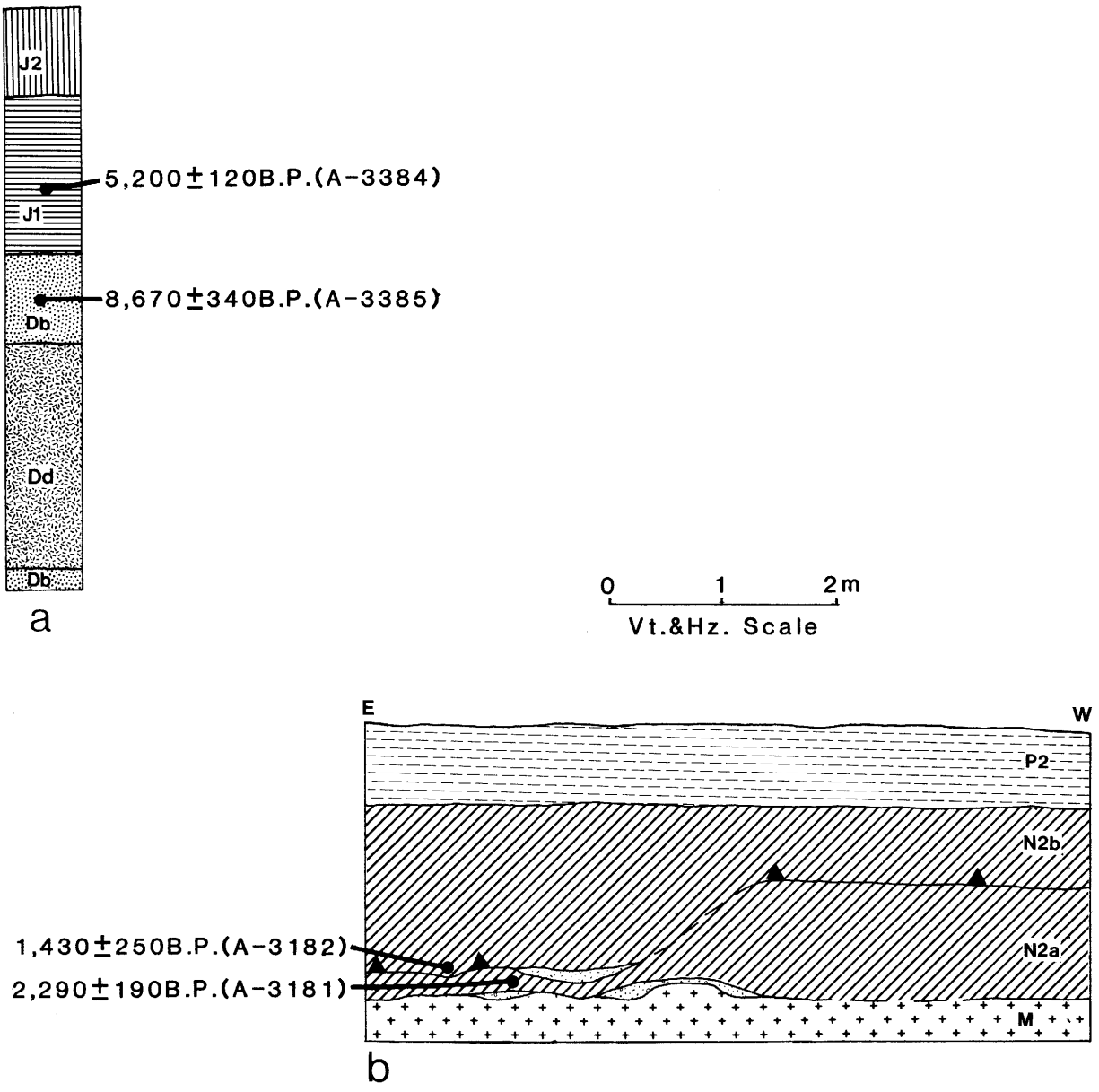


Figure 2.20. Stratigraphy of Crystal locality (*a*) and geologic cross section of site Arizona FF:10:16 (*b*). Explanation: sand, unit Db; silt, unit P2; clay-silt, unit J1; clay, units Dd, J2, M, N2a, and N2b.

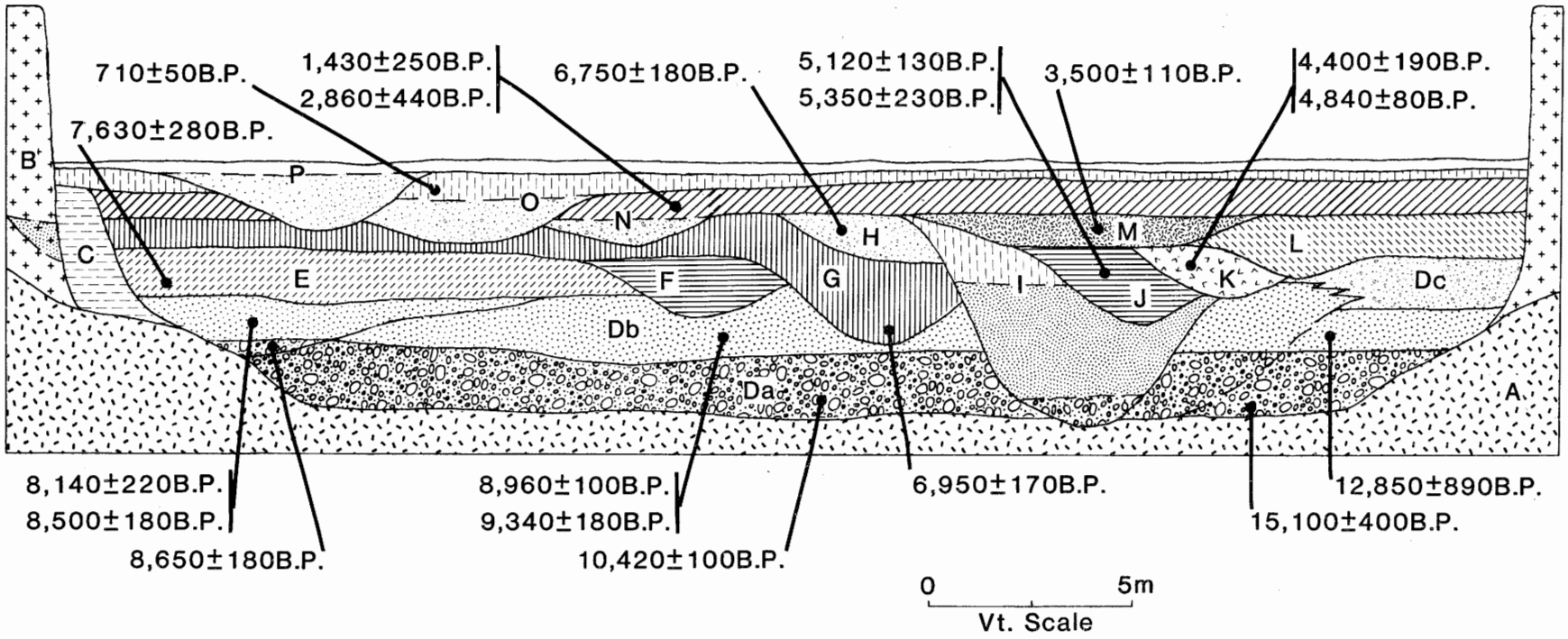


Figure 2.21. Generalized composite geologic cross section of Whitewater Draw, Arizona. Explanation: A, pink clay; B, terrace gravel, sand, and clay; C, marl; Da, gravel; Db, sand; Dc, silty sand; E, clayey sand to silty clay; F, marl; G, clay and silt; H, clayey sand; I, gravel, sand, silt, and clay; J, clay-silt and clay; K, clay; L, clay; M, clay; N, silty sand and clay; O, silty sand and silty clay; P, silty sand and silt.

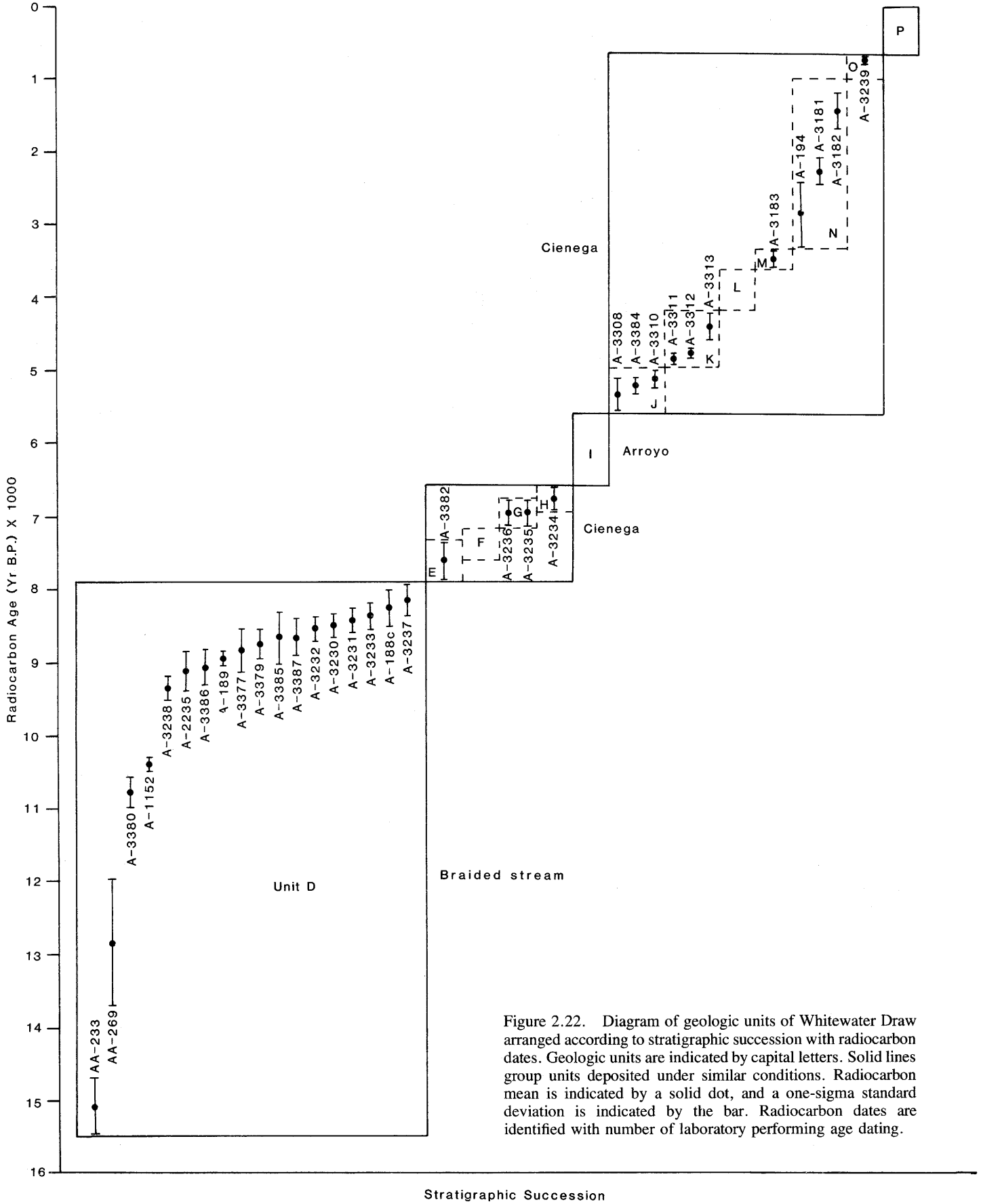


Figure 2.22. Diagram of geologic units of Whitewater Draw arranged according to stratigraphic succession with radiocarbon dates. Geologic units are indicated by capital letters. Solid lines group units deposited under similar conditions. Radiocarbon mean is indicated by a solid dot, and a one-sigma standard deviation is indicated by the bar. Radiocarbon dates are identified with number of laboratory performing age dating.

Figure 2.23. Modern braided stream in southeastern Arizona. This could be an approximate analog of the conditions existing from 15,000 to 8,000 yr B.P., in the Douglas basin.

correlate with major climatic perturbations documented by paleoecologists. However, the complex degradation and aggradation documented during apparently stable climatic periods must have been dominantly controlled by geomorphic parameters. Modern arroyo cutting could have been human induced, although this is debatable.

The deposition of gravel and sand in a braided stream from 15,000 to 8,000 yr B.P. corresponds to the mesic conditions defined by Spaulding, Leopold, and Van Devender (1983) for the Southwest during this time. These paleoecologists, through the study of packrat middens, have suggested that prior to 8,000 yr B.P. the Sonoran and Chihuahuan desert climate was characterized by decreased summer but increased winter precipitation, and milder winter but cooler summer temperatures. Because the Douglas basin lies on the edges and between these two deserts, similar conditions are presumed to have prevailed in the Douglas basin. If so, braided stream deposition from 15,000 to 8,000 yr B.P. in the Douglas basin appears to correlate with the mesic conditions of the late Pleistocene and early Holocene.

Deposition in cienegas dominates the alluvial record of Whitewater Draw after 8,000 yr B.P. Numerous cycles of erosion and deposition are documented between 8,000 and 6,750 yr B.P. and from 5,500 yr B.P. to the historic period. This change in depositional environments corresponds to the introduction and persistence of the modern arid desert climatic pattern. Paleoecologists (Spaulding, Leopold, and Van Devender 1983) have suggested that after 8,000 yr B.P. modern airflow circulation and precipitation patterns were emplaced. Therefore, the replacement of the braided stream environment by a cienega depositional environment appears to correlate with the introduction of semiarid conditions at 8,000 yr B.P.

The only interruption in the cycles of erosion and deposition in cienegas after 8,000 yr B.P. was the middle Holocene arroyo cutting and filling episode. In the Douglas basin an

Figure 2.24. Modern cienega in southeastern Arizona. This could be an approximate analog of the cienega conditions documented in the Douglas basin after 8,000 yr B.P.

arroyo was cut to a depth of 4.3 m after 6,750 yr B.P. and filled with clastic alluvium and a cienega clay before 5,500 yr B.P. This arroyo cutting and filling event correlates to a regional climatic perturbation defined by Antevs (1955, 1983; Sayles and Antevs 1941) as a time of greater aridity, known as the Altithermal.

Therefore, major shifts in the environments of deposition recorded in the alluvial record of Whitewater Draw appear to correspond with large scale climatic changes documented by paleoenvironmental evidence. However, there is no correlation between climate and the numerous cycles of degradation and aggradation documented by the cienega deposits. There were four cycles of erosion and cienega deposition between 8,000 and 6,750 yr B.P., four cycles between 5,500 and 3,500 yr B.P., and many other cycles of erosion and deposition through the historic period. Therefore, a geomorphically dominated explanation (for example, complex response, crossing of intrinsic geomorphic thresholds) for this observed cutting and filling seems more plausible than a climatic explanation as suggested by Schumm (1977) and Patton and Schumm (1981).

The cienega depositional environment is inherently unstable, and invoking climatic changes to account for cutting and filling is unnecessary. Erosion and deposition could result from the crossing of intrinsic geomorphic thresholds with no change in external geomorphic variables (for example, climate; Schumm 1977). The following hypothetical model (Fig. 2.26) is presented to show how such cutting and filling might occur: (1) a shallow, highly vegetated channel flows through the central portion of a cienega; (2) fine-grained sediments become deposited in the channel and eventually fill it; (3) with the channel filled, deposition of fine-grained sediment continues over the channel and in the marginal areas of the cienega, because water is no longer confined to the channel and it flows over the area as a shallow sheet; (4) sediment continues to accumulate, soil formation occurs

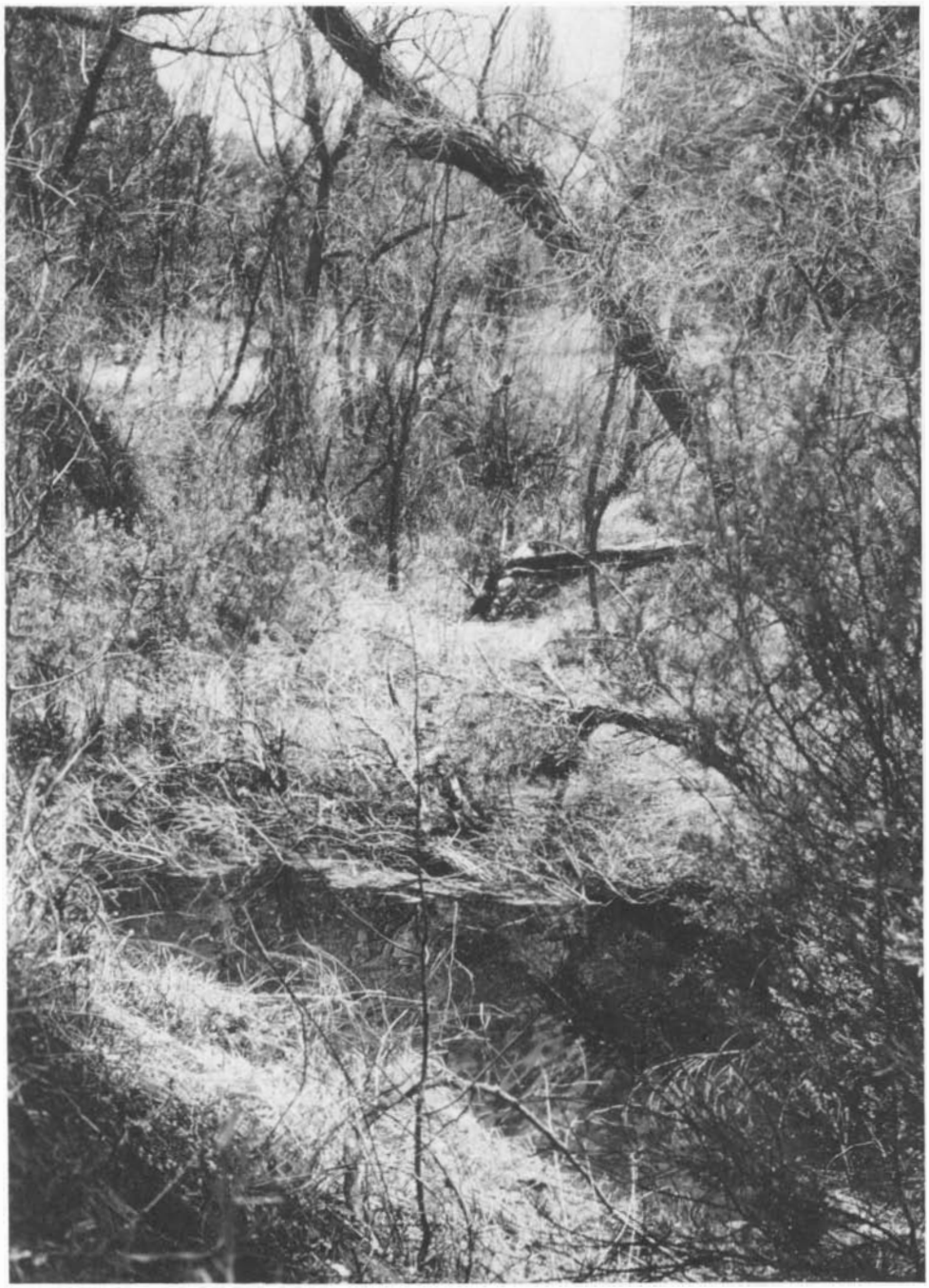


Figure 2.25. Highly vegetated channel flowing through a cienega in southeastern Arizona.

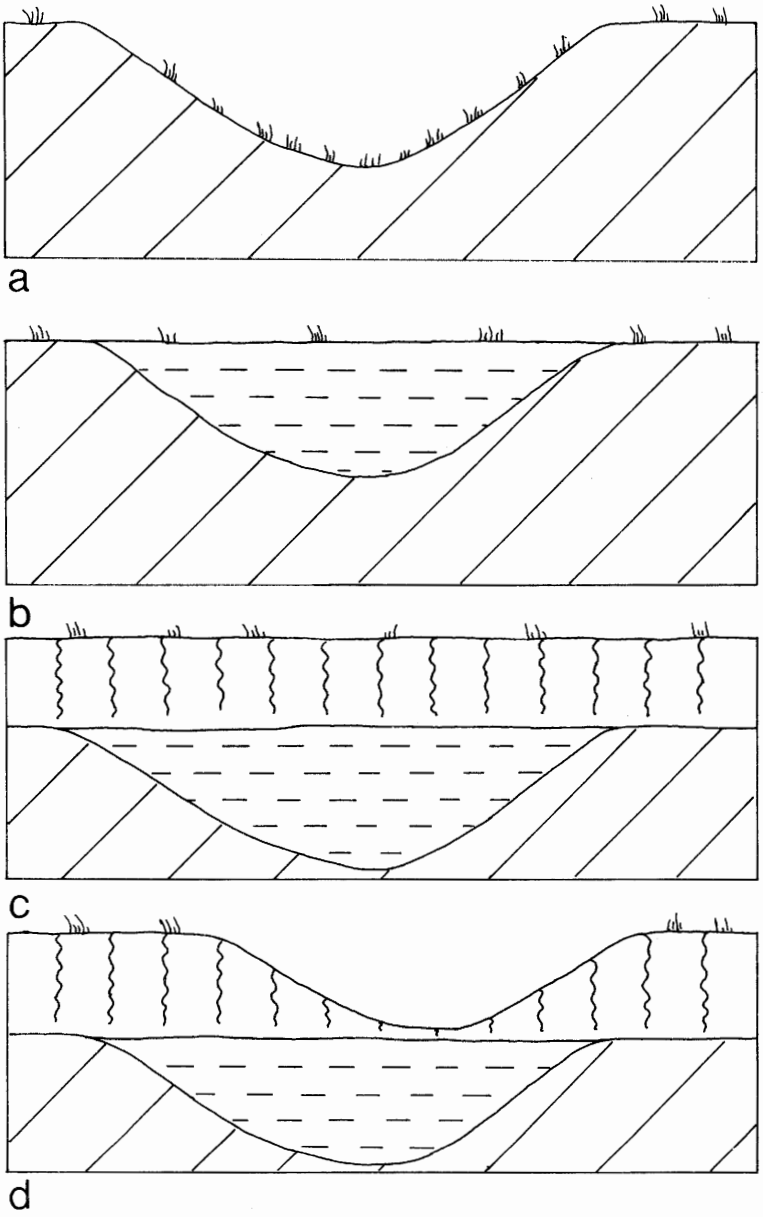


Figure 2.26. Geomorphic explanation for degradation and aggradation in a cienega: *a,* a shallow, highly vegetated channel flows through the central portion of a cienega; *b,* fine-grained sediments become deposited in the channel and eventually fill it; *c,* with the channel filled, deposition of fine-grained sediment continues over the channel and in the marginal areas of the cienega, because water is no longer confined to the channel and it flows over the area as a shallow sheet. Sediment continues to accumulate and soil formation occurs under saturated conditions. The sediment accumulation becomes increasingly unstable as the gradient steepens; *d,* cutting is initiated as a result of the oversteepening and migrates through the cienega. The process then begins again.

under saturated conditions, and the sediment accumulation becomes increasingly unstable as the gradient steepens; (5) cutting is initiated as a result of the oversteepening and migrates through the cienega, and the process begins again. The crossing of intrinsic geomorphic thresholds, perhaps slope as in this simplistic example, might be responsible for the cutting observed. Alternatively, the cutting may be the result of a complex fluvial response (Schumm 1977) to changes in the downstream reach of the stream. Regardless of what the true cause is (which we may never be able to determine with absolute certainty), it may be seen that cutting and filling can occur by crossing intrinsic geomorphic thresholds without changing external geomorphic variables such as climate. In short, climatic changes need not be introduced to account for the cutting and filling documented by the cienega deposits of Whitewater Draw. Cutting and filling epicycles are an expected part of the cienega depositional system.

Historic arroyo cutting in the Douglas basin has been interpreted to have been human induced (Sayles and Antevs 1941; Antevs 1983). Few precise data are available on the development of the modern arroyo, but what is known is summarized by Meinzer and Kelton (1913) and Cooke and Reeves (1976). Prior to A.D. 1885, Whitewater Draw lacked a channel; it was a draw, a shallow subtle depression that was mostly grass covered and it expanded out to mudflats and cienegas. Whitewater Draw was transformed into an arroyo beginning in 1885 and entrenchment was largely completed before 1910. The cause of the entrenchment is unclear, but Antevs (Sayles and Antevs 1941; Antevs 1952, 1983) believed it was the result of overgrazing, vegetation change, and a consequent increase in runoff. Evidence for this idea is circumstantial and this interpretation is controversial (Cooke and Reeves 1976).

In subsequent years there has been slight headward erosion of the arroyo into the area south of Elfrida, tributary headcutting, and a widening of the channel. Since 1953, the arroyo has filled with up to 1 m of clastic alluvium and a narrow channel has incised into the fill leaving a bench or terrace in the arroyo channel. This aggradation and degradation may be an example of a fluvial complex response as defined by Schumm (1977).

In conclusion, the late Quaternary alluvial history of Whitewater Draw supports the belief of Patton and Schumm (1981) that the major components of an alluvial record will reflect climatic shifts, but that the details of the record are the result of geomorphic parameters.

LATE QUATERNARY ALLUVIAL STRATIGRAPHY OF THE UPPER SAN PEDRO VALLEY

The alluvial stratigraphy at the Murray Springs and Lehner archaeological sites, located on tributary arroyos of the upper San Pedro River (Fig. 1.1), has been described by Haynes (1968, 1981, 1982a). Other tributary arroyos in the region record a similar succession of alluvial sediments and this stratigraphy, for the most part, is also considered by Haynes (1968, 1981) to characterize the upper San Pedro River that drains an area in excess of 3,800 square kilometers south of the Murray Springs site. Over 74 stratigraphically controlled radiocarbon dates have been obtained from the Murray Springs site and a large number have also been obtained from the Lehner site (Haynes 1981, 1982a). The following discussion summarizes the alluvial stratigraphy at the Murray Springs site and is based on Haynes (1981). A similar succession of deposits was exposed at the Lehner site (Haynes 1982a).

The oldest deposit at Murray Springs, of interest to this discussion, is the Coro marl (Qco), which was deposited in a spring fed pond or marsh from 30,000 to 13,000 yr B.P. Between 13,000 and 11,000 yr B.P., a small shallow tributary channel was entrenched and became filled with sand and gravel (Graveyard sand, Qgr). Deposition of the Clanton clay (Qcl), a cienega deposit, followed between 10,800 and 9,700 yr B.P. This was followed by reactivation of the graveyard channel between 9,000 and 8,000 yr B.P. After this time, between 8,000 and 7,000 yr B.P., tributary valleys became filled with the Donnet silt (Qdo), an eolian and slope wash deposit. Sometime between 7,000 and 6,000 yr B.P. an arroyo channel was cut, and between 6,000 and 4,000 yr B.P. it became filled with the Weik alluvium (Qwk), a gravel and sand overlain by pond clays and a gray cienega soil. At least three more periods of arroyo cutting and filling occurred after 4,000 yr B.P., but before the modern arroyo cutting of the 1880s. These periods of arroyo cutting and filling are documented by the Hargris (Qha) and McCool (Qmc) alluvium.

CORRELATIONS

The alluvial record of Whitewater Draw may be compared on a specific level with the alluvial sequence for the Murray Springs (Fig. 2.27) and Lehner sites in the adjacent San Pedro Valley, Arizona (Haynes 1981, 1982a) and at a general level with Haynes's (1968) alluvial chronology for the West. At both levels, the correlation is poor. The alluvial records of the Murray Springs and Lehner sites are characterized by much more arroyo cutting and filling and fewer periods of cienega deposition. Further, most of the periods of degradation and aggradation recorded in the San Pedro Valley are out of phase in number, character, and timing in comparision to the alluvial history of Whitewater Draw. The only exception is the rough correlation of the middle Holocene arroyo cutting event that occurred in the Douglas basin with one that occurred in the San Pedro Valley.

In the Douglas basin an arroyo was cut to a depth of 4.3 m after 6,750 yr B.P. and filled with clastic alluvium and a cienega clay (unit I) before 5,500 yr B.P. At the Murray Springs site in the adjacent San Pedro Valley, an arroyo was

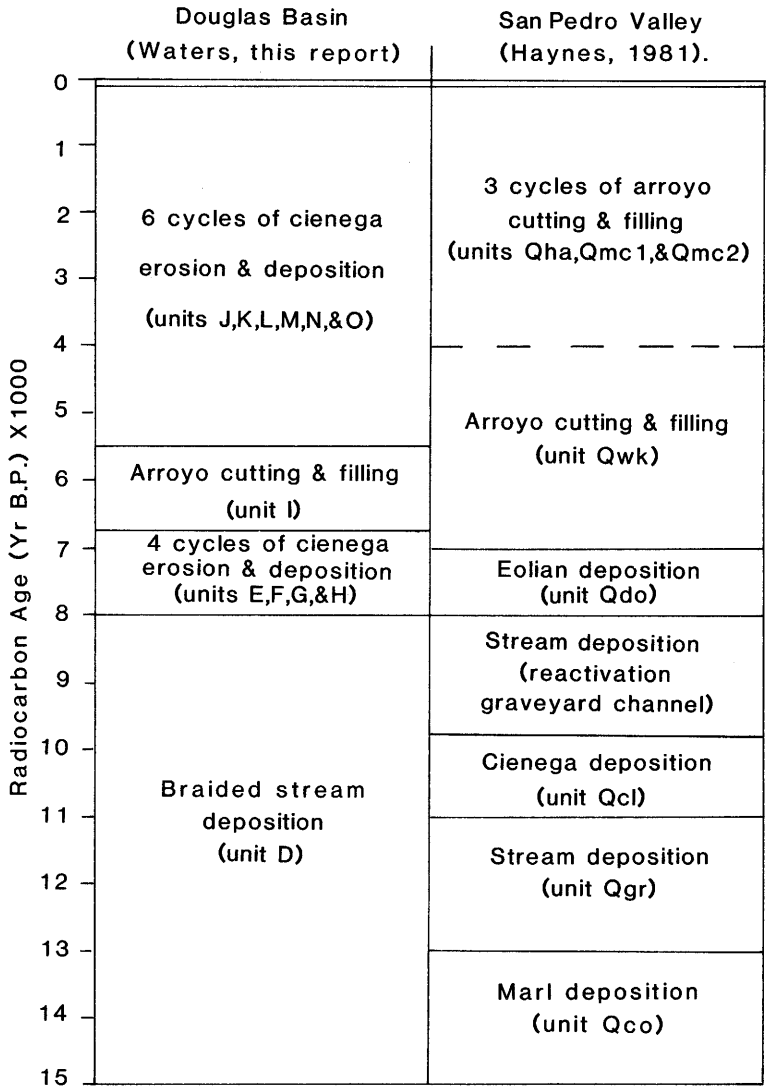


Figure 2.27. Comparison of the alluvial sequence for Whitewater Draw with the alluvial sequence for the Murray Springs site in the San Pedro Valley, Arizona.

cut to a depth of 4.5 m between 7,000 and 6,500 yr B.P. and was filled with clastic alluvium and a cienega clay (Weik alluvium, Qwk) between 6,000 and 4,000 yr B.P. (Haynes 1981). A similar event took place at the Lehner site in the San Pedro Valley and is evidenced by the deposition of unit G1 at this site (Haynes 1982a). The Douglas basin and the San Pedro Valley were affected similarly at this time; both had arroyos cut to similar depth and both became filled with a similar type of alluvium at approximately the same time. This event is noted by Haynes (1968) on a regional scale in the West and correlates with unit C2 of his generalized alluvial chronology.

With the exception of this similarity, the differences between the alluvial records of the upper San Pedro Valley and the Douglas basin indicate that the fluvial systems in the two valleys responded differently to external climatic perturbations, presumably because of local unique geomorphic controls. Also, in some cases the fluvial systems in the Douglas basin and the San Pedro Valley might not have been responding to changes in external variables, but instead were independently crossing intrinsic geomorphic thresholds peculiar to each basin, thus accounting for differences in the alluvial records of the two adjacent valleys.

Comparisons between the alluvial record of the Douglas basin and the San Pedro Valley also demonstrate that regional correlation of late Quaternary alluvial units from one valley to the next without absolute dating control should not be attempted. Such correlations commonly are made by

presuming that the fluvial systems in adjacent or nearby valleys responded similarly to external climatic changes that influenced sedimentation and erosion in both drainages equally. This assumption does not take into consideration intrinsic geomorphic variables that may influence the response of the fluvial system in a particular valley. Also, changes may occur independently from one valley to the next without any changes in external variables. Therefore, the correlation of alluvial deposits from one valley to the next must take into consideration the complexity of fluvial processes. In conclusion, comparison of the alluvial stratigraphic record of Whitewater Draw with the alluvial record for the adjacent upper San Pedro River supports the belief of Patton and Schumm (1981) and Begin and Schumm (1984) that degradation and aggradation in the West may not have been synchronous because of geomorphic parameters and that intervalley correlation of late Quaternary alluvial deposits without absolute dating control is problematical.

CHAPTER THREE

Pleistocene Extinctions and Palynology in Whitewater Draw

PLEISTOCENE EXTINCTIONS

The remains of six genera of extinct Pleistocene megafauna, mammoth (*Mammuthus*), horse (*Equus*), camel (*Camelops*), dire wolf (*Canis dirus*), sloth (*Nothrotherium*), and bison (*Bison*), have been recovered from the upper Quaternary deposits of Whitewater Draw (Sayles and Antevs 1941; Antevs 1983; Haury 1960). They have been found in six separate geologic units dating from the late Pleistocene to approximately 7,000 yr B.P. (Fig. 3.1, Table 3.1). These include the terrace deposits (unit B), white clay (unit C), gravel (unit Da), sand (unit Db), laminated marl (unit F1), and massive marl (unit F2).

The early Holocene occurrences of megafauna in Whitewater Draw conflict with the accepted date for late Pleistocene extinctions in North America. Traditionally, the maximum accepted date for megafaunal extinctions has been placed at 11,000 yr B.P. (Martin 1967). A reevaluation of the radiocarbon evidence, however, suggests that these extinctions could have taken place as late as 10,000 yr B.P. but not more recently (Kurtén and Anderson 1980; Meltzer and Mead 1983). Whalen (1971) has advanced two explanations to account for the early Holocene occurrence of extinct fauna in Whitewater Draw. He postulated that the evidence could be interpreted to suggest that either relict megafaunal populations survived in selected congenial environments beyond the terminal date ascribed for the extinctions, or the fossil remains are older than the deposits in which they occur and have been redeposited from older alluvial units. Two criteria were used to evaluate these hypotheses: radiocarbon dates associated with bone, with reference to the ascribed date for extinctions, and the articular nature of the bones associated with these dates.

Disarticulated mammoth, sloth, and horse bones occur in shallow channel sediments within the terrace deposits (unit B). Mammoth and horse bones have also been found scattered in the white clay (unit C). The terrace deposits and the white clays are undated, but the oldest radiocarbon date from the overlying gravel (unit Da), which is inset against these units, places a minimum age on them of 15,100 ± 400 yr B.P. (AA−233). These units surely date to the Pleistocene and thus should be expected to contain the bones of extinct fauna.

Mammoth, horse, camel, dire wolf, and bison bones have been recovered from the unit Da gravel and unit Db sand in the Double Adobe site area (Arizona FF:10:1) and at site Arizona FF:10:14 (Sayles and Antevs 1941; Antevs 1983). The mammoth and camel bones found in the gravel at the latter site pose no problem because they are associated with a date of 15,100 ± 400 yr B.P. (AA−233). Most fossils from the unit Da gravel and unit Db sand have been collected from the Double Adobe area. Most of the bones are isolated finds (Fig. 3.2), but two finds of articulated remains have been reported: (1) Haury (1960) recovered articulated leg bones of a camel in the sand from which Sulphur Spring artifacts had previously been recovered, and (2) Windmiller (1970) uncovered the remains of a single mammoth in gravel (unit Da) 240 m downstream from locality 5 at Arizona FF:10:1 (Fig. 3.3). At the second locality, two lumbar vertebrae were found in normally articulated position and the humeri and ulnae were close together, with the remainder of the bones scattered in the gravel over a 60-square-meter area (Huckell 1972). Radiocarbon dates on charcoal from the gravel near the mammoth are 10,420 ± 100 yr B.P. (A−1152) and 8,920 ± 1150 yr B.P. (Tx−1199). The latter date, with a large standard deviation, was obtained on a small sample and is of questionable accuracy. The date for the other sample is considered to be accurate and close to its true age, even though the soluble humates were not removed prior to radiocarbon analysis. Usually if the humates are not removed from a sample, a slightly younger age will result. Three humate samples from the gravel and sand (unit D), however, are of comparable age or older than their charcoal counterparts. Therefore, the presence of humates in the sample does not affect its reliability. Thus, because the bones are articulated and in one case associated with charcoal radiocarbon dated at 10,400 yr B.P. (before the maximum date of 10,000 yr B.P.), they are considered to be in primary association within the gravel.

The bones recovered from the sand (unit Db) in radiocarbon-dated contexts between 9,400 and 8,000 yr B.P. are probably reworked from older sediments. They are not articulated, there are abundant older sediments from which they could have been dislodged, and they occur in a radiocarbon-dated context well beyond the maximum acceptable date of extinctions in North America.

The skull of a mammoth was recovered by Byron Cummings in 1926 in the laminated marl (unit F1) at Arizona FF:10:1. Mammoth vertebrae and ribs were later recovered from this same deposit (Antevs 1983). Saunders (1970) examined the teeth from the mammoth and based on dental

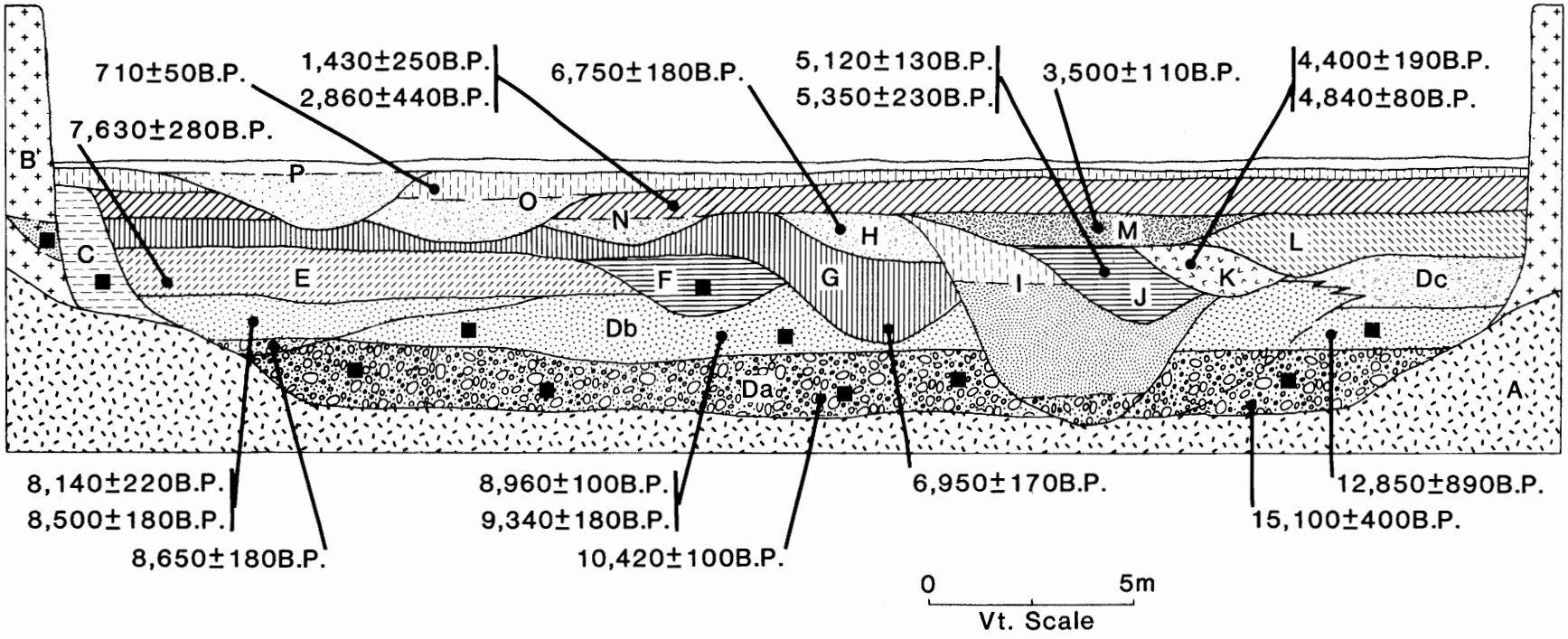


Figure 3.1. Generalized geologic cross section of Whitewater Draw, showing the position of megafaunal remains (excluding bison). Solid squares represent position of megafaunal remains. For explanation, see Figure 2.21.

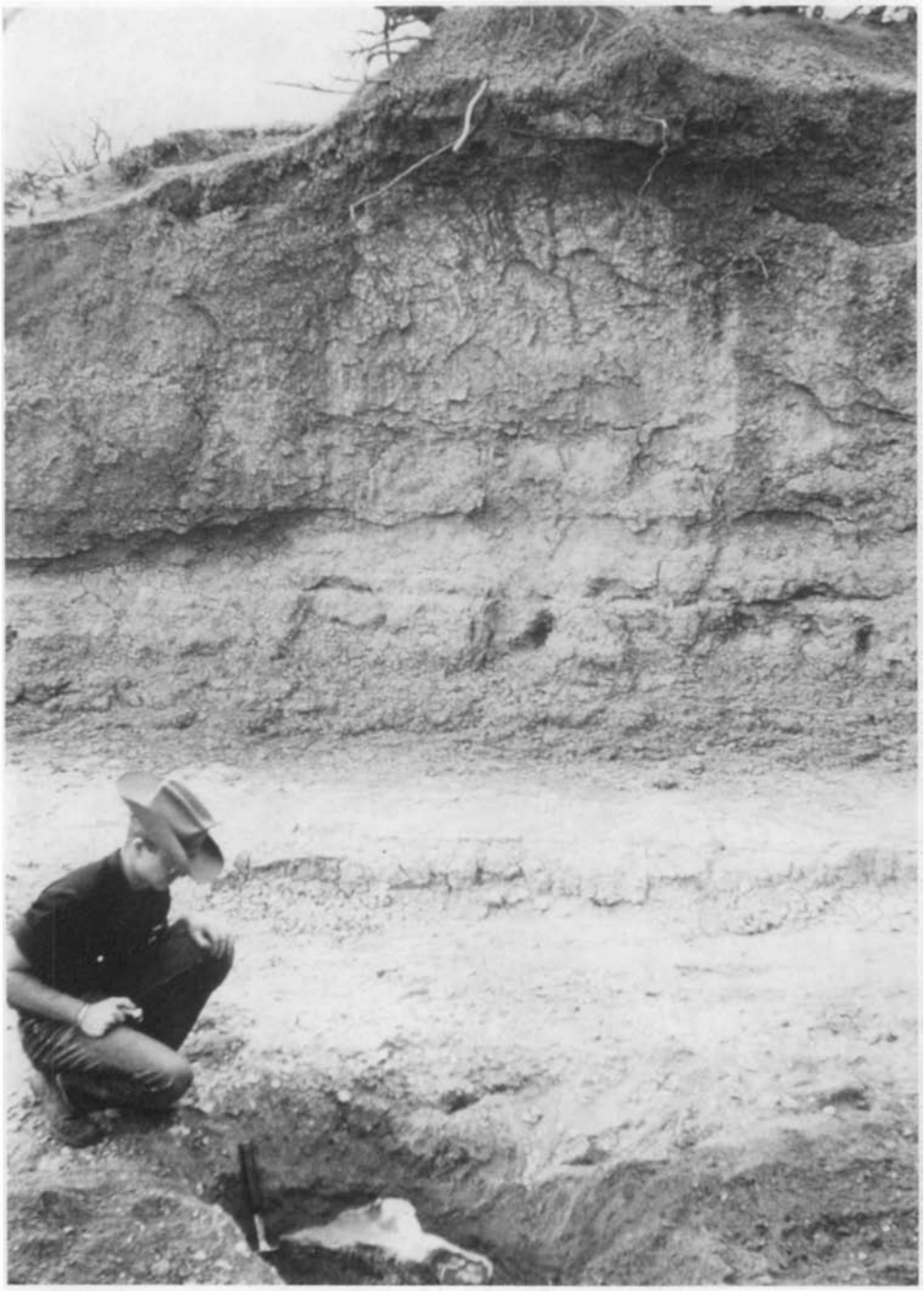


Figure 3.2. Isolated mammoth scapula found in sand unit Db near Double Adobe. (Photograph courtesy of the Arizona State Museum, University of Arizona.)

Figure 3.3. Excavation of mammoth remains 240 m downstream from Double Adobe in 1970. (Photograph by C. Vance Haynes.)

morphology suggested that the mammoth skull represented a highly advanced form of *Mammuthus (Parelephos) columbi*. No reliable radiocarbon dates exist from this unit, but two dates on calcium carbonate are 10,980 ± 90 yr B.P. (SMU−128) and 9,730 ± 100 yr B.P. (SMU−129). Radiocarbon dates from the top of the underlying sand (unit Db) and from clays (unit G1) in an overlying channel bracket the laminated marl (unit F1) between 8,000 and 7,000 yr B.P. The mammoth remains from the laminated marl were probably redeposited because they are not articulated (except for the upper tusk fragments, which were still attached to the skull), and there is no precedence for megafauna of this age anywhere in North America. The mammoth skull may have been originally deposited in the white clay (unit C) or sand

(unit Db), and a shallow channel could have cut down to and through the clay or sand, uncovered the skull, allowing it to become "cleaned-up" (because it was too heavy to transport in the low-energy environment), and then the skull could have been reburied by the laminated marl (unit F1), thus giving the illusion that it was in primary association within the laminated marl. This argument is strengthened by the presence of mammoth bones in the sand (unit Db) and the white clay (unit C). Mammoth bones have been found by both C. Vance Haynes and myself in unit C, 15 m directly behind the site where Cummings discovered the mammoth skull (Fig. 2.12*d*).

Antevs (1983) reported a camel bone from the massive marl (unit F2) at Arizona FF:10:1, locality 1. This bone would also date roughly between 8,000 and 7,000 yr B.P. and was probably in a secondary context. It may have been dislodged from one of the older units and then redeposited in the massive marl (unit F2).

In summary, remains of extinct fauna found in the terrace deposits (unit B), the white clay (unit C), and the older gravel and sand (units Da and Db) dating 10,420 yr B.P. or older are considered to be in primary contexts. Remains of extinct fauna found in the younger portion of units Da and Db and in units F1 and F2 are considered to be in secondary contexts. Therefore, the radiocarbon date of 10,420 ± 100 yr B.P. (A−1152) may be viewed as a tentative date for megafaunal extinctions in the Douglas basin.

Table 3.1 Geologic Occurrence of Megafaunal Remains from Whitewater Draw, Arizona

	Occurrence of Megafauna[1]					
Unit	Sloth	Mammoth	Camel	Horse	Dire Wolf	Bison
Post−I	0	0	0	0	0	0
IIa and IIb	0	0	0	0	0	+
F2	0	0	+	0	0	0
F1	0	+	0	0	0	0
Dc	0	0	0	0	0	+
Db	0	+	+	+	0	+
Da	0	+	+	+	+	+
C	0	+	0	+	0	0
B	+	+	0	+	0	0

1. + = present, 0 = absent.

PALYNOLOGY

The only palynological studies of Whitewater Draw have been conducted by Martin (1963b). He collected pollen from four sites (Fig. 1.1): Arizona FF:10:1, locality 5 (designated Double Adobe I) and locality 2 (designated Double Adobe II); Arizona FF:10:4, a Chiricahua stage site (designated Double Adobe III); and Arizona FF:6:2, a San Pedro stage site (designated Double Adobe IV). Data from the Whitewater Draw pollen profiles were used to redefine the Altithermal as warm and mesic (Martin 1963a, 1963b) rather than warm and xeric (Sayles and Antevs 1941; Antevs 1948, 1955b, 1962). My geological investigations show that there is a problem with the data used to formulate Martin's redefinition of the Altithermal.

The deposits sampled by Martin (1963a, 1963b) for pollen at the Double Adobe I profile are, from bottom to top: pink clay (my unit A; Martin's pink clay), gravel (unit Da; sand, silt, gravel), sand (unit Db; rusty sand, silt, charcoal), clay (unit Dd; gray clay and charcoal), silty sand (unit O1a; white silt, clay), silty clay (unit O2; indurated silt), and sandy silt and silt (units P1 and P2; sandy silt, channel fill, and yellow loose silt). This stratigraphy is essentially duplicated at the Double Adobe II pollen profile (Martin 1963a, 1963b). Based on correlations with my alluvial chronology of Whitewater Draw, the lower upper Quaternary units (Da, Db, and Dd) range from 10,400 to approximately 8,000 yr B.P. A major unconformity, as noted by Haynes (1968), separates unit Dd and the overlying units O1a, O1b, P1, and P2. The upper four units were deposited sometime between 1,500 yr B.P. and the historic period, based on correlation with my alluvial sequence.

The stratigraphy at the Double Adobe III and IV pollen profiles postdates 3,500 yr B.P. The deposits at Double Adobe III are similar to those at site Arizona FF:10:13 and are, from bottom to top: clay (my unit A; Martin's pink clay), sand and clay(?), clay (unit M; blue clay), clay and silty clay (unit N2 or unit 02; silt, silty clay), and sandy silt (unit P2; sandy silt). The upper stratigraphy containing the San Pedro phase pit house at the Double Adobe IV profile probably dates to less than 2,800 yr B.P., correlating with my units N2 and O2. The radiocarbon date obtained by Martin (1963b) from the pit house fill, 3,860 ± 200 yr B.P. (A−193) is considered too old and the date of 2,860 ± 440 yr B.P. (A−194) from below the pit house is accepted. The former date is not in accord with other dates from these units, whereas the latter date is. It is possible that charcoal from an older unit was introduced into the pit house.

In summary, the pollen profiles reported by Martin (1963b) from Whitewater Draw cover a range of sediments dating from approximately 10,400 to 8,000 yr B.P. and from 3,500 yr B.P. to the historic period. Therefore, the Altithermal (7,500−4,500 yr B.P.) is not represented in the pollen profiles as originally thought by Martin (1963a, 1963b). He used the palynological data from Whitewater Draw and Murray Springs to infer that the Altithermal was warm and mesic. This interpretation is greatly undermined by the proper placement of the pollen profiles in the Whitewater Draw alluvial sequence.

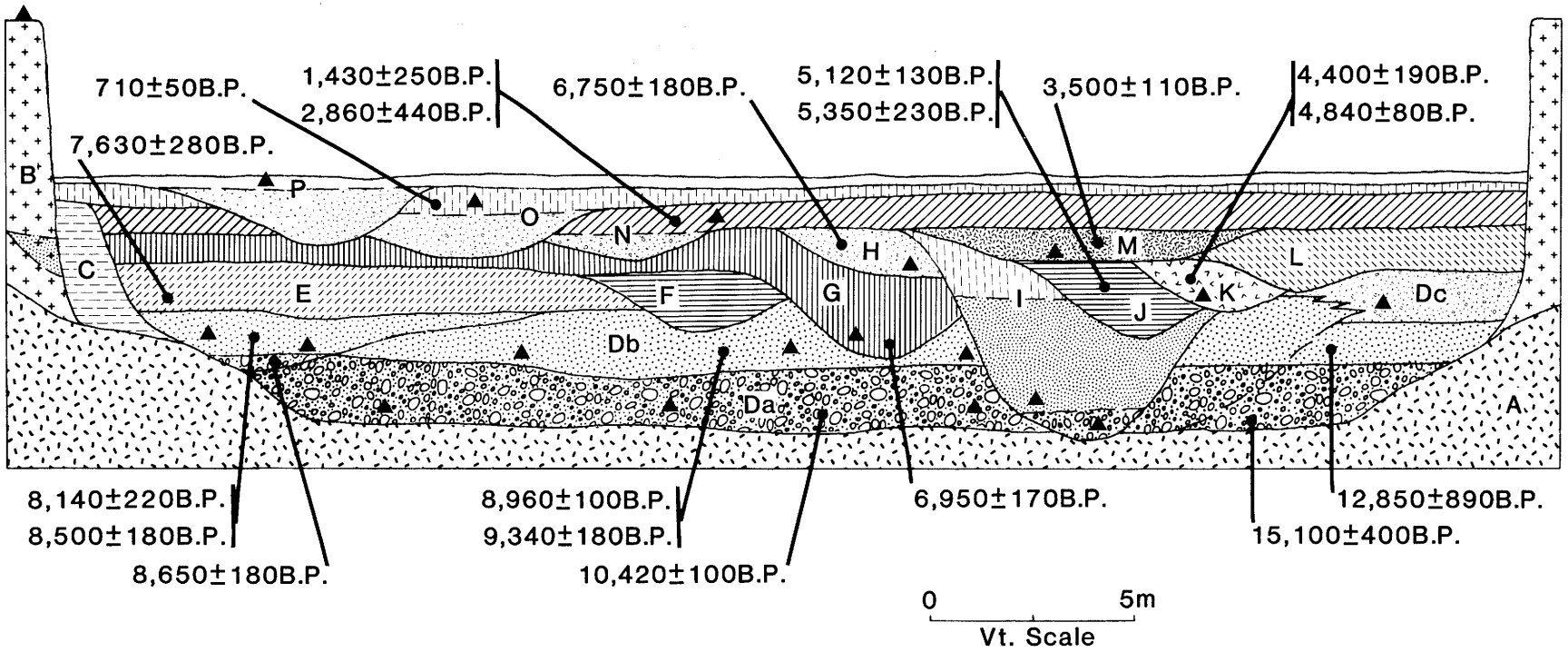


Figure 4.1. Generalized geologic cross section of Whitewater Draw, showing the position of artifacts (solid triangles). For explanation, see Figure 2.21.

CHAPTER FOUR

Archaeology of Whitewater Draw

Archaeological remains are found in nearly all the upper Quaternary deposits of Whitewater Draw (Fig. 4.1). This discussion focuses primarily on the Cochise culture, especially its earliest stage, the Sulphur Spring, followed by a review of the Cazador, Chiricahua, and San Pedro stages. Certain earlier interpretations are altered by my reassessment of the geologic events that occurred in the area and of the deposits containing artifacts.

EARLY PREHISTORY

No Clovis sites have been found in the Sulphur Springs Valley, despite its close proximity to the San Pedro Valley where the presence of the Clovis culture is established at the Lehner, Murray Springs, Escapule, and Naco sites (Fig. 1.1). One Clovis point was recovered in a dune area covering the northeastern portion of ancient Lake Cochise in the Willcox basin (Di Peso 1953). No Clovis artifacts are known from the Douglas basin (Huckell 1982), but the potential for such finds remains high because deposits of Clovis age occur in Whitewater Draw.

Three fluted obsidian projectile points from Whitewater Draw were reported by Myers (1976). All are isolated surface finds, considered by Myers to be typologically similar to Folsom points and manufactured by a regional manifestation of that culture. In my opinion these points are crudely made replications of recent manufacture. They are very thick and poorly fluted (sometimes only on one side) and are very "fresh" in appearance.

THE SULPHUR SPRING STAGE

The Sulphur Spring stage was defined by Sayles (Sayles and Antevs 1941; Sayles 1983) as the earliest stage of the Cochise culture. As originally defined, this artifact assemblage was characterized by milling stones, handstones, percussion-flaked knives, scrapers, and choppers, and by the absence of bifacially flaked knives and projectile points. These artifacts were considered to be in primary association with mammoth, horse, camel, dire wolf, and bison remains. Sulphur Spring artifacts were recovered from six sites along Whitewater Draw and one site on the shoreline of pluvial Lake Cochise. Antevs (Sayles and Antevs 1941; Antevs 1983) considered this stage to date from 12,500 to 11,000 yr B.P., based on a geologic estimate. The following discussion redefines the Sulphur Spring stage in terms of site identification, material culture, chronological placement, and association with extinct fauna.

Sites

Four Sulphur Spring stage sites occur in Whitewater Draw: Arizona FF:6:9 (GP Pearce 8:21); Arizona FF:6:8 (GP Pearce 8:10); Arizona FF:10:1 (GP Sonora F:10:1, Double Adobe site, localities 1, 2, 3, 4, and 5); and Arizona FF:10:14 (GP Sonora F:10:17). This is a revision of the original Sulphur Spring site inventory (Sayles and Antevs 1941; Sayles 1983), which included sites Arizona FF:6:10 (GP Pearce 8:17), Arizona FF:10:15 (GP Sonora F:10:40), and Arizona CC:13:3 (GP Arizona L:13:10) and did not include locality 2 at Double Adobe (Fig. 1.1). Early Cochise culture artifacts have also been found at the Lehner site in the San Pedro Valley, Arizona (Haynes 1982a).

At Arizona FF:6:9, Arizona FF:6:8, and Arizona FF:10:1 (localities 1–5), Sulphur Spring artifacts occur in a channel gravel, unit Da, and in the overlying sand, unit Db (Figs. 2.2, 2.5, 2.12). These artifacts occur in secondary contexts. The presence of abundant charcoal, the consistency of the dates, and the concentration of unabraided artifacts and hearthstones in the deposits suggest that this material was not transported far from its source and was probably eroded from campsites that were adjacent to the stream.

At Arizona FF:10:14, Sulphur Spring artifacts occur in unit Dc, a cross-bedded silty sand with dispersed gravel, which was probably deposited in a splay or levee (Fig. 2.16). Here, the artifacts have only been slightly disturbed because an articulated human burial and numerous secondary flakes were recovered from the deposit. The Sulphur Spring campsite was adjacent to the stream on the splay or levee and is the least disturbed of all Sulphur Spring stage sites.

Arizona FF:10:15 and Arizona FF:6:10, minor sites that produced only six artifacts, were not examined. I have reservations about assigning them to the Sulphur Spring stage based on the brief stratigraphic descriptions by Sayles and Antevs (1941) because of the problem of stratigraphic repetition within the Whitewater Draw alluvial sequence. Two possibilities exist for the placement of these artifacts: they occur either in units Da and Db, or in units I1a and I1b. If they occur in the former beds, they would be Sulphur Spring age; however, if they occur in the latter deposits, they would be

Table 4.1 Ground Stone Artifact Distribution at Sulphur Spring Stage Sites

Site	Handstones: Asymmetric Biface a	b	Asymmetric Uniface a	b	Symmetric Biface a	b	Fragments a	b	Milling Stones a	b	Totals
Arizona FF:6:9	2	(1)	1	(5)	0	(1)	1	(0)	1	(13)	25
Arizona FF:10:1	0	(2)	0	(20)	0	(2)	0	(0)	0	(38)	62
Arizona FF:10:14	1	(1)	2	(0)	0	(4)	5	(0)	9	(8)	30
Arizona FF:6:8	5	(0)	1	(0)	2	(0)	1	(0)	13	(0)	22
Totals	12		29		9		7		82		139

a columns: artifacts collected by Michael Waters, 1982–1983; total = 44.
b columns: artifacts reported by Sayles and Antevs (1941); total = 95.

later. These sites must remain problematical until they can be investigated further.

The greatest revision of the original site inventory is the inclusion of locality 2 at Double Adobe with the Sulphur Spring stage. Locality 2 was originally defined (Sayles 1983) as the type site of the Cazador, a stage intermediate between the Sulphur Spring and Chiricahua stages. My investigations have raised serious doubts about the Cazador stage and have shown the deposits at locality 2 to be the same age as the Sulphur Spring localities at Arizona FF:10:1 (see Cazador section for details).

Site Arizona CC:13:3, on the shoreline of pluvial Lake Cochise in the Willcox basin, is considered by Sayles (1983) and Haury, Antevs, and Lance (1953) to belong to the Sulphur Spring stage. Because the age of the deposits that contain the artifacts is unknown, the correlation of this site with the Sulphur Spring stage sites in Whitewater Draw is open to question.

Material Culture

The material culture of the Sulphur Spring stage is poorly represented. The artifact assemblage consists of 139 ground stone and 55 flaked stone artifacts. This material comes from sites Arizona FF:6:8, Arizona FF:6:9, Arizona FF:10:1 (localities 1, 2, 3, 4, and 5), and Arizona FF:10:14. All the artifacts I collected and some of the artifacts collected by Sayles and Antevs (1941) were used for this assessment.

The original definition of the Sulphur Spring material culture (Sayles and Antevs 1941) was based on 448 artifacts collected from six sites. I have reservations about the stratigraphic position of artifacts collected from some of these sites.

At sites Arizona FF:10:15 and Arizona FF:6:10, the artifact-bearing strata cannot be demonstrated conclusively to be the equivalent of the Sulphur Spring artifact-bearing gravel (unit Da) and sand (unit Db) elsewhere (see previous section). These sites yielded only six artifacts, a minor contribution to the total assemblage (Sayles and Antevs 1941), and they were not used in this analysis.

A major revision is the assignment of artifacts from site Arizona FF:10:1, locality 2, to the Sulphur Spring stage and their use in redefining the material content of that stage. The artifact-bearing strata (units Da and Db) at locality 2 do appear to be the same age as the other Sulphur Spring localities at Arizona FF:10:1 and elsewhere. However, only those artifacts collected during the October 1953 excavations were examined. There is some doubt about the stratigraphic position of the artifacts found in May 1953, especially 9 of the 12 projectile points that include side-notched and serrated forms. According to Sayles's (1953) notes, these artifacts were not excavated, but were collected from the modern streambed gravel adjacent to the arroyo bank and were inferred to have come from the artifact-bearing gravel (unit Da) and sand (unit Db). Some of the flaked stone tools and only a handful of the ground stone artifacts remain in the Arizona State Museum collections. None of Sayles's 1983 tabulations were used unless the artifacts were found in the museum collections and provenance data were available.

Site Arizona FF:6:8 was first described as a pure Sulphur Spring locality with artifacts occurring in five geologic units (Sayles and Antevs 1941). These were combined by Sayles in his 1941 artifact analysis. My investigations have shown that the upper two artifact-bearing strata (units G1 and H) from which most of the artifacts originated are not Sulphur Spring in age. Unfortunately, the collections were not available for reanalysis and it is impossible to determine which artifacts came from the upper and lower units; thus, the 1941 artifact tabulations for this site were not used.

There is no confusion concerning the stratigraphic position of artifacts collected by Sayles and Antevs (1941) from sites Arizona FF:6:9, Arizona FF:10:14, and Arizona FF:10:1 (localities, 1, 3, 4, and 5). All the existing artifacts were examined and Sayles's 1941 tabulations were used herein.

The following analysis is descriptive because the total collection of 194 artifacts (86 collected by me; 108 collected by Sayles and Antevs) is inadequate for a statistical study. I retained Sayles's 1941 ground stone artifact categories and tabulations (with only slight modifications) because the col-

Table 4.2 Flaked Stone Artifact Distribution at Sulphur Spring Stage Sites

Site	Flaked Stone Artifacts												Totals
	Unifacial Scrapers		Plano-convex Scrapers		Choppers		Projectile Points		Bifacial Knives		Hammerstones		
	a	b	a	b	a	b	a	b	a	b	a	b	
Arizona FF:6:9	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0
Arizona FF:10:1	0	(8)	0	(8)	0	(9)	0	(3)	0	(3)	0	(7)	38
Arizona FF:10:14	9	(2)	2	(1)	1	(1)	1	(0)	0	(0)	0	(0)	17
Arizona FF:6:8	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0
Totals	19		11		11		4		3		7		55

a columns: artifacts collected by Michael Waters, 1982–1983; total = 13.
b columns: artifacts reported by Sayles and Antevs (1941); total = 42.

lections were not available for reanalysis. The total number of ground stone versus flaked stone tools is biased because of the nature of the available collections. In site contexts, ground stone artifacts far outnumbered flaked stone tools at all sites except Arizona FF:10:14 and Arizona FF:10:1, locality 2.

Ground Stone Artifacts

Ground stone artifacts are the most common element of the Sulphur Spring assemblage (Sayles and Antevs 1941; Sayles 1983). These artifacts are milling stones and handstones (Figs. 4.2, 4.3; Table 4.1).

Milling stones made from tabular pieces of sandstone or quartzite are unshaped and modified only through use (Fig. 4.2). The grinding surfaces are flat to slightly concave (maximum depth observed, 1.5 cm) and occasionally show evidence of pecking. Milling stones commonly have been used on both sides. They range from large (about 40 cm across) to small (about 10 cm across), possibly suggesting different functions such as food or pigment grinding. Complete specimens are rare; most milling stones are fragmentary and show evidence of firecracking.

Unifacial and bifacial handstones (Fig. 4.3) are common (Sayles and Antevs 1941; Sayles 1983). They are generally made from sandstone or quartzite cobbles and are unmodified except through wear. Complete specimens range in size from 12 cm by 8 cm by 6 cm to 8.5 cm by 8 cm by 3.5 cm. A few specimens have been shaped by pecking the entire periphery of the stone. On the short axes of these tools, grinding surfaces are either flat or slightly convex and are occasionally modified by pecking. Many of the bifacial handstones are wedge shaped in cross section and have grinding faces that merge at the edge. The edges of many handstones are battered, and frequently specimens are fire-cracked.

Flaked Stone Artifacts

Flaked stone artifacts are predominantly unifacial; bifacial flaking is rare. Basalt, rhyolite, chalcedony, chert, siliceous mudstone, quartzite, and obsidian were used to make tools (Figs. 4.4, 4.5; Table 4.2).

The most common tools are unifacial percussion-flaked side scrapers, end scrapers, and side-and-end scrapers made on primary flakes ranging in size from 8.7 cm by 6.1 cm by 2.7 cm to 4.2 cm by 3.5 cm by 1.4 cm (Figs. 4.4*e–j*, 4.5*b*). The worked edges are commonly straight to convex, but several have concave edges (Fig. 4.5*c*) and graver tips. Reverse flaking, a method of preparing opposite faces on opposite edges of a flake, is noted in the collection (Sayles 1983). Two unifacially retouched cortical or teshoa flake scrapers were found. In general, the scrapers are small and well reduced.

Domed or plano-convex scraper-cores are common (Fig. 4.5*d–f*). These tools have either a prepared or, more commonly, a natural flat platform from which flakes were derived. They vary in size from 5.1 cm by 3.5 cm by 2.0 cm to 2.7 cm by 2.4 cm by 2.3 cm. The flaked edges are steep, ranging from 80 to 85 degrees. Again, the scrapers are small and well reduced to the point of exhaustion.

Cobble core-choppers are usually unifacially flaked along one edge of the cobble, leaving cortex at the other (Fig. 4.5*a*). Only a few bifacial specimens were found.

Three biface (projectile point?) fragments were found at Arizona FF:10:1 (locality 2) by Sayles (1983), and I found one fragment at Arizona FF:10:14 (Fig. 4.4*b*). The three projectile points (Fig. 4.4*a*, *c*, *d*) from Arizona FF:10:1 were originally assigned to the Cazador stage by Sayles (1983) and are here reassigned to the Sulphur Spring stage based on the dated deposits in which they were found. Of these pieces, two are rounded base fragments made of chert (Fig. 4.4*a*, *b*), another is the midsection of a chalcedony biface (Fig. 4.4*c*), and the fourth is the tip of an obsidian projectile point (Fig. 4.4*d*). Three bifacially retouched flake knives also were recovered.

Hammerstones are made from either a waterworn cobble or an exhausted core-chopper. Unmodified debitage has been found at most sites. Two bifacial thinning flakes were recovered from Arizona FF:10:14 and indicate that soft hammers were used.

Figure 4.2. Unshaped milling stone, Sulphur Spring stage.

Figure 4.3. Unshaped handstones, Sulphur Spring stage.

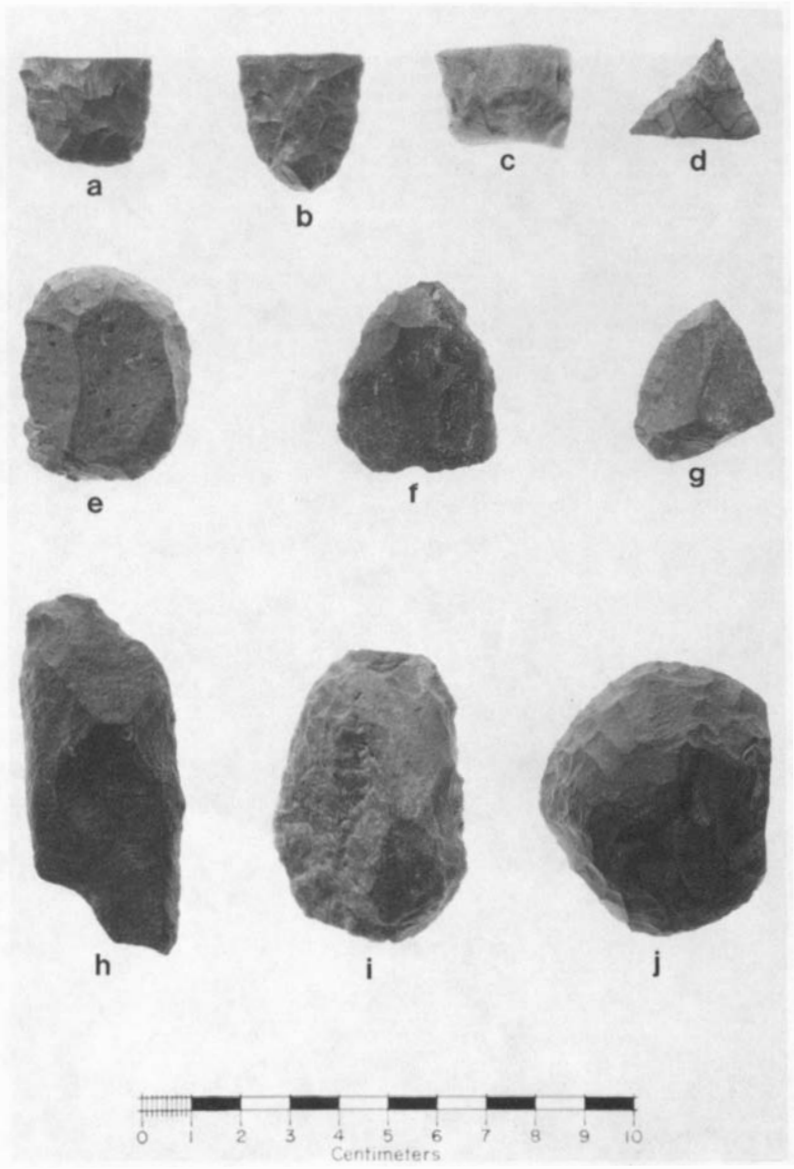


Figure 4.4. Flaked stone artifacts, Sulphur Spring stage: *a*–*d*, bifaces (projectile points); *e*–*j*, side and end flake scrapers. Photograph by Helga Teiwes, Arizona State Museum, Tucson.

Shell and Bone

A fragment of a marine gastropod (*Olivella*) was recovered from the unit Db sand containing Sulphur Spring artifacts at Arizona FF:10:1 (Sayles and Antevs 1941). This shell obviously was transported to this site by man and may have been part of a shell ornament.

A bone, possibly a tool, from a mammoth leg is reported from Arizona FF:10:1, locality 1 (Sayles 1983). It is spirally fractured and extremely waterworn. Spirally fractured bone is not the exclusive work of man, and the artifactual nature of the bone is doubtful.

Burials

In Whitewater Draw a Sulphur Spring stage burial was found in alluvial deposits dating 10,400 to 8,200 yr B.P. These early human remains are the oldest known from the Southwest and provide data on the earliest inhabitants of North America.

The burial was located at site Arizona FF:10:14 (GP Sonora F:10:17), which is located on the west side of Whitewater Draw approximately 2 km southeast of Double Adobe (Fig. 1.1). This site was first identified by Sayles and Antevs (1941) as belonging to the Sulphur Spring stage of the Co-

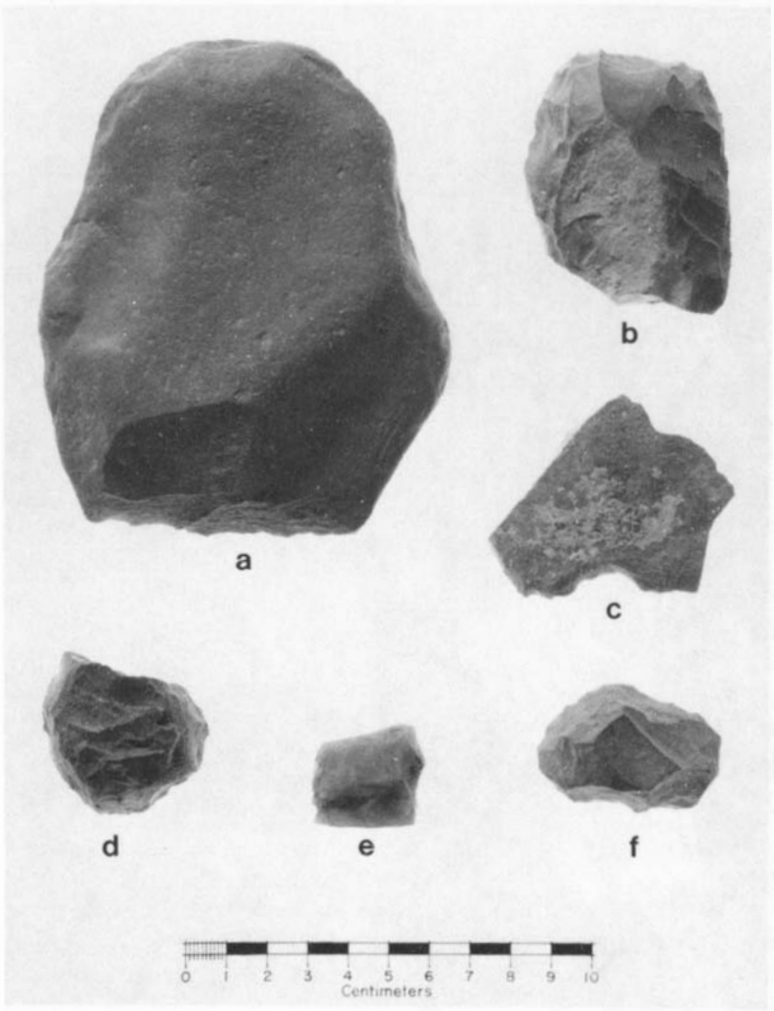


Figure 4.5. Flaked stone artifacts, Sulphur Spring stage: *a*, cobble core-chopper; *b*, side scraper; *c*, concave flake scraper; *d*–*f*, domed or plano-convex scraper cores (*e* is shown in cross section). Photograph by Helga Teiwes, Arizona State Museum, Tucson.

chise culture. They conducted limited excavations here, which led to the recovery of the first human remains from this site. These are now in the collections of the Peabody Museum at Harvard University. As part of my investigations to understand the geologic context and date the Sulphur Spring stage, I relocated and reinvestigated this site in February 1983. A backhoe was used to excavate a 70-m-long trench parallel to the arroyo wall and two 17-m-long trenches perpendicular to it. Nine stratigraphic units are defined at this site and they were discussed in the geologic section. The stratigraphic relationships are shown in Figure 2.16.

The burial was exposed during geologic testing of the site with a backhoe. The skeleton was encountered in trench C 5.5 m from the arroyo bank at a depth of 2 m (Fig. 4.6). The bones were found in a calcareous silty sand with dispersed pebble gravel, designated unit Dc (Figs. 4.7, 2.16). These sediments were deposited in a splay or levee. Most of the bones were removed from their context in one scoop of the backhoe, leaving only the upper skull and a portion of the mandible in situ (Fig. 4.8). The bones left in situ demonstrated that the burial was in primary context within unit Dc and not intrusive into this unit from overlying units. Large pieces of the hard calcareous sediment matrix removed by the backhoe contained articulated bones and they were taken back to the lab for more meticulous excavation. The remaining sediment removed from the trench was carefully searched for any bone fragments.

Based on the articulated elements preserved in the blocks of sediment (such as large sections of opposed ribs), it is clear that the skeleton was articulated in its undisturbed context. Further, because the burial was confined to a small area no greater than 60 cm in width (width of the backhoe trench), it

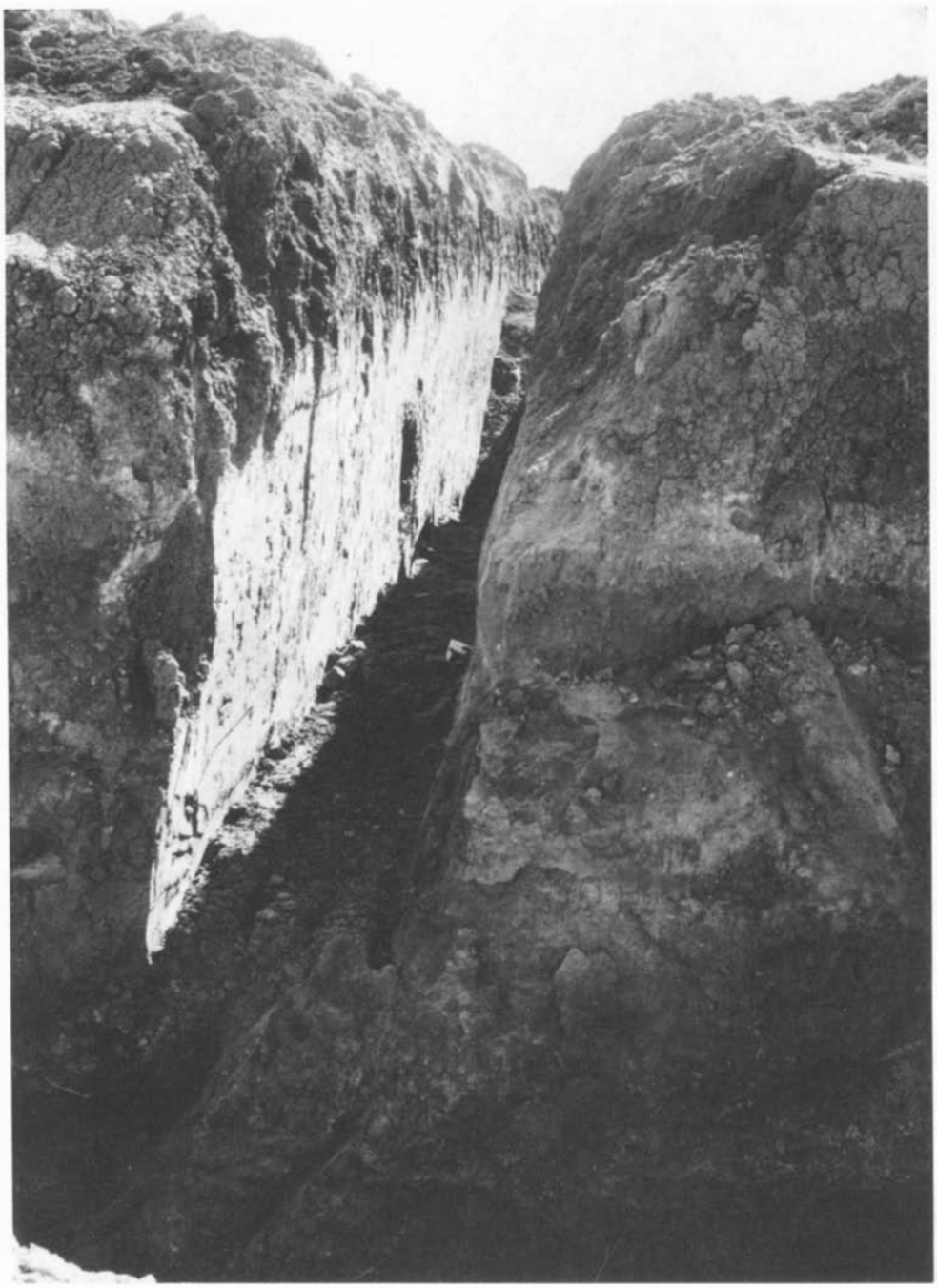


Figure 4.6. Side trench at site Arizona FF:10:14, showing position of deeply buried human skeleton in unit Dc, *center* of left trench wall.

Figure 4.7. Site Arizona FF:10:14, showing the stratigraphy overlying skeletal remains.

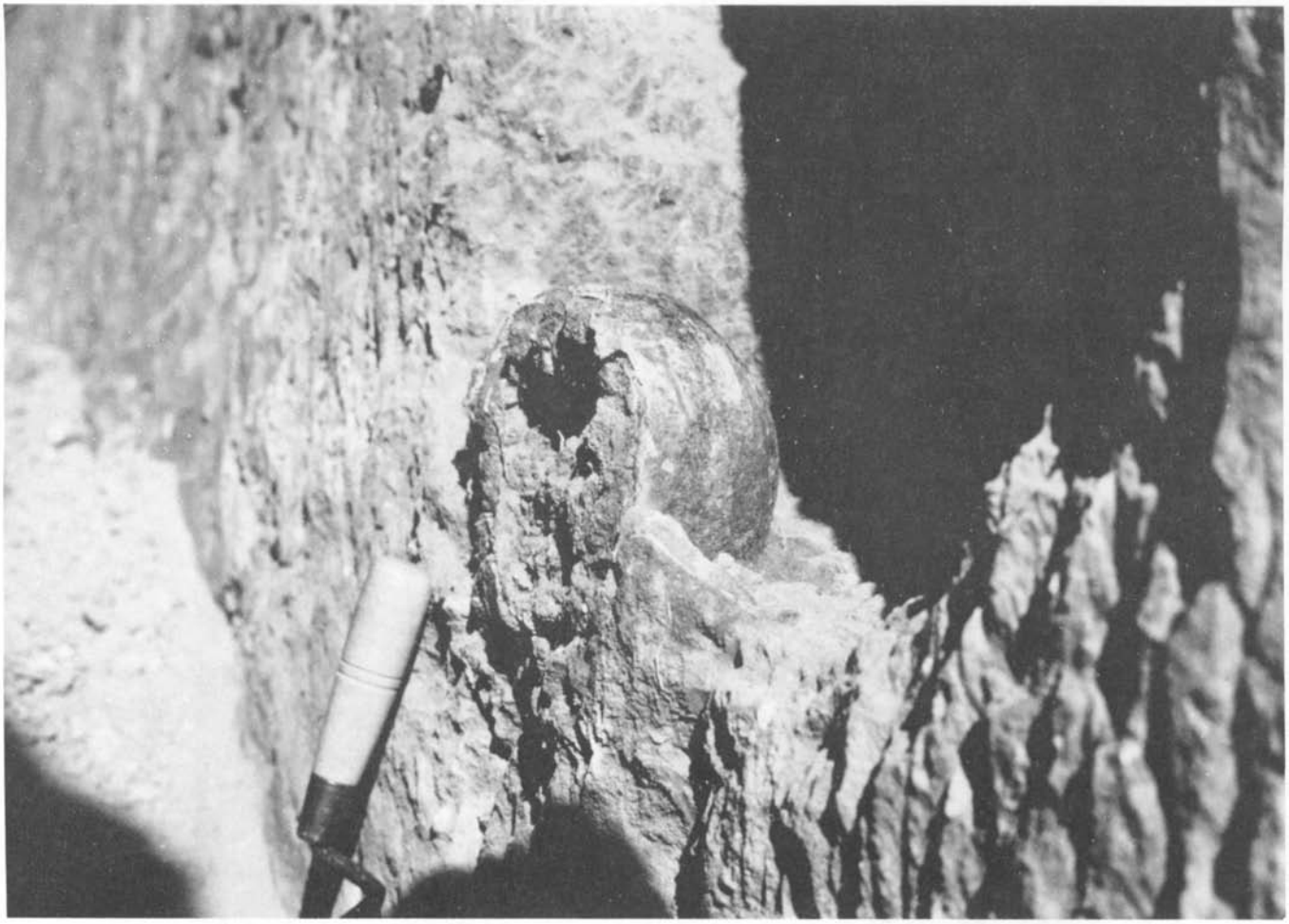


Figure 4.8. Human skull and mandible fragment in situ within unit Dc at site Arizona FF:10:14.

seems likely that the burial had been in a tightly flexed position. This is a typical burial pattern in southeastern Arizona and elsewhere. The in situ position of the upper skull indicates that the face was oriented to the northwest. No grave offerings were apparent within the sediment matrix, although numerous ground stone and flaked stone artifacts were found in unit Dc.

The bones are well preserved and highly mineralized. A nitrogen analysis on the bones indicates an extremely low collagen content. Many of the bones were fragmented by the backhoe and reconstruction efforts are ongoing.

The skeleton appears to be that of an adult female, based on the nonrobust appearance of the osteological material. Dr. Walter Birkby, on the basis of dental wear patterns and the eruption of the wisdom teeth, estimates that she was probably 25 to 35 years old at the time of her death. Skeletal elements of the entire body have been reconstructed by Dr. Birkby and his laboratory assistants and include: calvarium fragments (frontal, left and right parietal, occipital), maxilla, mandible (Fig. 4.9), representative vertebrae (including the sacrum), scapulae, clavicles, ribs, humeri, radii, ulnae, hand bones, pelvis, femurs, patella, tibiae, fibulae, and foot bones. The incisors, canines, premolars, and molars display marked wear, the result of an abrasive diet. The teeth display the sinudonty dental pattern as defined by Turner (1983). This is a different individual than the one reported by Sayles and Antevs (1941), as many of the skeletal elements duplicate those found by them.

With absolute certainty the burial may be bracketed in time between the two radiocarbon dates of 12,850 ± 890 yr B.P. (AA−269) and 5,350 ± 230 yr B.P. (A−3308), which respectively underlie and overlie unit Dc at the site (Fig. 2.16). A more precise dating of the burial may be obtained by examining its geological and archaeological context.

A minimum date for the burial is indicated by the stratigraphic superpositioning of unit Dc in relation to the other radiocarbon-dated alluvial deposits in Whitewater Draw. Geologic work at numerous sites has resulted in the radiocarbon-dated alluvial sequence illustrated in Figure 2.21. Unit Dc is stratigraphically early, and the oldest radiocarbon

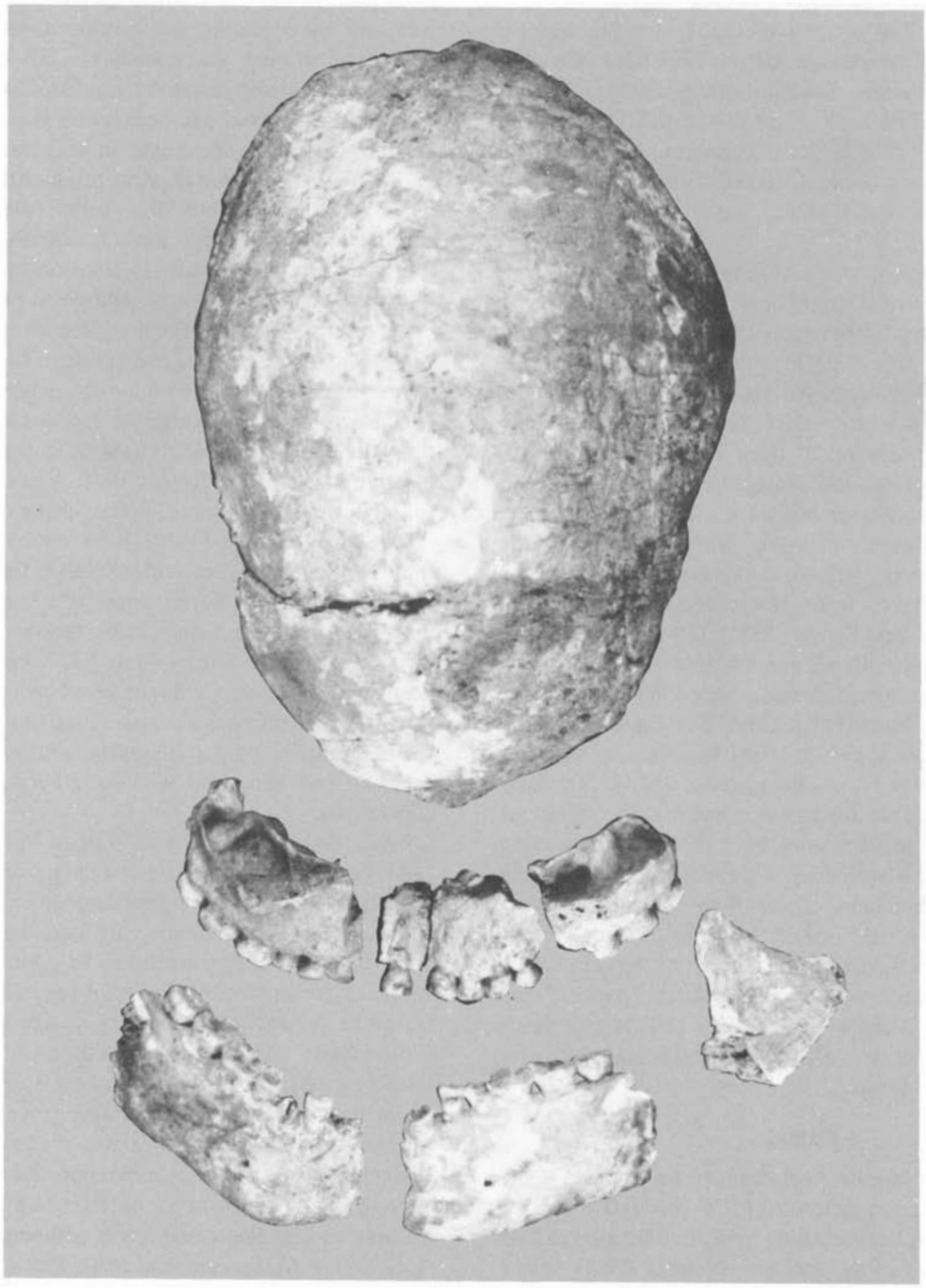


Figure 4.9. Upper skull, maxilla, and mandible of human skeleton from unit Dc at site Arizona FF:10:14.

date from the geologic unit immediately overlying unit Dc at other localities is 7,630 ± 280 yr B.P. (A−3282), which comes from unit E2, placing a minimum date on the burial.

An even more precise estimation of the age of the burial may be made with reference to its archaeological context. Artifacts from unit Dc have been assigned to the Sulphur Spring stage of the Cochise culture on typological criteria by Sayles and Antevs (1941) and Sayles (1983), and on geological criteria by Antevs (1983). Ten radiocarbon dates from three Sulphur Spring stage sites in Whitewater Draw, Arizona FF:6:9, FF:6:8, and FF:10:1, range from 9,340 ± 180 yr B.P. (A−3238) to 8,140 ± 220 yr B.P. (A−3237). Sulphur Spring artifacts occur in geologic deposits below the first date at site Arizona FF:6:9 and a similar situation occurs

at Arizona FF:10:1. The Sulphur Spring stage may date as early as 10,420 ± 100 yr B.P. (A−1152), based on a single radiocarbon date obtained near Arizona FF:10:1. In the adjacent San Pedro Valley, Sulphur Spring artifacts are associated with dates of 9,860 ± 80 yr B.P. (SMU−197) and 9,900 ± 80 yr B.P. (SMU−204). Therefore, the burial may be placed confidently between 10,000 to 8,000 yr B.P. and possibly as early as 10,400 yr B.P., based on its archaeological context.

Both the geological and archaeological contexts, then, place the burial between approximately 10,400 and 8,000 yr B.P. These dates are further supported by the occurrence of bison (Sayles and Antevs 1941) within the deposits containing the skeleton. The bones will be dated eventually by the atomic accelerator, after they have been thoroughly analyzed. A large amount of bone is needed to date the specimen because of its low collagen content.

The Sulphur Spring stage burial from Whitewater Draw is the oldest human skeleton from the Southwest and one of the oldest in North America. These remains rank in age with the early human remains from Midland, Texas (Wendorf, Krieger, Albritton, and Stewart 1955); Gordon Creek, Colorado (Breternitz, Swedlund, and Anderson 1971); Marmes Shelter, Washington (Fryxell and others 1968); Santa Rosa Island, California (Orr 1968); Cerro Sota and Palli Aike Caves, Chile (Turner and Bird, 1981); and Anzick, Montana (Taylor 1969; Lahren and Bonnichsen 1974). The significance of the Sulphur Spring burial and the other skeletons is not simply their great antiquity, but rather that they provide information on the morphological characteristics and origin of the earliest inhabitants of the New World. The most important feature of the Sulphur Spring fossil is that it displays the sinudonty dental pattern defined by Turner (1983). The other early human remains also show this pattern. This find adds continued support to Turner's (1983) hypothesis that the earliest inhabitants of the New World originated from what is now north China.

Dating

Antevs (1983) placed a final estimate on the age of the Sulphur Spring stage of more than 12,500 to 11,000 yr B.P., based on geologic-climatic dating, a method he used to date archaeological sites in the arid and semiarid West (Antevs 1955a, 1955b). It consists of attributing a deposit with archaeological remains to a particular dated climatic period. A relative regional climatic history for the West was deduced from a variety of data and roughly dated by correlation to the North American and Finno-Swedish varve chronologies. The climatic episodes defined by Antevs (Sayles and Antevs 1941; Antevs 1948, 1955a, 1962, 1983) were, from oldest to youngest: subhumid Provo Pluvial (more than 14,000 to 10,000 yr B.P.), semiarid Anathermal (10,000 to 7,500 yr B.P.), arid Altithermal (7,500 to 4,000 yr B.P.), and semiarid Medithermal (4,000 yr B.P. to present). Fundamental to the geologic-climatic dating method is the dependence of geological processes, and thus the physical characteristics of a deposit, on vegetation and specific climatic regimes (especially temperature and moisture). For example, Antevs (1955b) considered distinctly laminated deposits indicative of subhumid Pluvial age sediments. He also believed that calcium carbonate accumulation occurred during the arid Altithermal. The parent deposits in which the calcium carbonate accumulated and the beds below the calcium carbonate-bearing strata were interpreted to be pre−Altithermal, and the deposits in channels cut into them post-Altithermal. Supplementary data were provided by vertebrate fossils and macrofloral evidence; extinct fauna indicated Pluvial sediments and modern fauna post−Pluvial sediments. Thus, by examining the deposits for diagnostic characteristics and assigning the deposits to a specific climatic phase it was possible to date an archaeological site.

Antevs (Sayles and Antevs 1941; Antevs 1955b) used the following logic to date the Sulphur Spring stage at the Double Adobe site (Arizona FF:10:1). In stream-deposited gravel (unit Da) and sand (unit Db), Sulphur Spring artifacts, remains of mammoth, horse, camel, dire wolf, and bison, and hickory charcoal are found. These deposits are overlain by a distinctly laminated marl (unit F1) containing mammoth bones, which Antevs (1983) believed lay in primary context. Overlying this unit was a massive marl (unit F2). These pond sediments are heavily impregnated with soft calcium carbonate and interlaminated with hard flat calcium carbonate concretions.

From these observations, Antevs (Sayles and Antevs 1941; Antevs 1955b) considered the gravel, sand, and marl deposits to indicate permanent water and a subhumid pluvial climate. The heavy calcium carbonate accumulation in the pond deposits was interpreted to be Altithermal; therefore, the pond deposts themselves were pre−Altithermal or Pluvial. The occurrence of hickory charcoal and remains of extinct fauna, especially mammoth, in the sand and gravel also suggested a moist pluvial climate. Antevs concluded that the artifacts of the Sulphur Spring stage belonged to the Provo Pluvial and dated in excess of 10,000 yr B.P.

Antevs (1983) proposed a more precise dating of the Sulphur Spring stage in 1983 by reference to the mammoth remains in the laminated pond sediments, the assumed moisture requirements of mammoth, and a late Provo Pluvial drought, the Datil, which occurred between 12,500 and 10,500 yr B.P. Antevs (1983) assumed that mammoth required a dense luxurious vegetation to survive and concluded that a climate more moist than now must have prevailed in the area. Consequently, he concluded that mammoth became extinct in the Southwest during either the first late Pluvial or a post−Pluvial drought. Antevs (1983) favored the former date and believed that the mammoth became extinct by about 11,500 yr B.P. during the Datil Drought. He concluded that the Sulphur Spring artifacts, occurring in a moist-climate bed beneath mammoth remains, were derived from the Double Adobe I Subpluvial (before the Datil Drought) of the late

Table 4.3 Radiocarbon Dates from Materials Associated with Sulphur Spring Stage Artifacts

Site	Unit	Laboratory Number	Material dated	Date (yr B.P.)
Arizona FF:6:9	Db	A–3233	Charcoal	8,390 ± 190
		A–3230	Charcoal	8,500 ± 180
	Da	A–3231	Charcoal	8,420 ± 180
		A–3232	Charcoal	8,650 ± 180
		A–3314	Humates	8,860 ± 160
Arizona FF:6:8	Db	A–3237	Charcoal	8,140 ± 220
		A–3238	Charcoal	9,340 ± 180
	Da			No dates
Arizona FF:10:1	Db[1]	A–3377	Charcoal	8,840 ± 310
		A–3379	Charcoal	8,760 ± 210
		A–3378	Humates	8,970 ± 220
	Da[2]			No dates
Arizona FF:10:14	Dc			No dates
Lehner site, Arizona		SMU–197	Charcoal	9,860 ± 80
		SMU–204	Charcoal	9,900 ± 80

1. Ten additional radiocarbon dates range from 8,000 yr B.P. to 9,340 yr B.P. for unit Db at Arizona FF:10:1, but their source material was not directly associated with artifacts (see Table 2.1).
2. Two radiocarbon dates on charcoal of 10,420 ± 100 yr B.P. (A–1152) and 8,920 ± 1150 yr B.P. (Tx–1199) were obtained from unit Da 240 m downstream from Arizona FF:10:1, but the charcoal was not directly associated with artifacts (see Table 2.1).

Provo Pluvial and, therefore, dated in excess of 12,500 yr B.P. Similar logic was employed to date other sites to the Sulphur Spring stage.

Sayles and Antevs returned to Whitewater Draw in 1951 after the introduction of the radiocarbon dating method to collect samples to date the stages of the Cochise culture, especially the Sulphur Spring stage. In the Double Adobe area they discovered charcoal and artifacts in a gravel and sand similar to the Sulphur Spring stage sediments at other localities at Double Adobe, but they considered this material to be Cazador, not Sulphur Spring. Therefore, all the early radiocarbon dates derived by the solid radiocarbon method from locality 2 were attributed to the Cazador and not to the Sulphur Spring stage. My research has shown that the sediments at locality 2 are Sulphur Spring in age and that those dates did apply to the Sulphur Spring stage. These dates are 7,756 ± 370 yr B.P. (C–216) and 8,200 ± yr B.P. (A–67). A single date of 6,210 ± 450 yr B.P. (C–511) was obtained from the Sulphur Spring artifact-bearing sand at Arizona FF:6:8. Antevs (1983) considered this date incorrect and disregarded it in favor of his geologic estimate.

No more radiocarbon dates were obtained until Martin's (1963b) palynological work at the Double Adobe I pollen profile. He obtained six dates, ranging from 8,960 to 8,000 yr B.P. (Table 2.1) on charcoal and carbonaceous sediments from deposits he believed were correlative with the Sulphur Spring stage sediments at locality 5. Sayles (1965, 1983) and Antevs (1983) disagreed with this geologic assessment and reassigned the section to the Cazador stage by correlation to locality 2. Rogers (1959) visited the Double Adobe I profile late in 1959 and found a horse tooth in the gravels. His find would tend to support Martin's correlation. Nevertheless, these dates apply to the Sulphur Spring stage because, as stated previously, locality 2 now has been demonstrated to be of Sulphur Spring age. Martin (1963b) also obtained two dates directly from locality 2, which are 8,240 ± 960 yr B.P. (A–184c) and 7,030 ± 260 yr B.P. (A–184e).

In the early 1960s, the solid carbon residue of sample A–67 from locality 2 was found and redated by the carbon dioxide radiocarbon method; it gave an age of 9,350 ± 160 yr B.P. (A–67bis; Damon and Long 1972). During a highway salvage excavation near Double Adobe in 1970, Haynes (1971) obtained two dates, 10,420 ± 100 yr B.P. (A–1152) and 8,920 ± 1,150 yr B.P. (Tx–1199) on charcoal from the unit Da gravel in association with mammoth bones. Although no artifacts were found at that time, artifacts had previously been found in similar gravels 240 m upstream.

Much speculation has surrounded the dating of the Sulphur Spring stage because of the unreliability of solid radiocarbon dates, the poor quality of the early carbon dioxide dates (pretreatment, material dated), and confusion over the correlation of the Cazador and Sulphur Spring stages. Twelve dates (10 charcoal, 2 humate samples) from deposits containing Sulphur Spring stage remains at four sites (Table 4.3) and additional dates from the units Da and Db alluvium (Table 2.1) provide dating control.

Four radiocarbon dates on charcoal from the unit Da gravel and unit Db sand containing Sulphur Spring artifacts at Arizona FF:6:9 range from approximately 8,650 yr B.P. to 8,390 yr B.P. (Fig. 2.2; Table 4.3). The Sulphur Spring artifact-bearing unit Db sand at Arizona FF:6:8 dates between about 9,340 yr B.P. and 8,140 yr B.P. on the basis of

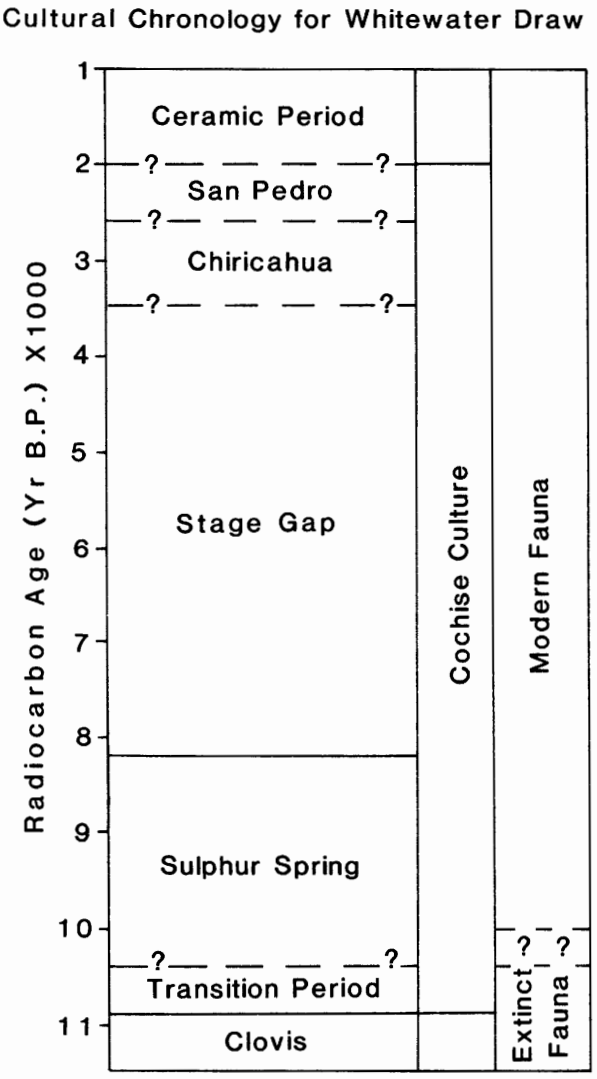


Figure 4.10. Chronological placement of the Cochise culture stages in Whitewater Draw, based on radiocarbon evidence.

two charcoal radiocarbon analyses (Fig. 2.5; Table 4.3). The artifact-bearing unit Da gravel is undated, but is older than 9,340 yr B.P. At Arizona FF:10:1 charcoal dates of 8,840 ± 310 yr B.P. (A−3377) and 8,760 ± 210 yr B.P. (A−3379) are associated with artifacts in the unit Db sand (Fig 2.12; Table 4.3). Ten additional radiocarbon dates on charcoal from the unit Db sand at Double Adobe range from approximately 9,350 to 8,000 yr B.P. (Table 2.1). Artifacts have also been recovered from the underlying gravel (unit Da) that is older than 9,350 yr B.P. Only two dates have been obtained from the gravel: 10,420 ± 100 yr B.P. (A−1152) and 8,920 ± 1150 yr B.P. (Tx−1199); these were associated with mammoth remains but not artifacts. These two dates may be applicable to the artifact-bearing gravel (unit Da) at Double Adobe and Arizona FF:6:8. However, this assignment must remain speculative because these dates are not associated with Sulphur Spring artifacts. No dates were obtained from the Sulphur Spring deposit (unit Dc) at Arizona FF:10:14. Two radiocarbon dates on charcoal, 9,860 ± 80 yr B.P. (SMU−197) and 9,900 ± 80 yr B.P. (SMU−204), are associated with Cochise culture artifacts at the Lehner site, according to Haynes (1982a). These artifacts directly overlie the Clovis horizon that has been dated at 10,890 ± 40 yr B.P. (average of 15 dates) by Haynes.

Radiocarbon dates from strata containing Sulphur Spring artifacts at three sites in Whitewater Draw and from the Lehner site place the Sulphur Spring stage between approximately 10,000 and 8,000 yr B.P. (Fig. 4.10). At two sites in Whitewater Draw, artifacts occur in gravel (unit Da) of unknown age below deposits dated at 9,400 yr B.P. If the dates from the unit Da gravel at Double Adobe can be applied to the Sulphur Spring stage, which I believe they can, it would indicate that this stage extends back to 10,400 yr B.P. Although the evidence for a beginning date of 10,400 yr B.P. for the Sulphur Spring stage is compelling, additional data are needed to ascertain its true maximum age.

Extinct Faunal Associations

No remains of extinct fauna were found in Sulphur Spring artifact-bearing deposits at sites Arizona FF:6:8 or Arizona FF:6:9. Bison was found in the Sulphur Spring artifact-bearing unit Dc sand at Arizona FF:10:14, and mammoth and camel bones were found in deposits below unit Dc, but these bones were not associated with artifacts. The only associations between extinct fauna and Sulphur Spring stage artifacts occur at Arizona FF:10:1, where remains of mammoth, horse, camel, dire wolf, and bison have been recovered from the unit Da gravel and unit Db sand along with artifacts of the Sulphur Spring stage (Sayles and Antevs 1941; Sayles 1983).

As mentioned earlier, Whalen (1971) advanced two explanations to account for the early Holocene occurrences of extinct fauna at the Double Adobe site (Arizona FF:10:1). On one hand, the late fossil occurrences could suggest that relict megafaunal populations survived in select congenial environments beyond the terminal date ascribed for terminal Pleistocene extinctions, and are temporally associated with Sulphur Spring stage artifacts. If this situation existed, articulated megafaunal remains or remains with definite evidence of butchering should be found with Sulphur Spring stage artifacts or occur in deposits of similar age. This is the only way contemporaneity between the extinct megafauna and Sulphur Spring stage artifacts can be demonstrated conclusively. Alternatively, the fossil remains could be older than the deposits in which they occur and could have been redeposited from older alluvial units, and therefore are not temporally associated with Sulphur Spring stage artifacts. In this case, only disarticulated fossil remains showing no evidence of butchering should be found with Sulphur Spring stage artifacts and articulated remains would not be found in deposits of similar age to Sulphur Spring artifact-bearing units.

Fossils from the unit Da gravel and unit Db sand from the Double Adobe area are mostly isolated disarticulated finds, but two discoveries of articulated remains have been reported. Haury (1960) recovered articulated camel leg bones in the sand (unit Db) at Double Adobe from which Sulphur Spring artifacts had previously been recovered, and Windmiller (Sayles 1983) uncovered the remains of a single mammoth in gravel (unit Da) 240 m downstream from Arizona FF:10:1. At the latter locality, two lumbar vertebrae were found in normal articulated position and the humeri and ulnae were very close together with the remainder of the bones scattered in the gravel over a 60-square-meter area (Sayles 1983). Radiocarbon dates on charcoal collected from the gravel near the mammoth are 10,420 ± 100 yr B.P. (A−1152) and 8,920 ± 1150 yr B.P. (Tx−1199; Sayles 1983). The latter date, with a large standard deviation, was obtained on a small sample and is of questionable accuracy. The date of 10,420 yr B.P. is considered accurate and close to its true age. This radiocarbon date is the youngest date associated with articulated megafaunal remains in Whitewater Draw and falls before the maximum accepted date of 10,000 yr B.P. for extinctions in North America (Meltzer and Mead 1983). Therefore, the mammoth and camel remains appear to be in primary position within the older portion of the unit D alluvium. However, no Sulphur Spring stage artifacts were directly associated with either of these remains.

The megafaunal remains recovered from the younger portion of the unit D alluvium in association with Sulphur Spring stage artifacts, dated between 10,000 and 8,000 yr B.P., are all isolated and disarticulated. These bones were probably eroded from older deposits that formed the banks of a braided stream and became reworked into younger deposits with the Sulphur Spring artifacts. Three lines of evidence support such an interpretation: (1) none of the bones of extinct fauna from the unit D alluvium in association with Sulphur Spring stage artifacts are articulated or show evidence of butchering; (2) there are abundant older sediments from which the bones could have been derived (units B, C, and older Da and Db); and (3) the bones occur in a radiocarbon-dated context beyond the conventionally accepted maximum date of extinctions in North America. Mammoth remains in the overlying marl (unit F), especially the skull of a mammoth recovered by Cummings in 1926 from this unit, were possibly redeposited because they are not articulated, and there is no precedent for megafauna of this age anywhere in North America. In short, megafaunal remains are probably not in primary association with Sulphur Spring stage artifacts dated between 10,000 and 8,000 yr B.P.

To be fair, if the Sulphur Spring stage dates earlier than 10,000 yr B.P. (possibly to 10,400 yr B.P.), it is conceivable that the Sulphur Spring people did temporally overlap with relict populations of Pleistocene megafauna, but only during the terminal Pleistocene. To date, however, no Sulphur Spring stage artifacts have been found in direct association with articulated megafaunal bones, including the mammoth bones dated at 10,400 yr B.P. or the articulated camel remains reported by Haury (1960), although Sulphur Spring artifacts have been found in close proximity in the same or similar deposits. The evidence for a Sulphur Spring−Pleistocene fauna overlap during the terminal Pleistocene is possible, but the question remains unresolved until Sulphur Spring stage artifacts are recovered with articulated megafaunal remains or unequivocal evidence of butchering on these bones is found.

Discussion of the Sulphur Spring Stage

The presence of two divergent tool assemblages, one emphasizing hunting (Clovis) and the other plant gathering (Cochise), of seemingly similar antiquity in southeastern Arizona has led to much speculation. Some researchers (Martin and Plog 1973; Haury 1983) have suggested that the Sulphur Spring stage sites could represent specialized plant-gathering stations of the Clovis culture. However, failure to find diagnostic artifacts of the two cultures mixed on a site, their superposition at the Lehner site (Haynes 1982a), and the chronological placement of the Sulphur Spring stage show that they are not temporally equivalent.

Instead, the Sulphur Spring stage of the Cochise culture, dated between 10,000 and 8,000 yr B.P. and possibly as early as 10,400 yr B.P., is the oldest recognized archaic manifestation in southeastern Arizona. It is encompassed under the "Desert Culture" concept (Jennings 1964, 1978) at the adaptational level and is suggested to be part of a wider early archaic tradition in southern Arizona as suggested by Haury (1950) and Rogers (1958).

The Sulphur Spring artifact assemblage is dominated by ground stone artifacts, as are all later assemblages at Cochise culture sites in Whitewater Draw. These artifacts indicate that the Douglas basin was the site of specialized plant gathering and processing. Other Sulphur Spring artifacts indicate that limited hunting and other activities took place, but that plant processing was the primary concern. These sites probably represent part of a wider pattern of seasonal resource exploitation followed by a single people who traveled widely.

Ventana Cave in Pima County, south-central Arizona, is the only dated site in the Southwest of similar antiquity to which comparisons with the Sulphur Spring stage artifacts may be made. The Ventana complex was defined by 90 artifacts, including projectile points (2), knives (11), scrapers (63), gravers (3), choppers (3), planes (6), a hammerstone, and a handstone. The artifacts were recovered from the volcanic debris layer in association with remains of horse and four other extinct species, and a radiocarbon date of 11,300 ± 1200 yr B.P. (A−203) was obtained on dispersed charcoal (Haury 1950; Haury and Hayden 1975). This assemblage was first interpreted as a blending of the western San Dieguito I complex and the Folsom culture. This interpretation was based on Haury's (1950: 531) conclusion

that the typology of the San Dieguito I tools from Ventana Cave were "not only similar, but identical" to those in the West and that the Folsom influence was evidenced by a basalt projectile point. Haury and Hayden (1975: v) have since decided that the point is a "local imitation of a Clovis point." The basalt concave-base projectile point from Ventana Cave is similar in outline to Folsom-Clovis lanceolate points but is unfluted and made on a flake, not by the Clovis bifacial reduction technique.The other Ventana complex artifacts do not resemble other kinds of Clovis artifacts, and the handstone seems especially out of place in a Clovis assemblage. Rogers (1958, 1966) and Hayden (1976) agree that the San Dieguito I complex is strongly represented in the Ventana complex.

Rogers (1958, 1966), Hayden (1976), and Irwin-Williams (1979) also feel there are strong similarities between the Ventana complex and the Sulphur Spring stage, which include flaked stone tool types and technology, the handstone, stone projectile points, and the probable association with extinct faunal remains. Differences in age and the relative percentage of flaked versus ground stone tools are the only stumbling blocks to equating the Sulphur Spring stage and the Ventana complex.

The date from the volcanic debris layer at Ventana Cave has wide margins of error and could fall anywhere between 12,500 and 10,100 yr B.P., thus overlapping the early part of the Sulphur Spring stage. The differences between the Ventana complex and Sulphur Spring assemblages may be attributed to varying regional food resources due to environmental differences between southeastern and southwestern Arizona (McGuire 1982; Haury 1950, 1983). The physiography of southern Arizona produces an east-west environmental gradient resulting in greater aridity moving westward. Even though the early Holocene climate was different from the climate today, the east-west gradient still would have made the west more arid than the east. Thus, a single contemporary adaptation would not be expected in both southwestern and southeastern Arizona. The lack of emphasis on food grinding in the west is also shown by a qualitative east-west decline in ground stone artifacts in later Chiricahua-Amargosa II and San Pedro-Amargosa III sites from east to west.

The correlations between the Ventana complex, the Sulphur Spring stage, and the San Dieguito I complex appear reasonable. Most Ventana complex and Sulphur Spring artifacts seem to fit Rogers's (1958, 1966) trait list for San Dieguito I, with the exception of the presence of ground stone tools and stone projectile points in the Sulphur Spring. As mentioned above, the absence of ground stone in the western San Dieguito I sites may be due to less emphasis on grinding because of the more arid environment of the west. The absence of projectile points in San Dieguito I sites in the west may be due to a lack of preservation. Perhaps perishable materials more commonly were used to make points and thus they are not preserved on surface San Dieguito I sites. Nonstone projectile points are known from Clovis sites ancestral to the San Dieguito I sites (Haynes 1982b), early stone projectile points are rare at both Ventana Cave and Whitewater Draw, and the steep-angled form of many of the San Dieguito I, Ventana, and Sulphur Spring tools suggests a woodworking tool kit.

Thus, the Sulphur Spring stage and the San Dieguito I complex are brought into chronological agreement through the linking site of Ventana Cave, as suggested by Haury (1950) and Rogers (1958). There were two early archaic traditions that appear to be related in southern Arizona during the terminal Pleistocene: the western San Dieguito I complex (southern California and western Arizona) and the eastern Sulphur Spring stage (southeastern Arizona and western New Mexico).

The origin of the Sulphur Spring stage is unknown. A pre-Clovis ancestry is possible, but at present not supportable, because unequivocal evidence for the existence of man in North America prior to 11,500 yr B.P. does not exist (Haynes 1967; Waters 1985). Alternatively, Irwin-Williams (1979) states there is also little evidence for the derivation of early archaic peoples from a Paleo-Indian base.

Although there are vast differences between the archaic and Paleo-Indian cultural materials, the rudiments of the archaic ground stone technology are present in the Paleo-Indian artifacts. In the Clovis assemblage, there is evidence of grinding on flaked stone artifacts and bone tools, and grinding-hammerstones occur in the Clovis horizon at Blackwater Draw, New Mexico (Hester 1972) and at the Colby site, Wyoming (Frison 1978). Grinding technology is well established in the later Folsom assemblage, which is unquestionably derived from Clovis. From the Lindenmeier site in Colorado Wilmsen and Roberts (1978) reported 27 Folsom ground stone artifacts, 10 of which were used for pigment grinding. The Paleo-Indians occupying the West during the onset of the Holocene apparently did not retain big-game hunting equipment as the later Folsom people did in the Plains to hunt bison. Instead they may have reorganized their tool kit to exploit the changing environment in the West. Development of early archaic western traditions from a Paleo-Indian base is not unrealistic, although there are few data to support this speculation.

The shift in emphasis from hunting to gathering probably began before the complete extinction of megafauna during the onset of the Holocene (Haury 1983). The timing of this transition is imprecisely known and it probably took place at different times in different areas. An archaic lifestyle is well established in the Great Basin at Danger Cave by 10,270 ± 650 yr B.P. (M−202; Jennings 1957), in southwestern Arizona by 11,300 ± 1200 yr B.P. (A−203) at Ventana Cave (Haury and Hayden 1975), and in southeastern Arizona by 10,000 yr B.P. and possibly as early as 10,400 yr B.P. as evidenced by the Sulphur Spring stage sites. Thus, the trans-

ition to an archaic lifestyle appears to have begun during the terminal Pleistocene and earliest Holocene in western North America.

THE CAZADOR STAGE

The Cazador was suggested by Sayles (1983) as a stage transitional between the Sulphur Spring and Chiricahua stages of the Cochise culture. As originally defined, it was characterized by milling stones, handstones, flaked stone tools comparable to those of the Sulphur Spring stage, and the first appearance of pressure-flaked projectile points. These artifacts are associated only with modern fauna. Antevs (1983) considered this stage to date from 11,000 to 8,000 yr B.P., based on a geologic estimate that placed the artifacts in late Provo Pluvial (Double Adobe II Subpluvial) deposits formed after the Datil Drought. Cazador artifacts were recognized at three sites: Arizona FF:10:1, locality 2; Arizona FF:6:9; and Arizona FF:6:8. The following discussion considers the validity of Cazador as a stage of the Cochise culture.

At the type site, Arizona FF:10:1, locality 2, Cazador artifacts occur in a gravel and sand. Three radiocarbon dates on charcoal, 8,240 ± 960 yr B.P. (A−184c; Martin 1963b), 8,760 ± 210 yr B.P. (A−3379), and 8,840 ± 310 yr B.P. (A−3377); a date on humates, 8,970 ± 220 yr B.P. (A−3378); and a date on carbonaceous alluvium, 7,030 ± 260 yr B.P. (A−184e; Martin 1963b) were obtained from the sand. The date for sample A−184e is rejected because the material dated has questionable reliability and it is much younger than the other three dates on charcoal from the same deposit. The remaining four dates place the Cazador artifacts in deposits equivalent to the unit Da gravel and unit Db sand of the alluvial sequence. At sites Arizona FF:10:1 (localities 1, 3, 4, and 5), Arizona FF:6:8, and Arizona FF:6:9, units Da and Db contain Sulphur Spring artifacts that date between 9,400 yr B.P. and 8,000 yr B.P., and possibly as early as 10,400 yr B.P. (see Sulphur Spring stage dating section). The artifact-bearing gravel and sand deposits at the Cazador type site are not younger than the Sulphur Spring artifact-bearing sand and gravel deposits at localities 1 and 3 through 5, but are their equivalents. Therefore, the artifacts assigned to the Cazador stage at locality 2 are actually Sulphur Spring in age.

At site Arizona FF:6:8, Cazador artifacts were recovered by Sayles (1983) and Antevs (1983) from a blue-gray clay (unit G1) and a clayey sand (unit H). Charcoal samples collected from unit G1 dated 6,940 ± 190 yr B.P. (A−3235) and 6,950 ± 170 yr B.P. (A−3236). A radiocarbon date on charcoal and humates from unit H is 6,750 ± 180 yr B.P. (A−3234). The Cazador artifacts from this locality date about 2,000 years younger than those at the type site of Arizona FF:10:1, locality 2, which has been erroneously termed Cazador. The artifacts from Arizona FF:6:8 were assigned to the Cazador stage by Sayles (1983) and Antevs (1983) solely on geologic criteria, and the artifacts from this site do not appear typologically or technologically distinctive.

At site Arizona FF:6:9 Cazador artifacts were collected also from a blue-gray clay (unit G1; Sayles 1983; Antevs 1983). No radiocarbon dates were obtained from unit G1 at this site, but the deposit is correlative with unit G1 at Arizona FF:6:8, suggesting these artifacts are about 7,000 years old. Again, my assessment of Arizona FF:6:8 applies here.

Thus, the Cazador artifacts as defined by Sayles in 1983 appear to have come from a mixture of Sulphur Spring stage and younger contexts, raising serious doubts about the validity of the Cazador stage.

THE CHIRICAHUA STAGE

The Chiricahua was considered originally by Sayles (Sayles and Antevs 1941) as a transitional stage between the Sulphur Spring and San Pedro stages of the Cochise culture. Later, Sayles (1983) placed Chiricahua between the Cazador and San Pedro stages. As defined, it is characterized by milling stones (especially shallow basin forms), handstones (especially shaped), proto-pestles, and a variety of unifacially and bifacially flaked tools that display a greater variety of forms and occur in greater frequency than in the preceding stages. The small side and basal notched projectile point is the most diagnostic element of this stage. These artifacts are associated only with modern fauna. Antevs (1983) believed Chiricahua artifacts ranged in age from 8,000 to 3,500 yr B.P., based on a geologic estimate that placed these artifacts in post-Pluvial deposits ranging in age from the late Anathermal, through the Altithermal, and into the early Medithermal. Chiricahua artifacts were recovered from six sites in Whitewater Draw and from a number of other sites in southern Arizona and New Mexico.

Based on my investigations, I feel that the time depth suggested for the Chiricahua stage in Whitewater Draw may have been overestimated by Antevs. Antevs utilized his geologic-climatic dating method to estimate the age of the Chiricahua stage sites in Whitewater Draw. Using this method, Antevs (Sayles and Antevs 1941; Antevs 1983) derived a maximum age of 8,000 yr B.P. for the Chiricahua stage occupation at sites GP Sonora FF:10:31 and GP Sonora FF:10:30. Other Chiricahua stage sites in Whitewater Draw were inferred to be of similar age. I investigated a site near Double Adobe (Arizona FF:10:13) that is only 3 to 4 km southeast of sites FF:10:30 and 31, and it essentially duplicates the stratigraphy described by Antevs (Sayles and Antevs 1941; Antevs 1983) at these sites (especially that at site 31). Deposit M at Arizona FF:10:13 may be correlated with a large degree of reliability to the Chiricahua artifact-bearing deposits at sites 30 and 31. A charcoal sample from the Chiricahua deposit (unit M) at Arizona FF:10:13 yielded a

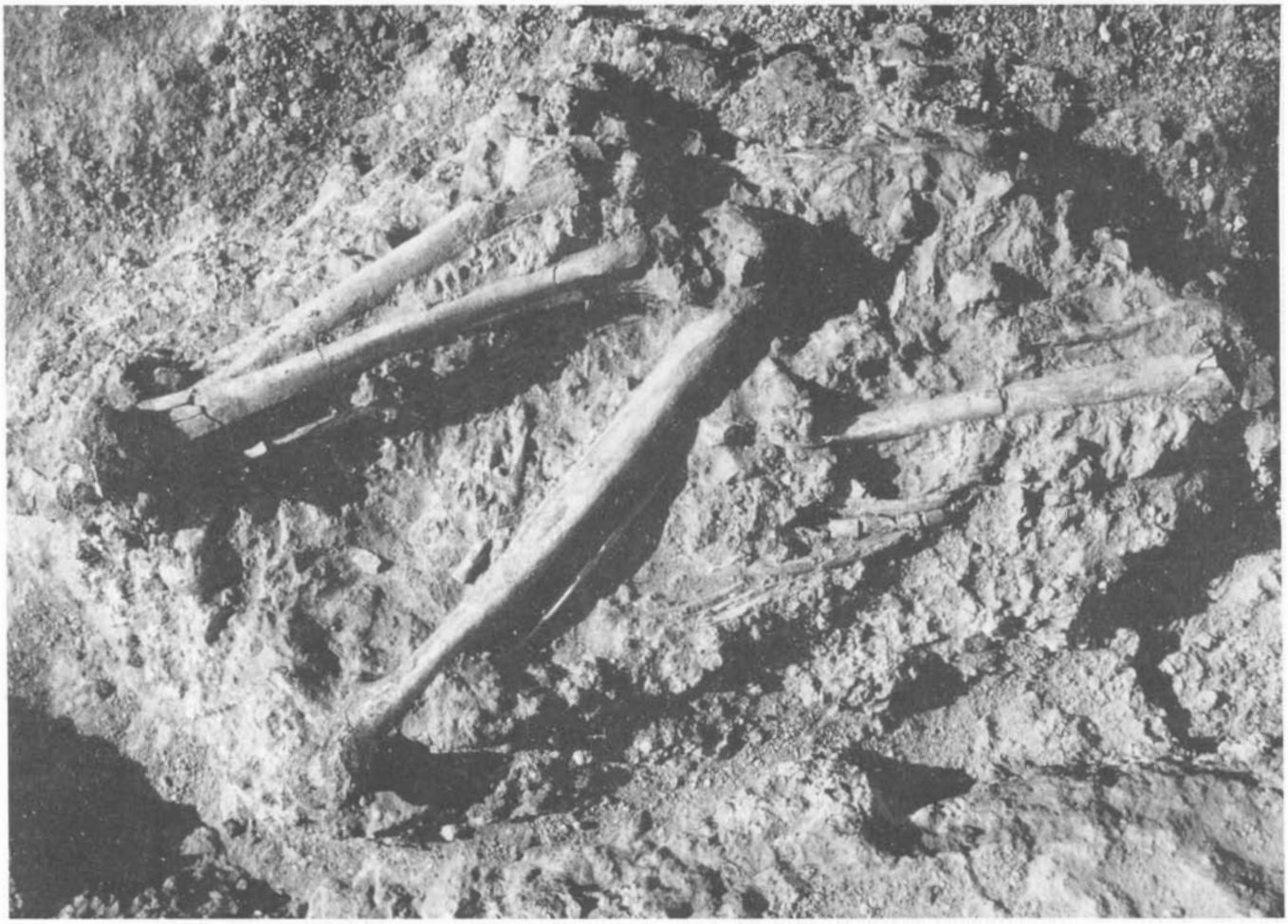


Figure 4.11. Flexed human skeleton found 2 km northwest of Double Adobe below sediments dating approximately 4,000 yr B.P.

date of 3,500 ± 100 yr B.P. (A−3183). The correlative deposits at sites FF:10:30 and 31, therefore, would date also to approximately 3,500 yr B.P. This date is much younger than Antevs's geologic estimate of 8,000 yr B.P. for these deposits. It should be noted that this is the only deposit in Whitewater Draw that has yielded the distinctive Chiricahua points.

The time depth for the Chiricahua stage in Whitewater Draw is unknown, and evidence suggests that the maximum age for the Chiricahua stage may have been overestimated. Redefining the beginning date of the Chiricahua stage would leave a major gap in the archaeological record of Whitewater Draw from 8,000 yr B.P. (end of the Sulphur Spring stage) to 3,500 yr B.P. (oldest documented Chiricahua stage material). There are artifacts in the intervening deposits but they are primarily nondiagnostic ground stone artifacts. The only exception is a serrated point recovered by Sayles and Antevs (1941) from deposit G1 at site Arizona FF:6:9, which has been radiocarbon dated to approximately 7,000 yr B.P. Irwin-Williams (1979) has suggested that the Chiricahua stage began at approximately 5,500 to 5,000 yr B.P. in western New Mexico. Radiocarbon dates associated with diagnostic "Chiricahua" stage artifacts are needed from Whitewater Draw to determine if this beginning date may be applied to southeastern Arizona.

It is appropriate here to mention a second human burial that I discovered in Whitewater Draw. The skeleton was found in a calcareous silty sand approximately 2 km northwest of Double Adobe. It is difficult to precisely place this unit in the alluvial sequence, and the only statement that can be made with certainty is that the burial occurred below cienega sediments that dated 3,920 ± 110 yr B.P. (A−3315). The skeleton was in a very tightly flexed position in the lower 10 cm of the silty sand (Fig. 4.11). The skull cap was recovered above the rest of the burial in the same silty sand. No grave offerings were found with the bones.

THE SAN PEDRO STAGE

The San Pedro is the final stage of the preceramic Cochise cultural sequence (Sayles and Antevs 1941; Sayles 1983). It is marked by changes in the ground stone and flaked stone tool assemblages that clearly distinguish it from the preceding Chiricahua stage. Antevs (Sayles and Antevs 1941; Antevs 1983) estimated this stage ranged from 3,500 to approximately 2,000 yr B.P. (introduction of pottery). My investigations add little concerning the San Pedro stage other than to suggest that the maximum time depth of 3,500 yr B.P. for this stage may be overestimated. A terminal date for the Chiricahua phase is unknown and typical Chiricahua points and artifacts are found in deposits dating 3,500 ± 100 yr B.P. (A−3183). Therefore, 3,500 yr B.P. as a beginning date may be too early, and the San Pedro stage may have a slightly more restricted time range.

CHAPTER FIVE

Geoarchaeological Assessment

The application of geological concepts and methods to investigate archaeological sites is known as geoarchaeology (Butzer 1982). Whitewater Draw has had a long history of geoarchaeological investigations, because in order to understand the archaeology of the Draw it is necessary to have a clear comprehension of its alluvial geology. The interdisciplinary research of E. B. Sayles and Ernst Antevs in the late 1930s utilized geology to establish an archaeological sequence and to provide approximate ages for that sequence. Their interpretations of the archaeology and geology have become problematical as additional data have been gathered from other archaeological sites in the Southwest. The geoarchaeological investigations reported herein were undertaken to resolve some of the questions that have arisen since the work of Sayles and Antevs and has resulted in a new understanding of the geology of Whitewater Draw, providing a framework with which to reassess the Cochise cultural sequence.

A complex sequence of late Quaternary alluvial strata is exposed in Whitewater Draw arroyo. These deposits are cut into an old valley fill of late Tertiary or early Pleistocene age and are inset against terraces of Pleistocene age. The Late Quaternary alluvial history of Whitewater Draw is characterized by: (1) deposition of gravel and sand in a braided stream from 15,000 to 8,000 yr B.P., (2) cycles of erosion and deposition of silts and clays in large wet meadows or cienegas from 8,000 to 6,700 yr B.P., (3) arroyo cutting and filling with gravel, sand, and cienega deposits between 6,700 and 5,500 yr B.P., (4) cycles of erosion and deposition of silts and clays in cienegas from 5,500 yr B.P. to the historic period, and (5) arroyo cutting initiated in A.D. 1885.

The broad sedimentological and depositional changes recorded in the Whitewater Draw alluvial record—changes from a braided stream, to a cienega environment, to an arroyo, and back to a cienega environment—appear to be coincident with large scale climatic changes recognized by paleoecologists. However, the complex degradation and aggradation documented during apparently stable climatic periods must have been dominantly controlled by geomorphic parameters. Nineteenth-century arroyo cutting is suggested to have been human induced, but evidence is ambiguous (Cooke and Reeves 1976).

Comparison of the alluvial record of Whitewater Draw with that of the adjacent San Pedro Valley shows that there are vast differences between the alluvial records of the two valleys. The alluvial record of the adjacent San Pedro Valley is characterized by many more periods of arroyo cutting and filling and fewer periods of cienega deposition. Most of this degradation and aggradation is out of phase in number, character, and timing in comparison with the alluvial history of Whitewater Draw. The only exception is the near synchronous cutting and filling of arroyos in both valleys during the middle Holocene. These differences indicate that for the most part the fluvial systems in the Douglas basin and the San Pedro Valley responded differently to external climatic perturbations because of local unique geomorphic controls. Also, in some cases the fluvial systems in the Douglas basin and the San Pedro Valley may not have been responding to changes in external variables, but instead were independently crossing intrinsic geomorphic thresholds peculiar to each basin, thus accounting for differences in the alluvial record of the two valleys. This demonstrates that regional correlations of late Quaternary deposits from one valley to the next should not be attempted without absolute temporal control and that intervalley correlations must take into consideration the complexity of fluvial processes.

Remains of six genera of Pleistocene megafauna—mammoth, horse, camel, dire wolf, sloth, and bison—were recovered from six upper Quaternary deposits in Whitewater Draw dating from the late Pleistocene to 7,000 yr B.P. Megafaunal remains dating 10,400 yr B.P. or older are considered to be in primary context, while mammoth, horse, camel, and dire wolf remains from deposits dating 10,400 to 7,000 yr B.P. appear to be in secondary contexts, redeposited from older sediments.

The Cochise culture was defined by Sayles (Sayles and Antevs 1941) as the "pre-pottery and essentially pre-house culture in southeastern Arizona and adjacent New Mexico." At that time the Cochise culture was divided into three developmental stages on the basis of material culture (artifact typology), association with either extinct or modern fauna, and geologic occurrence. These stages, from oldest to youngest, were the Sulphur Spring, Chiricahua, and San Pedro. Later in 1953 Sayles added a fourth stage, the

Cazador, between the Sulphur Spring and Chiricahua stages. Age estimates were placed on these stages by Antevs utilizing the geologic-climatic dating method. My investigations of Whitewater Draw indicate that the Cochise culture stages should be reevaluated.

Artifacts of the earliest stage, the Sulphur Spring, are found at four sites in Whitewater Draw and possibly at the Lehner site where early Cochise culture artifacts overlie the Clovis horizon (Haynes 1982a). The Sulphur Spring artifact assemblage is characterized by milling stones, handstones, unifacial flake tools, and a few bifacially flaked knives and projectile points. The Sulphur Spring artifacts do not appear to be significantly distinct, either typologically or technologically, from artifacts found in younger deposits in Whitewater Draw. Artifacts are recognized as belonging to the Sulphur Spring stage mainly on the basis of geologic occurrence and dating. If any of these artifacts were found on the surface, it would be difficult to distinguish them from artifacts of a younger age.

The preponderance of milling stones and handstones at Sulphur Spring sites indicates that the Douglas basin was the site of intensive plant gathering and processing, and other artifacts suggest that only limited hunting and other activities took place. This activity-specific artifact assemblage indicates that these sites probably represented only one aspect of a wider subsistence pattern, followed by a single people, that may be related to the San Dieguito I complex of the Lower Colorado River region.

Radiocarbon dating places the Sulphur Spring stage between 10,000 and 8,000 yr B.P. and probably as early as 10,400 yr B.P. Megafaunal remains appear not to be in primary association with Sulphur Spring stage artifacts dated between 10,000 and 8,000 yr B.P. It is conceivable that the Sulphur Spring people did temporally overlap with relict populations of Pleistocene megafauna during the terminal Pleistocene, but this issue remains unresolved.

An early Sulphur Spring stage human burial was discovered in Whitewater Draw. The skeletal material was from an alluvial deposit that was dated between 10,400 to 8,000 yr B.P. These early human remains are the oldest known from the Southwest and provide data on the earliest inhabitants of North America.

Questions have been raised concerning the validity of the Cazador stage, added later to the cultural sequence by Sayles (1983). At the type site (Arizona FF:10:1, locality 2), artifacts assigned to the Cazador stage occurred in gravel and sand deposits that yielded dates equivalent in age to sediments containing Sulphur Spring stage materials. Cazador artifacts also occurred in deposits at two sites dating 6,750 yr B.P. and 6,950 yr B.P. Thus, the Cazador artifacts are shown to have come from a mixture of Sulphur Spring and younger contexts.

The time depth of the Chiricahua stage in Whitewater Draw appears to have been overestimated by approximately 4,500 years. This leaves a large time gap between 8,000 and 3,500 yr B.P. unfilled by any cultural stages. Nondiagnostic ground stone artifacts are found in deposits of this age. In addition, the lower time boundary established by Sayles (1983) for the San Pedro stage may be too early. All these points indicate that problems remain with the cultural chronology and terminology for the archaic of southern Arizona.

Description of Geologic Units

ARIZONA FF:6:9 (GP PEARCE 8:21)

Unit	Maximum Thickness (cm)	Description
P2	25	Silt and very fine sand, dull brown (7.5 YR 5/3)d, dark brown (7.5 YR 3/3)w; faint lamination, platy structure; soft; visible reaction; equivalent to unit K of Antevs (1983: 38).
O2	95	Silty clay, dull brown (7.5 YR 5/3)d to grayish brown (7.5 YR 4/2)d, brown (7.5 YR 4/3)w; medium subangular to crumb structure; hard; visible reaction; equivalent to unit j (upper) of Antevs (1983: 38).
I3	110	Clay, dull brown (7.5 YR 6/3)d, dull brown (7.5 YR 4/4)w; strong, fine angular to subangular blocky structure; hard; audible reaction, abundant <2−cm hard $CaCO_3$ nodules, especially along ped surfaces; equivalent to unit j (lower south half) of Antevs (1983: 38).
I2	140	Sand, silt, and clay, dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/4)w, fine, horizontally laminated to bedded very fine sand, silt, and clay; soft to slightly hard; visible reaction; limonite staining; overall fining upward sequence; equivalent to unit i of Antevs (1983: 38).
IIb	180	Sand, light-gray (10 YR 8/1−8/2)d, moderately sorted, subangular to angular, medium to fine arkosic sand; soft; no reaction; prominent planar cross bedding, minor silt and pebble-gravel interbeds; no equivalent unit.
IIa	160	Gravel, light gray (10 YR 8/1−8/2)d, well-rounded to subrounded, small pebble to coarse cobble gravel, clay balls; loose; no reaction; coarse sand interbeds; limonite and manganese staining; no equivalent unit.
G4	135	Clay, dull brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; strong, fine to medium prismatic to medium angular blocky structure; hard; audible reaction, abundant hard $CaCO_3$ nodules; equivalent to units g and j (lower north half) of Antevs (1983: 38).
G3	100	Clay, dull brown (7.5 YR 5/4)d, dark brown (7.5 YR 3/4)w, mottled; upper part medium to coarse angular blocky structure, base massive; hard; visible reaction, sparse $CaCO_3$ nodules; transitional into unit G4; equivalent to units h and f (upper) of Antevs (1983: 38).
G2	40	Silt, dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/4)w; massive, vuggy; soft; visible reaction; equivalent to unit f (lower) of Antevs (1983: 38).
G1	105	Clay, grayish yellow-brown (10 YR 5/2)d, brownish black (10 YR 2/3)w; weak, coarse prismatic structure, mottled; hard; audible reaction, sparse hard <1−cm $CaCO_3$ nodules, especially along ped surfaces; shells; equivalent to unit e of Antevs (1983: 38).
E2	90	Sandy clayey silt, dull yellow orange (10 YR 6/3)d, dull yellowish brown (10 YR 5/3)w; coarse prismatic structure; hard; persistent reaction; equivalent to unit d of Antevs (1983: 38).
Db	110	Sand, light gray (10 YR 7/1)d, grayish yellow-brown (10 YR 5/2)w; moderately to poorly sorted, subangular to angular, coarse to fine arkosic sand; soft; no reaction; discontinuous, undulatory, <5−cm−thick clay and silt interbeds, brownish gray (10 YR 5/1)d, brownish gray (10 YR 4/1)w to grayish yellow-brown (10 YR 4/2)w, occasional fine pebble-gravel lens; limonite staining; equivalent to unit c of Antevs (1983: 38).
Da	60	Gravel, light gray (10 YR 7/1)d, grayish yellow-brown (10 YR 5/2)w, well-rounded to subrounded, small pebble to

		small boulder gravel, average small cobble; loose; no reaction; medium to coarse sand interbeds; limonite and manganese staining; equivalent to unit b of Antevs (1983: 38)
A	150+	Clay, dull orange (2.5 YR 6/3)d, dull reddish brown (2.5 YR 5/3)w; very hard; visible reaction, abundant $CaCO_3$ nodules; equivalent to unit a of Antevs (1983: 38).

ARIZONA FF:6:8 (GP PEARCE 8:10)

Unit	Maximum Thickness (cm)	Description
P2	20	Silt and very fine sand, grayish brown (7.5 YR 5/2)d, dark brown (7.5 YR 3/3)w; faint lamination, platy structure; soft; visible reaction; equivalent to unit j of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
O2	120	Silty clay, grayish brown (7.5 YR 4/2)d, grayish brown (7.5 YR 4/2)w; medium angular to subangular blocky to crumb structure; hard; visible reaction; interbedded silty sand, channel sand and gravel at base; equivalent to unit i of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
N2(?)	125	Clay, dull brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; medium angular to subangular blocky to crumb structure; hard; visible reaction, <1−cm $CaCO_3$ nodules; shallow clayey sand channels with reworked $CaCO_3$ nodules; equivalent to unit h of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
I3	130	Clay, dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/4)w; strong, fine angular to subangular blocky structure; hard; audible reaction, abundant <2−cm hard $CaCO_3$ nodules, especially along ped surfaces; some dispersed very fine sand, interbedded clayey sand; equivalent to unit h of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
I2	150	Sand, silt, and clay, dull brown (7.5 YR 5/4−6/3)d, dark brown (7.5 YR 3/4)w to brown (7.5 YR 4/4)w; fine horizontally laminated to bedded very fine sand, silt, and clay; soft to slightly hard; visible to persistent reaction; salts; upper 50 cm alternating clay-silt laminations with hard <1−cm irregular $CaCO_3$ nodules; limonite staining; overall fining-upward sequence; equivalent to unit g of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
I1a and I1b	75	Sand and gravel, light gray (10 YR 8/1−8/2)d; subangular to angular, very fine to coarse arkosic sand and well-rounded pebble gravel with clay balls; loose; no reaction; interbedded <1−cm−thick clay and silt lenses; limonite and manganese staining; equivalent to unit g of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
H	95	Clayey sand, dull brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; subangular to angular, coarse to medium arkosic sand with clay matrix; slightly hard; visible reaction; shells; equivalent to unit f of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
G4	150	Clay, dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/4)w; strong, fine to medium prismatic structure; hard; audible reaction, abundant <2−cm $CaCO_3$ nodules, especially along ped surfaces; minor clayey sand interbeds, base (G3?) massive to coarse prismatic; equivalent to unit e of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
G2	20	Silt, dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; massive, vuggy; soft; visible reaction; equivalent to unit e of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
G1	125	Clay, grayish yellow-brown (10 YR 5/2)d, brownish black (10 YR 3/2)w, mottled; coarse to medium prismatic structure; hard; audible reaction; few 4- to 8−cm−thick medium to coarse sand and small pebble gravel lenses in lower 30 cm, upper half scattered <2−cm $CaCO_3$ nodules, especially along ped surfaces; base massive; shells; equivalent to unit e of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
E2	125	Clay to sandy clay, dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; coarse prismatic to medium angular blocky structure, vuggy; hard; visible reaction, scattered hard 0.25−cm $CaCO_3$ nodules; shells; equivalent to unit d of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
E1	35	Clayey sand, dull brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; angular to subangular medium sand with clay matrix; hard; persistent reaction; shells; equivalent to unit d of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
Db	80	Sand, light gray (10 YR 7/1)d, grayish yellow-brown (10 YR 5/2)w; moderate to well-sorted, subangular to angular, coarse

		to fine arkosic sand; soft; no reaction; discontinuous undulatory <5−cm−thick laminated sandy clay, clay, and silt interbeds, brownish gray (10 YR 5/1)d, brownish gray (10 YR 4/1)w to grayish yellow-brown (10 YR 4/2)w, occasional fine-pebble gravel lens and thick clay; limonite staining; equivalent to units c and b of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
Da	175	Gravel, light gray (10 YR 7/1)d, grayish yellow-brown (10 YR 5/2)w; well-rounded to subrounded, small pebble to small boulder gravel, average small cobble; loose; no reaction; occasional thin, medium to coarse sand interbed; limonite and manganese staining; equivalent to unit a of Sayles and Antevs (1941: 49) and Antevs (1983: 39).
A	50+	Clay, dull orange (2.5 YR 6/3)d, dull reddish brown (2.5 YR 5/3)w; very hard; visible reaction, $CaCO_3$ nodules; no equivalent unit.

ARIZONA FF:10:1 (GP SONORA F:10:1) AND ARIZONA FF:10:13

Unit	Maximum Thickness (cm)	Description
P2	20	Silt, dull orange (7.5 YR 7/3)d, dark brown (7.5 YR 3/4)w; platy structure; soft; visible reaction; equivalent to unit f of Sayles and Antevs (1941: 46−47) and Antevs (1983: 37).
P1	200	Sandy silt, dull orange (7.5 YR 7/3)d, dark brown (7.5 YR 3/4)w; soft; visible reaction; no equivalent unit.
O2	80	Silty clay, grayish brown (5 YR 5/2)d, grayish brown (5 YR 4/2)w; fine subangular blocky to crumb structure; soft; audible reaction; equivalent to unit e of Antevs (1983: 37).
Olb	155	Clay-silt, light gray (7.5 YR 8/1)d, light brownish gray (7.5 YR 7/2)w; alternating clay-silt laminations, coarse to medium, subangular to angular blocky structure; soft; visible to persistent reaction; lower portion arkosic sand with abundant reworked $CaCO_3$ nodules; no equivalent unit.
Ola	160	Sandy silt, grayish yellow-brown (10 YR 6/2)d, dark brown (10 YR 3/4)w; hard; strong reaction, abundant reworked $CaCO_3$ nodules; equivalent to units d^1-d^3 of Antevs (1983: 37).
N2	140	Clay, grayish brown (5 YR 5/2)d, grayish brown (5 YR 4/2)w; medium subangular blocky structure; hard; audible reaction, sparse to no $CaCO_3$ nodules; no equivalent unit.
M	80	Clay, gray (7.5 Y 5/1)d to grayish olive (7.5 Y 5/2)d, gray (7.5 Y 4/1)w to grayish olive (7.5 Y 4/2)w; massive; hard; audible reaction; shells; no equivalent unit.
L	170	Clay to silty clay, grayish brown (7.5 YR 6/2)d, dark brown (7.5 YR 3/3)w; strong, fine to medium prismatic structure; very hard; visible to audible reaction, abundant hard <1−1.5−cm irregular $CaCO_3$ nodules, especially along ped surfaces; shells; possibly equivalent to units d and e of Sayles and Antevs (1941: 46−47).
K(?)	160	Clay, yellowish gray (2.5 Y 5/1)d, yellowish gray (2.5 Y 4/1)w, mottled; medium prismatic structure to massive; hard; visible reaction, small soft $CaCO_3$ nodules; shells; 2 cm silt interbed near base, dull-orange (5 YR 7/3)d, dull reddish brown (5 YR 4/4)w, vuggy, soft; audible reaction. Lower 70 cm in channel, clay, gray (5 Y 4/1)d, gray (5 Y 5/1)w; fine laminated to massive; hard; audible reaction; fissile; flat seams of charcoal and decayed flora along laminations; limonite staining; no equivalent unit.
J1	50	Clay-silt, grayish brown (5 YR 6/2)d to dull brown (7.5 YR 6/3)d, dull reddish brown (5 YR 4/3)w; fine horizontal clay-silt laminations, fissile; slightly hard; visible reaction; no equivalent unit.
F2	125	Marl, light gray (10 YR 8/1)d, light gray (10 YR 8/2)w; clayey, coarse prismatic structure to massive, vuggy; very hard; persistent reaction; equivalent to unit c^2 of Sayles and Antevs (1941: 46−47).
F1	100	Marl, dull yellow-orange (10 YR 7/2)d, brownish black (10 YR 3/2)w; laminated clay, silt, and $CaCO_3$, coarse prismatic structure, interbedded with hard flat $CaCO_3$ nodules; persistent reaction; equivalent to unit c^1 of Sayles and Antevs (1941: 46−47).
Dd	65	Clay, yellow-gray (2.5 Y 5/1)d, yellowish gray (2.5 Y 4/1)w to dark olive-brown (2.5 Y 3/2)w; massive, laminated at base, silt interbeds; hard; audible reaction; equivalent to unit c of Antevs (1983: 37).

Db	95	Sand, light brownish gray (7.5 YR 7/2)d to dark grayish yellow (2.5 Y 5/2)d, dull brown (7.5 YR 5/3)w to dark grayish yellow (2.5 Y 5/2)w; very fine to very coarse arkosic sand with 30−cm−thick silt and clay interbeds; soft to loose; audible to no reaction; limonite staining; equivalent to unit b^2 of Sayles and Antevs (1941: 46−47) and Antevs (1983: 37).
Dd	100	Clay, light gray (10 YR 8/1)d to gray (5 Y 5/1)d, grayish yellow-brown (10 YR 6/2)w to gray (5 Y 4/1)w; massive to laminated; hard; audible reaction; limonite staining; no equivalent unit.
Da	155	Gravel and sand, grayish brown (7.5 YR 6/2)d to grayish yellow-brown (10 YR 5/2)d, brown (7.5 YR 4/3)w to grayish yellow-brown (10 YR 4/2)w; well-rounded, small pebble to small cobble gravel, average large pebble, interbeds of poorly to moderately sorted, subrounded to angular, medium to very coarse arkosic sand, clay balls, <10−cm−thick silty clay and clay interbeds; loose; audible to no reaction; limonite and manganese staining; equivalent to unit b^1 of Sayles and Antevs (1941: 46−47) and Antevs (1983: 37).
C	260	Sandy clay, light gray (10 YR 8/1)d to dull orange (2.5 YR 6/3)d, dull yellow-orange (10 YR 7/2)w to dull reddish brown (2.5 YR 5/4)w; medium prismatic to angular blocky structure to massive; very hard; persistent reaction, hard irregular $CaCO_3$ nodules; locally 50−cm−thick porous tufa beds; no equivalent unit.
A	100+	Clay, reddish brown (10 R 5/3)d, reddish brown (10 R 4/3)w, mottled light gray (7.5 Y 8/2)d, grayish olive (7.5 Y 6/2)w; very hard; visible reaction, <4−cm $CaCO_3$ nodules; equivalent to unit a of Sayles and Antevs (1941: 46−47) and Antevs (1983: 37).

ARIZONA FF:10:14 (GP SONORA F:10:17) AND THE TORTOISE AND BULL LOCALITIES

Unit	Maximum Thickness (cm)	Description
P2	40	Silt to very fine sand, dull brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; faint lamination, platy structure; soft; visible reaction; equivalent to unit i of Sayles and Antevs (1941: 51).
N2	200	Silty clay to clay, dull brown (7.5 YR 5/3)d to brown (7.5 YR 4/3)d, dark brown (7.5 YR 3/3)w; fine to medium subangular blocky to crumb structure; hard; visible reaction; equivalent to unit h of Sayles and Antevs (1941: 51).
N1	20	Silty sand, dull brown (7.5 YR 5/3)d, dark brown (7.5 YR 3/3)w; slightly hard; audible reaction; no equivalent unit.
L	180	Clay, gray (10 Y 5/1)d, gray (10 Y 5/1−4/1)w, with dull reddish brown (5 YR 4/4)d, dark reddish brown (5 YR 3/4)w mottles; strong medium prismatic to medium subangular to angular blocky structure, banded; hard; visible reaction, abundant <2−cm hard to soft $CaCO_3$ nodules, especially along ped surfaces, nodules form bands; in places lower quarter massive; shells; equivalent to unit g of Sayles and Antevs (1941: 51).
K	120	Clay, gray (5 Y 4/1)d to gray (7.5 Y 6/1)d, gray (5 Y 6/1−5/1)w to gray (7.5 Y 5/1)w; very finely laminated to massive, fissile; hard; audible reaction; flat charcoal and decayed flora along laminations; limonite staining; base sandy clay; shells; equivalent to unit f of Sayles and Antevs (1941: 51).
J1	210	Clay-silt, grayish brown (5 YR 6/2)d to dull brown (7.5 YR 6/3)d, dull reddish brown (5 YR 4/3)w to dull brown (7.5 YR 5/4)w; very fine horizontal clay-silt laminations, fissile; slightly hard; visible reaction; few sand to silt interbeds at base, occasionally reduced dull yellow (2.5 Y 6/3)d, yellowish brown (2.5 Y 5/3)w; occasional flat seams of charcoal and decayed flora along laminations; equivalent to units e^1 and d of Sayles and Antevs (1941: 51).
IIb and IIa	100+	Sand and gravel, grayish brown (7.5 YR 6/2)d to dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; subrounded to subangular, medium arkosic sand with pebble gravel interbeds; loose; audible reaction; limonite staining; no equivalent unit.
E2	260	Sandy clay, grayish brown (7.5 YR 5/2)d, dark brown (7.5 YR 3/4)w; medium prismatic to medium subangular blocky structure, dispersed fine to medium sand in clay matrix, vuggy; hard; visible reaction, hard <2−cm $CaCO_3$ nodules; base massive; no equivalent unit.

Dc	120	Sand to silty sand, dull orange (7.5 YR 6/4)d, brown (7.5 YR 4/3)w; poorly sorted, subangular to angular, fine to coarse arkosic sand with dispersed small to large pebble gravel; very hard; visible reaction, sparse <2−cm $CaCO_3$ nodules; limonite staining; cross bedding; equivalent to unit c of Sayles and Antevs (1941: 51).
Db	220	Sand and silt, dull brown (7.5 YR 6/3)d, dull brown (7.5 YR 5/4)w to brown (7.5 YR 4/4)w; very fine, subangular arkosic sand, minor gravel lenses; slightly hard; audible reaction; equivalent to unit a (upper) of Sayles and Antevs (1941: 51).
Da	235	Gravel and sand, dull yellow-orange (10 YR 7/2)d, dull yellowish brown (10 YR 4/3)w; moderately sorted, angular to subangular, medium to coarse arkosic sand and well-rounded small pebble to small cobble gravel, average large pebble; loose; no reaction; some cross bedding; limonite and manganese staining; equivalent to unit a (lower) of Sayles and Antevs (1941: 51).
A	150+	Clay, dull reddish brown (5 YR 5/3)w; hard; persistent reaction, $CaCO_3$ nodules; no equivalent unit.

ARIZONA FF:10:16

Unit	Maximum Thickness (cm)	Description
P2	70	Silt to very fine sand, dull brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; horizontally laminated, platy structure; soft; visible reaction.
N2b	160	Clay, grayish brown (5 YR 5/2)d, grayish brown (5 YR 4/2)w; medium subangular blocky structure; hard; audible reaction, sparse small $CaCO_3$ nodules; interbedded clayey sand.
N2a	110	Clay, grayish brown (5 YR 5/2)d, grayish brown (5 YR 4/2)w; fine blocky to fine prismatic structure; hard; audible reaction, sparse $CaCO_3$ nodules; interbedded clayey sand.
M	60+	Clay, gray (7.5 Y 5/1)d to grayish olive (7.5 Y 5/2)d, gray (7.5 Y 4/1)w to grayish olive (7.5 Y 4/2)w, massive; hard; audible reaction; gastropods.

CRYSTAL LOCALITY

Unit	Maximum Thickness (cm)	Description
J2	80	Silty clay, grayish brown (5 YR 5/2)d, grayish brown (5 YR 4/2)w; strong, medium prismatic structure; hard; visible reaction, <2−cm $CaCO_3$ nodules.
J1	180	Clay-silt, grayish brown (5 YR 5/2)d, dull reddish brown (5 YR 5/3)w; alternating clay-silt horizontal laminations, upper 50 cm coarse to medium prismatic to blocky structure with <3−cm $CaCO_3$ nodules; shells; transitional into unit J2.
Db	110	Silt and very fine sand, dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; horizontally laminated to massive; soft; audible reaction.
Dd	200	Clay, dark bluish gray (10 BG 3/1)d, bluish black (10 BG 2/1)w; very coarse prismatic structure to massive; hard; audible reaction; gypsum crystals; shells.
Db	10+	Silt and sand, dull brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; soft; audible reaction.

References

Antevs, Ernst
1937 Climate and early man in North America. In *Early Man*, edited by G. G. MacCurdy, pp. 125–132. New York: J. P. Lippincott.
1948 Climatic change and pre-white men. *Utah University Bulletin* 38(20): 168–191.
1952 Arroyo cutting and filling. *Journal of Geology* 60: 375–385.
1955a Geologic-climatic dating in the West. *American Antiquity* 20(4): 317–335.
1955b Geologic-climatic method of dating. In Geochronology, edited by T. L. Smiley, pp. 151–169. *University of Arizona Bulletin Series* 26(2).
1962 Late Quaternary climates in Arizona. *American Antiquity* 28(2): 193–198.
1983 Geologic dating. In The Cochise Cultural Sequence in Southeastern Arizona, by E. B. Sayles, pp. 26–43. *Anthropological Papers of the University of Arizona* 42. Tucson: University of Arizona Press.

Antevs, Ernst, and E. B. Sayles
1937 Geologic cross section of the Double Adobe site, Arizona. Archives, Arizona State Museum Library, University of Arizona, Tucson.

Begin, Z. B., and S. A. Schumm
1984 Gradational thresholds and landform singularity: significance for Quaternary studies. *Quaternary Research* 21: 267–274.

Breternitz, D. A., A. C. Swedlund, and D. C. Anderson
1971 An early burial from Gordon Creek, Colorado. *American Antiquity* 36(2): 170–182.

Butzer, Karl W.
1982 *Archaeology as Human Ecology: Method and Theory for a Contextual Approach*. Cambridge and New York: Cambridge University Press.

Coates, D. R., and R. L. Cushman
1955 Geology and ground-water resources of the Douglas basin, Arizona. *U.S. Geological Survey Water-Supply Paper* 1354.

Cooke, R. U., and R. W. Reeves
1976 *Arroyos and Environmental Change in the American Southwest*. Oxford: Clarendon Press.

Cummings, Byron
1927 Cochise's yesterday. *The Tombstone Epitaph* 449(4): 12, 25.
1928 Cochise of yesterday. *Arizona, Old and New* 1(4): 9–10, 26–28.

Damon, P. E., and Austin Long
1972 Arizona radiocarbon dates III. *Radiocarbon* 4: 239–249.

Di Peso, C. C.
1953 Clovis fluted points from southeastern Arizona. *American Antiquity* 19(1): 82–85.

Frison, G. C.
1978 *Prehistoric Hunters of the High Plains*. New York: Academic Press.

Fryxell, R., T. Bielicki, R. D. Daugherty, C. E. Gustafson, H. T. Irwin, and B. C. Keel
1968 A human skeleton from sediments of mid-Pinedale age in southeastern Washington. *American Antiquity* 33(4): 511–515.

Haury, E. W.
1950 *The Stratigraphy and Archaeology of Ventana Cave, Arizona*. Tucson: University of Arizona Press, and Albuquerque: University of New Mexico Press.
1960 Association of fossil fauna and artifacts of the Sulphur Spring stage, Cochise culture. *American Antiquity* 25(4): 609–610.
1983 Concluding remarks. In The Cochise Cultural Sequence in Southeastern Arizona, by E. B. Sayles, pp. 158–166. *Anthropological Papers of the University of Arizona* 42. Tucson: University of Arizona Press.

Haury, E. W., and J. D. Hayden
1975 Preface in *The Stratigraphy and Archaeology of Ventana Cave*, by Emil W. Haury, 2nd Edition. Tucson: University of Arizona Press.

Haury, E. W., Ernst Antevs, and J. F. Lance
1953 Artifacts with mammoth remains, Naco, Arizona. *American Antiquity* 19(1): 1–14.

Haury, E. W., E. B. Sayles, and W. W. Wasley
1959 The Lehner mammoth site, southeastern Arizona. *American Antiquity* 25(1): 2–42.

Hayden, J. D.
1976 Pre-Altithermal archaeology in the Sierra Pinacate, Sonora, Mexico. *American Antiquity* 41(3): 274–289.

Haynes, C. V.
1967 Carbon–14 dates and early man in the New World. In *Pleistocene Extinctions, The Search for a Cause*, edited by P. S. Martin and H. E. Wright, pp. 267–286. New Haven: Yale University Press.
1968 Geochronology of late Quaternary alluvium. In *Means of Correlation of Quaternary Successions*, edited by R. B. Morrison and H. E. Wright, pp. 591–631. Salt Lake City: University of Utah Press.
1971 Field notes, in files of C. V. Haynes, Department of Anthropology, University of Arizona, Tucson.
1981 Geochronology and paleoenvironments of the Murray Springs Clovis site, Arizona. *National Geographic Society Research Reports* 13: 243–251.
1982a Archaeological investigations at the Lehner site, Arizona. *National Geographic Society Research Reports* 14: 325–334.
1982b Were Clovis progenitors in Beringia? In *Paleoecology of Beringia*, edited by D. M. Hopkins, J. V. Mathews, Jr., C. E. Schweger, Jr., and S. B. Young, pp. 383–398. New York: Academic Press.

Hendrickson, D. A., and W. L. Minckley
1984 Cienegas—Vanishing climax communities of the American Southwest. *Desert Plants* 6: 129–176.

Hester, J. J.
1972 Blackwater Locality No. 1, a stratified, early man site in eastern New Mexico. *Fort Burgwin Research Center Publication* 8.

Huckell, B. B.
1972 The Double Adobe mammoth: 1970 excavations along Whitewater Draw. Ms, Arizona State Museum Library, University of Arizona, Tucson.
1982 The distribution of fluted points in Arizona, a review and an update. *Arizona State Museum Archaeological Series* 145. Tucson: Arizona State Museum, University of Arizona.

Irwin-Williams, Cynthia
1979 Post-Pleistocene archeology, 7000–2000 B.C. In *Handbook of North American Indians, Southwest*, No. 9, edited by A. Ortiz, pp. 31–42. Washington: Smithsonian Institution.

Jennings, J. D.
1957 Danger Cave. *University of Utah Anthropological Papers* 27. Salt Lake City: University of Utah Press.
1964 The desert West. In *Prehistoric Man in the New World*, edited by J. D. Jennings and Edward Norbeck, pp. 149–174. Chicago: University of Chicago Press.
1978 Prehistory of Utah and the eastern Great Basin. *University of Utah Anthropological Papers* 98. Salt Lake City: University of Utah Press.

Kelley, J. C.
1959 The desert cultures and the Balcones phase: archaic manifestations in the Southwest and Texas. *American Antiquity* 24(3): 267–288.

Kurtén, Björn, and Elaine Anderson
1980 *Pleistocene Mammals of North America*. New York: Columbia University Press.

Lahren, L., and R. Bonnichsen
1974 Bone foreshafts from a Clovis burial in southwestern Montana. *Science* 186: 147–150.

Martin, P. S.
1963a Early man in Arizona: the pollen evidence. *American Antiquity* 29(1): 67–73.
1963b *The Last 10,000 Years*. Tucson: University of Arizona Press.
1967 Prehistoric overkill. In *Pleistocene Extinctions, The Search for a Cause*, edited by P. S. Martin and H. E. Wright, Jr., pp. 75–120. New Haven: Yale University Press.

Martin, P. S., and Fred Plog
1973 *The Archaeology of Arizona*. Garden City, New York: Doubleday-Natural History Press.

McGuire, R. H.
1982 Problems in culture history. In *Hohokam and Patayan, Prehistory of Southwestern Arizona*, edited by R. H. McGuire and M. B. Schiffer, pp. 153–222. New York: Academic Press.

Meinzer, O. E., and F. C. Kelton
1913 Geology and water resources of the Sulphur Spring Valley, Arizona. *U.S. Geological Survey Water-Supply Paper* 320.

Melton, M. A.
1965 The geomorphic and paleoclimatic significance of alluvial deposits in southern Arizona. *Journal of Geology* 73: 1–38.

Meltzer, D. J., and J. I. Mead
1983 The timing of late Pleistocene mammalian extinctions in North America. *Quaternary Research* 19(1): 130–135.

Myers, T. P.
1976 Fluted points from the Sulphur Springs Valley, Cochise County, Arizona. *The Kiva* 42(2): 209–213.

Orr, P. C.
1968 *Prehistory of Santa Rosa Island*. Santa Barbara: Santa Barbara Museum of Natural History.

Patton, P. C., and S. A. Schumm
1981 Ephemeral-stream processes: implications for studies of Quaternary valley fills. *Quaternary Research* 15: 24–43.

Rogers, M. J.
1958 San Dieguito implements from the terraces of the Rincon-Pantano and Rillito drainage system. *The Kiva* 24: 1–23.
1959 Field notes, in files of J. D. Hayden, Archaeologist, Tucson, Arizona.
1966 *Ancient Hunters of the Far West*. San Diego: The Union-Tribune Publishing Company.

Saunders, J. J.
1970 The Distribution and Taxonomy of *Mammuthus* in Arizona. Ms, master's thesis, Department of Geosciences, University of Arizona, Tucson.

Sayles, E. B.
1953 Field notes. Archives, Arizona State Museum Library, University of Arizona, Tucson.
1965 Late Quaternary climate recorded by Cochise Culture. *American Antiquity* 30(4): 476–480.
1983 The Cochise cultural sequence in southeastern Arizona. *Anthropological Papers of the University of Arizona* 42. Tucson: University of Arizona Press.

Sayles, E. B., and Ernst Antevs
1941 The Cochise Culture. *Medallion Papers* 29. Globe, Arizona: Gila Pueblo.

Schreiber, J. F. Jr.
1978 Geology of the Willcox Playa, Cochise County, Arizona. In Land of Cochise, southeastern Arizona, edited by J. F. Callender, J. C. Wilt, and R. E. Clemons, pp. 277–282. *New Mexico Geological Society Guidebooks, Twenty-ninth Field Conference*.

Schumm, S. A.
1977 *The Fluvial System*. New York: John Wiley and Sons.

Spaulding, W. G., E. B. Leopold, and T. R. Van Devender
1983 Late Wisconsin paleoecology of the American Southwest. In *Late Quaternary Environments of the United States: the Late Pleistocene*, edited by H. E. Wright, Jr. and S. C. Porter, pp. 259–293. Minneapolis: University of Minnesota Press.

Taylor, D. C.
1969 The Wilsall excavations: an exercise in frustration. *Proceedings, Montana Academy Science* 29: 147–150.

Turner, C. G., II
1983 Dental evidence for the peopling of the Americas. In *Early Man in the New World*, edited by R. Shutler, Jr., pp. 147–158. Beverly Hills: Sage Publications.

Turner, C. G., II, and J. Bird
1981 Dentition of Chilean Paleo-Indians and peopling of the Americas. *Science* 212: 1053–1055.

Van Devender, T. R.
1977 Holocene woodlands in the Southwestern deserts. *Science* 198: 189–192.

Van Devender, T. R., and W. G. Spaulding
1979 Development of vegetation and climate in the southwestern United States. *Science* 204: 701–710.

Wasley, W. W.
1957 *The Archaeological Survey of the Arizona State Museum*. Tucson: Arizona State Museum, The University of Arizona.

1983 Environmental setting. In The Cochise cultural sequence in southeastern Arizona, by E. B. Sayles, pp. 6–19. *Anthropological Papers of the University of Arizona* 42. Tucson: University of Arizona Press.

Waters, M. R.
1985 Early man in the New World: an evaluation of the radiocarbon dated pre-Clovis sites in the Americas. In *Environment and Extinctions: Man in Late Glacial North America*, edited by J. I. Mead and David Meltzer. Orono, Maine: Center for the Study of Early Man.

Wendorf, Fred, A. D. Kreiger, C. C. Albritton, and T. D. Stewart
1955 *The Midland Discovery*. Austin: University of Texas Press.

Whalen, N. B.
1971 Cochise Culture Sites in the Central San Pedro Drainage, Arizona. Ms, doctoral dissertation, University of Arizona, Tucson.

White, N. D., and Dallas Childers
1967 Hydrologic conditions in the Douglas basin, Cochise County, Arizona. *Arizona State Land Department Water-Resources Report* 30. Phoenix.

Willey, G. R., and Philip Phillips
1958 *Method and Theory in American Archaeology*. Chicago: University of Chicago Press.

Wilmsen, E. N., and Frank H. H. Roberts, Jr.
1978 Lindenmeier, 1934–1974, concluding report on investigations. *Smithsonian Contributions to Anthropology* 24.

Windmiller, Ric
1970 Archaeological salvage excavations of mammoth remains and a Cochise culture site near Double Adobe, southeastern Arizona, a preliminary report. Ms, Arizona State Museum Library, University of Arizona, Tucson.

INDEX