AFTER THE DELUGE

A PALAEOGEOGRAPHICAL RECONSTRUCTION OF BRONZE AGE WEST-FRISIA (2000-800 BC)

Wilko Kornelius van Zijverden

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The photo in the background is one of the 4000+ arial photographs of West-Frisia by Wil Metz. It shows a former creek which became visible after ploughing.

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Preface

In 1974 my father was appointed as town clerk of Medemblik, a small medieval town in eastern West-Frisia. Our family moved from the village of Rozendaal in the central part of the Netherlands to Medemblik. My mother started to work as a teacher in history at the local high school. Visiting relatives and friends complained to my parents that they had moved to “the end of the world”. No wonder, from the city of Hoorn they had driven over an 18 kilometers long brick road through a flat seemingly endless open landscape, divided by a myriad of canals disrupted with lines of characteristic Haubargs. As townspeople, they didn’t grasp the fascinating beauty of West-Frisia. A region co-created in the Middle Ages by God, man and nature. A region where the wind always blows, where you can see beyond the horizon in all directions, where the skylines of towns are identified by their church towers, a region that smells of rotten cabbages in the fall.

After my sixth birthday in august 1975, I went to the primary school in Opperdoes, a small nearby hamlet. The first day I drove on my brand new *Piet Pelle* bike to school together with my older brother Jan. We cycled along the railway track of the local steam train through the open fields with cabbages, potatoes, carrots, beetroots and onions. In Opperdoes, after crossing the railway by the sauerkraut factory, we passed Mr. Smit’s farm on the main street of Opperdoes. Countless times I saw Mr. Smit, or Smitje as he was called by the villagers, trying to get his young stock onto his barque and lifting the milk cans from his barque to the quay.

Back from school, during dinner, my father often spoke about the land consolidation projects. I remember my mother complaining about the slippery and muddy roads due to the land consolidation works, especially about the new road to Enkhuizen. I remember my father telling the mayor had visited farmers and forced them to clear the roads of mud. I remember the new asphalt roads to Hoorn, Enkhuizen and Opperdoes and of course the opening of McDonalds in 1978. That is all I remember from the land consolidation projects.

After the land consolidation projects, the typical barques disappeared slowly. Farmers replaced their two wheel tractors by “real” tractors, John Deere’s were my favourite. The traditional wooden crates for potatoes were replaced by plastic crates. In 1981 I started working during holidays and later on in weekends at Jan Klaver’s farm. Jan grew onions, carrots, beetroots, brussels sprouts and, of course, the tasty potato “Opperdoezer Ronde”. This potato was harvested by hand. I crawled up and down Jans fields many times, sowing, planting, weeding and harvesting. During those years I never found anything of archaeological interest. In 1984, on my way to Jan, I passed the excavation in Opperdoes (Woltering 1985) many times without even knowing it was there.

In 1987 I left West-Frisia and moved to the city of Utrecht to study physical geography. In Utrecht I met people who couldn’t distinguish white from green cabbages, people who didn’t know the way sprouts grow on a plant. I even met people who couldn’t recognize a potato plant. It was a different world. In Utrecht I joined a symphonic orchestra and a student association and learned to enjoy the attractions of the city. I promised myself never ever to go back to that end of the world called West-Frisia.

During my study in Utrecht Leendert Louwe Kooijmans gave a lecture as alumnus of Utrecht University. He inspired me to start a second master, prehistoric archaeology, at Leiden University. One thing led to another and after my graduation in 1993 I started a career as physical geographer in the field of archaeology. From 2000 onwards I was involved in more and more excavations in West-Frisia: *Grootebroek* (Lohof 2001), *Schagen* (Gerrets and Schutte 2003), *Hoogwoud* (Lohof and Vaars 2005), *Zwaagdijk* (Van der Meij 2007), *Medemblik* (Van Benthem 2007), *Opmeer* (Bouma *et al.* 2008) and so on. In 2004 I visited an excavation of an Iron Age settlement site in Opperdoes (Jongste and Knippenberg 2005) to sample a soil section for pollen and micromorphology. I didn't recognize the location at first, they were the fields right next to those of Jan Klaver! How many times had I missed prehistoric pottery, flint and so on between the carrots, potatoes and onions? It was then and there that my interest in the archaeology and landscape of West-Frisia became an obsession. In 2006 I was asked to investigate a development site in Enkhuizen (Van Zijverden 2006). It turned out to be a well preserved Bronze Age settlement site which is nowadays known as the site *Enkhuizen-Kadijken* (Roessingh and Lohof 2011; Van der Linde and Hamburg 2014).

During and after the excavation of this site by Wouter Roessingh and his team many questions were raised (Van Zijverden 2013). How was it possible that the site had survived the period of land consolidation? Why was it not situated at a creek ridge? Why were there so many indications of woodlands? Why the lack of any indications for peat growth? How to explain the huge amount of eel and the presence of European flounder when there was no connection to the coast at all? All these questions and the large amount of unpublished data of excavations from the decades of the land consolidation projects inspired Harry Fokkens to begin the "*Farmers of the Coast*" project. When Harry asked me to participate in this project I didn't hesitate. For a period of five years I have been back to the land of my youth. However a lot has changed since then, the wind is still blowing in your ears, the smell of rotten cabbages in the fall is as strong as ever. Only some weird flats in Medemblik, the tallest windmill of Western Europe and the orange glow at night of an immense greenhouse complex named Agriport are new and unfamiliar landmarks on the horizon. Being in West-Frisia is one of those inevitable special geographical experiences which are described by Koppen (2012) and Hospers (2013). To me it feels like home.

Prologue

The amount of data on the subsurface of West-Frisia is overwhelming, at least for the first 120 centimeters. This is – not coincidently – the length of a classic *Edelmanboor,* the standard manual coring equipment of an earth scientist in the Netherlands. Below this depth, the amount and detail of data rapidly decreases. The processed subsurface data is easily obtainable in standardized soil, geomorphological and geological maps and used widely within the field of archaeology. These maps reflect the ideas and traditions of earth scientists of the seventies and eighties of the 20th century. Not all archaeologists ***and*** earth scientists are aware of this mind-set and the research traditions in both fields. One of the main challenges during this project was to breach these traditions mutually. For example it took me more than a year to understand why archaeologists think that the habitation of Bronze Age West-Frisia took place in a tidal marsh environment. With a parable in the tradition of Flannery (1976) starring my good friend the field archaeologist (FA) and a well-meaning earth scientist (ES), I will try to clarify the crux of the matter.

Once upon a time in West-Frisia

"So if I understand it right, you are able to reconstruct the environmental conditions by analysing the molluscs and other fossil organisms in the sediment", said FA standing in front of a neat soil section. "Yes, that is possible. For instance, these *Scrobicularia plana* are typical for a shallow brackish environment" ES said, pointing out a layer of molluscs in the soil section. "So this clay represents a brackish environment?" FA asked thoughtfully. "Sure it does." ES said, "One can find this type of mollusc nowadays in sheltered shallow tidal flat environments like "*De Slufter*" at Texel or "*Het Verdronken Land van Saefthinge*" in the Province of Zeeland. Furthermore this typical sedimentary layering, fining and thinning upwards, is characteristic for sediments influenced by tidal movement." "Wow, amazing what you can tell from a few shells and some clay!" FA said in admiration. "Why do all these *Scrobi*-something appear in a single layer?" "It is some sort of mass-extinction", ES explained picking a few molluscs out of the soil section. "Well, because most individuals are adults and all individuals are in living position there are three options. First the molluscs died because of a change in salinity of the water. Second the organisms died due to a high sedimentation rate, for example during a storm surge. Third the molluscs died due to a change in water movement caused by a change in gully pattern", ES rattled. "Most plausible is a change in salinity, hence the fining- and thinning upwards sequence." ES organized his thoughts and said: "It is a very common pattern in marine wetlands when tidal flats develop into tidal marshes." "So it is a tidal marsh!", FA concluded. "Right, it is a tidal marsh deposit", ES replied.

And this is where the confusion starts.

"In order to pinpoint the exact environment it would be wise to sample the sediment", ES said. "For instance, you could analyse the environment of the upper part of the section by an analysis of a soil sample for molluscs, diatoms, ostracods and foraminifera. A sample for a thin section could inform you about the influence by man, like burning vegetation, ploughing, and so on." "You guys have an interesting job, it's just like Crime Scene Investigation!", FA sighed. "Is it also possible to get information on the vegetation during the habitation?" "That is less easy. The soil is rich in calcium carbonates and aerated. Therefore, pollen is badly preserved or not preserved at all and charred botanic remains only provide information of the local vegetation or crops. You could try to sample the fill of a ditch or other deep features for pollen", ES suggested. During their conversation, FA had taken notes for his daily technical report. In the distance the excavator honked for a break. ES and FA made their walk for the construction trailer and a well-deserved hot cup of coffee talking about the weather, gossiping about colleagues and so on.

Three months later ES and FA meet again during a project meeting with amongst others the archaeobotanist AB and many other specialists.

AB starts with a presentation of her results on the vegetation. "Based on low percentages of tree pollen in the assembled pollen data the environment can be characterized as almost treeless. The macrobotanical remains consist largely of charred grains and spikelets of barley and some seeds of weeds indicating the presence of arable land. Barley is the only cereal that withstands very low salinity rates, contrary to other cereals. Interesting is a seed of pickle weed we found in a soil sample from a water pit. This illustrates the tidal marsh environment very well." At this point FA nudges ES saying: "Great huh, fits the picture perfectly." ES pops promptly the question: "Why do you think it is a tidal marsh during the period of habitation?" FA replies: "You said it yourself! Furthermore the geomorphological map shows a plain of tidal deposits, the geological map presents Dunkerque 0 deposits. Last time I checked, it is a lithostratigraphical unit for marine deposits which are described for this specific location as tidal flat and tidal marsh deposits." "That is all true", ES replied "But after the closure of the inlet or after silting up to a level above MHW, the tidal marsh is outside the reach of marine flooding and within a short period, say 10 years, the area can be characterized as an freshwater environment. Woodlands will develop as well as freshwater swamps and fens." "But the results of AB? What about her observations?" FA asked less confidently. "Small pollen catchment areas represent small surfaces, as is shown by studies of Sugita, Broström and many others. One wouldn't expect a forest or woodland in a settlement site would you?" ES replied. "Certainly not", said FA. "But the seeds of pickle weed cannot be denied, right?" "The seeds of pickle weed are well preserved beneath the groundwater level in the natural sediment as well as in the infill and can be explained as contamination." FA processed the information. In all the publications about West-Frisia the environment was described as an open landscape characterized by creek ridges and tidal marshes. At last FA grasped the idea: "So it is some kind of post-tidal marsh situation" he summarized. ES sighed: "No! During the habitation in the Bronze Age it is a tidal marsh in a geomorphogenetical sense but not in an environmental sense. Although the word tidal marsh is the same, it points to something completely different." As if struck by lightning ES stopped talking. Damn right it ***is*** confusing to use one word for two different concepts!

In the world of ES it makes sense, a levee and a levee deposit. The levee stays a levee long after the abandonment of the riverbed. The levee in an environmental sense is flooded yearly. The levee after the abandonment of the riverbed, in a geomorphogenetical sense, is just a piece of land with a characteristic morphology and lithology. The implications for the exploitation possibilities and thus the archaeological appearance are huge. A river dune in the Rhine Meuse delta stays a river dune until over 10.000 years after the active phase. And a crevasse splay…

FA interrupted the thoughts of ES: "Let's score some beers in the pub and I'll show you an interesting proposal for an excavation of a Bronze Age settlement at a crevasse…"

Postscript

Like ES I am just one of many physical geographers blinded by certain conceptual frameworks and traditions in my field of expertise. In this thesis I have tried to be as unambiguous as possible when it comes to terminology. Nevertheless, time will tell if I have succeeded.

1 After the deluge: an introduction

1.1. Project outlines

The project "*Farmers of the Coast*" revolves around the thesis that Bronze Age coastal communities were thriving farming communities with their own cultural identity and with a central position in communication networks (Fokkens 2011, 1). The region of West-Frisia is well suited for studying prehistoric communities on the North Sea coast. Not only was its location central in a transport geographical sense, but it is also one of the best investigated and preserved Bronze Age landscapes in north-western Europe. Since the 1960s, dozens of hectares have been excavated in this region and hundreds have been surveyed by field surveys and with remote sensing techniques (aerial photography). Due to the clayey subsoil the conditions for conservation of organic material are excellent. At the start of the project in 2011 only a few preliminary publications were available. Only the excavations of *Hoogwoud*, *Zwaagdijk*, *Medemblik* and *Enkhuizen-Kadijken* (Lohof & Vaars 2005; De Wit and Stokkel 2011; Schurmans 2011; Roessingh & Lohof 2011) had been published at that time. The majority of the research, surprisingly, had not been published. Interestingly the bone assemblages and most of the botanical analyses were published (IJzereef 1982; Runia 1987; Buurman 1996). Furthermore the pottery of *Hoogkarspel* was studied by Brandt (1988) and the bone material of this site was published by Clason (1967).

The project "*Farmers of the Coast*" focuses on these extensively excavated, but poorly published archaeological sites as case-study of coastal farming communities. The project is divided into four subprojects that study the people of the coastal wetlands from different perspectives. The first project deals with the physical environment and possibilities for habitation in the period between 2000 and 800 cal BC and is the subject of this PhD-thesis. It provides the environmental framework for the analysis of the settlements, farming practices and the place of coastal communities in communication networks. The settlements are the subject of a PhD-thesis by Wouter Roessingh (Roessingh in prep.). The farming practices are studied by Yvonne van Amerongen (Van Amerongen 2016). The communication networks are part of the research project by Patrick Valentijn (Valentijn in prep.).

In order to provide such an environmental framework for these studies to the settlements, farming practices and the place of coastal communities in communication networks several research questions have been formulated. The following three research questions are central in this study of the physical environment of the West-Frisian coastal wetlands (Fokkens 2011, 8):

1. How was the physical landscape of West-Frisia structured and how did it develop between 2000 and 800 cal BC?
2. Which parts were favoured for settlement?
3. What restraints and opportunities did it offer people?

1.2. Structure and development of the physical landscape between 2000 and 800 cal BC

The current model for the genesis of the West-Frisian landscape was developed in the fifties and sixties based on the work of Stiboka, the Netherlands Soil Survey Institute (Pons and Wiggers 1959; 1960). The soil scientist Ente of Stiboka was the first to map systematically a large area (over 61.000 hectares) for archaeological purposes (Ente 1963). He achieved this during the soil survey prior to the land consolidation project of *De Streek*. This work of Stiboka and Ente (1963) has been of great influence on the ideas of landscape and habitation dynamics in the Bronze Age of West-Frisia. Based on the large scale excavations of the sites *Andijk*, *Hoogkarspel, Bovenkarspel-Het Valkje* and the subsurface model of Ente and his co-workers a simple and elegant model was developed for the habitation in the Bronze Age (Van Geel *et al.* 1982; figure 2.9). In 1997 Van Geel *et al.* (1997) published in a convincing article a climatological cause for the abandonment of West-Frisia at the end of the Bronze Age, which seemed to fit the data at that time. It is this model that raised many questions during the processing of the data of the site *Enkhuizen-Kadijken* as described in the preface. This settlement site is situated on top of tidal marsh deposits instead of a creek ridge as is expected according to the model. Many indications for woodlands are present at this site whilst the model suggests the presence of an open almost treeless landscape. Indications for peat growth are absent at this site in contradiction to the model, which expects a peat cover up to several meters. Are these contraditions just minor details which can be explained with a few modifications of the existing model or are they caused by a more fundamental problem? In chapter 2 the history of landscape research in West-Frisia will be dealt with extensively, in order to grasp the model in full detail.

In 2011 a new national palaeogeographical reconstruction was published (figure 2.10; Vos *et al.* 2011). The coastal development model of the eighties plays an important role in the configuration of this map (Vos *et al.* 2011, 32). Furthermore, the available data from archaeological research has not been used to its full potential. This is well illustrated by the number of settlement sites situated on top of peat deposits in figure 2.10. Not a single Bronze Age settlement site situated on top of peat deposits has been excavated in West-Frisia yet. In order to understand the position of West-Frisia in a transport geographical sense and develop ideas on communication routes and networks, the palaeogeographical map should at least fit the available archaeological data. Therefore a new palaeogeographical map is needed, which is one of the goals in this project.

For the development of such a map at this scale, three ingredients are needed: subsurface information, a coastal development model and a time-framework. In chapter 3 these are presented, evaluated and used for the construction of a new palaeogeographical map. In chapter 3 the three inlets which have influenced the development of West-Frisia, Bergen inlet, Oer-IJ estuary and Vliestroom, are studied in relation to each other including the rivers Vecht and Vecht-Angstel debouching in the accompanying tidal basins. First the available set of dates is evaluated in detail. Second a set of 29 key sites within the Bergen tidal basin is described in more or less detail depending on the amount of information. Thirdly the study by Van der Spek (1994) of the evolution of tidal basins as presented in chapter 2 is incorporated in a new development model for West-Frisia. This new model is applied in the presentation of three small scale (1:100.000) palaeogeographical reconstructions for 2100, 1500 and 800 BC.

A palaeogeographical reconstruction at this small map scale can be used to provide answers on communication and transport routes in general, as needed for the project of Valentijn. It does not provide answers at the scale of the settlement site or the area exploited at a daily base, needed for the projects of Van Amerongen and Roessingh. At this map scale, the reconstruction of the landscape in abiotic terms is less relevant. Arnoldussen (2008, 48) expresses this very clearly with the statement that: "…*the different types of vegetation…will have been noticed by, and have mattered to, prehistoric communities*." The question is, is it possible to provide a reliable palaeogeographical reconstruction including the biotic environment?

Firstly, it is important to note what information the archaeologist needs for answering questions on the exploitation of the catchment area. Therefore an inventory of palaeogeographical reconstructions compiled for archaeological purposes is carried out. Secondly, there are various ways to establish a reconstruction of the biotic environment. In the recent past several studies concerning this topic, with quite different approaches, have been published (Van Beurden 2008; Groenewoudt *et al.* 2008;

Gaillard *et al.* 2008; Schepers 2014). In chapter 4 a method for the reconstruction of the landscape including the vegetation in phytosociological classes at a larger map scale is presented. The basis for this method is the idea that the succession of a vegetation depends largely on soil properties, hydrology and water quality. This idea has been applied previously within the research project "*Living in a dynamic (cultural) landscape*" (Fokkens 2003; Arnoldussen 2008; Van Beurden 2008). In this project the phytosociological classes were reconstructed based on pollen assemblages and reconstructed abiotic factors. An important disadvantage in this research strategy is the lack of actual indicator species because classification of pollen is rarely possible at a species level. Therefore the reconstruction of the vegetation classes in such a way largely depends on expert knowledge (Van Beurden 2008). Schepers (2014) recently presented a reconstruction of a palaeovegetation in phytosociological classes based on macrobotanical remains from a channel lag deposit. Schepers (2014, 35) argues that the macrobotanical remains in this deposit represent different vegetation types in a wider area. These can be identified in phytosociological classes using the indicator species present in the sample. In the present study this idea of Schepers (2014) has been applied to the botanic databases of several excavations in West-Frisia. In line with the thought of Schepers (2014), these macrobotanical assemblages represent the phytosociological vegetation classes of a wider area. In chapter 4 this idea, combined with the method developed in the project "*Living in a dynamic (cultural) landscape*" has been applied to the land consolidation area Westwoud resulting in two palaeogeographical reconstructions for 1500 and 800 BC (figure 4.9A and 4.9B).

1.3. Site location preferences

Within West-Frisia little less than a hundred excavations of sites dating to the Bronze Age have been carried out (Roessingh in prep.). Every site contributes to our knowledge of site location preferences of societies from the Bronze Age. Not only have a large number of excavations been conducted, large parts of West-Frisia have also been surveyed by field surveys and surveys with aerial photography (De Vries-Metz 1993). Furthermore large parts have been surveyed by hand corings (a.o. Ente 1963; Mulder *et al.* 1983; Manning and Van der Gaauw 1987). This high density of information should facilitate the relating of site locations to soil properties, vegetation or topography. One of the goals in this study is to clarify these presumed relationships in order to use this information. This knowledge can be used for management and planning in future development projects.

It is impossible to analyse all excavated sites within the scope of this project. For this study, a selection has been made of several well-documented, large scale excavations. The site location information of this selection of sites regarding soil properties, relief and so on will be evaluated in detail. The resulting information is tested during fieldwork. The evaluation and the results of the field work are used for recommondations for predictive modelling in the future.

In chapter 3 the site distribution in West-Frisia for late Neolithic and Bronze Age sites is explained in general. Figure 3.13 explains why soil maps and geomorphological maps or LIDAR-images cannot be used in the analysis of site distributions in West-Frisia, as is a common practice (De Boer and Molenaar 2006; Molenaar and Van Berkel 2013). In chapter 4 the palaeogeographical reconstruction of West-Frisia at a large map scale is verified with the actual site distribution and the available air photographs (figure 4.9A and 4.9B). An alternative relationship between landscape and site distribution can be deduced from this analysis. Based on this chapter, it could be argued that site distribution is related to vegetation, soil properties and hydrology. In chapter 5 the case *De Rikkert* is presented, a location selected to test ideas on site distribution and site visibility (Roessingh and Valentijn in prep.). Furthermore the stratigraphy of the settlement sites *Andijk*, *Hoogkarspel*, *Bovenkarspel-Het Valkje*, *Medemblik-Schepenwijk* and *Enkhuizen-Kadijken* is discussed in detail. Based on this analysis the site distribution of Bronze Age sites and Late Neolithic sites in relation to the geomorphology is evaluated. At the end of the chapter an important question has to be answered: to what extent is our idea on site distribution biased by research history?

This question is one of the main topics of chapter 6. In this chapter, the present day archaeological practice of predictive modelling in The Netherlands is presented and analyzed for the situation in West-Frisia in particular. The influence of the effectuated policy on archaeological research in the eastern part of West-Frisia is evaluated, based on an analysis of 54 inventories carried out after the publication of the actual policy document in 2006 (De Boer and Molenaar 2006). This analysis is used for an evaluation of the effectiveness of different techniques of field research. These techniques have been tested at *De Rikkert* during four successive years. This analysis and the results of the fieldwork at *De Rikkert* result in an ideal flow chart for predictive modelling in eastern West-Frisia.

1.4. Restraints and opportunities of the environment

The new development model of West-Frisia presented in chapter 3, describes on the one hand limitations for the exploitation of the landscape in general, for example by the distribution of lakes and peatlands. The characterization of the landscape for the different periods on the other hand provides opportunities for land use in general. In chapter 4 the restraints for land use for agricultural purposes are investigated (§ 4.3.1 and 4.3.2). An analysis at site level in chapter 5 provides information on the actual use of the landscape in excavated sites. With the information assembled in chapters 3, 4 and 5, general ideas for restraints and possibilities in land use can be formulated. Based on the assembled information an answer is formulated in chapter 7 to one of the main research questions of the "*Farmers of the Coast*"-project: "To what extent did the physical and biotic landscape determine possibilities for habitation, subsistence, accessibility and contacts?"

1.5. For what use?

The palaeogeographical reconstructions at different map scales presented in chapters 3, 4 and 5 are considered to be of use for predictive modelling. The presumption for this use is that there is a relationship between the nature of the subsurface and the distribution of archaeological sites. The evaluation of techniques used in predictive modelling presented in chapter 6, will leave us disillusioned with regard to this presumption and the use of detailed soil maps. Therefore chapter 6 concludes with an idea for a new type of policy document, which meets the demands of the new legislation which will be introduced in 2018. This idea is inspired by the preservation model developed by De Beer *et al.* (2011) for the medieval city of Bryggen (Norway). Such a policy document helps with finding the unknown instead of affirming the known archaeological remains. Such a document gives the possibility of incorporating new insights far more easily compared to the present day documents, which have been developed for fixed 10 year periods. The predictions from this model are directly based on data instead of postulated relationships. This line of thought is elaborated in chapter 6. I hope this line of thought will help to create a sustainable archaeological policy document for the nearby future.

2 The history of landscape research in West-Frisia

2.1. Introduction

The soil map of *De Streek*, constructed by Ente (1963) in the early sixties of the nineteenth century, is used as a solid base for present day policy documents for eastern West-Frisia (De Boer and Molenaar 2006). This soil map has been of great influence on the ideas about the genesis and habitation history of the West-Frisian landscape, as mentioned in the previous chapter. In order to understand the strong influence of a soil map on our thinking over the landscape and its habitation, it is important to be aware of the history of its construction and the history of landscape research in West-Frisia in general. Therefore this chapter is dedicated to the history of landscape research in West-Frisia.

Paragraph 2.2 deals with the development of soil science of alluvial sediments in The Netherlands. This is of importance to understand the Dutch focus on coring as the most important technique for landscape research. The following paragraph 2.3 describes the development of landscape research in West-Frisia just after World War II, a period which is characterized by thorough and fundamental landscape research. The ideas developed in this period are reflected in the present day soil, geological and geomorphological maps. Although the ideas on landscape genesis have largely changed (Vos 2015, 8-10), new maps are not (yet) available. In order to understand the compilation of the available datasets, the

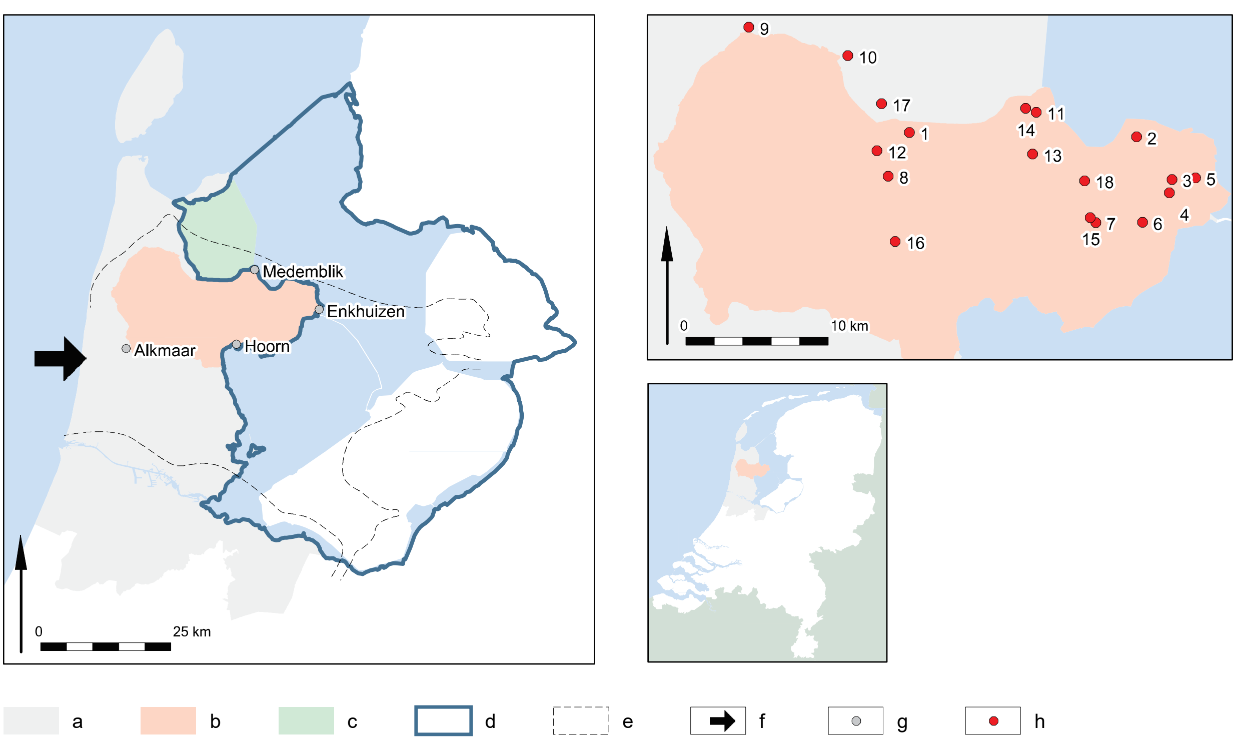


Figure 2.1: Topography and sites mentioned in text. Legend: a Province of North-Holland, b West-Frisa, c Wieringermeer, d former Zuiderzee, e maximum size of Bergen tidal basin, f Bergen inlet, g cities, h sites: 1 Aartswoud, 2 Andijk, 3 Bovenkarspel-Het Valkje, 4 Bovenkarspel-Monument, 5 Enkhuizen-Kadijken, 6 Grootebroek, 7 Hoogkarspel, 8 Hoogwoud, 9 Keinsmerbrug, 10 Kolhorn, 11 Medemblik-Schepenwijk, 12 Mienakker, 13 Oostwoud, 14 Opperdoes-Markerwaardweg, 15 Westwoud II (Noorderboekert), 16 Zandwerven, 17 Zeewijk, 18 Zwaagdijk.

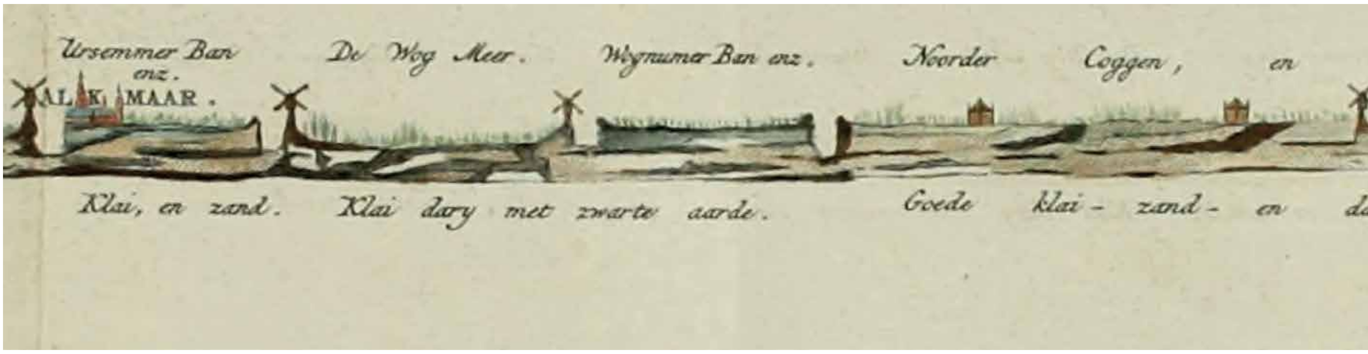


Figure 2.2: Part of a cross-section of West-Frisia as published by Le Franq van Berkhey (1771, plaat III).

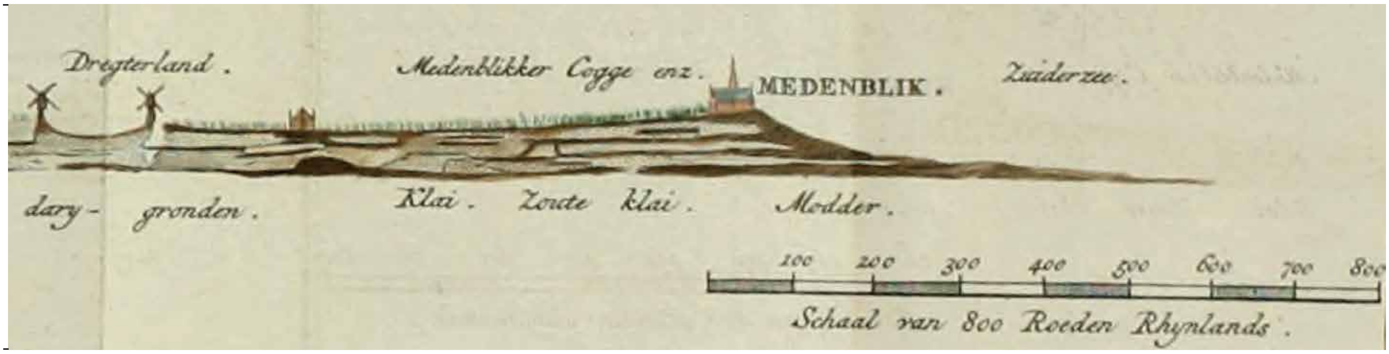
period of land consolidation projects is described in paragraph 2.4. In this period an enormous database of soil sections and a large archaeological database have been created, a treasure chest which we still profit from today. In paragraphs 2.5 to 2.7 the scientific result of the previous research is presented. In these paragraphs, the models for the genesis of the landscape, habitation and palaeogeography are critically evaluated. The last paragraph (2.8) deals with the results of post-Valletta archaeology. The results of this post-Valletta research differ from the results of the previous period and present arguments for the need of a new palaeogeographical model for West-Frisia. In figure 2.1 the topography mentioned in this chapter is depicted.

2.2. Prelude

During the 18th century geology and biology still had to be invented (Zagwijn 2004, 30). Scholars in this century were unaware of geological time (Zagwijn 2004, 27). In this period the Dutch naturalist Johannes Le Franq van Berkhey studied the origin of Holland. Between 1769 and 1811 he published in six volumes his lifework "*Natuurlyke Historie van Holland*" (the natural history of the western part of the Netherlands). In this study a broad variety of topics is dealt with, geography and climate, the deposits and mineral resources, inhabitants of Holland and animals. The second volume on the deposits and mineral resources is partly based on research in sand quarries, gravel pits and descriptions of corings up to 5 meters below the surface (Le Franq van Berkhey 1771). Many of these corings were carried out by the author himself, however he also used archived descriptions of soil sections and corings. Unique in his work is the detailed description of a soil section of approximately 10 meters in a sandpit in the dunes near Katwijk and the description of a coring in the centre of Amsterdam to a depth of approximately 72 meters below the surface carried out in 1605. In the publication a cross-section of North-Holland including West-Frisia is presented (figure 2.2). In the description of the cross-section the interpretation of the different layers is based on observations by the author of the existing landscape. This uniformitarianistic interpretation is quite modern for the 18th century. With this interpretation Le Franq van Berkhey implied successive changes of the landscape in the past. Therefore the publication of this cross-section marks the start of the palaeogeographical research of West-Frisia.

In the 19th century, amongst others, the disciplines of biology, geology and soil science developed (Zagwijn 2004, 30). In 1813 the first geological map of the Netherlands was compiled by d'Omalius d'Halloy and published in 1822 (d'Omalius d'Halloy 1822). In this map, the Netherlands is depicted as a single unit: "*terrains mastozootiques*". This unit represents all the sediments from the later defined Tertiary and Quaternary. Between 1858 and 1867 Staring published a geological map of the Netherlands at scale 1:200.000 (Faase 2004, 129). In this map the Quaternary sediments were subdivided into 21 units. The marine clays and marine sands of West-Frisia are depicted in this map. In the same period Staring published his magnum opus "*De bodem van Nederland*" (The soil of the Netherlands; Staring 1856; Staring 1860). The publication of Staring and the geological map are generally accepted as the start of modern geology in the Netherlands (Zagwijn 2004, 5).

In the first part of the 20th century large parts of the Netherlands were mapped in detail. In 1918 the Geological Survey was established by the government. This service was established in order to



map the geology of the Netherlands at scale 1:50:000 which was almost finished by the end of the project more than 30 years later in 1951 (Faasse 2002, 62). Shortly after the Geological Survey started with the construction of a second series of geological maps at the scale of 1:50.000 which has never been finished. West-Frisia is only partly mapped in this second series (Westerhoff *et al.* 1987).

In the nineteen thirties Oosting developed a modern approach in soil mapping (Oosting 1936). In this method principles from geology, geomorphology, topography, hydrology and archaeology were combined (Hartemink and Sonneveld 2013, 2). Field observations obtained with hand auger equipment constituted the basis for the construction of soil maps. Oosting (1936) applied his method in a relatively small area. After the draining of the Wieringermeer, the first of a series of polders in the former Zuiderzee bordering the northeast part of West-Frisia, the soil scientist Zuur mapped this area using Oosting's method (Zuur 1936). Zuur (1936) systematically mapped this considerable area with a regular grid of corings. In his publication he used the information gathered for an analysis of the genesis of the landscape and an analysis of the soil properties to investigate the optimal use for agriculture of the drained parcels. This approach follows the tradition started by Staring, who stated that: *"…men dient niet te vergeten, dat geologische kennis de agronomische dient vooraf te gaan, dat deze een uitvloeisel is van gene en als 't ware hare toepassing op de praktijk (*Staring 1856, 9). *"*[1] Oosting's method (1936) and the strategy used by Zuur (1936) was followed by other soil scientists and brought to perfection under the direction of Edelman.

1 "…one shouldn't forget that knowledge of geology precedes the knowledge of agronomy, agronomy is a consequence of geology and can be considered as its practical use."

2.3. Pioneers

During World War II Edelman started mapping the soil of the Bommelerwaard, an area in the Rhine-Meuse valley, inspired by the work of, amongst others, Oosting (Edelman 1950, 4). Shortly after, he was followed by several colleagues in other regions. Soil maps constructed in this period, proved to be very useful for agricultural purposes. In 1945 Edelman founded Stiboka in order to construct various soil maps for the Netherlands. Stiboka proved to be a very successful organization, national as well as international. The success of Stiboka was partly due to the timing of its foundation. The last winter of World War II ended in a famine due to food shortages. The first task of Sicco Mansholt, the newly appointed minister of Agriculture, Fishery and Food supply after World War II, was to restore the food production and food supply. Therefore Mansholt presented a plan to stimulate the modernization of Dutch agriculture in order to achieve a self-sufficient food producing economy (Van den Bergh 2004, 48). In his opinion it was necessary to execute an extensive program of land consolidation in combination with up-scaling and soil improvement to achieve this goal. Soil maps were needed to execute this ambitious program. Therefore, in 1952 Stiboka was asked to provide a soil map for the Netherlands at a scale of 1:25.000. This scale appeared to be far too ambitious for the small organization of Stiboka and soon it was changed to a scale 1:50.000. The work of Stiboka provided an avalanche of data and publications on the origin of the Dutch subsoil. Many dissertations, monographs and articles were published using Stiboka's data. The first publication presenting an overview of the genesis of the province of North-Holland including West-Frisia based on these data is the publication by Pons and Wiggers (1959/1960), both leading soil scientists of Stiboka.

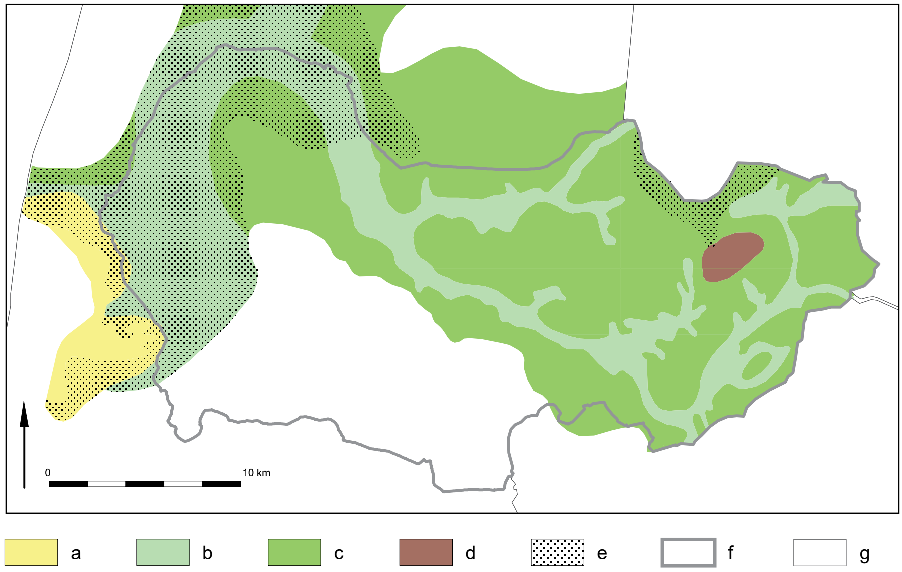


Figure 2.3: The distribution of the Westfrisian deposits in the Bergen tidal basin (After: Pons and Van Oosten 1974, 27, figure 15). Legend: a coastal dunes b mud flat deposits, c tidal marsh and fen deposits, d fen deposits, e Westfrisian deposits covered by younger deposits, f West-Frisia, g North-Holland.

In this publication Pons and Wiggers (1959/1960) present a compendium of the previously published data. A complicating factor to summarize the data was the absence of a neat stratigraphical framework at that time. In their work they put a lot of effort into combining all the available data in a single stratigraphical framework for the province of North-Holland. Pons and Wiggers (1959/1960) reconstruct a tidal inlet near the present-day town of Bergen, the so-called Bergen tidal inlet. This tidal inlet unlocked the hinterland where marine sediments were deposited in a tidal basin, including West-Frisia. The younger marine sediments in this tidal basin are labeled as Wieringermeer and Westfrisian deposits. The Wieringermeer deposits are dated between 2900 BC and 2300/2200 BC, based on archaeological finds and a set of radiocarbon dates (Pons and Wiggers 1959, 152). The Westfrisian deposits are subdivided into Westfrisian deposits I and II and dated between 2100-1900 BC and 1600-1250 BC respectively (Pons and Wiggers 1960, 28). The authors distinguish three successive types of environments within the Wieringermeer and Westfrisian deposits: tidal flats, tidal marshes and fens (figure 2.3) (Pons and Wiggers 1959, 149). The tidal flats present a gradual change in salinity from west (salt) to east (light brackish), which is confirmed by the presence of certain types of molluscs, foraminifera and ostracods (Pons and Wiggers 1959, 150). The tidal flats are situated along a broad (app. 100 m) and deep (app. 15 m) tidal channel (Pons and Wiggers 1959, 150). The sediments of the tidal marshes are characterized by a higher percentage of lutum and decalcification (Pons and Wiggers 1959, 135). The tidal marshes, as well as the fens, are intersected by creeks. The fens are characterized by unconsolidated or partly consolidated clay with reed remnants and thin layers of peat. The foraminifera in these sediments represent a brackish environment changing over time into an environment with less available oxygen and less influence of the sea (Pons and Wiggers 1959, 150). Due to relief inversion the former tidal channels are well visible in the landscape as creek ridges. Away from the influence of the sea, bogs developed represented by peat layers. After the closure of the Bergen inlet the bogs expanded rapidly over the fens, tidal marshes and tidal flats.

Apart from soil scientists and geologists, archaeologists also conducted research into the origin of the subsoil. In Dutch archaeology a tradition of bio-archaeological research had been developed before World War II by Van Giffen. In 1942 Van Giffen excavated a barrow near Zwaagdijk (Van Giffen 1944). After the excavation several soil samples were examined on his request for pollen, foraminifera, ostracods and diatoms. The results turned out to be as expected. The base of the soil had been formed in a salt to brackish marine environment gradually developing towards a freshwater environment at the top on which the barrow had been constructed. The soil sample on top of the infill of the ditch around the barrow turned out to be of anthropogenic origin (Van Giffen 1944, 177-182). In 1947 Van Giffen conducted an excavation of a barrow in Grootebroek (Van Giffen 1953; Van Giffen 1954). This time

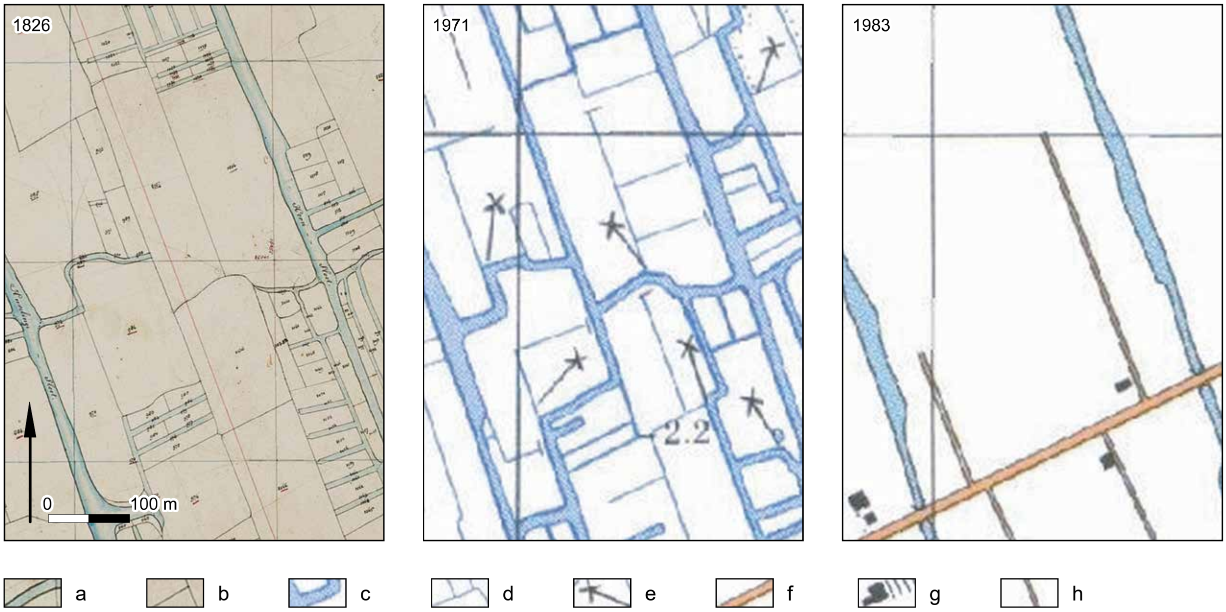


Figure 2.4: Topography of a parcel in the community of Andijk, situation in 1826 (left) 1971 (middle) and 1983 (right). Legend: a canal, b legal boundary or ditch, c canal, d ditch, e windmill, f road, g building and greenhouses, h dirt road.

he sampled the soil section underneath the barrow stratigraphically for pollen, ostracods, foraminifera, diatoms and molluscs. The foraminifera samples suggested a gradual change from a salt/brackish environment towards a light brackisch environment (Van Giffen 1954, 114). Van Giffen interprets this as a change from a tidal flat into a tidal marsh (Van Giffen 1953, 40). In the supplements Van Voorthuysen (the geologist involved in the project) suggests, based on this single analysis, a regional change of a transgression into a regression which is not adopted by Van Giffen. It demonstrates the different approach and scale between both disciplines, a topic which will be addressed in chapter 4. Van Giffen concludes his excavation report with an observation on the relative height of the present day surface level. He wonders why the present day surface level is almost the same as the surface level during the Bronze Age, approximately 150/170 cm -OD. He assumes that the present day surface level should equal mean high water (MHW). Subsidence due to drainage can explain a surface height under MHW as observed at many other places. However, it does not explain why the Bronze Age surface is situated more or less at the present day surface. He concludes the article with the comment:

> *"Het is dus zonder nader in te gaan op dit probleem, wel duidelijk, hoezeer het gewenst is het begonnen onderzoek voort te zetten (Van Giffen 1953, 40)."* [2]

This remark is the start of a perennial debate on the existence of a peat cover in West-Frisia in an attempt to explain this peculiar phenomenon.

2.4. Land consolidation

Many excavations would follow that of Van Giffen (1953) due to rapid intensifying of agriculture preceded by land consolidation. Land consolidation is an instrument for improving the agrarian sector. From 1850 until 1922 the agrarian sector in the Netherlands flourished. Innovation and export thrived. Small farms were especially successful in this period. In 1922 the world market was flooded by cheap cereals from Canada and the United States and dairy products from Australia and New Zealand. This situation lead to a crisis in Dutch agriculture. The government reacted with several laws to facilitate and improve the agrarian sector. One of these laws was the Land Consolidation Act which was accepted by parliament in 1924 (Van den Bergh 2004, 25-36). In advance of land consolidation projects, soil maps

2 "Without going into detail, additional research is obviously needed."

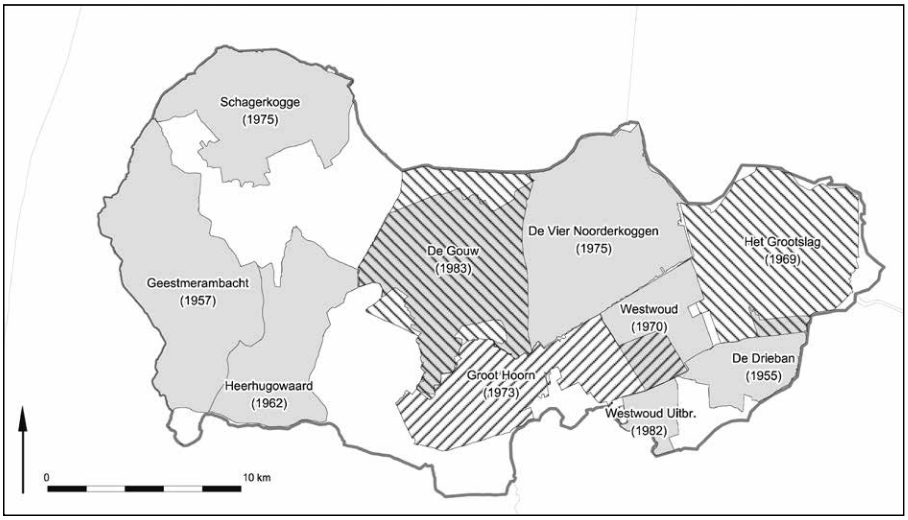


Figure 2.5: Overview of published soil maps within the framework of land consolidation projects in West-Frisia. The soil maps of De Gouw, Het Grootslag and Groot-Hoorn partially overlap earlier published soil maps.

Land consolidation area	Year	Area (ha.)	Soil map
De Drieban	1955	± 1865	Du Burck 1955
Geestmerambacht	1957	± 6601	Du Burck 1957
Heerhugowaard	1962	± 3893	Van den Hurk 1962
Het Grootslag	1969	± 6167	Ente 1963
Westwoud	1970	± 2203	Bles and Rutten 1972
Groot Hoorn	1973	± 4812	Bles and Steeghs 1973
Schagerkogge	1975	± 4472	Kleinsman, Stoffelsen and Van den Hurk 1975
De Vier Noorder Koggen	1975	± 11930	Du Burck and Dekker 1975
Westwoud uitbreiding	1982	± 706	Kiestra and Rutten 1982
De Gouw	1983	± 7057	Mulder, Van Berkum and Van Pruissen 1983

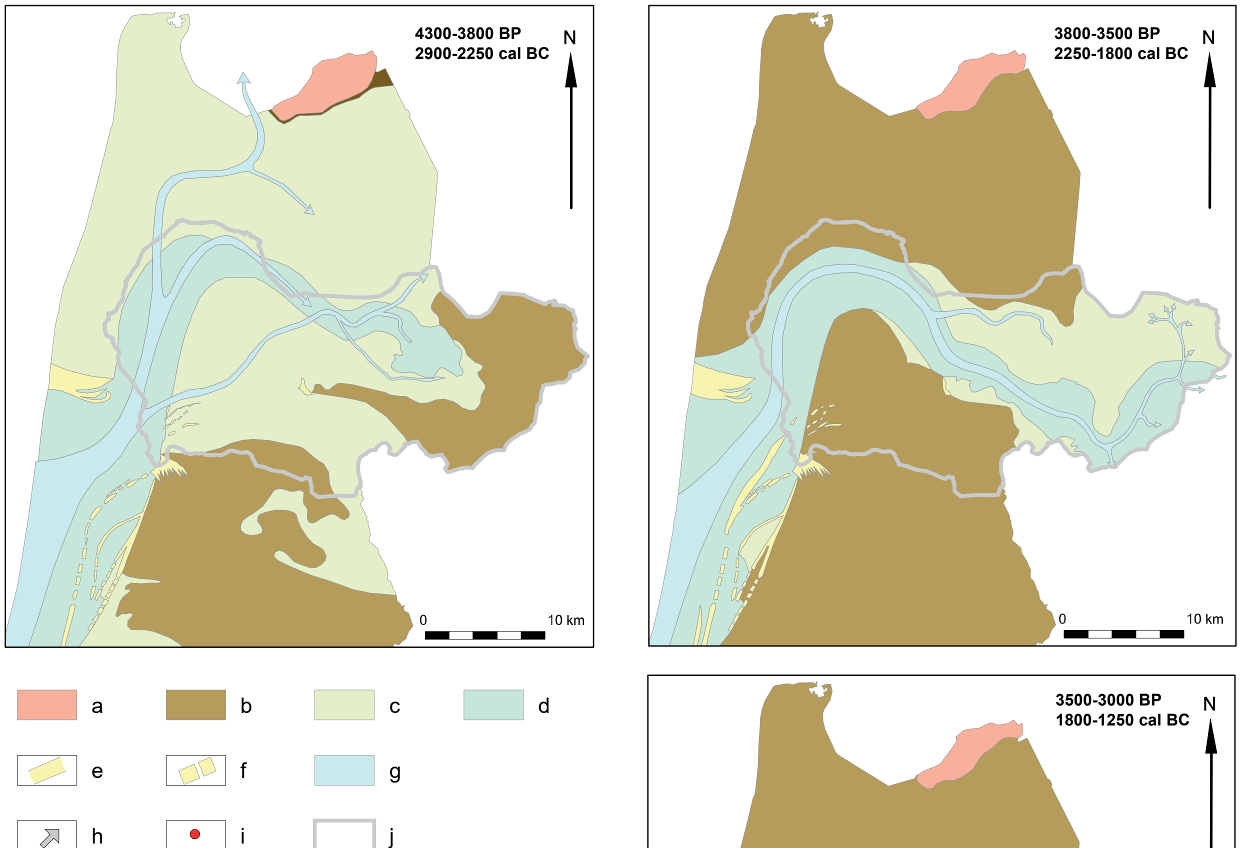
Table 2.1: Overview of published soil maps within the framework of land consolidation projects in West-Frisia.

were constructed in order to redistribute parcels fairly amongst the land owners. Therefore these projects resulted in series of detailed soil maps. In West-Frisia it would take until 1940 before the first project under this Act was effectuated (Van den Bergh 2004, 208).

Improvements for a more efficient agricultural system were strongly needed in West-Frisia. Parcels belonging to a single farm were small, scattered over large areas and only accessible by boat (Ente 1963, 3). The last large scale improvements in this area dated from the Dutch Golden Age (16^{th} and 17^{th} century). During this period the economy flourished, lakes were drained and the overall drainage was improved by an ingenious system of windmills, spill-ways and sluices (Borger 1975, 21). Only small scale changes in land division can be seen in topographical maps from the 18^{th} century onwards until the period of land consolidation projects (figure 2.4).

The first small scale project in West-Frisia was carried out in 1940 (Van den Bergh 2004, 208). The area affected by this project was only 42 hectares. After World War II plans were made for extensive land consolidation programs in West-Frisia which were carried out between 1963 and 2012. To improve the efficiency of the individual farms in West-Frisia, one of the goals of the land consolidation projects was to transform the area in such a way that every parcel could be reached by motor vehicle (Ente 1963, 3). These projects covered almost the entire region (table 2.1 and figure 2.5). The impact on the subsoil was huge, old canals were (partly) filled, new canals were dug, parcels were leveled and extensive areas were ploughed up to a depth of 80 centimeters. On top of these physical disturbances of the subsoil, the mean groundwater level was lowered by one to two meters. Remarkably, soil scientists, not archaeologists, were the first to understand the implications for the archaeological archive of the intended activities (Oosting 1940).

After World War II soil surveys were undertaken by Stiboka prior to the land consolidation projects. The first soil maps, like for instance the soil map



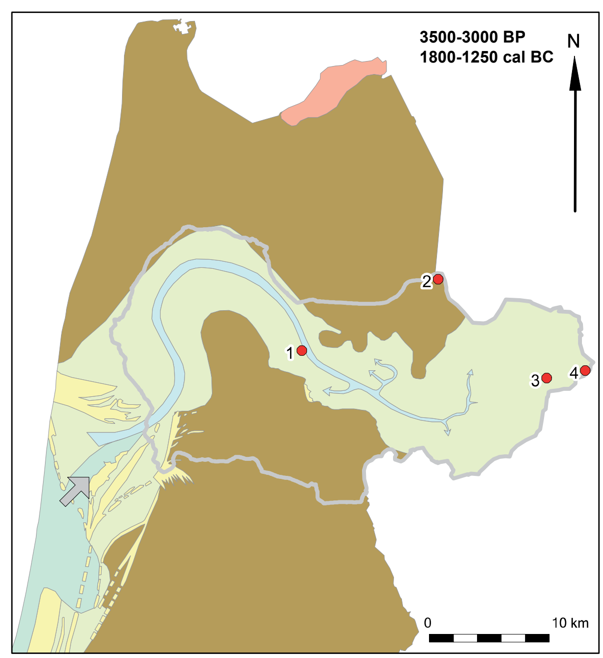


Figure 2.6: The palaeogeographical development of West-Frisia (After: De Mulder and Bosch 1982, 144-147, figure 20-22). Legend: a Pleistocene deposits at surface, no deposition of Holocene sediments, b Continuous peat growth and/or absence of clastic deposition, c end of clastic deposition and/or peat growth, d continuous marine sedimentation throughout the period, e beach barriers/sand ridges, f idem assumed, g orientation of the main tidal channel, h location of Bergen inlet, i settlement site (1 Hoogwoud, 2 Medemblik-Schepenwijk, 3 Bovenkarspel-Het Valkje, 4 Enkhuizen-Kadijken), j West-Frisia.

of the land consolidation area *De Drieban*, present the unit "*oude cultuurgronden*" (old cultivated soils) (Du Burck 1955). This unit represents deep humic soils originated by an intensive antropogenic use and includes settlement soils dating to the Bronze Age. The soil scientist Ente was aware of the presence of Bronze Age sites in West-Frisia due to the excavation reports by Van Giffen. He and his co-workers undertook the first systematic archaeological survey between 1953-1955 during the soil survey of the land consolidation project *Het Grootslag* (Ente 1963, 5-6). In his map he presents the unit "ancient settlement soils" which represent settlement sites dating to the Bronze Age or Iron Age (Ente 1963, 156-159).

In 1966 the first large scale excavation was conducted at the site *Hoogkarspel* in West-Frisia by archaeologists of the University of Amsterdam (IPP) (Bakker *et al.* 1977 188-189). The excavation revealed a well-preserved Bronze Age settlement site and several burial mounds just beneath the plough layer. It was only in this project when archaeologists began to realize the enormous impact on the archaeological archive of the upcoming land consolidation in this area (IJzereef and Van Regteren Altena 1991, 61). Alarmed by these finds and the expected destruction due to activities for soil improvement, the Dutch State Archaeological Service (ROB) started an intensive field survey and a first excavation in Andijk. Based on the survey and the experience during the excavation in Andijk, the State Service decided to excavate an area of 18 hectares in Bovenkarspel and to preserve a comparable area for future research (IJzereef and Van Regteren Altena 1991, 61-62). A synthesis of these excavations will be published by Roessingh (Roessingh in prep.). Articles and dissertations on the palaeobotany, palaeozoology and landscape were published relatively shortly after the end of the excavation of the Bronze Age settlement site *Opperdoes-Markerwaardweg* in 1985. This excavation was the last large scale excavation of a Bronze Age site in West-Frisia within the framework of a land consolidation project. It was assumed that little or no remains from the Bronze Age were left due to the soil improvements after such projects.

In the last large scale land consolidation project in West-Frisia, *De Gouw*, archaeologists focused on newly discovered well preserved Late Neolithic sites. Between 1979 and 1986 the Late Neolithic site of *Kolhorn* had been excavated by archaeologists of Groningen University (BAI; Van der Waals 1989). Based on the excavation results an archaeological survey was carried out between 1985 and 1986 in advance of the project (Manning and Van der Gaauw 1987). During this survey the traditional "*archäologische landsaufnahme*"[3] was combined with aerial photography and manual corings. Several new Late Neolithic sites were discovered leading to the excavations of *Keinsmerbrug* (1986), *Mienakker* (1990) and *Zeewijk* (1992-1994) (resp.: Smit *et al.* 2012; Kleijne *et al.* 2013; Theunissen *et al.* 2014). Other Late Neolithic sites were preserved for future research opportunities (Van Heeringen and Theunissen 2001, 43-44). With the completion of *De Gouw* in 2012 the period of large scale land consolidation projects in West-Frisia came officially to an end.

3 An "*archäologische Landesaufnahme*" is a regional field survey consisting of a desktop study, inventory of collections and systematic field walking.

2.5. The palaeogeographical model

The land consolidation projects and excavations resulted in much information on the genesis of the subsoil. This information was used for the construction of a palaeogeographical model. In 1982 a well-documented study on the development of the Bergen Inlet was published by the Geological Survey of the Netherlands (De Mulder and Bosch 1982). In this publication the development of the physical landscape is described from a lithostratigraphical point of view. The palaeogeographical maps in this publication present the distribution of the lithostratigraphical units at a certain period in time (figure 2.6). The clastic lithostratigraphical units are not subdivided into, for example, tidal flat deposits and tidal marsh deposits. Due to the lack of such a subdivision and the map scale, the publication was little used in archaeological projects afterwards.

A time-framework was added to the lithostratigraphy, based on an extensive overview of available radiocarbon dates including a wide range of dates from archaeological excavations.[4] The quality of the dates used for the stratigraphical framework is, in retrospect, of a poor quality. The radiocarbon dates are all conventional dates from the seventies or older. Most dates concern gyttjas, molluscs, clayey peat and bone. Conventional dates on gyttjas are suspected to be too old due to the hard water effect. These dates display substantial age differences up to several hundreds of years compared to AMS dates of selected macrobotanical remains from gyttjas (Törnqvist *et al.* 1992, 573). Conventionally dated bulk samples of clayey peat remnants also differ from AMS samples due to mechanical and botanical contamination depending, amongst other things, on the accumulation rate and the clastic sediment content (Törnqvist and Van Dijk 1993, 133). Bivalves are known to date too old due to the reservoir effect. Molluscs in the Bergen tidal basin lived in a brackish environment, a mixture of freshwater from the hinterland with an unknown ageing effect and salt water from the North

4 The time-framework is published in dates BP as is the tradition in geology instead of cal BC or BC as is the tradition in archaeology. In this text dates based on actual radiocarbon dates are presented as a 2σ cal BC date. The documentation on the original dates is included in Appendix 1. Archaeological dates based on multiple radiocarbon and/or other dating techniques are presented as BC dates. The BP dates used in the publication by De Mulder and Bosch (1982) are presented between brackets. In chapter 3 this problem is dealt with in detail.

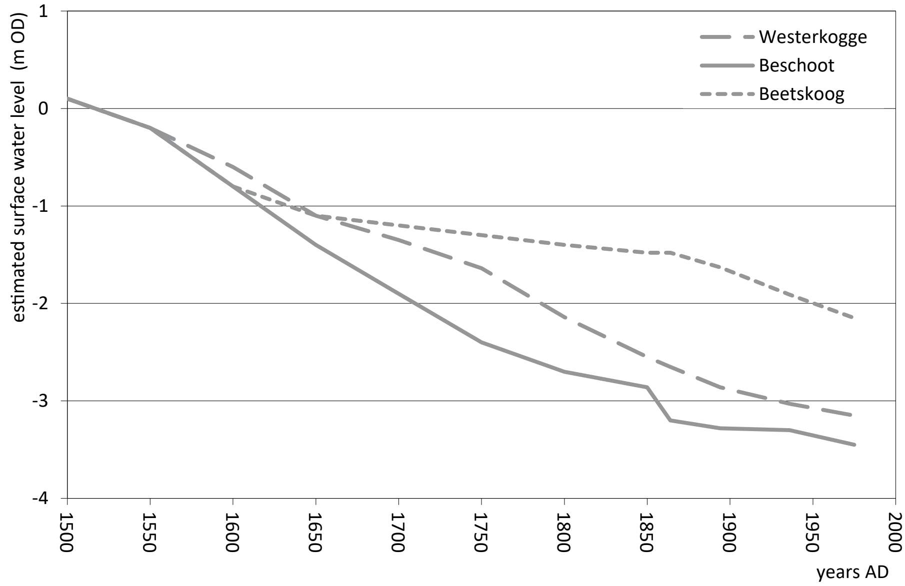


Figure 2.7: Graph of the estimated surface water level in three polders in West-Frisia based on data assembled by Borger (After: Borger 1975, 74).

Sea with a known ageing effect. Bone is susceptible to ageing due to a partly marine diet (Barret *et al.* 2000). Due to these problems the time-framework has to be handled with care.

Three observations in this study by De Mulder and Bosch (1982) are of interest in relation to the habitation history. The first observation concerns the closure of the Bergen inlet. The second observation in the article of De Mulder and Bosch (1982) concerns the development of a peat cover. The third observation in the article of De Mulder and Bosch (1982) concerns the transgression-regression model. These observations will be discussed below.

2.5.1. Closure of the Bergen Inlet

De Mulder and Bosch (1982) provide a date for the closure at 3000 BP, which corresponds with a date around 1250 cal BC. This date is based on a conventional ^{14}C-date on a clayey gyttja obtained from a gully close to the inlet and supported by a conventional radiocarbon date for the start of accumulation of organic matter (clayey gyttja) in the western part of the tidal basin.[5] These two dates are supported by several conventional radiocarbon dates for the start of peat growth in the eastern part of West-Frisia between 1500 and 1322 cal BC (3150 BP) and two dates for the start of peat growth close to the inlet at some distance from the tidal channel between 1628-1523 cal BC (3300 BP) (De Mulder and Bosch 1982, 147).[6] Therefore a closure of the Bergen inlet shortly before 1250 cal BC (3000 BP) seems likely according to the authors. The authors state clearly that after the closure: "*Minor quantities of marine deposits might have been deposited behind a chain of beach barriers in front of the inlet* (De Mulder and Bosch 1982, 147)." In other words, the inlet was geologically closed because almost no sedimentation took place in the remaining tidal basin. Geologically closed is therefore not the same as literally closed. In an archaeological sense it means that after the geological closure fish and boats were still able to enter the remaining tidal basin through the inlet.

The date of the closure of the Bergen Inlet was, after this publication, discussed by Roep and Van Regteren Altena (1988, 219). Roep and Van Regteren Altena (1988) date the closure before 1516-1297 cal BC at least, which marks the start of peat growth in the vicinity of the city of Alkmaar and after 2198-1641 cal BC, a date of a bivalve from a beach deposit close to the city of Alkmaar.[7] In order to pinpoint the closure of the Bergen inlet more exactly, the authors reasoned that permanent settlements on top of the former tidal channels were only possible after relief inversion of these tidal channels, ergo: after closure of the Bergen inlet. The start of Bronze Age habitation in the eastern part of West-Frisia is marked

5 Appendix 1, date 163 and 164; GrN-6763 3360 ± 50 BP and GrN-823 2950 ± 85 BP.

6 Appendix 1, date 165-170; GrN-5554 3440 ± 90 BP, GrN-6603 3150 ± 35 BP, GrN-7782 3270 ± 35 BP, GrN-8094 3265 ± 40 BP, GrN-611 3155 ± 110 BP, GrN-9067 2690 ± 60 BP.

7 Appendix 1, date 171 and 172; GrN-5217 3140 ± 50 BP, GrN-6309 3560 ± 40 BP.

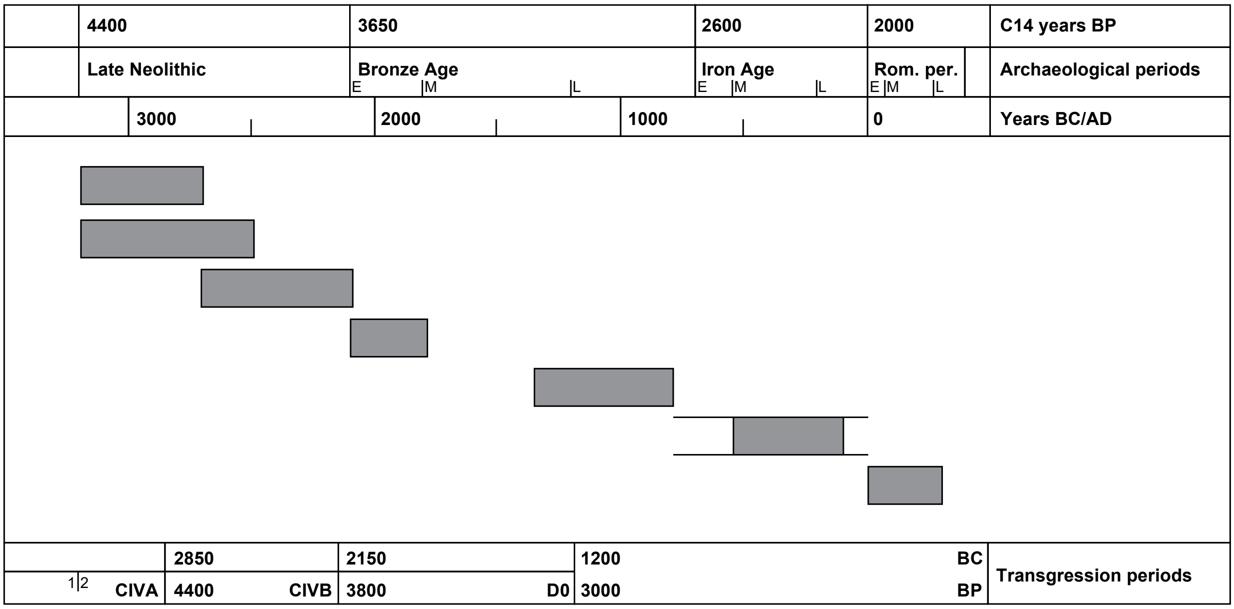


Figure 2.8: Habitation phases in West-Frisia in relation to transgression periods (C = Calais, D = Dunkerque, E = Early, M = Middle and L = Late) (Woltering 1985, 210, figure 8).

by the date of charcoal from a ringditch associated with a burial mound from the site *Bovenkarspel-Het Valkje* at 1634-1454 cal BC (Roep and Van Regteren Altena 1988, 219).[8] This "oldest" date from a settlement site supported the argument for an early closure of the Bergen inlet at 1570 cal BC (3300 BP). Consequently, after the publication of this article, 1570 cal BC has been reproduced repeatedly as the date for the closure of the Bergen inlet (Van der Spek 1994; Beets *et al.* 1996; Kok 2008).

The uncritical adoption of this date is remarkable. First, there were several older dates available in 1988 from settlement sites in West-Frisia. For example the site of *Oostwoud* is considerably older compared to the site *Bovenkarspel-Het Valkje* (Lanting and Van der Plicht 2002, 86-87). In several articles it has been argued that the northern branch in the Bergen tidal basin ceased approximately 2100 cal BC (3700 BP) (Van Heeringen and Theunissen 2001, 52). Apparently it was thought that after relief inversion the tidal channel deposits of the northern branch became exploitable. Second, Havinga, one of the leading soil scientists in the Netherlands, published in 1986 an article on the mechanism of relief inversion (Havinga 1986). In this article he argued that the archaeological community used the mechanism of relief inversion the wrong way (Havinga 1986, 395). His title is a pretty clear statement: "*Op dwaalwegen met de omkering van het bodemrelief*", which means something like: "*On the wrong track with relief inversion*" (Havinga 1986, 393). In his article Havinga explains in detail the process of relief inversion and explains why relief inversion is not applicable to the situation in West-Frisia. The main argument is the absence of bogs prior to the formation of marine sediments in this area (Havinga 1986, 399). Third, Pons and Wiggers (1959/1960) discussed the different landscapes simultaneously available within West-Frisia during the formation of the Wieringermeer and Westfrisian deposits; tidal flats, tidal marshes and fens. The authors specifically mention the presence of creeks and the influence of differential subsidence on the relief in the different landscapes. In retrospect it is curious that these publications have been neglected.

2.5.2. The development of a peat cover

In the article of De Mulder and Bosch (1982) the development of a peat cover is simply mentioned as a fact. The authors write: "*When the former sedimentation area had been drained, differential compaction set in. In the lowest parts swampy conditions caused the development of peat. These environmental conditions gradually extended over the entire area, and finally the whole of West-Frisia was covered with peat* (De Mulder and Bosch 1982, 146-147)." Obviously

8 Appendix 1, date 162; GrN-7472 3275 ± 35 BP.

the discussion started by Van Giffen (1953, 40) with his remark on the relatively low surface height was solved with the invention of a peat cover, an idea that was generally adopted at the time of publication.

After the publication of the excavation of the barrow of Grootebroek by Van Giffen (1953) several authors addressed the problem of the low surface height. Several years after the publication by Van Giffen (1953), Edelman suggests that the low surface height and the absence of younger clastic sediments can be explained by the existence of a peat cover for entire West-Frisia (Edelman 1958). Pons and Wiggers (1959/1960), as well as Ente (1963), rejected this idea. Pons and Wiggers (1960, 31-32) accepted a partial cover in the lower parts of West-Frisia but rejected the idea of a complete coverage. Ente (1963) rejects the entire idea. In his opinion the low surface height is caused by compaction due to a long tradition of intensive drainage since 1200 AD. In addition he noticed the presence of a thin cover of lake sediments known as "*kiekklei*" which had been overlooked by Van Giffen (Ente 1963, 188-189).

A new element was introduced in this discussion when in 1972 a peat layer was found under the church of Hoogwoud (Roldaan 1972; Havinga *et al.* 1992). The church is situated in central West-Frisia on top of a creek ridge. The base of this peat remnant was dated at 1500-1320 cal BC.[9] This find ended the discussion, the existence of a peat cover of entire West-Frisia was generally accepted. In 1975 the peat cover of West-Frisia was studied by the historical geographer Borger. Based on historical sources he reconstructs the change of the surface water level over time from 1500 AD onwards for three polders in West-Frisia (figure 2.7) (Borger 1975, 75). He argues that the peat cover has mainly disappeared due to oxidation (Borger 1975, 219-223). The original thickness of the peat cover was estimated at approximately four meters by Pons (Pons 1992, 48).

2.5.3. The transgression-regression model

The dates presented by De Mulder and Bosch (1982) do not fit in the transgression-regression model. Trans- and regressions were supposed to vary with changes in the pace of the relative rise in sea level and changes in sediment supply. Progradation or retrogradation therefore depended on small changes in the rise of the relative sea level, fluctuations in precipitation causing changes in river discharge and fluctuations in storm surge frequency and magnitude (Vos 2015, 8). During transgressions retrogradation took place and clastic deposits were formed. During regressions progradation occurred, parts of the tidal area emerged, soil formation took place and organic deposits were formed (Vos 2015, 9). This model was used by archaeologists to explain the occupation dynamics of the coastal area (Vos 2015, 9). It was widely believed that during regressions the risk of flooding diminished and land became inhabitable. During transgressions the risk of flooding enlarged and land became uninhabitable (figure 2.8). Due to the large amount of available radiocarbon dates De Mulder and Bosch (1982) observed a different staging of the trans- and regression phases in the Bergen tidal basin compared to other parts of the Dutch coast. In the article it is carefully suggested that the size and morphology of the tidal basin were possibly of influence on the sedimentation history next to changes in sediment supply, isostatic and eustatic sea level movements (De Mulder and Bosch 1982, 149).

Not only in the Netherlands was the simultaneous cycle of trans- and regressions along the coast questioned. Baeteman published in 1983 a critical overview of the Belgian coastal development and observed local differences in the various tidal basins (Baeteman 1983). This publication marks a turn in thinking over the development of coastal environments. Local factors like accommodation space, morphology of the tidal basin and so on were thought to be of importance in the development of a tidal basin. In the nineties these new ideas were applied to the development of the Bergen tidal basin by Van der Spek (1994, 152-180). Surprisingly these new ideas were not adopted by the archaeological community.

2.5.4. A new model for coastal development

In the previously mentioned publication by Van der Spek (1994) the erosion and sedimentation history is explained by three components: accommodation space, tidal asymmetry and tidal range. The accommodation space of a tidal basin is determined by the morphology of the subsurface and the relative sea level rise. A tidal basin enlarges when the accommodation space is larger than the sediment supply and vice versa (Coe *et al.* 2003,

9 Appendix 1, date 166; GrN-6603 3150 ± 40 BP.

56-61). The morphology of the subsurface of the Bergen tidal basin is determined by the morphology of the Pleistocene surface, the former river valley of the river Rhine. The valley is confined by ranges of ice pushed ridges. In the north ice pushed ridges occur along the line Texel-Wieringen-Gaasterland-Steenwijk-Coevorden. In the south these ridges are present along the line Haarlem-Utrecht-Nijmegen (De Mulder *et al.* 2003, 219). Approximately 28.000 BP the river Rhine changed its course to the central parts of the Netherlands, the present day Rhine-Meuse delta. From 28.000 BP onwards the valley was drained by the river Overijsselse Vecht and smaller tributaries like the Tjonger, Eem and the predecessor of the river IJssel (De Mulder *et al.* 2003, 208-209).

The tidal asymmetry is the difference between the length of the flood and ebb tidal current. Tidal asymmetry is influenced by several factors. Along the Dutch coast the ebb tidal current is larger compared to the flood tidal current due to the morphology of the North Sea basin. Due to the stronger flood tidal current in comparison with the ebb tidal current a net sediment supply will occur in the tidal basins along the Dutch coast (Dronkers 1986, 121-122). The morphology of the tidal basin and the presence of tidal flats are of influence on the asymmetry. If the surface covered by tidal flats within a tidal basin enlarges the flood tidal current is obstructed and the length of the flood tidal current enlarges (Van der Spek 1994, 14). An enlargement of the flood tidal current results in a loss of energy and thus sediment transport.

The tidal range is the difference between high tide and low tide. Within a tidal basin the tidal range can change from location to location, depending on the length of the tidal basin with respect to the tidal wave (Van der Spek 1994, 169-170). The former Zuiderzee is a good example of the influence of the basin length at the tidal range. In the former Zuiderzee the length of the tidal basin equaled a half tidal wave. The outgoing ebb tidal current met the incoming flood tidal current resulting in a minimal tidal range and a raised mean sea level (Elias 2006, 55).

The development of the Bergen tidal basin between 4350 cal BC (5500 BP) and 1570 cal BC (3300 BP) as described by Van der Spek (1994) is relevant to this study. Approximately 4350 cal BC (5500 BP) the Bergen tidal basin could be characterized as a flood dominated tidal basin. Behind the Bergen inlet a multi-channel system was present. The channels were flanked by tidal flats and enclosed shallow lagoons. The tidal range decreased from the inlet in an eastward direction whereas the mean water level increased and the flood period shortened. Around 2100 cal BC (3700 BP) a remarkable change occurred. The eastern part of the tidal basin area was disconnected from the western part and turned into a freshwater lake. This resulted in a substantial decrease of the accommodation space in the tidal basin. The surface reduction of the tidal basin was estimated at approximately 85%. As a result the sediment balance in the tidal basin changed dramatically. The basin consisted after 2100 cal BC (3700 BP) of a single channel flanked by tidal flats and salt marshes. As a result of the reduced accommodation space, tidal wave length and mean water depth, the tidal range increased for the area between the inlet and Hoogwoud. In the area between Hoogwoud and Enkhuizen the tidal range decreased. Simultaneously the mean water level east of Hoogwoud was strongly increased. In addition west of Hoogwoud the tidal basin changed from flood dominated into ebb dominated. As a result, the basin west of Hoogwoud

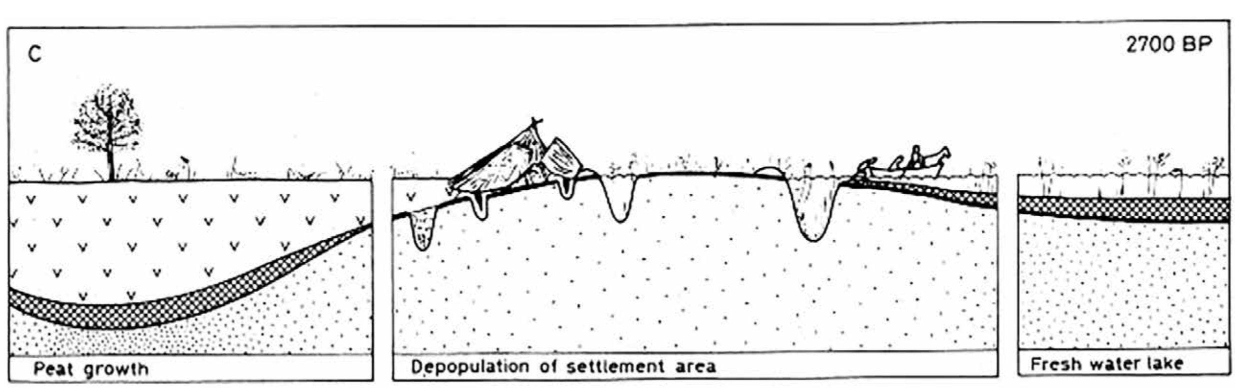


Figure 2.9: The abandonment of West-Frisia at the end of the Late Bronze Age (Van Geel et al. 1982, 306, figure 7c).

silted up rather quickly and the area east of Hoogwoud silted up to a level above mean sea level (Van der Spek 1994, 169-180). However the ideas on the why and how of the sedimentation and erosion history in this area changed, the proposed date for the closure at 1570 cal BC (3300 BP) was unaffected.

2.6. The habitation model

The landscape development models presented before the publication by Van der Spek (1994) have been of great influence on the development of a habitation model. The archaeologists involved in the 1966 excavation of the *Hoogkarspel* site used amongst others the soil map of Ente as a palaeogeographical map. A relationship was observed between the sandy and loamy soils mapped by Ente and the location of the settlement sites (Bakker *et al.* 1977, 192-196). The sandy and loamy soils were interpreted as former tidal channels. To explain the exploitation of these former tidal channels it was argued that these channels were completely silted up prior to the colonization of West-Frisia and transformed into creek ridges as a result of relief inversion (Van Geel *et al.* 1982, 273; Roep and Van Regteren Altena 1988, 219). After this transformation these ridges were colonized. The first house plans situated on these ridges were thought to date between 1500 and 1400 BC. There was no evidence for permanent settlements on these ridges in the area prior to this date. Only one settlement site dating prior to the Middle Bronze Age was known in West-Frisia until the nineties. This site, *Zandwerven*, was excavated in 1929 (Van Giffen 1930). This site was situated at a former coastal dune instead of tidal marsh deposits. Other types of sites dating prior to the Bronze Age were some ard marks and burials dating to the Late Neolithic which were found during an excavation at the site of *Oostwoud* in 1956 and the site of *Aartswoud* excavated in 1972 (Van Giffen 1961; Van Iterson Scholten and De Vries-Metz 1981). All Late Neolithic sites were interpreted as sites where activities had taken place temporarily. The few sites in West-Frisia dating in the period 1800-1500 BC, the burial mound of *Bovenkarspel-Het Valkje* and the poorly excavated site *Westwoud II*, confirmed the ideas of the colonization of a "virgin soil" in the Middle Bronze Age (IJzereef 1981; De Vries-Metz 1993).

The archaeologists who excavated in West-Frisia assembled data on site for detailed landscape reconstructions. Based on multi-proxy evidence from several excavations it was argued that the vegetation could be characterized as an open, almost treeless area from the start of the colonization phase to the end of the Late Bronze Age (Buurman 1996, 186). During the Bronze Age the environment became wetter resulting in the enlargement of fens and the development of bogs (Van Geel *et al.* 1982, 304-308). Based on algae derived from multiple excavated ditches, the landscape was characterized as a pure freshwater environment throughout the Middle and Late Bronze Age (Van Geel *et al.* 1997, 159-161). The fish bone assemblages of the excavations also indicated a freshwater environment, excluding the possibility of brackish water in the vicinity (IJzereef 1981, 126). The samples of cultivated cereals dating to the Middle Bronze Age settlement phase contained mainly wheat. The samples dating to The Late Bronze Age contained mainly barley. This shift from wheat to barley was interpreted as an indication for wetter environments (Buurman 1999, 134-135). This shift coincided with a rise in the amount of weeds that prefer more humid conditions. Moreover molluscs, mostly snails derived from excavated ditches, indicated a more humid environment at the end of the Bronze Age compared to the start of the Bronze Age (Buurman 1999, 134-135). In addition it has been suggested that the attested change from meat to dairy production is an indication of wetter conditions (Runia 1987, 190; Buurman 1996, 192). A last indication of wetter conditions is derived from small mammal habitats. Small mammal remains from late contexts represent a wider range of habitats compared to the start of the Bronze Age. According to the researchers this implies that the habitats of small mammals were smaller i.e. in closer proximity of each other in the Late Bronze Age (Buurman 1999, 134).

The end of Bronze Age habitation is marked by a change in settlement construction. The youngest house plans of the Bronze Age settlements in West-Frisia are dated between 900 and 750 BC. In this youngest period the houses were situated on small artificial mounds on the creek ridges, suggesting a wetter environment. The ongoing rise of the relative sea level was thought to cause a wetter landscape, a substantial enlargement of the fens and the start of the formation of peatbogs. After 750 BC West-Frisia was thought to have become uninhabitable and the settlements sites were abandoned (figure 2.9) (Van Geel *et al.* 1982).

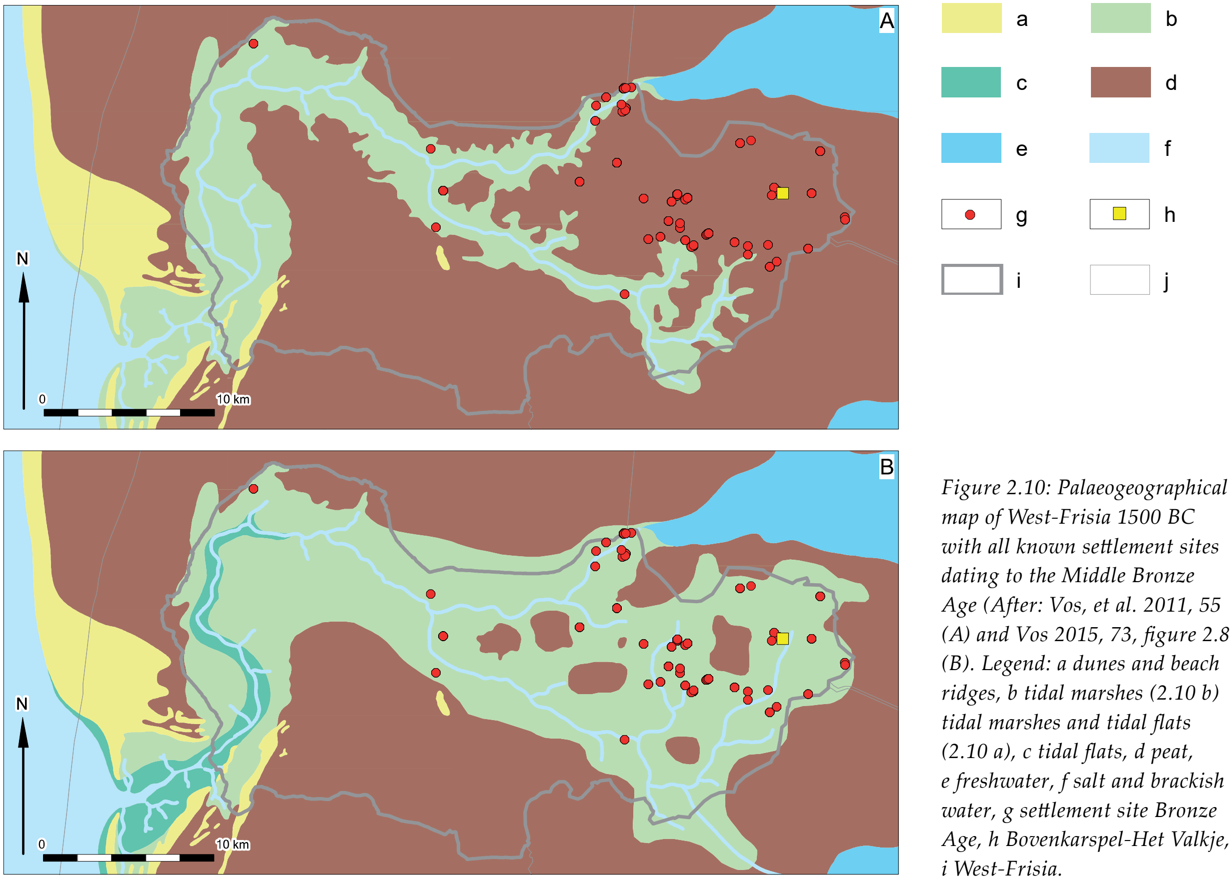


Figure 2.10: Palaeogeographical map of West-Frisia 1500 BC with all known settlement sites dating to the Middle Bronze Age (After: Vos, et al. 2011, 55 (A) and Vos 2015, 73, figure 2.8 (B). Legend: a dunes and beach ridges, b tidal marshes (2.10 b) tidal marshes and tidal flats (2.10 a), c tidal flats, d peat, e freshwater, f salt and brackish water, g settlement site Bronze Age, h Bovenkarspel-Het Valkje, i West-Frisia.

In the nineties the theory of solar forcing as the explanation for the sudden abandonment of settlement sites in West-Frisia was introduced (Van Geel *et al.* 1996, 453-454). Based on a peat remnant under the Westfriese Omringdijk and the Engbertdijksveen in the eastern part of the Netherlands a change was attested from *Sphagnum* species which favour dry summers to species favouring cooler, wetter and cloudier circumstances. This change in *Sphagnum* species coincides with a change in the delta ^{14}C-value, indicating a period with a substantially smaller amount of solar flares. It is suggested by the authors that this change in solar radiation led to a small climatic change analogous to the Maunder minimum during the Little Ice Age. This change in climate led to a higher pace of peat formation and suddenly increasing wetter conditions in West-Frisia. Therefore a direct link was suggested between the abandonment of West-Frisia around 750 BC and the change in solar radiation (Van Geel *et al.* 1996, 453-454).

Although this habitation model seems to fit the data very well, there are two anomalies in this well documented and thorough research project. The first is the find of an Early Iron Age (750-500 BC) settlement site near the village of Opperdoes in 1985. This site, *Opperdoes-Markerwaardweg* is the only known excavated settlement site with features dating to the Bronze Age and Early Iron Age. The date of the Iron Age site is based on the presence of Ruinen-Wommels I type of pottery (Diederik 2011). Only one radiocarbon date is available from this site but it is unclear what this date (charcoal from a feature) represents.[10] Settlement sites dating to the Middle Iron Age and Late Iron Age are rare but not unknown. The presence of the site *Opperdoes-Markerwaardweg* was explained by the relatively high altitude (-0.25 m O.D.) of the excavated location compared to the sites *Hoogkarspel* and *Bovenkarspel-Het Valkje* (-1.25 m O.D.) (Woltering 1985, 225).

The second anomaly is the find of several Neolithic sites in the last land consolidation project *De Gouw* (figure 2.5). The presence of the Late Neolithic sites in *De Gouw* is explained by the shift of the main tidal channel to the south eastern part of the tidal basin.

10 Appendix 1, date 139: GrN-10015 2210 ± 55 BP.

Due to this shift the area of *De Gouw* was relatively stable and therefore suitable for exploitation (Van Heeringen and Theunissen 2001, 54). The eastern part of West-Frisia was thought to be uninhabitable during this period. Therefore the idea of the exploitation of a virgin soil during the Bronze Age was unaffected. The recent find of two Late Neolithic sites in the eastern part of West-Frisia in advance of the construction of a motorway proves differently (Knippenberg in prep.).

2.7. The palaeogeography of the Netherlands

The changing ideas on the development of the landscape and habitation possibilities are well reflected in the series of palaeogeographical maps at a national scale which have been published over the years. The first national palaeogeographical map series was published by Pons *et al.* (1963). This map series is a joint effort of the soil scientists of Stiboka and the geologists of the Geological Survey. These maps were improved by Zagwijn (1986) mainly based on the newly published geological maps, palaeobotanic data and radiocarbon dates. This series contains 10 maps of the Netherlands during the Holocene. In 2003 a series of palaeogeographical maps was published by De Mulder *et al.* (2003). These maps were an improved version of the maps constructed by Zagwijn using regional studies of Zeeland and the Rhine-Meuse delta and the results of the Coastal Genesis Project by Rijkswaterstaat. The published maps were schematic and the palaeodrainage pattern was not at an exact scale. In 2005 TNO published a set of seven maps (Vos and Kiden 2005), commissioned by the Cultural Heritage Agency. These maps were drawn at a scale of 1:500.000. An important difference with maps published before is the use of a selection of archaeological sites. In 2011 an improved and extended version of these map series was published consisting of 11 sheets (Vos *et al.* 2011). A new source used in the construction of this series was the elevation model of the Netherlands (AHN). In this series the relationship with archaeology was amplified. All the palaeogeographical maps published after 1986 were subject to debate, due to a lack of a description of the methods used for the compilation of these maps.

The research project "*Farmers of the Coast*" started just after the publication of the latest national palaeogeographical map in august 2011. In this series a map presenting the palaeogeography in the Middle Bronze Age is incorporated (figure 2.10A). A quick glance at the distribution of the Bronze Age settlement sites, plotted on the newly published map, shows the imperfection of the national reconstruction for the palaeogeography in West-Frisia around 1500 BC. Almost all known settlement sites dating to the Middle or Late Bronze Age are plotted in an area covered by peat, whilst in reality all excavated sites were situated on top of clastic sediments.

During the research project an improved set of 11 palaeogeographical maps was published in "*Origin of the Dutch coastal landscape*" (Vos 2015). A big improvement by this publication is the presentation of a methodological base for the construction of the maps. The maps have been compiled at scale 1:100.000 and show, therefore, a larger degree of detail. In this 2015 reconstruction the "peat problem" as described above is mainly solved (figure 2.10B). Although in this reconstruction another problem occurs. In this reconstruction Middle and Late Bronze Age sites are situated along active tidal creeks despite the absence of any indication for the habitation of tidal marshes along tidal creeks. The landscape of eastern West-Frisia is characterized by archaeologists as an entirely freshwater landscape during the Middle and Late Bronze Age. This idea is based on a large amount of data from many different proxies and is confirmed in many excavations. Specifically, the situation for the site *Bovenkarspel-Het Valkje* is peculiar. During the excavation a cross-section through the entire main tidal channel was made. This tidal channel was silted up completely in the Middle Bronze Age, even house plans dating to the Middle Bronze were situated on top of the infill of the residual gully. This implies a complete abandonment of the tidal channel prior to the habitation in the Middle Bronze Age. In chapter 3 an alternative palaeogeographical reconstruction will be proposed.

2.8. After "Valletta"

The publication by Van Geel *et al.* (1996) completed the entire habitation model and did not conflict with both previously presented landscape development models. The ratification of the Valletta Treaty in 1998 by the Dutch government provided an opportunity to validate the presented models. In anticipation of the new Monuments Act based on the Valletta Treaty, archaeological research was obligatory in advance of ground disturbances. This change of legislation and policy led to the start of a new archaeological practice where excavations were undertaken by commercial companies. Far more important was the change in focus. Archaeological excavations were no longer research led projects but became development led projects, exploring larger areas and areas which were previously thought of less importance. Thomas (2013) deals with this topic in his publication "*Bridging the gap?*" in which he emphasizes the different nature and results of these two research foci in Great Britain. Due to the new legislation in the Netherlands transparent procedures were needed for the obligatory archaeological research. One of the tools for achieving these transparent procedures are policy documents and their accompanying maps which have been published by the local government.

In 2006 a policy document and map were presented by the local government for eastern West-Frisia (De Boer and Molenaar 2006). In this document the landscape and habitation model by Van Geel *et al.* (1982) and De Mulder and Bosch (1982) are repeated. The known Bronze Age sites from the ArchIS database and the sites mapped by Ente (1963) were plotted on the detailed soil map of the land consolidation project. In order to distinguish areas with a high, medium or low risk for the presence of archaeological values dating to the Bronze Age, the method presented by Deeben *et al.* (2002) was applied. In this method the number of sites per soil unit is counted. Soil units with a more than average amount of sites are classified as an unit with a high indicative archaeological value. Soil units with an average amount of sites are classified as a unit with a medium indicative archaeological value. Soil units with a less than average amount of sites are classified as a unit with a low indicative archaeological value. Using this method three classes were distinguished for the policy document of eastern West-Frisia. The sandy and silty soil units turned out to contain a more than average amount of sites compared to clayey, humic and peaty soils and therefore represent the high and medium units. For these high and medium units the local government is advised to conduct an intensive survey in advance of planned ground disturbances. For areas with a low indicative value the local government is advised to conduct an extensive survey in order to validate the low value (De Boer and Molenaar 2006, 48-49).

Three critical remarks can be made on this policy document. Although the authors mention explicitly the effect of land use on the visibility of sites, they ignore the fact that there is a strong relationship between land use and subsoil. The sandy and silty soils were mainly in use as arable fields whereas clayey and especially humic and peaty soils were in use as pastures during the large scale archaeological surveys. The site visibility is higher in the former compared to the latter. A second topic which is briefly addressed is the sedimentation and the peat formation after the Bronze Age. However, little sediment is supposed to have been formed after the Bronze Age. This post-Bronze Age sediment layer is supposed to be thicker at locations with soils more vulnerable to compaction, i.e. clayey, humic and peaty soils. A third topic which is not dealt with in the document is the process of churning in relation to preservation of archaeological remains. Especially soils with a high lutum and/or organic matter content are vulnerable to churning. The survival opportunity for pottery is therefore greater in sandy and silty soils compared to the other soil classes. Therefore there is a causal relationship between the observed site distribution and observed soil classes. However, this does not imply a relationship between the actual site distribution and observed soil classes! In chapter 6 this problem will be dealt with.

In West-Frisia several excavations were undertaken based on the new legislation and policy. Three large scale excavations revealed Middle Bronze Age (1600-1100 BC) and Late Bronze Age (1100-800 BC) settlement sites: *Hoogwoud*, *Medemblik-Schepenwijk* and *Enkhuizen-Kadijken* (Lohof and Vaars 2005; Schurmans 2010; Roessingh and Lohof 2011). The site of *Hoogwoud* dates between 1300 and 1000 BC. The site of *Medemblik-Schepenwijk* dates between 1450 and 800 BC. Features and pottery dating between 1100 and 900 BC seem to be absent at this site. The site of *Enkhuizen-Kadijken* dates between 1600 and 800 BC. These three sites all provided data contradicting the existing palaeogeographical and habitation models. For example the site *Enkhuizen-Kadijken* is not situated at a creek ridge but at a former tidal marsh, an area which is supposed to be uninhabitable according to the presented models.

Pollen is poorly preserved in all three sites due to the alkaline soil and deep artificial drainage (Dimbelby 1957, 18). Despite the poor conservation palynological research of samples from ard marks in *Medemblik-Schepenwijk* presents pollen percentages for alder up to 25%, indicating the presence of alder carr in the immediate vicinity of the settlement site. Palynological research of several coprolites from dogs present in addition a relatively high percentage (7%) of willow which is a poor pollinator. This indicates the presence of willow woodland or willow shrubs in the vicinity of the settlement site (Schurmans 2010, 162-165).

In all three sites the preservation of uncharred macrobotanical remains is poor due to the deep artificial drainage of the soil. Despite the poor conservation all three settlement sites provide macrobotanical remains representing different habitats ranging from freshwater environments with nutrient rich dry arable soils to very wet pastures in the direct vicinity of the settlement site for the entire period. Indications for an enlargement of wetter habitats in the Late Bronze Age are clearly present. This is in accordance with both models. Contradictory is the presence of poorly preserved wood from oak, alder and willow in features dating to the Late Bronze Age in *Medemblik-Schepenwijk* and indicators for shrubs (or possibly woods) like seeds of bramble and elder (Van Zijverden 2013). The range of wood species found in *Enkhuizen-Kadijken* is even larger compared to *Medemblik-Schepenwijk* and comprises oak, alder, ash, birch, willow and pine (one object) (Roessingh and Lohof 2011, 247). Apparently woodlands or at least patches of woodland and shrubs have been present, which contradicts both models.

All three sites provide fish bones due to a-select sieving of features and the good preservation of bone due to the alkaline subsurface. The fish remains of *Hoogwoud* comprise specimens indicating full marine environments (Atlantic cod and sting ray), brackish environments (European flounder and thinlip mullet) and freshwater specimens (cyprinids and northern pike). Approximately 75% of the remains at this site represent a brackish environment (Van Amerongen 2015). The fish remains of *Medemblik-Schepenwijk* indicate a full freshwater environment with mostly northern pike, cyprinids and several other species. In the Late Bronze Age a few remains of European flounder and mullet are present indicating brackish environments or at least a distant connection with a marine environment (Van Amerongen 2015). Remains from *Enkhuizen-Kadijken* are almost similar compared to those of *Medemblik-Schepenwijk*: mainly "freshwater" fishes, a few mullets and large numbers of eel (Van Amerongen 2015). The presence of marine and brackish species in the western part and species indicating a distant connection with the sea contradict the habitation model as well as the palaeogeographical model (Van Amerongen 2015). The presence of species indicating a distant connection with the sea in the Late Bronze Age is especially hard to understand within the current palaeogeographical model.

Mammal and bird remains are well-preserved at all three sites due to the alkaline soil. The large faunal remains from *Medemblik-Schepenwijk* represent animals like goose, elk, deer, wild boar, fox and beaver for the Middle Bronze Age. In the Late Bronze age wild cat and otter are also represented in the assemblage (Schurmans 2010, 86). The assemblage of large faunal remains of *Hoogwoud* is small and represent red deer and roe deer (Lohof and Vaars 2005, 37). The faunal remains from *Enkhuizen-Kadijken* comprise wild boar, brown bear, elk, deer, and beaver (Roessingh and Lohof 2011, 203-204). Of interest from the small faunal remains of this site are northern goshawk and the woodcock both indicative of woodland and shrubs (Roessingh and Lohof 2011, 204-205). Both these landscapes are supposed to be absent according to the habitation model and palaeogeographical model (Van Amerongen 2014).

At some locations within the site *Enkhuizen-Kadijken* the original stratigraphy was intact. At two locations a soil sample was studied using micromorphology. Based on this research it was noticed that, after the abandonment of the settlement site, renewed sedimentation took place Roessingh and Lohof 2011, 46). Distinct layers of charcoal particles alternate with very small silt particles after the abandonment. Apparently man burned the vegetation regularly, indicating a continuing presence in the area after the abandonment of the settlement area. After a while sedimentation took place in a back swamp environment, uninterrupted by burning activities and without any indications of peat growth which contradicts both models.

The new data confirms the enlargement of wet habitats in the Late Bronze Age without any doubt (Roessingh and Lohof 2011, 268). However *Enkhuizen-Kadijken* proves that the rise of the water table didn't always lead to peat formation at the end of the Bronze Age. The situation of this settlement site at tidal marsh deposits influenced by differential subsidence, combined with the absence of raised mounds in the Late Bronze Age contradicts the disastrous events sketched by the models. This new data also presents indications of a much more differentiated landscape than previously thought. A patchwork of lakes, marshy grasslands, dry arable fields alternating with patches of woodland and shrubs like alder carrs, willow woods or willow shrubs could have been present in the eastern part of West-Frisia. Apart from these types of shrubs and woodlands, riparian forests with ash and oak could have been present as well. The game assemblage with animals like wild boar, brown bear, Northern goshawk and woodcock is consistent with the presence of these specific woodland biotopes. In chapter 4 this topic will be dealt with in more detail.

2.9. Concluding remarks

In this chapter the palaeogeographical and habitation models for Bronze Age West-Frisia have been introduced and placed in a historical perspective. The framework for both models was built using the work of the soil scientists of Stiboka. These soil scientists practiced the genetic approach during soil surveys, carried out in advance of land consolidation projects. The maps and models generated by Stiboka were of great use to understand the development of the environment in the past and the nature of Bronze Age archaeology in West-Frisia. It was widely thought that with the exception of the monument at Bovenkarspel all features from Bronze Age West-Frisia were destroyed due to the land consolidation projects. Therefore little to no research has been carried out in West-Frisia after 1985. New development-led research, carried out as a consequence of the Valletta Treaty, proved different. Not only well-preserved Bronze Age sites appeared to be present, but also the generated data contradicted the existing models.

Several problems in the palaeogeographical and habitation model have been addressed in this chapter. According to the present model, the start of Bronze Age habitation is marked by the closure of the Bergen Inlet. The early closure of the Bergen inlet at 3300 BP is, despite the geological evidence as presented by De Mulder and Bosch (1982) and the archaeological evidence from the site *Hoogwoud*, not yet ruled out. A later closure implicates a salt to freshwater gradient and the influence of tidal movement during at least part of the Bronze Age. A dynamic environment with changes in salinity has a radical influence on the biotic and physical environment. Furthermore, it also has implications for the geographical position of West-Frisia during (a part of) the Bronze Age. An open coast line with a sheltered tidal inlet is an attractive location for fisherman and traders. The end of habitation in the Bronze Age is marked by the development of a complete peat cover in West-Frisia. At at least at one excavated site (*Enkhuizen-Kadijken*) a peat cover is absent which raises discussion of the degree of completeness of this peat cover. The new model for the coastal development of West-Frisia as presented by Van der Spek (1994) has not yet been translated into a new palaeogeographical reconstruction. Chapter 3 will cover these topics in detail and a new regional palaeogeography, which is in accordance with the archaeological evidence, will be presented.

In this chapter the strong "belief" in a preferred settlement site location at creek ridges has been discussed. On one hand the explicit article by Havinga on this topic is systematically ignored as is the evidence from a site like *Enkhuizen-Kadijken*. On the other hand, without any doubt, creek ridges are present in the landscape of West-Frisia. There is indeed a distinct correlation between find distribution and soil units suggesting a correlation between these creek ridges and settlement sites. In this chapter it has been argued that this statistical correlation is not the same as a causal relationship between settlement sites and creek ridges. Furthermore, in the models it is suggested that the vegetation of West-Frisia can be characterized as a treeless, almost open landscape. In this chapter it has been argued that the broad spectrum of wood species combined with a broad spectrum of animals preferring cover in the find assemblages, is at least an indication for the presence of woodlands. In chapter 4 the problem of the creek ridge and the almost treeless landscape will be dealt with.

3 Communicating vessels, reconstruction of the landscape of West-Frisia at scale 1:100.000

3.1. Introduction

In the previous chapter the history of landscape research in West-Frisia has been discussed. It has been argued that the existing national palaeogeographical map for 1500 BC does not fit the archaeological dataset of West-Frisia. Furthermore it has been argued that the existing habitation and landscape model is not in agreement with recent results from several excavations. In this chapter one of the problematic elements in the palaeogeography, the development of the Bergen tidal basin, is discussed. In order to create a new palaeogeographical map that fits the available archaeological and environmental data, the previously published data will be evaluated and completed with new data from excavations within the Bergen tidal basin. Several key sites within the Bergen tidal basin will be addressed in detail. Based on this evaluation and the presented new data, a map for three time frames will be drawn, the Late Neolithic (2850-2000 BC), Middle Bronze Age (1800-1100 BC) and Late Bronze Age (1100-800 BC). The legend of the

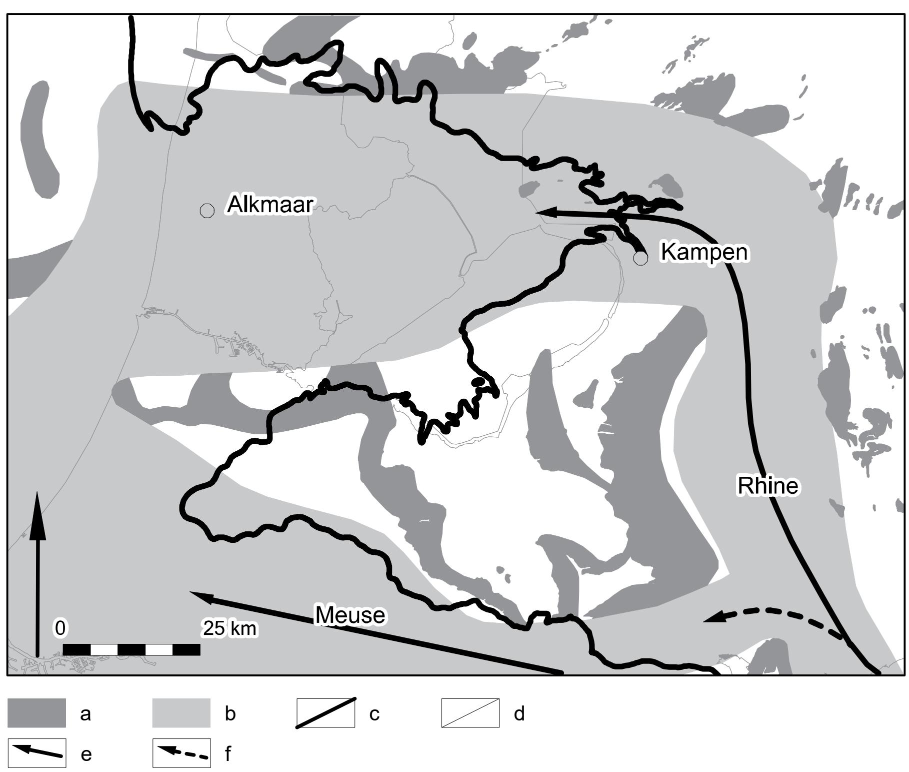


Figure 3.1: The location of the Middle-Pleniglacial river valley of the rivers Rhine and Meuse and Saalien glacial-tectonic landforms in relation to the development of the Bergen tidal basin. Legend: a Saalien glacio-tectonic ridges, b channel belts Middle-Pleniglacial, c boundary: marine and fluvial deposits(west) versus peat and Pleistocene deposits (east) 3850 BC, d present-day outlines of The Netherlands, e main course of the rivers Meuse and Rhine, f Montferland Rhine pathway (After: Busschers 2008, 22, figure 2.2; Vos 2015, 71, figure 2.6).

recently published reconstructions by Vos (2015) is used as well as the outlines outside the research area. This way the results of this study of the Bergen tidal inlet can easily be combined with the national palaeogeographical map.

3.2. Model: coastal development and the appearance of the landscape

Until approximately 28.000 years ago the river Rhine followed more or less the course of the present-day river IJssel (Busschers 2008, 64). From the confluence with the river Vecht the Rhine followed its course westwards in the direction of the present-day city of Alkmaar. This river valley of the Rhine is confined by Saalien ice pushed ridges to the north and south (figure 3.1). After approximately 28.000 years ago the Rhine abandoned its northern river valley and changed its course to the present-day Rhine-Meuse valley in the central part of the Netherlands. The river Vecht and some smaller tributaries like the Tjonger still followed the former course after the abandonment of the valley by the river Rhine. Therefore the valley is sometimes referred to as the Vecht river valley or Vecht basin (Vos 2015, 12). At the start of the Holocene the sea level rose quickly due to the melting of the ice sheets. Two factors played a main role in this sea level rise, the eustatic sea level rise caused by an increase of the amount of sea water and the isostatic sea level rise caused by subsidence of the land surface (Vos 2015, 29). During these early days of the Holocene the former Rhine river valley was inundated by the sea and changed into a tidal basin. This basin is usually referred to as the Bergen tidal basin. This Bergen tidal basin functioned as a 'sediment sink' in which large amounts of sediments were transported by the sea (Vos 2015, 38). The Bergen tidal basin extended itself at its uttermost position around 3850 BC as far as the city of Kampen (figure 3.1). From this moment onwards the pace of the sea level rise decreased and a continuous row of beach barriers and dunes developed along the Dutch coast. At several points these beach barriers were separated by tidal inlets (De Mulder *et al.* 2003, 223). The location of these inlets and the morphology of the accompanying basins changed over time. For the study of West-Frisia three inlets and their accompanying basins are of importance, the Bergen inlet, Oer-IJ estuary and Vliestroom (figure 3.2). The present-day knowledge on the development of these three basins is summarized below.

3.2.1. Bergen inlet

Due to the partial closure of the coast after 3850 BC, the character of the Bergen tidal basin changed. Before the partial closure of the coast with beach barriers, the Bergen tidal basin could be compared with the present-day Waddenzee, an area characterized by tidal channels, a shallow sea and tidal flats. After the partial closure of the coast the Bergen tidal basin can be described as an area dominated by large tidal channels with high levees accompanied by marine crevasse splays and vast open basin areas (Westerhof *et al.* 1987, 124-129).

The appearance of this landscape has been described in contradicting ways by archaeologists. Hogestijn, one of the researchers of sites like *Zeewijk*, *Mienakker* and *Keinsmerbrug*, describes the landscape as an open tidal marsh area with ponds, lakes and creeks intersected by creek ridges (Van Ginkel and Hogestijn 1997, 19-24). According to this researcher the borders of the pools and lakes were covered with reed. The marshland vegetation was characterized by plants like thrift, red fescue and closer to the coast common salt marsh grass and even common glasswort. The creek ridges and creek levees must have been approximately one meter higher compared to the surrounding marsh land. These slightly elevated areas have been covered with oak, hazel, ash and at the lower parts alder and willow. In the words of this researcher: "an ecological paradise" (Van Ginkel and Hogestijn 1997, 24).

Based on the same dataset, a contradicting image of the landscape in this period is presented in the recently published reports of the excavations of *Keinsmerbrug*, *Mienakker* and *Zeewijk* (Smit *et al.* 2012; Kleijne *et al.* 2013; Theunissen *et al.* 2014). In all three reports the landscape is presented as an open landscape with tidal flats and tidal marshes divided by creeks and creek ridges. It is argued that the exploited levees and marshes were flooded by brackish water during spring tides, preventing the development of deciduous forests. According to the authors man has lived in an open tidal marsh area comparable to the present-day landscape of "*De Slufter*" at Texel. The overview of plants and animals presented by the

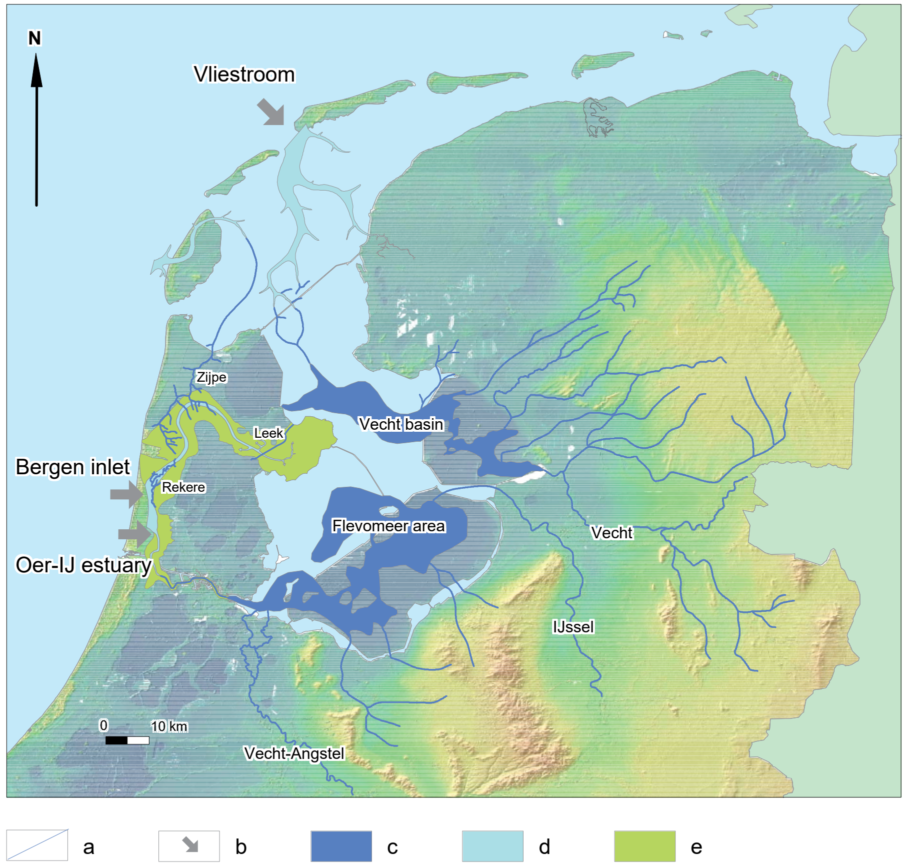


Figure 3.2: Study area with toponyms used in the text and the main palaeogeographical elements ± 1500 cal BC, with the exception of the Vecht-Angstel riversystem, Vliestroom, Rekere, Zijpe and Leek (After: De Mulder & Bosch 1982; Kok 2008; Vos 2015) plotted on a LIDAR-image of The Netherlands. Legend: a rivers mentioned in the text and small tributaries, b tidal inlets, c lakes, d creeks, e tidal marsh deposits.

authors gives a general idea of the environment. The macrobotanical remains present a wide variety of brackish and salt environments as do the fish bones, supporting the interpretation of the environment by the authors. Although, the fish bones also represent various freshwater environments. The presence of a wide variety of deciduous trees in the charcoal spectra is explained by the authors by the use of driftwood and the exploitation of deciduous forests at the Pleistocene outcrop of Wieringen 12-20 kilometers up north (Smit *et al.* 2012, 220; Kleijne *et al.* 2013, 252; Theunissen *et al.* 2014, 260).

The main argument for the absence of deciduous forests during the Late Neolithic is the very low percentage of tree-pollen in the pollen spectra derived from two water pits at the site of *Keinsmerbrug* (Smit *et al.* 2012, 87). The idea of the absence of a deciduous forest is strengthened by the nature of charred botanic remains at the different sites. The charcoal assemblage of *Keinsmerbrug* mainly consists of branch wood of willow and alder which is considered an ineffective fuel. The charcoal assemblage of *Zeewijk* mainly consists of alder. Nonetheless, oak is second in abundance at this site. It is supposed to be a non-local specimen, based on the macrobotanical analysis which presented a dominance of plants characteristic for tidal flats and salt marshes. In this open landscape, patches or scatters of small trees or shrubs of willow, alder and aspen and possibly birch can be expected at places where freshwater accumulated, unlike oak (Theunissen *et al.* 2014, 141). The charcoal assemblage at *Mienakker* mainly consisted of reed and poplar. Both are considered ineffective fuels indicating the lack of better ones (Kleijne *et al.* 2013, 153-154).

These two contradicting interpretations, an "ecological paradise" with patches of deciduous forests and alternating freshwater and brackish environments (Van Ginkel and Hogestijn 1997) versus an open tidal marsh area analogue to the present day landscape of "*De Slufter*", need an explanation. After a broad analysis of environmental data from the entire Bergen tidal basin this problem will be settled in § 3.6.

At the end of the Neolithic, approximately 2100 BC, the size of the Bergen tidal basin diminished due to a decline of the sea level rise and a supposed disconnection with the drainage basin area of the river Vecht (De Mulder and Bosch 1982, 146). Within the Bergen tidal basin this disconnection led to a rise of the mean high water level and an increased sedimentation rate, especially in the eastern part of the remaining tidal basin as described in chapter 2 (Van der Spek 1994, 152-180). In this period the landscape changed into a tidal marsh area comparable to the present day tidal marsh area "*Verdronken land van Saeftinghe*". Approximately 1600 BC the Bergen inlet closed, causing a drop in the groundwater level within the tidal basin (Roep and Van Regteren Altena 1988, 219). After 1600 BC the eastern part of West-Frisia can be described as a former tidal marsh area, which is characterized as a freshwater environment with a patchwork of lakes, marshy areas and arable soils with a high natural fertility (Van Zijverden 2013, 164).

It is hypothesized that after the closure of the Bergen inlet, the tidal creek ridges became inhabitable due to relief inversion (Van Geel *et al.* 1982, 273; Roep and Van Regteren Altena 1988, 219). Based on multi-proxy evidence from the excavations from the seventies it has been argued that at the start of the exploitation of the landscape, the vegetation could be characterized as freshwater, open and almost treeless (§ 2.6). Towards the end of the Late Bronze Age the environment became increasingly wetter, as is illustrated by the erection of small terp mounds in order to prevent houses from flooding. At the end of the Late Bronze Age the settlement sites of West-Frisia were abandoned due to ongoing rise of the water level and expanding lakes, fens and bogs (Buurman 1999, 194). This development and the seemingly sudden abandonment could be explained by the theory of solar forcing causing cloudier and wetter circumstances leading to a higher pace of peat formation (Van Geel *et al.* 1997). As a result it is thought that West-Frisia should have been covered entirely by raised peat bogs or inundated by lakes after the Bronze Age.

3.2.2. Oer-IJ estuary

The Oer-IJ estuary and the Bergen tidal inlet coexisted during a large part of their lifespan. After the closure of the Bergen inlet the Oer-IJ estuary drained not only the Flevomeer area but also the Vecht basin (figure 3.2). In this way the development of the Oer-IJ estuary is relevant for the habitation history of eastern West-Frisia. Therefore the development of the Oer-IJ estuary will be briefly summarized In this paragraph.

The Oer-IJ estuary originated around 3000 BC (Vos 2015, 112). This estuary drained the Flevomeer area which was initially separated from the Vecht basin by peatland (Lenselink and Koopstra 1994). From 2600 BC onwards an oligotrophic peat developed in the hinterland of the Oer-IJ estuary.[11] According to Vos, this can be interpreted as an indication for a relatively stable environment within the Oer-IJ estuary (Kok 2008, 83). Around 2000 BC these raised peat bogs were flooded. According to Vos, this indicates an enlargement of the discharge from the hinterland (Kok 2008, 83). The cause of the larger discharge is unclear but coincides more or less with the date of the disconnection of the Vecht basin and the Bergen tidal inlet. However, Vos explicitly states a connection between the Flevomeer area and the Vecht basin didn't take place until 400 BC (Vos 2015, 115). After 1700 BC the stream bed of the Oer-IJ enlarges significantly (Kok 2008, 85).[12] From this moment onwards there is a clear increase in marine activity within the Oer-IJ estuary. This event coincides more or less with the supposed date for the closure of the Bergen inlet. The period between 1000 and 600 BC[13] can be characterized as a relatively stable period in which peat growth took place on the previously formed marine sediments. Based on research on molluscs, the water quality within the estuary can be characterized as light brackish to freshwater. This change in environment coincides with the origination of the Vecht-Angstel river around 1050 BC (Bos 2010, 54-55).[14] The period 600-500 BC[15] is characterized as a short period with an increased marine influence, although not as extensive as in the previous marine period between 1700 and 1000 BC. Vos suggests the enlargement of the freshwater discharge is caused by land clearances in the peat area, which increases surface runoff and lowers the surface level, causing an enlargement of the tidal range (Kok 2008, 90). The influence of man in the Oer-IJ estuary is in the same period also clearly visible through the occurrence of

11 Appendix 1, date 202-203: GrN-1649 4140 ± 70 BP; GrN-1663 3970 ± 70 BP.

12 Appendix 1, date 204-205: KiA-9492 3430 ± 35 BP; GrN-11630 3380 ± 70 BP.

13 Appendix 1, date 206-220: UtC-11919 3180 ± 42 BP; UtC-12021 3116 ± 36 BP; UtC-11894 3060 ± 38 BP; UtC-11891 3030 ± 41 BP; UtC-11897 3034 ± 29 BP; UtC-12015 3016 ± 40 BP; UtC-11881 3018 ± 35 BP; GrN-11242 2620 ± 30 BP; GrN-11243 2670 ± 80 BP; KiA-9490 2605 ± 50 BP; GrN-6400 2600 ± 50 BP; GrN-8337 2520 ± 30 BP; GrN-12099 2570 ± 60 BP; GrN-11629 2460 ± 70 BP; GrN-8686 2465 ± 30 BP.

14 Appendix 1, date 221: UtC-14584 2870 ± 47 BP.

15 Appendix 1, date 222-224: KiA-9486 2862 ± 27 BP; KiA-9495 2745 ± 26 BP; KiA-9487 2740 ± 27 BP.

extensive drift sands. From 400 BC[16] onwards the gullies in the estuary started to fill in. The discharge of the Vecht-Angstel diminished after 200 BC (Bos 2010, 52). Although Bos suggests that this lower discharge is the cause for the silting up of the Oer-IJ estuary, the actual silting up started considerable earlier (Bos 2010, 56). Vos therefore suggests an early opening of the coast to the north, the so-called Vliestroom (Kok 2008, 91; Vos 2015, 115). Traditionally the opening of the Vliestroom is dated in the first century AD (Ente *et al.* 1986, 61). The closure of the tidal inlet was finalized between 200 and 100 BC and behind the inlet a freshwater environment remained (Vos 2015, 115).

3.2.3. Vliestroom

After the closure of the Oer-IJ estuary the Vliestroom became the estuary of the river Vecht and therefore of influence to the landscape of eastern West-Frisia. The Vliestroom is the tidal gully dividing the barrier islands Vlieland and Terschelling. Based on written sources from the Roman period, it is assumed by some authors that a connection between the Vliestroom and the freshwater lakes of the Vecht and Flevomeer area existed in Early Roman times (Vos and Knol, 2005, 127). Although, some other authors disagree, based on the position of a Roman naval base at Velsen close to the mouth of the Oer-IJ (Ente *et al.* 1986, 61; Gerrets 2010, 31-33). They reason that the Romans would have preferred a direct and safer navigational route towards the north across the lakes towards the Vliestroom and had no need for a naval base at the mouth of the Oer-IJ, if such a route existed.

It is supposed that due to the opening of the Vliestroom the environment in the Vecht basin changed from freshwater into light brackish (Vos 2015, pagina 64). Such a change in environment is clearly visible in ostracod assemblages. This change coincides with the lithostratigraphical units Flevomeer Bed (Nieuwkoop Formation) and Almere Bed (Naaldwijk Formation). There are no radiocarbon dates available for the base of the Almere Bed or the top of the Flevomeer bed, due to the large amount of reworked organic material of both units. In the literature a date for the first brackish influences in the basins is suggested at the start of the Roman period based on a pollen analysis (Ente *et al.* 1986, 63, 79-80). However, in many reconstructions prior to the Roman period, a connection between the Vecht basin, Flevomeer and the Vliestroom is suggested (Ente *et al.* 1986; Lenselink and Koopstra 1994; Vos and Knol 2005; Vos *et al.* 2011). The earliest proposed date for a connection is 500 BC (Vos and Knol 2005, 127). A solid argument for this date is absent.

Due to erosion of the top of the peat during the formation of the Zuiderzee, it is impossible to obtain data from intact Iron Age sites within this area. Although little is known from sites dating to the Iron Age within the Flevo area, based on the site distribution it is evident that the borders of the lake have been exploited from the Middle Iron Age onwards. Rare finds like a canoe indicate the presence of man in the Flevomeer area during the Iron Age. Based on a few finds of pottery dating in the Iron Age, habitation of the peat has been suggested by some authors (a.o. Ten Anscher 2012, 532). Although, the absence of archaeological sites leads to limited detailed information on the environment for this period in this area.

3.3. Morphology: constructing an image

In the previous paragraph the current information on the development of the three openings in the Dutch coast that influenced the development of the environment of West-Frisia has been described in detail. This information is of importance to understand the palaeogeography, but for the construction of a palaeogeographical map several other ingredients are needed. First of all, the sequence and the spatial distribution of the lithology has to be known. Second, the age of the different lithological layers has to be known. Third, the environmental conditions during and after the deposition of the lithological layers has to be known. Different sources are available for each of the required ingredients.

The sequence and spatial distribution of the lithology is well-known for the first 120 cm below the present-day surface. This knowledge is mainly based on archived coring descriptions (figure 3.3). The largest database of these coring descriptions is derived from the land consolidation projects. The density of these corings is different for each land consolidation project, but is approximately 1-4 corings per hectare

16 Appendix 1, date 227-237: UtC-11886 2774 ± 42 BP; UtC-11884 2702 ± 37 BP; UtC-11885 2678 ± 37 BP; NCL-313011 477 ± 157 BC; NCL-313008 411 ± 145 BC; UtC-11881 2564 ± 38 BP; GrN-11477 2300 ± 30 BP; UtC-11892 2296 ± 34 BP; NCL-313013 365 ± 163 BC; NCL-313006 250 ± 146 BC; NCL-313007 239 ± 136 BC.

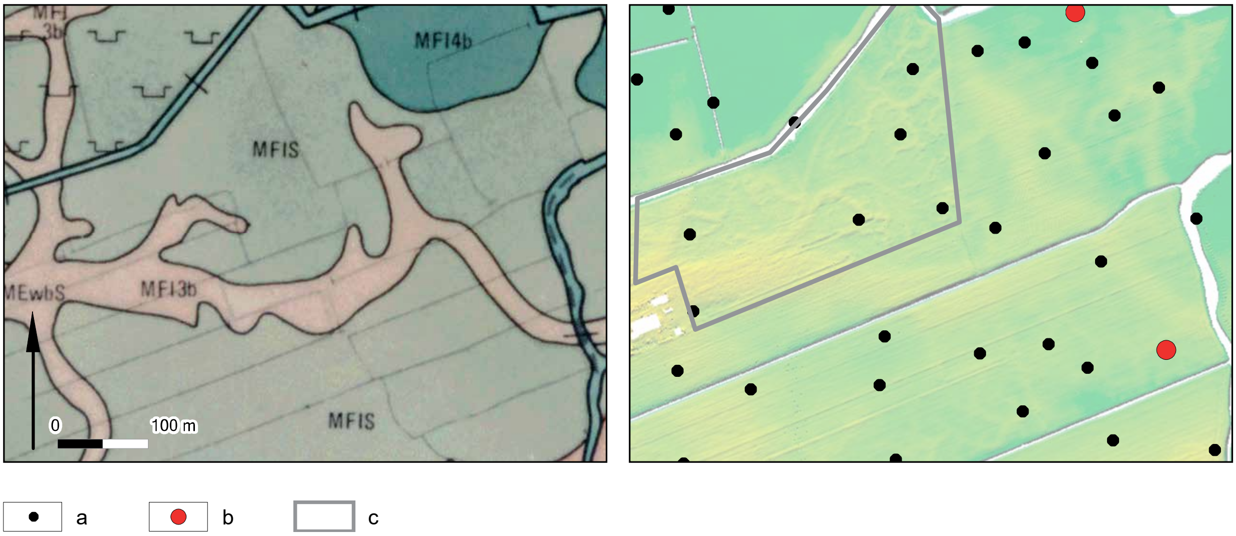


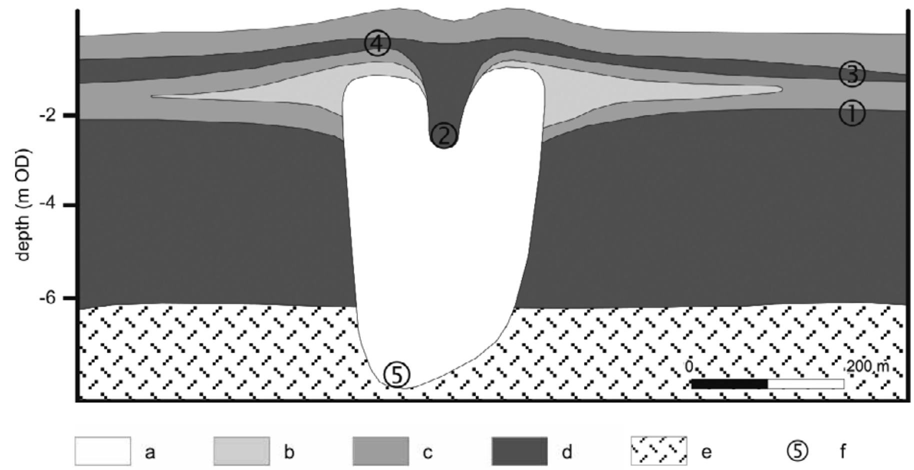
Figure 3.3: Detail of a soil map (Du Burck and Dekker 1975) and a LIDAR-image. Legend: a corings for land consolidation project, b corings from DINO-database, c unlevelled parcel.

(a.o. Ente 1963; Bles and Rutten 1972; Mulder *et al.* 1983). The corings have been carried out in a more or less regular grid. The quality of the lithological descriptions of these corings is high. Only part of this information is digitally available via the web interface www.bodemdata.nl. The coring descriptions for the land consolidation projects *De Vier Noorderkoggen*, *Westwoud* and *Westwoud Uitbreiding* have been digitized within this research project. The original data of the land consolidation projects *Het Grootslag* and *De Drieban* have been destroyed. For these areas only the soil maps and corings incorporated in the DINO-database (Data and Information on the Dutch Subsurface) are available.

The lithological sequence from 120 cm below the present-day surface to the Pleistocene surface is less well-known. This sequence is mainly based on archived coring descriptions in the DINO-database. The DINO-database comprises mainly data derived by the Geological Survey of the Netherlands, but also data from other sources. The density of these corings in West-Frisia is approximately 5 corings per 100 hectare. These corings are unevenly distributed over the landscape and of a variable quality, depending on the purpose of the corings. The available data for non-terrestrial locations within the research area is very limited compared to the terrestrial locations. This and the erosion in the former Zuiderzee is the reason for the low resolution of the palaeogeographical reconstructions in the IJsselmeer-area. In the past, soil maps, geological maps and geomorphological maps have been drawn based on the aforementioned coring descriptions. These maps, not the original data, in combination with earlier published regional palaeogeographical maps are used for the morphology of the different units of the palaeogeographical map of the Netherlands (Vos 2015, 50).

In addition to these maps, LIDAR-images of the Netherlands (AHN) have been used for the morphology of the palaeogeographical map of the Netherlands (Vos 2015, 54). LIDAR-databases are available for free for the entire country of the Netherlands. Three versions are available AHN1, AHN2 and AHN3 (available since september 2015). The ambitions for the point density and reliability have increased over the years. The data resolution within each version varies. The administration organisation aims for a point density between 6 and 10 points per square meter and a reliability of 15 cm (2 σ-range) in the AHN2-version (Van der Zon 2013). Within the current research project the AHN2-pointcloud for West-Frisia has been converted into a colour image according to the procedures described by De Boer *et al.* (2004). This image has a standard blue to red colour code from low to high altitudes and a hill-shade with light sources from two directions with an azimuth of 0 degrees. In order to enhance small relief differences, a kriging-interpolation is used with a relevant nugget and sill instead of a "quick and dirty" inverse distance interpolation. The altitude classes are then manually adjusted in order to emphasize the creek ridges. Because the large creek ridges are almost

Figure 3.4: Simplified cross-section of a channel belt, illustrating the method of radiocarbon dating of channel belts (After: Berendsen and Stouthamer 2001, 43, figure 4.10). Legend: a channel deposits, b peat, c levee deposits, d floodbasin deposits, e Pleistocene deposits, f 1 beginning of sedimentation, 2 end of sedimentation, 3 end of sedimentation, 4 minimum age for end of sedimentation, 5 maximum age for beginning of sedimentation.



entirely levelled and only the small creek ridges are emphasized after the subtraction of a trend surface, this last procedure has only been applied to small areas. Figure 3.3 illustrates the difference in detail which can be provided by a LIDAR-image in relation to a soil map and the different coring databases. One of the most distressing observations in the resulting image is the enormous impact of levelling for agricultural purposes to the micro relief and with that the archaeological record.

Translating a LIDAR-image into a morphological map is a relatively simple procedure. It is however impossible to unravel the successive creek systems based on a LIDAR-image. Differential subsidence troubles simple relationships between age, altitude, sand depth and decalcification depth. These simple relationships have been applied previously very successful in the Rhine Meuse-delta (Berendsen 1982; Berendsen and Stouthamer 2001; Cohen *et al.* 2009). In chapter 4 and 5 this problem will be dealt with at an intermediate and large map scale respectively. At this small map scale the previously drawn creek systems are used and only locally adjusted, based on the relation between relative altitude and the presence of sand bodies in coring descriptions of the DINO-database exceeding 6 meters in depth or more.

3.4. Time: dating the landscape

The date of a lithological layer can be determined using different dating techniques: conventional radiocarbon dates, AMS, OSL, dendrochronology and archaeological finds. In the field of archaeology it is conventional to publish age in years (cal) BC or (cal) AD. In the field of archaeology, contexts are usually not dated by a single radiocarbon date nor multiple radiocarbon dates. Contexts are dated using for instance typochronologies based on the development of ground plans, pottery, burials, metal objects, stone objects and so on. Therefore, radiocarbon dates are just one of many elements contributing to the date of a context. In the field of Quaternary geology the use of BP is preferred. Therefore palaeogeographical maps are usually published in years BP (Zagwijn 1986; De Mulder *et al.* 2003). For reconstructing the palaeogeography of West-Frisia, where dates of archaeological contexts based on archaeological chronologies play an important role, it is chosen to use the (cal) BC convention to indicate age. The original radiocarbon dates, OSL-dates, dendrochronological dates and archaeological dates contributing to this palaeogeographical reconstruction are presented in Appendix 1.

Not only the dating technique but also the dating strategy used to date a lithological layer is of influence to the obtained date. Berendsen and Stouthamer (2001, 42-44) discuss this problem of different strategies of dating sedimentation phases. In this publication the authors distinguish four stratigraphical radiocarbon samples dating the start and end of sedimentation phases following earlier publications (Berendsen 1982, 115; Verbraeck 1970, 60). According to Berendsen and Stouthamer (2001) the end of a sedimentation phase can be established by dating organic matter of the base of a residual gully or the base of peat on top of accompanying floodbasin deposits (figure 3.4). Dates from residual gullies provide consistent and reproducible dates in the case of applying AMS radiocarbon dates on selected organic remains (Berendsen and Stouthamer 2001, 42). Dates from floodbasins differ in age according to their position within a floodbasin (Berendsen and Stouthamer 2001, 43). Dates taken from the centre of floodbasins are usually consistent with dates taken from residual gullies contrary to dates obtained from floodbasins close to the levees (Berendsen and Stouthamer 2001, 43). Therefore it is important to be aware of the geographical position of radiocarbon samples taken from a floodbasin. A radiocarbon date for the start of a sedimentation phase can be obtained from organic remains in channel lags or the top of a peat layer underneath floodbasin deposits (Berendsen and Stouthamer 2001, 42). The first option contains the possibility of an older date due to transport of previously eroded organic material. The second option is considered as the best sample location. However, it has to be taken into account that erosion, oxidation or a period of decreased peat growth preceded the sedimentation of floodbasin deposits (Berendsen and Stouthamer 2001, 44; Makaske *et al.* 2008, 332-333).

The strategy for dating as described above is only partially applicable in a tidal basin. Within a fluvial context residual gullies are a common phenomenon contrary to the environment in a tidal basin, where residual gullies are rare. Therefore the dating of the end phase of sedimentation in tidal basins is usually based on radiocarbon dates of the base of overlying peat. For this strategy the same restrictions apply as for dating organic matter in floodbasins. A specific problem for West-Frisia is the different nature of the base of peat remnants. Well-studied locations like for instance the sites *Klokkeweel* (Pals *et al.* 1980), *Enkhuizen-Omringdijk* (Van Geel *et al.* 1982) and *Hoogwoud-Church* (Havinga and Van den Berg van Saparoea 1992) show a completely different genesis. The peat remnant from *Klokkeweel* starts as a lake deposit which regularly dries, illustrated by the cracks in the underlying clay deposit and the nature of the macrobotanical remains. Samples from the base of this kind of environment are suspected to be affected by mechanical contamination. The *Enkhuizen-Omringdijk* peat remnant consists at the base of a gyttja. Gyttjas are known to be vulnerable for ageing due to the hard water effect. The base of the *Hoogwoud-Church* sample is a typical coastal Carex peat with marine influxes. This type of environment is susceptible to a low accumulation rate. All three sites have been dated with conventional radiocarbon dates. A comparison of conventional dates and AMS-dates for these kinds of environments presented clear ageing effects for conventional dates due to mechanical contamination, the hard water effect and a slow accumulation rate (Tornqvist *et al.* 1992). In this study (Törnqvist *et al.* 1992) the largest age differences between conventional dates and AMS-dates are attested for gyttjas and measure between 200 and 600 years. Berendsen and Stouthamer (2001, 43) estimated the hard water ageing effect for conventional dates of gyttjas in the Rhine-Meuse delta between zero and 750 years.

An alternative source of carbon for dating lithological units in marine and brackish environments are molluscs. In fluvial contexts molluscs are rare, contrary to marine and brackish contexts, where molluscs are usually abundantly present. Cleveringa (2000) used molluscs in a study of the genesis and palaeogeography of the Dutch coast. Cleveringa (2000) demonstrates that even pristine single shells of juvenile molluscs provide reliable and consistent radiocarbon dates. In the Bergen tidal basin *Scrobicularia plana* is omnipresent in tidal marsh deposits. This species lives at the high water mark. Therefore zones within tidal marsh deposits characterized by these shells in living position are often regarded as an indicator for a change in environment. For example indicating the transition from regularly flooded to irregularly flooded marshlands or a sudden increase in sediment supply. Therefore this specific species is sometimes used as an indicator for the end phase of sedimentation in tidal marshes (for example Vos 2015, 139-175).

A large number of the available radiocarbon dates in the Bergen tidal basin concern molluscs (Appendix 1). It is important to note that in the period before the disconnection of the Vecht river system the Bergen tidal basin was a mixture zone from freshwater with an unknown ageing effect and marine water with a known ageing effect. Therefore radiocarbon dates on molluscs from this period are suspect due to an unknown ageing effect. A second problem with dating molluscs is the pre-treatment procedure for molluscs which has changed over time. In the eighties Sutherland (1986) attested a variable age difference between the outer and inner part of shells caused by differential leaching of carbon in the outer part of the shell (Sutherland 1986). Therefore a date of the inner part is nowadays preferred (Lowe and Walker 1997, 246). Conventional dates of molluscs carried out before the eighties are therefore considered suspect due to an unknown ageing effect.

As previously described molluscs and macrobotanical remains are the main sources of radiocarbon in a marine environment and concern the largest number of dates in the database (Appendix 1). A relatively new technique which has also been used for dating marine sediments is OSL-dating. With OSL-dating it is possible to date the last exposure to light of quartz and feldspar particles. This technique makes it possible to measure the age of the sedimention itself instead of the *terminus ante quem* date generated by the first peat growth on top of the tidal marsh deposits or the *terminus post quem* date for the start of sedimentation generated by the last peat growth before sedimentation. The first trial in dating the development of a tidal marsh in an archaeological project provided remarkable results (Dijkstra and Zuidhoff 2011, 398-400). The period in which a tidal marsh deposit had been formed was dated considerably shorter by OSL compared to AMS. Furthermore the dates were in accordance with the archaeological record contrary to the AMS-dates. Based on the OSL dates and the archaeological record it was concluded that the marine phase at this location (Serooskerke, Province of Zeeland) must have been considerable shorter (75-100 instead of 300 years) as was previously thought based on radiocarbon dates.

It is not only hard to obtain a reliable date of natural sediments in West-Frisia. Dating the archaeological record in West-Frisia is also difficult. Metal finds are rare and therefore of no use in dating, the same goes for remains of wood and therefore dendrochronology. No temporal change in the ground plan of houses is attested for the Middle Bronze Age and the first part of the Late Bronze Age (1600-950 BC) (Roessingh in prep.). Pottery is helpful in dating sites to some extent. Three phases can be distinguished based on a typological study of pottery by Brandt (1988): Hoogkarspel Oud (until 1100 BC), Hoogkarspel Jong early phase (1100-950 BC) and Hoogkarspel Jong late phase (950-800 BC) (Brandt 1988; Fokkens 2005). The boundaries between the different classes are based on a few indirect radiocarbon dates. Roessingh (in prep.) analysed a large number of well-dated archaeological contexts. Based on this analysis Roessingh (in prep.) disproves the young and late phases of both categories, Hoogkarspel Oud and Jong. According to Roessingh (in prep.) Hoogkarspel Oud is dated in the Middle Bronze Age between 1600 and 1100 BC. Hoogkarspel Jong is dated between 1100 and 750 BC. Differentiating typologically with pottery is therefore only possible in these two rather long periods. Next to macrobotanical remains and pottery, bone and undifferentiated food remnants are often used as a source for radiocarbon dates in settlement sites. In West-Frisia these last two categories are both vulnerable to ageing effects due

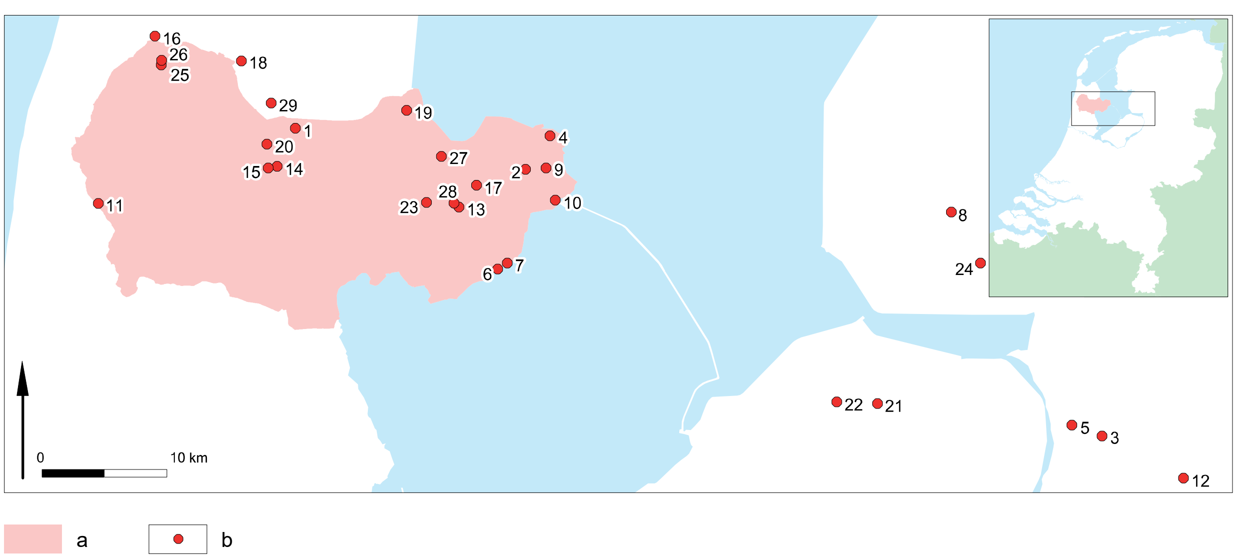


Figure 3.5: Topography and sites mentioned in text. Legend: a West-Frisia, b sites: 1 Aartswoud, 2 Bovenkarspel-Het Valkje, 3 De Enk-Zuid, 4 De Rikkert, 5 De Slaper, 6 De Spuiter, 7 Elbaweg, 8 Emmeloord J97, 9 Enkhuizen-Kadijken, 10 Enkhuizen-Omringdijk, 11 Geestmerambacht-De Druppels, 12 Hattemerbroek, 13 Hoogkarspel-Watertoren, 14 Hoogwoud, 15 Hoogwoud-Church, 16 Keinsmerbrug, 17, Klokkeweel, 18 Kolhorn, 19 Medemblik-Schepenwijk, 20 Mienakker, 21 Nieuwe Land Site IX, 22 Nieuwe Land Site VII, 23 Rijweg, 24 P14, 25 Schagen-De Hoep, 26 Schagen-De Nes, 27 Wervershoof, 28 Westwoud II (Noorderboekert), 29 Zeewijk.

to a partial marine diet and therefore unreliable. In Appendix 1 an overview of all available radiocarbon dates is presented.

A large number of sites have been excavated in the Bergen tidal basin. In order to use the temporal information from these sites in a palaeogeographical reconstruction, the sites have been ranked into three reliability classes. The first class with the highest reliability consists of sites with a clear, consistent, well-dated stratigraphy and information regarding the development of the environment over a long period of time. These sites are referred to as key-sites. The second reliability class consists of sites which have a well-defined and consistent start and end date, preferably based on radiocarbon dates. The third reliability class concerns sites which can be placed in an archaeological period based on typological elements like pottery, house plans, burial tradition, etcetera. In addition to excavated sites there is a large database of finds. A large part of these finds concern finds in the national archaeological database ArchIS. This database is supplemented with the results of several unpublished surveys. Only finds with a proper typological date and coordinates are incorporated. In the following paragraph the key-sites will be described in detail. The other sites will be briefly addressed in a selective way.

3.5. Habitation: the archaeological record

In this paragraph the key-sites will be discussed from east to west. The first two sites, *Hattemerbroek, De Slaper* and *De Enk-Zuid* are actually not situated in the Bergen tidal basin but in the lower valley of the present-day river IJssel. This valley is strongly influenced by changes in the Flevomeer area and Vecht basin and therefore relevant to this study. The second pair of sites, *Hanzelijn Nieuwe Land site VII* and *IX*, are situated in the Flevomeer area. These two sites are relevant to this study because they provide information on the connection between the Vecht basin and the Flevomeer area. The other key-sites are situated in the Bergen tidal basin. An overview of the location of the key sites mentioned in this paragraph is given in figure 3.5. The summarized data presented in this paragraph is based on reports of many specialists. Most of these reports are incorporated into excavation reports. For each site is referred to these excavation report(s), the specialists responsible for the analyses are mentioned in a footnote.

3.5.1. East of the Bergen tidal basin; Hattemerbroek and De Slaper[17]

The site of *Hattemerbroek* is a complex of several excavations which have been executed near Hattem (Hamburg and Knippenberg 2006; Lohof and Alders 2008; Hamburg 2010; Hamburg *et al.* 2011; Lohof *et al.* 2011). The site *Hattemerbroek* is situated on a Pleistocene river terrace covered by a thin layer of aeolian sand near a broad Pleistocene river valley. In the publication it is suggested that this river valley is probably a former valley of the river Vecht (Lohof *et al.* 2011, 71-73). The excavations of the site *Hattemerbroek* were carried out within the course of a new railroad from Lelystad to Zwolle, the Hanzelijn. At both sides of the course of the railroad near Hattem industrial areas (78 ha) have been planned. In advance of the development of these areas several excavations were conducted. During the excavations features dating from the Late Palaeolithic to the Iron Age onwards were revealed. The highlights of these excavations were 463 hearth pits spread over several complexes dating in the Mesolithic, a palisade enclosing a terrain with a diameter of *c.* 100 meters dating to the Late Neolithic and a Middle Bronze Age settlement site. An extensive research program on the genesis of the environment of these sites was carried out. Amongst others two samples were taken from a residual gully close to the ridge of the river terrace. The residual gully was sampled with the high quality Begemann sampler of GeoDelft. In the GeoDelft-laboratory 30 subsamples were taken from the cores and analysed for pollen (Lohof *et al.* 2011, 423-464). The time-depth of the five meters long cores, based on 10 AMS dates, is approximately 8000 years.[18]

In the same river valley two other sites were excavated, *De Slaper* and *De Enk-Zuid*. At both sites samples were taken for environmental research (Lohof *et al.* 2011, 423-464). At the location *De Slaper* four high quality samples were taken with the Begemann sampler of GeoDelft. The 125 cm long peat samples from this location reflect the development of the environment over a period of approximately 3500

17 The excavation of these sites was a joint effort by ADC-ArcheoProjecten and ArchOL. The research on pollen and macrobotanical remains was done by H. van Haaster, L.I. Kooistra, L. Kubiak-Martens and M. van Waijen (all BIAX Consult). The physical geographical research and sampling was carried out by W.K. van Zijverden (EARTH-Integrated Archaeology).

18 Appendix 1, date 241-247.

years. Twelve subsamples were analysed for pollen. The different layers have been dated with 5 AMS dates.[19] At the location *De Enk-Zuid* an approximately 110 cm long peat sample was taken from a soil section. This peat sample reflects a period of approximately 3200 years. Nine subsamples were analysed for pollen. Due to oxidation the quality of the sample was poor in macrobotanical remains and provided insufficient material for AMS dates of the distinguished pollen zones. Therefore this sample is not discussed. Within the framework of the "*Farmers of the Coast*" project, especially the trajectory between the Late Neolithic and the Late Iron Age of *Hattemerbroek* and *De Slaper* is of interest.

At the location *Hattemerbroek* the vegetation in the valley is characterized from *c.* 2650 cal BC onwards by an alder carr.[20] This alder carr is gradually replaced by a more open and wetter vegetation represented by a strong increase of *Poaceae*, which probably reflects *Phragmites australis*. This increase coincides with an increase of *Cyperaceae* and the appearance of typical water plants like *Nuphar lutea*, *Lobelia*-type and *Lemna*. Approximately 1390 cal BC the environment can be described as a genuine reed swamp.[21] The increase of *Dryopteris*-type indicates a hydrosere. In three successive slides from this moment onwards the amount of *Alnus* increases from 18 to 35 and 80%. After this recovery of the alder carr it develops, once again, gradually, into a reed swamp. A phase which has been dated after *c.* 600 cal BC.[22] After this date the area is drained, indicated by a partial oxidation of the peat. In this period the alder carr has once again recovered. The high amounts of *Dryopteris*-type indicate the presence of an alder carr of the type *Thelypterido-Alnetum*. This type of alder carr is characterized by shallow stagnant water and large open spaces covered with ferns.

At the location *De Slaper* the first peat growth was dated at the end of the Late Neolithic *c.* 2270 cal BC.[23] The peat contains abundant spores of *Sphagnum* and can be characterized as a genuine oligotrophic peat bog. In six successive slides the character of the environment does not change. In small eolian sand laminae the influence of man in the area is visible by the presence of low percentages of *Hordeum/Triticum*-type, *Artemisia, Fallopia convolvulus*-type, *Persicaria maculosa*-type, *Spergula arvensis, Urtica, Plantago lanceolata* and *Rumex acetosa*-type. Approximately 1120 cal BC the bog is drained, illustrated by a strong decrease of *Sphagnum* spores followed by an increase of *Calluna vulgaris*-type and *Ericaceae*.[24] In the following two slides the drainage of the peat continues. From *c.* 490 cal BC onwards marine elements like *Limonium vulgare, Armeria maritima*, *Plantago coronopus*, marine dinoflagellates *Hystrichospheridae* and marine diatoms *Podosira stelliger* are present in very low percentages.[25] It illustrates a change of the water quality in the downstream part of the valley, the Flevomeer area and Vecht basin.

3.5.2. South of the Bergen tidal basin; Hanzelijn Nieuwe Land site VII and IX[26]

In advance of the construction of the new "Hanzelijn" railroad from Lelystad to Zwolle the environment of 16 locations in the Flevopolder have been investigated with high quality Begemann samples (De Moor *et al.* 2009). The focus in this research was the reconstruction of the environment in the vicinity of supposed Late Palaeolithic to Neolithic sites. During the project two peat remnants of Subatlantic date were analyzed for micromorphology, pollen and macrobotanical remains. The result of this research is summarized below.

At Site VII a 650 centimeter long sample was taken from a residual gully. The depth of the residual gully was approximately 400 centimeters. The residual gully has been mapped by Ente *et al.* (1986) and was thought to be an erosion gully which connected the Flevomeer area and Vecht basin probably with the Waddenzee. Fifteen subsamples were taken from the core for pollen and macrobotanical analyses. The gully is partially filled with eroded plant material. Based on a micromorphological analysis the base of the gully was filled with locally grown peat and clay. The base of the residual gully is dated in the Atlantic (De Moor *et al.* 2009, 68). The central part of the gully is filled with eroded material which is

19 Appendix 1, date 248-250.
20 Appendix 1, date 247: GrA-38091 4090 ± 30 BP.
21 Appendix 1, date 242: GrA-38090 3115 ± 30 BP.
22 Appendix 1, date 244: GrA-38087 2455 ± 30 BP.
23 Appendix 1, date 248: GrA-34963 3820 ± 40 BP.
24 Appendix 1, date 249: GrA-34959 2920 ± 35 BP.
25 Appendix 1, date 250: GrA-35488 2415 ± 30 BP.
26 The research on pollen and macrobotanical remains in this project was done by J.A.A. Bos, M.T.I.J. Bouman and C. Moolhuizen (all ADC-ArcheoProjecten). The physical geographical research and sampling was carried out by J.J.W. de Moor (ArcheoSpecialisten).

visible in the pollen assemblage as well as by the AMS dates which date from young (bottom) to old (top) instead of the reverse. The upper 100 centimeter is oxidized and lacks macrobotanical remains. Therefore it was not possible to obtain AMS-dates for the upper part. Based on the *Fagus*-curve the three upper slides can be placed in the Subatlantic. The absence of *Carpinus betulus* suggests a relatively early date in the Subatlantic. At the start of the Subatlantic the environment can be characterized as an alder carr. The numbers of pollen of *Alnus* and *Dryopteris* diminish in the upper three slides. At the same time the environment becomes more oligotrophic indicated by an increase of *Sphagnum* and *Betula*. Furthermore the surface with open water enlarges and deepens as is indicated by the presence of algae like *Botryococcus braunii* and the disappearance of plants like *Nuphar lutea* and a decrease of typical plants for levees. More dynamic conditions are indicated by an increase of *Salix* in the last slide. Remarkable is the complete absence of any indication for brackish or salt conditions in the entire channel fill.

At *Site IX* a 250 centimeter long sample was taken from a depression within the Pleistocene surface. The depression was successively filled with peat, humic clay and clay. The base of the peat was dated at *c.* 5300 cal BC.[27] Eighteen subsamples were taken for analyses of pollen and macrobotanical remains. The upper 150 centimeter is oxidized and lacks macrobotanical remains. Therefore it was not possible to obtain AMS-dates for the upper part. Based on the *Fagus*-curve the upper five slides can be dated in the Subatlantic. Based on the interrupted presence of *Carpinus betulus* the upper slides probably date in the early part of the Subatlantic. The presence of *Cerealia* in the upper three slides indicate probably the presence of *Secale*, which is the only known *Cerealia* type which produces pollen in substantial amounts. Macrobotanical remains of *Secale* have been found in several well-dated Early Iron Age contexts, like for instance Texel Beatrixlaan and Zwolle Ittersummerbroek. The upper slides can therefore be dated in the Iron Age, possibly in the earlier part. At the start of the Subatlantic the environment can be characterized as an alder carr with an undergrowth of ferns. During the Subatlantic the water conditions gradually alter into a more dynamic and wetter environment, indicated by a slight decrease of *Alnus* and a simultaneous increase of *Poacaea* and *Salix*. The surface of open water enlarges simultaneously, indicated by the appearance or increase of algae like *Pediastrum*, *Botryococcus braunii*, *Scenedesmus* and the non-pollen palynomorph type 128 and the diminishing of *Nymphaea alba*. In the last two slides diatoms, foraminifera and dinoflagellates are present, indicating an open connection to the sea. Other indications for brackish or salt water environments are completely absent in the entire section.

3.5.3. Emmeloord J97[28]

Emmeloord J97 is a well-known site in Dutch archaeology due to the find of 44 fykes and 10 fish weirs in a residual gully of a tributary of the river Vecht. The site has been known since the fifties (Bulten *et al.* 2002, 11). In 1984 and 1988 the University of Amsterdam conducted field surveys at this site. During the field surveys 375 corings were carried out to an average depth of 4 meters below the surface, in order to locate the outer limits and the geological setting of the site (Palarczyk 1986). In 1988 five test-pits were excavated, which revealed a large amount of artefacts (Gehasse 1995). Most artefacts, dating to the Middle and Late Neolithic, were thought to be situated in a secondary position. Based on the results of the test-pits, the site was thought to be situated on the natural levee of a gully. Despite the intensive coring campaign the nature of the gully and its topography remained unclear. In 1999, in advance of the development of an industrial area, several test trenches were carried out by ADC-ArcheoProjecten (Van der Heijden 2000). During this campaign a fish weir and two fykes were discovered and was followed by two succeeding excavations in 2000 and 2001 (Bulten *et al.* 2002). The excavation covered only a part of the entire site. During this excavation the lack of a basic knowledge of the genesis of the sediments hampered development of a sound excavation strategy and archaeological interpretation of the site and its finds. In order to understand the development of the natural environment of the surroundings of the site,

27 Appendix 1, date 251:Ua-36473 6320 ± 55 BP.

28 The research of macrobotanical remains and molluscs in this project was done by W.J. Kuijper (Leiden University), the diagrams were compiled by N. Mink (Saxion University for Applied Sciences). The wood analysis was carried out by P. van Rijn (BIAX Consult). The analysis of fish bones was done by F. Kerklaan (Leiden University). The physical geographical research and sampling was carried out by W.K. van Zijverden (ADC-ArcheoProjecten).

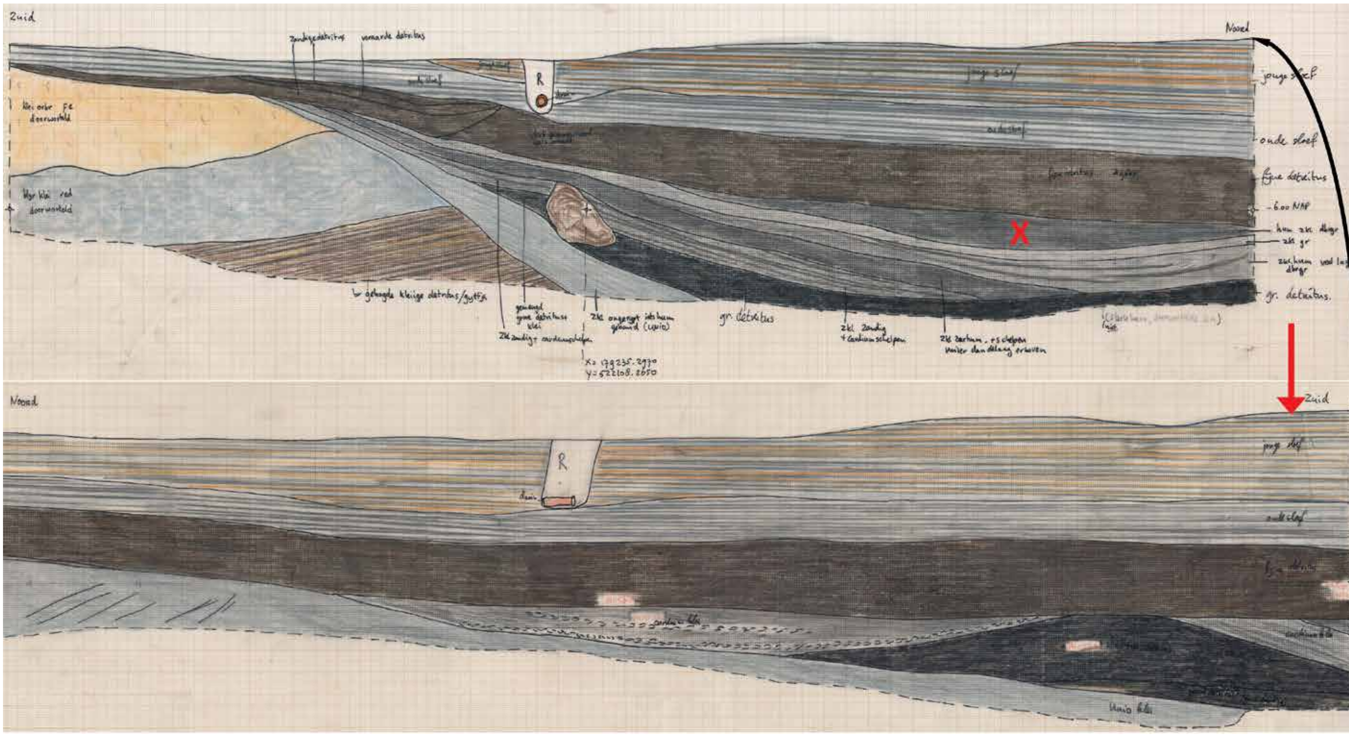


Figure 3.6: Original drawings of the section through the residual gully (Source: ADC-ArcheoProjecten). The drawing at the bottom is the continuation of the section in the diagonally opposite pit (black arrow). The section has been sampled at the location of the red arrow. The layer marked with a red x was not incorporated in the sample.

a team of earth scientists was invited prior to the last phase of the excavation and asked for their opinion (Bulten *et al.* 2002, 14).[29] Based on a discussion of the preliminary results a sampling strategy for environmental research was developed and executed by these earth scientists.

In order to investigate the nature of the landscape, the northern half of a soil section of the residual gully has been described in great detail, interpreted in lithogenetical terms and sampled (figure 3.6). Several samples for radiocarbon analysis were taken to understand the time-depth of the lithostratigraphical units. Every lithostratigraphical unit was sampled for diatom analysis. In addition a continuous sample of the residual gully with a length of over 300 centimeter from the present-day surface level into the underlying Pleistocene sediments was taken. The morphology of the gully was studied by an analysis of LIDAR-data combined with archived coring descriptions by Rijkswaterstaat and several additional corings. All fykes and weirs were sampled for a wood analysis. Nevertheless, after the excavation a selection had to be made of the topics which should be dealt with. Logically, the researchers chose a research focus on the fishing activities at the location. Only the wood analysis is incorporated in the excavation report. In the years following the publication of the excavation report, materials from the site have been the subject of several masters theses. Amongst others the research of fish remains, the macrobotanical remains and molluscs have been published in this way (Kerklaan 2013; Mink 2016).

The top of the peat underneath the levees of the gully has been dated at two locations. The youngest date *c.* 3600 cal BC is supposed to represent the *post quem* date for the origination of the gully.[30] The base of the infill of the residual gully was dated *c.* 3200 cal BC.[31] The top of the infill contained insufficient seeds suitable for an AMS-date. Therefore the top of the infill is dated by the last use of the residual gully,

29 Gerda Lenselink (RIZA), Ute Menke (RWS), Peter Vos (RGD) and Wilko van Zijverden (ADC-ArcheoProjecten).

30 Appendix 1, date 27-31: GrA-18857 5410 ± 60 BP; GrA-18852 5340 ± 60 BP; GrA-18757 4870 ± 70 BP; GrA-18855 4830 ± 60 BP; GrA-18856 4840 ± 60 BP.

31 Appendix 1, date 32: GrA-18854 4500 ± 60 BP.

the youngest fyke. The youngest available radiocarbon date is *c.* 1760 cal BC.[32] The youngest pottery in the find complex dates to the Middle Bronze Age A (1800-1500 BC) and is in consistence with this radiocarbon date. The excavated weirs have been dated with radiocarbon in three successive archaeological periods, Middle Neolithic (3220-3010 cal BC), Late Neolithic (2320-2080 cal BC) and Early and Middle Bronze Age (1960-1760 cal BC). The fykes have been dated in the Middle Neolithic (3210-3100 cal BC) and Late Neolithic (2300 -2030 cal BC).[33]

The wood of the weirs has been studied in detail and presents information on the woodlands, which were present in the area (figure 3.7 and 3.8). In all three periods the main type of woodland is an alder carr (*Alnion glutinosae*). In the first period the presence of riparian forests (*Salicion albae* and *Violo odoratae-Ulmetum*) is clearly visible in the wood spectra. A small part of the environment is forested with wet woodlands characterized by *Betula pubescens* (*Vaccinio-Betuletea pubescentis*) in this period. In the last two periods the riparian forest almost disappeared. The wet woodlands characterized by birch expanded in these two periods. The twigs of the fykes from willow (*Salix spec.*), hazel (*Corylus avellana*) and guelder rose (*Viburnum opulus*) are in consistence with the types of woodlands represented by the weirs.

The samples taken from the residual gully have been analysed in slices of 5 centimeters for molluscs and macrobotanical remains. Based on the macrobotanical remains six zones can be distinguished (figure 3.9). The plant remains of zone I are not incorporated in figure 3.9. This zone represents a plant community characteristic for a polar climate, which is illustrated by the abundant presence of leaves and seeds of *Betula nana*. The second zone is characterized by a wide variety of plant remains, which is characteristic for a freshwater environment. The presence of seeds and buds of *Alnus glutinosa* and *Salix spec.* in combination with seeds of *Lythrum salicaria* and *Urtica dioica* point to the presence of eutrophic wet woodlands in the vicinity, like *Alnion glutinosae* and *Salicion albae*. In the third zone a small amount of plant remains is present, which is, regarding the very fine sediments, probably caused by a low accumulation rate and high water depth. The presence of *Nymphaeaceae* and few remains of *Nuphar lutea* and *Nymphaea alba* represent a eutrophic, stagnant, freshwater environment The presence of these specific plants in combination with very little other plant remains in the sediment confirms a relatively high water depth. Zone IV indicates a very neat local succession which is characteristic for the infill of residual gullies in a stagnant, eutrophic, freshwater environment. The abundant presence of seeds, cones and buds of *Alnus glutinosa* combined with seeds of *Urtica dioica* points to an alder carr in the vicinity of the sampled location. In the top of this zone *Alnus glutinosa* is replaced by *Betula* spec. This change in combination with the increase of *Myrica gale* and *Menyanthes trifoliata* indicates a change to a more mesotrophic environment. Zone V represents a completely different biotope. Seeds of plants like *Salicornia europaea* s.l., *Suaeda maritima*, *Spergularia marina* and *Aster trifolium* represent environments with salt and brackish water. *Bolboschoenus maritimus* is a pioneer in brackish environments. This zone is dated by two fykes, one fyke situated at the bottom of this zone is dated *c.* 2170 cal BC and one in the top of this zone is dated *c.* 2130 cal BC.[34] Apparently the environment came abruptly, for a short period, under the influence of the sea. Between zone V and VI a hiatus occurs, the zone marked with a red x in figure 3.6. Zone VI contains a very fine detritus in which very little identifiable macrobotanical remains were present. The few remains present in this layer represent contradictory environments. For example *Nuphar lutea* is a representative of stagnant freshwater, where *Salicornia europaea* s.l. indicates a dynamic brackish to salt water environment. This mixture of plant remains indicating different environments can be expected in a detritus. The top of the infill is truncated by a horizontally layered organic rich clay. This clay is interpreted as a lake-deposit, which is usually found in large parts of the polders of the Flevo basin.

The mollusc fauna represents more or less the same environments as the plant remains. In zone I molluscs are absent. Zone II, III and IV are characterized by species indicating a more or less stagnant freshwater and fit very well the environment indicated by the macrobotanical remains. Zone V indicates a submerged brackish environment with a steady flow as can be expected in, for example, a creek. The presence of *Cerastoderma glaucum* instead

32 Appendix 1, date 26: GrN-26505 3450 ± 25BP.

33 An overview of all radiocarbon dates is presented in Appendix 1.

34 Appendix 1, date 8-9: GrN-26484 3760 ± 35 BP; GrN-26485 3730 ± 20 BP.

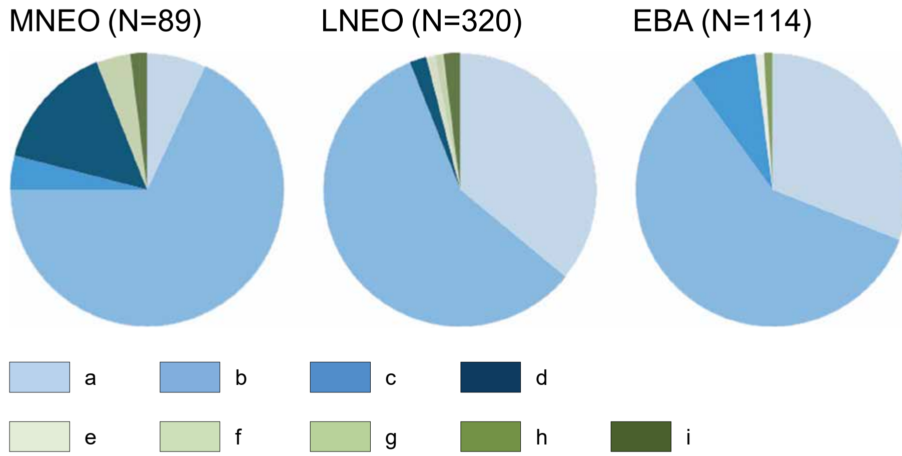


Figure 3.7: Wood types of poles present in fish weirs at Emmeloord J97. Legend: a birch, b alder, c poplar or willow, d willow, e ash, f hazel or ash, g elm, h elm or oak, i oak (After: Bulten et al. 2002, 73, figure 8.11).

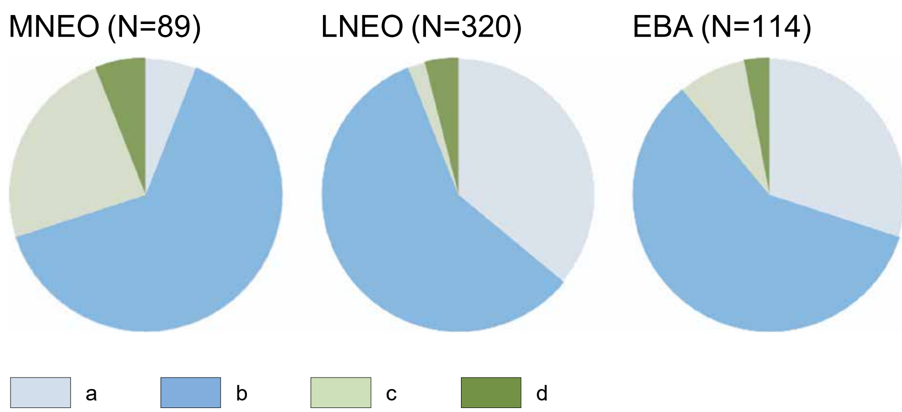


Figure 3.8: Woodland types present in fish weirs at Emmeloord J97. Legend: a birch carr, b alder carr, c riparian forest (softwood), d riparian forest (hardwood) (After: Bulten et al. 2002, 74, figure 8.12).

of *Cerastoderma edule* indicates a salinity of the water under 20‰. *Valvata cristata*, which tolerates a salinity smaller than 5,2‰, and other molluscs which are tolerant to light brackish environments are absent. Therefore, the environment can be characterized as mesohaline. The presence of *Bryozoa*, *Hydrozoa* and *Nereis* sp. complete this type of environment. Zone VI lacks any molluscs due to the acidic environment.

Contrary to the molluscs and macrobotanical remains, the exact stratigraphical context of the analyzed fish bones is unknown (Kerklaan 2013, 12). After the excavation, 5246 fish bones have been analyzed and categorized into 20 different species. The most common species are *Sularis glanis*, *Esox lucius* and *Abramis brama*. All species inhabit freshwater environments, but included also a few kata- and anadromous species, like for example *Anguilla anguilla* and *Liza ramada*. Species representing solely brackish and/or marine environments are absent. The species are classified into water type and salinity categories according to the method of Van Amerongen (2014, 83; figure 3.10). The diagrams for *Emmeloord J97* are comparable to the diagrams for the Middle Bronze Age of sites like *Enkhuizen-Kadijken*, *Medemblik-Schepenwijk*, *Westwoud* and *Bovenkarspel-Het Valkje* as published by Van Amerongen (2014, 84). These sites are interpreted as exclusively freshwater environments with a sea-connection.

Summarizing, the environment of the *Emmeloord J97* site can be characterized as a freshwater environment with a sea-connection. During most of the time the environment can be described as stagnant with a very low sediment influx and accumulation rate. After the formation of the creek eutrophic riparian forests developed at the levees accompanied by an alder carr at the lower and wetter locations. In the Late Neolithic the landscape changes to more mesotrophic conditions represented by the development of a birch carr and a reduction of the riparian forests. This change in water type is also reflected in the macrobotanical remains by *Myrica gale* and *Menyanthes trifoliate*. During a brief period between 2170 and 2130 cal BC the environment can be characterized as a mesohaline creek. This period

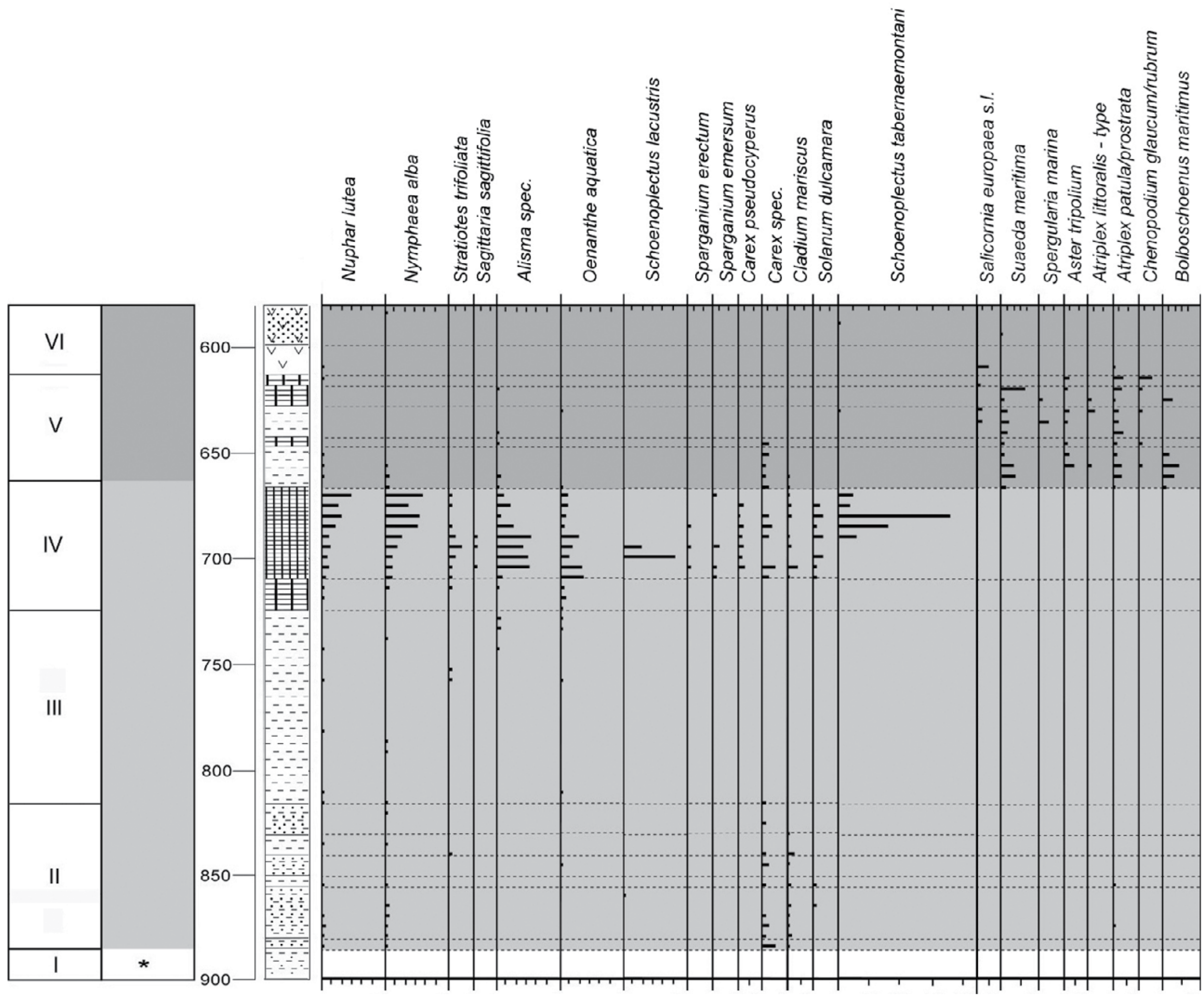


Figure 3.9: Part of the diagram of macrobotanical remains (After: Mink 2016, 69, figure 6.3).

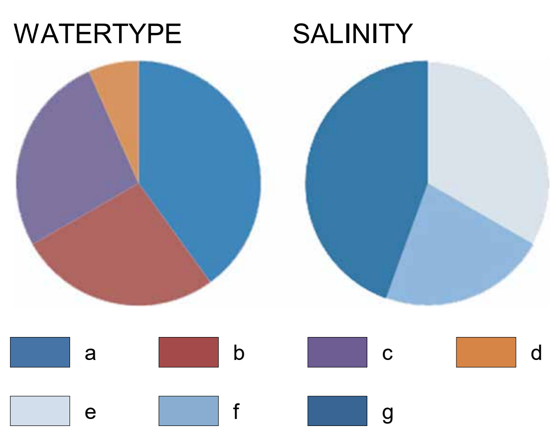


Figure 3.10: Water preference and maximal salinity tolerance for fish species of Emmeloord J97. Legend: a stagnant-slow, b open water, c sea-connection, d non-specific, e salinity 0-10‰, f salinity 10-15‰, g salinity >15‰.

is furthermore characterized by a high accumulation rate of clastic sediments. It is remarkable that there is no indication that the exploitation of the site has been influenced by this dramatic change of environment. Probably this episode reflects a single event like for example a storm surge. After this event the exploitation of the site continued until 1760 cal BC. After this date a fine detritus was deposited, covering the residual gully and the accompanying levees.

3.5.4. Enkhuizen-Omringdijk[35]

In 1976 a peat remnant was found near the city of Enkhuizen underneath the medieval dike confining Westfrisia (Van Geel *et al.* 1982). This dike is known as the Westfriese Omringdijk. This peat remnant was one of three peat samples which were used in the eighties to study the natural development of the landscape during and after the Bronze Age. The other two samples, *Klokkeweel* and *Hoogwoud-Church* are discussed below. Within the framework of the Delta Programme of the Ministry of Infrastructure and the Environment twelve sections of the dike were documented by archaeologists in 2010 and 2011 in advance of reconstruction works. Two locations, *Elbaweg* and *De Spuiter* provided peat samples which have been analyzed for macrobotanical remains and pollen (Sassi 2012). The peat remnant of the site *Elbaweg* has been taken from a ditch or a natural gully. Due to its dubious origin this sample is not discussed. The peat remnant of *De Spuiter* represents a natural layer.

The base of the sampled section underneath the dike, sampled in 1976, consists of a sandy clay. In the top of this clay a pitch dark A-horizon has developed. This soil horizon is covered by a sandy gyttja which is covered by peat. Multiple conventional dates have been used in order to understand the time-depth of the different layers. Although the date of the base of the gyttja is in line with the date of the overlying peat, it should be used carefully due to the nature of the sediment, a calcareous gyttja, and the problems associated with this type of date as described in § 3.4. Most probably the date is too old.

Based on the palynological analysis as well as the analysis of macrobotanical remains, the gyttja represents a plant community with plant species of shallow, alkaline and eutrophic water (Van Geel *et al.* 1982, 299). The abundant presence of epiphytic diatoms and the scarcity of planktonic diatoms confirm the environment indicated by plant remains (Van Geel *et al.* 1982, 300). Based on the macrobotanical plant remains the surface wasn't submerged during the entire year (Van Geel *et al.* 1982, 301). The change from gyttja to peat has been dated at *c.* 860 cal BC.[36] The peat represents a marsh vegetation characterized by plant species like *Carex riparia*, *Solanum dulcamara*, *Equisetum fluviatile*, *Lythrum salicaria*, *Stachys palustris* and *Lycopus europaeus*. After *c.* 640 cal BC the peat develops into a genuine willow carr.[37] Before *c.* 220 cal BC a sudden increase in acidity in the area is reflected by the expansion of *Carex rostrata*, *Potentilla palustris* and *Menyanthes*, probably caused by a drop in the water level.[38] After this event the peat develops gradually into a birch carr. Any indications for brackish environments are completely absent.

At the site *De Spuiter* the base of the sampled section consists of clay. In the top of the clay a soil horizon is absent. The clay is covered by peat. The base of the peat contains some clay particles. The base of the peat has been dated to *c.* 610 cal BC.[39] Macrobotanical remains were assembled from the lowest three centimeter of the peat. Due to the compression of the peat it is suggested the obtained date is possibly slightly younger than the actual date (Sassi 2012, 14). The top of the remnant has been dated at *c.* 400 cal AD.[40]

The top of the clay represents a willow carr, as is indicated by the increasing pollen percentages of *Salix* in combination with *cf. Lemna* and *Potamogeton/Triglochin*. In the top of the clay indicators for a brackish environment are absent. The combination indicates a shallow eutrophic freshwater environment. The base of the peat represents the abrupt development of a genuine alder carr, which is visible in the presence of macrobotanical remains as well as by an increase of pollen of *Alnus*. The appearance of several sedges like *Carex riparia* and *Carex acutiformis* and a sudden decrease of *Poacaea*e indicate also a drastic change in the water depth and water dynamics.

3.5.5. De Rikkert[41]

De Rikkert is an excavation site north of the city of Enkhuizen. At this location several very small scale excavations were carried out by the Faculty of

35 The research of pollen and macrobotanical remains in these projects was done B. van Geel and J. Sassi (both University of Amsterdam) under supervision of B. Van Geel.

36 Appendix 1, date 170: GrN-9067 2690 ± 60 BP.

37 Appendix 1, date 194: GrN-10994 2510 ± 35 BP.

38 Appendix 1, date 197: GrN-10995 2160 ± 40 BP.

39 Appendix 1, date 189: GrA-53538 2465 ± 30 BP.

40 Appendix 1, date 191: GrA 35539 1645 ± 30 BP.

41 The research of pollen in this project was done by M. Doorenbosch (Leiden University). The macrobotanical remains were analyzed by E.E. van Hees (Leiden University). The phytoliths were studied by W.A. Out (Moesgaard Museum). A micromorphological research was carried out by C. French (Cambridge University). The physical geographical research and sampling was carried out by W.K. van Zijverden (Leiden University).

Archaeology of Leiden University in 2013-2015. The excavations were conducted in order to test field survey techniques, sampling techniques and predictive models. At this site a section was sampled including the Bronze Age surface and the overlying peat and clay with a sampling unit of 50x10x10 centimeters. In addition a 5 liter soil sample for a charcoal analysis was taken from the peat layer. The samples were studied by using micromorphology, pollen analysis, macrobotanical analysis and phytolith analysis.

The base of the sampled section consists of calcareous sandy loam which is fining upwards and has horizontal bedding. The top of the layer is decalcified, enriched with organic matter and homogenized by ploughing and bioturbation and can be interpreted as a soil horizon. This layer is covered by a thin layer of strongly oxidized peat. The peat contains distinct particles of charcoal and small parts of wood and is covered with decalcified clay with a clay fraction over 60%. The top of this layer is incorporated in the modern plough zone. The entire section is situated above the groundwater level.

Several pieces of charcoal were selected for AMS dating and provided a date for the peat of *c.* 460 cal AD.[42] In the pollen analysis as well as the micromorphological analysis, a concentration of fine charcoal particles was attested. Therefore it is thought that the assembled charcoal occurs at the base of the peat. The date is therefore supposed to date the start of peat growth. Based on the micromorphological analysis the soil horizon represents a soil with a high groundwater table. The peat layer represents a peat which has been occasionally flooded, indicated by the presence of silt crusts. The top layer represents an environment with a variable stream velocity with a surface that submerged occasionally. The pollen analysis of the peat layer shows high percentages of *Alnus* and low percentages of *Sphagnum* and *Calluna vulgaris* and therefore represents a eutrophic peat, probably an alder carr. Phytholith samples were only taken from the soil horizon. Uncharred macrobotanical remains were absent in the entire sample.

42 Appendix 1, date 198: Suerc-51347 1608 ± 32 BP.

3.5.6. Noorderboekert[43]

In 1984 a few sherds of Late Neolithic and Early Bronze Age pottery were found in a newly dug ditch along the Westfrisiaweg north of the village of Westwoud (De Vries-Metz 1993; Van Heeringen and Theunissen 2001). A small (c. 100 m^2) excavation was carried out revealing three stratigraphically separated find layers dating to the Late Neolithic, Early Bronze Age and Middle Bronze Age. Traces of ard marks were present in the Late Neolithic level. The site was excavated in the winter of 2014/2015, due to the planned construction of a new road at the site location. It appeared to be situated at the top of a former creek ridge. Not only the top of the creek ridge, but also the lower parts of the levees and the basin area were excavated. The sediments in the basin area appeared to be situated under the mean low groundwater level, which is very rare in West-Frisia since the lowering of the groundwater level in the land consolidation projects. This situation gave the opportunity to investigate in detail the nature of the Late Neolithic landscape as described in § 3.2.1. Therefore a soil section was sampled for ostracods, diatoms, foraminifera, molluscs, pollen and macrobotanical remains. Apart from these samples for environmental proxy data, several samples for AMS and OSL were taken in order to obtain a solid time framework. The samples have been taken from the soil section with sample units of 10x10x50 centimeters. These samples were divided into subsamples of 5 cm and analyzed by different specialists. In figure 3.11 an overview of all the sampled units is presented.

The base of the sampled soil section consists of very fine calcareous loamy sand (S5060) which is fining upwards and has a horizontal bedding. The top of the layer is decalcified and enriched with organic matter and is covered with clayey peat (S5050). This layer is characterized by the presence of reed stems as well as leaves. This clayey peat is covered with a layer of carbonate poor, very sticky clay (S5040). The top of this clay is evenly non-calcareous. The clay shows no visible bedding. The layer is covered with partly

43 The research on pollen was done by M. Doorenbosch (Leiden University). The macrobotanical remains were analyzed by E.E. van Hees (Leiden University). The ostracods were analyzed by S. Troelstra (VU University Amsterdam), diatoms by G. Verweij (Koeman & Bijkerk) and molluscs by W.J. Kuijper (Leiden University). The physical geographical research and sampling was carried out by W.K. van Zijverden (EARTH-Integrated Archaeology).

oxidized peat, which contains reed stems as well as leaves (S5030). This peat is non-erosive covered by layer S5020. Layer S5020 has been documented as a single layer although it has been described in the field as two different layers. In figure 3.11 the two distinguished layers are represented by S5020a and 5020b. S5020a consists of a calcareous sticky clay. This clay shows horizontal bedding. The base of the clay is characterized by burrows of molluscs. In the top of this layer the first iron stains are visible. This implies that the oxidation of the underlying peat has occurred in the past. This layer is erosive covered with calcareous clay loam and sandy clay loam (S5020b) and has a horizontal bedding with alternating sandy and clayey laminae. It is characterized by the presence of high numbers of molluscs like *Cerastoderma glaucum* and *Scrobicularia plana*. This layer is erosive covered with calcareous non-sticky sandy loam and loamy sand (S5010). The layer has a horizontal bedding and contains incisions with cross-beddings, indicating the lateral displacement of former stream beds. The top of this layer is incorporated in the top soil.

The clayey peat layer transforms laterally into an A-horizon at the more elevated parts of the creek ridge. In this A-horizon finds of pottery dating to the Late-Neolithic are present. The peat layer also transforms gradually into an A-horizon at the more elevated parts of the creek ridge. In this A-horizon pottery dating to the Early Bronze Age is present. Underneath both A-horizons ard marks and other features are visible. Charred material from two features has been dated by AMS at respectively approximately 1950 cal BC.[44] Underneath the present day top soil only a few features are visible. These features contain pottery dating to the Middle Bronze Age. The clayey peat and peat are dated by AMS on terrestrial seeds at approximately 2100 cal BC and 1950 cal BC respectively.[45] An AMS date of organic material from one of the Middle Bronze Age features resulted in a date of approximately 1700 cal BC.[46]

The environment of S5060 is characterized by the presence of high amounts of *Peringia ulvae* and a large amount of marine spatfall, settled larvae of shellfish. The amount of spatfall decreases to the top of the layer which is an indication for a smaller influence of

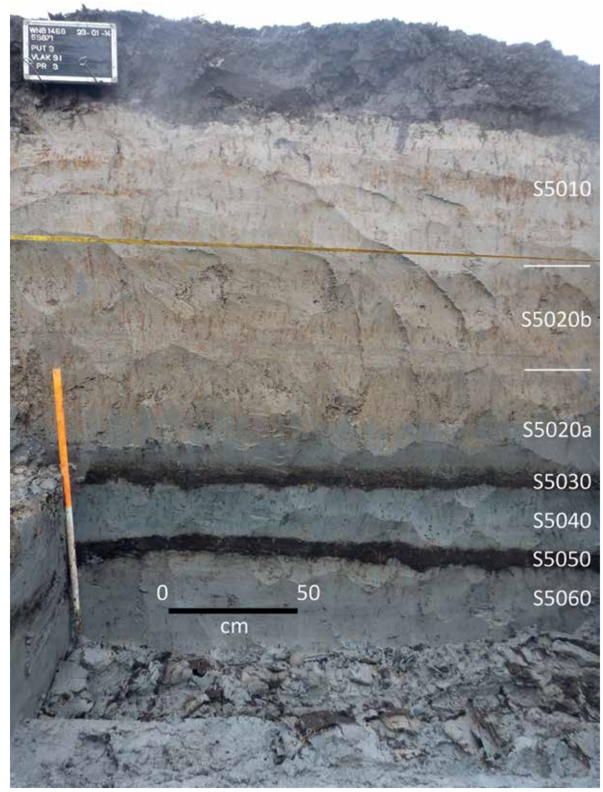


Figure 3.11: Soil section and lithological units from the site Noorderboekert. (Photo: ArchOL BV).

the sea or an increase of repeated drying of the surface. The amount of different species of foraminifera also decreases towards the top of the layer. In the top only a few individuals of *Haynesina germanica* occur. This species is indicative for shallow water and repeated exposure of a submerged surface. The change of the environment is best expressed by the diatoms. At the base of the layer 41 different taxa are present. *Cymatosira belgica* (39%), *Delphineis minutissima* (14%) and *D. surirella* (10%) are dominant. These taxa indicate a water depth of 3 to 10 meters and are characteristic for environments like tidal inlets and large tidal channels. To the top of the layer the population changes in composition. *Cymatosira belgica* (12%) and *Opephora* (11%) become dominant. The population at the top is characteristic for the transition zone of a marine tidal zone to small tidal creeks and brackish basin areas.

Not only the local environment is represented by these organisms. For example, the presence of spines of the *Echinocardium cordatum* indicates an open connection towards the sea. Fossil foraminifera like *Hedbergella* sp. and *Heterohelix* sp. are transported

44 Appendix 1, date 160-161: GrA 66702 3615 ± 35 BP; GrA 66675 3565 ± 35 BP.
45 Appendix 1, date 33-34: GrA 63737 3715 ± 35 BP; GrA 63736 3600 ± 35 BP.
46 Appendix 1, date 35: GrA 63741 3425 ± 35 BP.

from the Jurassic coast of England into the Bergen tidal basin. The decrease of these organisms towards the top in combination with a distinct decrease in grain size of the sediment reflects a decreasingly energetic level. The sediment reflects in first instance an environment in the direct vicinity of a larger tidal gully with a direct connection to the tidal inlet. The influence of the sea gradually diminishes to the top. The landscape changes into a submerged shallow basin area which from time to time is exposed.

The environment of S5050 is quite different from S5060. Due to the low carbonate content molluscs are absent. Therefore the layer is not analyzed for ostracods and foraminifera. The amount of diatom taxa present in the sediments is still high. The composition of the diatom population has drastically changed. *Navicula phylleptosoma* (15%), *Opephora* (12%), *Navicula* (10%) are the dominant taxa. The amount of freshwater taxa is small. The presence of cysts of *Chrysophyceae* and skeletons of *Ebria tripartita* indicate a stagnant sub tidal environment. The amount of broken shells is larger compared to the previous layer, indicating some sort of transport, possibly due to the formation of detritus. The macrobotanical remains are not as well preserved as was preliminary expected. The peat turned out to be amorphous to some extent, few plant remains could be identified. Seeds of *Carex riparia*, *Eupatorium cannabinum* are common together with different vegetative parts of *Phragmites australis* indicating a freshwater to light brackish environment. *Phragmites australis* grew locally and has been burned repeatedly. It indicates the presence of stagnant water. A few seeds of *Ranunculus sceleratus*, *Juncus* sp. and *Poceae* complete this environment. Seeds of *Salicornia europaea* are probably indicative for irregular flooding of the environment. The pollen spectra represent a reed swamp characterized by *Poaceae* and *Cyperaceae*, which is repeatedly flooded indicated by the presence of *Chenopodiaceae* and *Asteraceae tubuliflorae*.

The environment in this period can be described as a shallow, light brackish reed swamp. The surface was probably submerged during the entire year. The reed swamp was irregularly flooded by sea water, probably during for example storm surges. The influence of man is visible by repeated burning of the reed.

The environment of S5040 is not very different compared to S5050. Molluscs are absent in the entire layer. Foraminifera and ostracods are present, however in low numbers. *Elphidium craticulatum* is dominant and associated with *Haynesina germanica* and *Ammonia* sp. These foraminifera indicate a low energetic sedimentary environment. Indications for large changes in salinity and/or transport are absent. Towards the top the number of sand agglutinated species like *Jadammina macrescens, Arenoporella mexicana* and *Haplophragmoides maniloensis* increase. In the top *Elphidium, Haynesina* and *Nonion* indicate a lower pH in combination with a gradually increasing marine influence. The diatoms indicate a similar environment at the base of the layer and a similarly gradually increasing marine influence. The development at the top differs entirely. At the top, the amount of marine diatoms halves and are replaced by taxa, indicating a stagnant light brackish to freshwater environment. This change coincides with the change in carbonate content of the sediment. In the sediment very few identifiable macrobotanical remains of *Juncus* sp., *Alisma* sp. and *Phragmites australis* are present.

The environment in this period can be described in first instance as a shallow, low energetic, light brackish basin area. Towards the top there is a slight gradual increase of the salinity. At the top there is a sudden change to an almost freshwater environment. It is possible that a supply of freshwater from the hinterland causes a change in pH inducing a change to sand agglutinating foraminifera. The absence of molluscs can be caused by a hostile environment for example shallow water with severe changes in water temperature.

The peat layer S5030 is non calcareous and molluscs are absent. Therefore no ostracods and foraminifera have been analyzed from this layer. The number of diatom taxa is still high. *Staurosira subsalina* (19%) and *Cymatosira belgica* (15%) are dominant. A few taxa are epiphytic like *Tabularia fasciculata*, *Achananthes brevipes* and *Rhopalodia constricta*. These taxa indicate stagnant fresh to light brackish water with a soil covered by water plants. The presence of cysts like *Chrysophyceae* also indicates more or less stagnant water. The peat is amorphous to some extent, little plant remains could be identified. Seeds of *Carex riparia*, *Eupatorium cannabinum* are common together with different vegetative parts of *Phragmites australis* indicating a freshwater to light brackish environment. *Phragmites australis* grew locally and has been burned repeatedly. It indicates the presence of stagnant water. A few seeds of *Atriplex patula/prostrata*, *Aster tripolium*, *Suaeda maritima* and seeds of *Salicornia europaea* are indicative for irregular flooding of the environment. The pollen spectra confirm this image.

The environment in this period can be described as a light brackish to freshwater basin area. The basin area contained stagnant water and was covered with riparian plants and can probably be characterized as a reed swamp. Sporadically the submerged soil was exposed. The reed was burned repeatedly, probably by man.

The molluscs in S5020a present a gradual increase of the influence of the sea, a trend which continues uninterrupted into S5020b. Once again the spines of *Echinocardium cordatum* occur in combination with jaws of *Nereis* sp. Spatfall of *Peringia ulvae* and the presence of *Ecrobia ventrosa* illustrate the increase of the salinity. The analysis of ostracods and foraminifera also indicate an increase in salinity. In all samples in this layer *Haynesina germanica* is dominant together with diagnostic taxa like *Elphidium, Nonion* and *Ammonia*. The dominance of *Haynesina germanica* probably indicates a lowered salinity. Once again transport from the sea occurs as is shown by the presence of marine foraminifera like *Lagena* sp. and *Globocassidulina* sp. Also the presence of Cretaceous fossils like *Hedbergella* sp. and *Heterohelix* sp. indicates a renewed connection with the coast. This trend in the environment is confirmed by diatom analyses. The enlargement of the influence of the sea is illustrated by the occurrence of planktonic taxa from the coastal zone like *Skeletonema costatum* s.l., *Thalassiosira* ssp., *Hyalodiscus* ssp., *Odontella aurita*, *O. rhombus*, *O. longicruris*, *Paralia sulcata* and *Ardissonia crystallina*. In the lower part epiphytic and benthonic species are present like *Achnanthes brevipes*, *Cocconeis placentula*, *C. scutellum*, *Rhoicosphenia abbreviata*, *Rhopalodia constricta*, *Navicula digitoradiata*, *Psammodictyon panduriforme* and *Tryblionella apiculata*. This group is indicative for mud flats and tidal gullies. Towards the top the amount of epiphytic diatoms decrease and disappear completely at the top. At the top *Cymatosira belgica*, *Delphineis minutissima* and T*halassiosira* sp. are dominant which are marine species.

The environment of *Noorderboekert* changes in this period radically. In the previous period it could be characterized as a sheltered shallow basin with light brackish to freshwater conditions. At first the environment gradually changes into a more saline environment. In the upper part it has changed into a marine environment characterized by mudflats and tidal gullies with a slightly lowered salinity compared to open sea.

The analyses of the soil section gave a clear answer to the development of the nature of the environment at the location of *Noorderboekert*. A distinct change occurred after *c.* 1950 cal BC and before *c.* 1700 cal BC. Before *c.* 2100 cal BC the environment of *Noorderboekert* is dominated by the presence of a tidal creek. This tidal creek is well connected with the tidal inlet and therefore the sea. The basin area is directly fed by water from this tidal creek. The levees of the creek were probably only flooded during extreme high waters like for instance during storm surges. After 2100 cal BC the situation in the basin changed. It was no longer directly fed by a tidal creek probably due to an avulsion. The basin area changed into a reed swamp and was only irregularly flooded during extreme high water. The levees of the creek and creek ridge became inhabitable and were apparently suitable for agriculture including the growing of crops. The water quality in the basin became slightly more saline over time. Shortly before 1950 cal BC there is a clear supply of freshwater probably from the hinterland. The basin area once again turned into an irregularly flooded reed swamp. After 1950 cal BC the landscape changed rapidly into a classic mud flat environment with a slightly lowered salinity compared to the open sea. An OSL-date from the centre of this mudflat provided a date of 1384 ± 200 BC.[47]

3.5.7. Klokkeweel[48]

In 1973 the excavation of the *Hoogkarspel-Watertoren* site started. A good interpretation of the site was hampered by the lack of knowledge of the environment during and after the Bronze Age. Moreover, in 1976 the archaeologists were aware of a sudden abandonment of eastern West-Frisia at the end of the Late Bronze Age. It was suggested that a change in the environment possibly caused this abandonment. Archaeologists and palynologists selected a sampling site, the Klokkeweel bog, nearby the settlement site in order to evaluate both topics (Pals *et al.* 1980, 372).

47 Appendix 1, date 245: NCL-7515056 3.4 ± 0.2 kA.

48 The pollen, spores, diatoms and macrobotanical remains were analyzed by J.P. Pals and B. van Geel (both University of Amsterdam).

The base of the section consists of clay. In the top of the clay cracks occur indicating the sediment fell dry occasionally. Any indications for soil formation in the top of the clay are absent. The clay is covered with a layer which is described as "mud" or "lake deposit". The cracks in the underlying clay are filled with this "mud". The lake deposit is covered with peat. The base of the lake deposit is dated with a conventional radiocarbon date at *c.* 1500 cal BC.[49] The date has to be handled cautiously due to mechanical contamination and the hard water effect which can be expected in gyttjas. The base of the peat has been dated with a conventional date at 1030 cal BC.[50] In the upper part of the peat two samples have been dated with a conventional radiocarbon date at 870 cal BC and 780 cal BC.[51]

The diatoms, macrobotanical remains and pollen indicate that during the formation of the lake deposit the environment can be characterized as shallow, eutrophic, stagnant freshwater. The high number of Poacaea and the high numbers of plant remains of species like *Alisma*, *Eleocharis*, *Hippuris*, *Scirpus lacustris*, *Typha*, *Phragmites* and *Solanum dulcamara* indicate probably a reed swamp. After this phase the environment stayed shallow, eutrophic and stagnant with freshwater. Several diatoms indicate that the lake fell dry periodically. Probably the environment changes into a sedge peat and later into a willow carr. Just before 870 cal BC a change occurs. The environment becomes less eutrophic. Willow is replaced by birch indicated by a severe increase of Betula pollen and macrobotanical remains and a decrease of pollen of *Salix*. After 780 cal BC the peat is partly oxidized and represents a more eutrophic environment characterized by a sudden strong increase of *Dryopteris* spores and *Cyperaceae*. After this event the wet conditions are restored indicated by a strong decrease in *Dryopteris* and *Cyperaceae*, an increase in pollen and macrofossils of *Menyanthes* and a better conservation of macrobotanical remains in general.

3.5.8. Hoogwoud[52]

In 1972 underneath the church of Hoogwoud a peat remnant was sampled (Roldaan 1972). In 1992 the obtained radiocarbon dates, pollen and macrofossil diagrams were published (Havinga and Van den Berg van Saparoea 1992). The base of the sampled section consists of calcareous clay. The top of the clay is enriched with organic matter and homogenized and therefore interpreted as an A-horizon. The A-horizon is thought to date to the Bronze Age however, any evidence for this date is absent. The clay is covered with a 10-15 centimeters thin layer of slightly humic sand. The sand is covered with peat. The base of the peat is slightly clayey. The base of the genuine peat is dated at *c.* 1430 cal BC. The top of the peat is dated at *c.* 1200 cal BC.[53]

The clayey peat at the base represents a carex peat which has been flooded irregularly. Influence of the sea is indicated by the presence of pollen of *Plantago maritima* and *Plantago coronopus* and the presence of *Eleocharis palustris*. After the end of regular flooding the peat develops into a peat characterized by high numbers of seeds of *Carex* and high numbers of pollen of *Alnus*. In the macrobotanical remains several types of *Juncus* are present (*J. acutifloris*, *J. articulatus* and *J. bulbosus*) indicating shallow freshwater. This change is dated at 1430 cal BC. After 1200 cal BC the character of the peat alters drastically indicated by a strong increase in pollen of *Betula*, *Sphagnum*, *Ericaceae* and *Calluna*. This change is also visible in the macrobotanical remains by the presence of amongst others successive *Sphagnum cuspidatum* and *Sphagnum acutifolia*. It indicates a change into a genuine peat bog.

In 2004 an excavation of a Bronze Age settlement site (1300-1100 BC) was carried out close to the church of Hoogwoud (Lohof and Vaars 2005). The period of habitation coincides almost completely with the *Hoogwoud-Church* peat development. The assembled bone and macrobotanical remains complete the image of the local environment. The molluscs in the features, *Stagnicola palustris*, *Oxyloma elegans* and *Stagnicola palustris*, represent freshwater or terrestrial environments. The molluscs derived from the sediment indicate a marine fauna. The large

49 Appendix 1, date 185: GrN-7666 3230 ± 35 BP.
50 Appendix 1, date 186: GrN-7912 2860 ± 30 BP.
51 Appendix 1, date 187-188: GrN-7913 2735± 30 BP; GrN-7667 2590 ± 35 BP.
52 The pollen were analyzed by R.H. Roldaan, R.M. Van den Berg Van Saparoea and A.J. Havinga (all Wageningen University).
53 Appendix 1, date 166 and 196: GrN-6603 3150 ± 35 BP; GrN-6602 2975 ± 30 BP.

faunal remains, like all other sites in West-Frisia, consist of domestic animals with the exception of elk or deer (*Cervus elaphus* or *Alces alces*). The small faunal remains consist of three different species of duck (*Anas platyrhynchos*, *Anas crecca* or *querquedula* and *Anas penelope*) and five species of mice, indicating habitats from very wet and open environments to dry and shady environments. The fish remains of this site comprise specimens indicating full marine, brackish and freshwater environments indicated by fish species like *Raja clavata, Gadus morhua, Liza ramada, Platichthys flesus, Dicentrarchus labrax, Anguilla anguilla, Platichthys flesus, Abramis brama* and *Perca fluviatilis*. Approximately 75 % of the fish remains represent a brackish environment. The conditions for uncharred plant remains were poor. The charred remains comprise barley (*Hordeum vulgare*) and emmer wheat (*Triticum dicoccum*). Weeds from dry to very wet environments are present. The different species indicate a freshwater environment ranging from nutrient-rich dry arable soil to very wet pastures in the direct vicinity of the settlement sites.

3.5.9. Schagen-De Hoep/De Nes[54]

In the western part of West-Frisia two well-dated Bronze Age sites are available: *Schagen-De Hoep/De Nes* and *Geestmerambacht-De Druppels* (§ 3.5.9). Both sites have been excavated by a number of different organizations in various small to large projects. Therefore the environmental data is published scattered over various publications. *Schagen-De Hoep/ De Nes* is a development area of the city of Schagen. In this area several sites were mapped in 1997 by RAAP (De Rooij 1998). In 2002 a small site dating to the Bronze Age was unexpectedly discovered during construction works (Gerrets and Schutte 2003, 15).

This site became known as *Schagen-De Hoep*. A few (35) sherds were typologically dated in the Middle Bronze Age. In the find layer several shells of *Cerastoderma edule*, *Scrobularia plana*, *Barnea candida*, *Mytilus edulis*, *Macoma balthica* and *Spisula subtruncata* were found, indicating a brackish to marine environment (Gerrets and Schutte 2003). In 2003 and 2004 AWN excavated approximately 45 square meters of this site. Two conventional dates were obtained from 'organic sediment' from this, site presenting a date of between 2198 and 1693 cal BC (Zeiler *et al.* 2007).[55] It is unclear what exactly has been dated. Therefore the obtained dates are to be used with caution. A thorough research of the assembled bone gives an impression of the environment. During the period of habitation the landscape was open with clear marine influences. The environment provided a wide range of habitats. Freshwater habitats are indicated by fishes like *Esox lucius* and *Perca fluviatilis* and amphibians like *Rana temporaria* and *Natrix natrix*. Marine environments were also present as indicated by fish species like *Raja clavata*, *Dasyatis pastinaca, Clupea harengus, Clupea harengus/Sprattus sprattus, Gadus morhua/Merlangius merlangus, Liza ramada, Dicentrarchus labrax and Solea solea.* Even the mammals represent the presence of both environments. For example *Phoca vitulina* is present in the same context as *Cervus elaphus*, *Castor fiber, Lutra lutra*, *Putorius putorius* and *Vulpes vulpes*.

In 2011 a large scale excavation was carried out in the same development area (Geerts 2012). During this excavation a site, *Schagen-De Nes*, dating to the Middle Iron Age was exposed. During the excavation the researchers were aware of the complex stratigraphy and the possibility of the presence of Bronze Age sites. Therefore a large section was documented and sampled. In this section a soil horizon dating prior to the Middle Iron Age was present. Samples were taken for foraminifera, diatom and mollusc analyses. The soil horizon itself was sampled for macrobotanical and pollen analysis. The entire stratigraphy of the section was sampled for micromorphological analysis. The macrobotanical analysis provided insufficient organic material for an AMS-date. Therefore, the sediment below the soil horizon was dated with OSL and provided a date of 1186 ± 200 BC.[56] Based on the micromorphological analysis the subsoil has developed in a tidal environment. The supposed A-horizon was characterized by initial soil formation like decalcification, bioturbation and the formation of humus. The diatom analysis indicated a subtidal

54 The molluscs were analyzed by W.J. Kuijper (Leiden University). The bone assemblage was analyzed by J.T. Zeiler (Archaeobone). The diatoms were analyzed by H. Cremer and H. Koolmees (both TNO). Pollen and macrobotanical remains were analyzed by M.T.I.J. Bouwman, C. Moolhuizen and F. Verbruggen (all ADC-ArcheoProjecten). The micromorphological analysis was carried out by K. van Kappel (ADC-ArcheoProjecten and R.P. Exaltus (ArcheoPro). The physical geographical research and sampling was carried out by J.M. Brijker and W.K. van Zijverden (ADC-ArcheoProjecten).

55 Appendix 1, date 173-174: GrN-28921 3610 ± 100 BP; GrN-28922 3560 ± 100 BP.

56 Appendix 1, date 178: NCL-8113025 3.2 ± 0.2 kA.

environment like a creek or gully, based on the absence of aerophile species and the presence of species typical for marine to brackish environments. Molluscs and foraminifera were absent, probably due to the decalcification of the sampled section. The pollen indicated a vegetation characteristic of salt marshes, with pollen like *Armeria maritima*, *Aster* type and *Plantago maritima*. Based on the micromorphological analysis the sediment on top of the soil horizon has been formed in a shallow lake. After a while this lake changed into a intertidal environment, which is confirmed by the diatom analysis.

3.5.10. Miscellaneous site information

Wervershoof[57] is an early medieval site which was excavated in 1976. During the excavation a complete soil section was sampled in and close to the residual gully of the Leek for research on the genesis of the environment. Not only the deposits relevant to the medieval period were sampled but also the underlying deposits, which are thought to date to before the Middle Bronze Age. The sequence is analyzed in great detail and published by Kuijper (1979). The attested sequence of environments is comparable to the previously presented sequence of *Noorderboekert*. The sediments can be divided into three zones. The base of the sediments contain high percentages of arboreal pollen like Alnus (33%), Corylus (32%) and Quercus (20%), suggesting the existence of a wooded and freshwater environment nearby. The macrobotanical plant remains contained high numbers of seeds of *Ruppia maritima* and *Eupatorium cannabinum*. The first is representative for brackisch environments, the second characteristic for freshwater environments. The remaining plant species are representative for both brackish and freshwater environments. The sediment contains high numbers of foraminifera, but only from a few different species. The species present are representative for clear, shallow mesohaline water. This type of environment is confirmed by the presence of high numbers of jaws of *Nereis* sp. In the sediment also high numbers of molluscs are present. The molluscs represent mainly specimens characteristic for still, shallow (< 2 m) and clear brackish water. Remarkable is the presence of three types of freshwater snails. Two species of mites were present in the sediment, *Hydrozetes thienemanni* and *Carabodes labyrinthicus*. These mites represent exclusively freshwater environments. The first lives in nutrient rich freshwater like lakes and carrs. The second lives in the soil of forests. The lower zone is therefore interpreted as a shallow (0,5-1 m) lagoon with a fluctuating chlorinity due to influxes of freshwater. The water movement and tidal amplitude have been small. Very different types of environments have been in close range. In the second zone the water movement and salinity increases. The molluscs in this part of the soil section are characteristic for a tidal flat like *Mytilus edulis*. In the upper zone the fauna is completely different and characteristic for the intertidal zone with large numbers of *Scrobicularia plana*.

Geestmerambacht-De Druppels[58] is the most western site within the Bergen tidal basin dating to the Bronze Age. The site was accidentally found during the survey of newly dug ditches (Vos 2015, 294). The site is situated at 200 meters from a Roman settlement site (Zandboer 2012). Only few sherds of pottery have been found. Rim fragments and decorated pottery are absent. Therefore it was not possible to date the pottery typologically otherwise than "Bronze Age". Four AMS dates were obtained, three dates from the soil matrix and one date from a piece of bone. All four dates are subject to marine ageing effects and should be used with caution (Vos 2015).[59] Two OSL dates of the underlying sediments were obtained. The upper OSL sample dates 1187 ± 200 BC and the lower dates 1887 ± 200 (Vos 2015).[60] Without a solid argument Vos (2015) rejects the oldest AMS date and the youngest OSL date. There is no environmental data available from this site (Vos 2015).

57 The macrobotanical remains and molluscs were analysed by W.J. Kuijper (Leiden University. The foraminifera were analysed by J.J. Lobenstein (National Museum for Natural History). The mites were analysed by L. van der Hammen (National Museum for Natural History). The samples were taken by D.P. Hallewas (Dutch State Archaeological Service).

58 The physical geographical research and sampling was carried out by P.C. Vos (Deltares) and J.M. Brijker (ADC-ArcheoProjecten).

59 Appendix 1, date 179-182: Poz-47277 3615 ± 35, Poz-47275 3330 ± 35 Poz-47276 3490 ± 30, KiA-45558 3407 ± 27.

60 Appendix 1, date 177 and 176: Resp. NCL-6212042 3.2 ± 0.2 kA; NCL-6212043 3.9 ± 0.2 kA.

Enkhuizen-Kadijken[61] is a large scale excavation of a Bronze Age settlement site (Roessingh and Lohof 2011; Roessingh and Vermue 2011; Van der Linde and Hamburg 2014). This site has been exploited between 1600 and 800 BC. There are little indications for environmental change over time except for a rise of the groundwater level. The faunal remains consist of *Sus scrofa, Ursus arctos, Alces alces, Cervus elaphus* and *Castor fiber*. The small faunal remains consist of ducks, geese and *Rallus aquaticus*, indicating open water. The remains of *Accipiter gentilis* and *Scolopax rusticola* are interesting, both being indicative of woodland and shrubs. The fish remains indicate mainly "freshwater", exept a few *Mugilidae* and large numbers of *Anguilla anguilla*. Remnants of six different species of mice indicate a wide variety of biotopes ranging from shrubs and marshy grasslands to dry and arable land. The remnants of *Natrix natrix* are an indication of the presence of open water. Palynological research has been carried out on a soil horizon and a ditch. The pollen analysis indicates an open, almost treeless landscape with (marshy) grassland, which is no surprise considering the location of the samples. The presence of spores indicative for cow dung is to be expected within a settlement.

At some locations within the site *Enkhuizen-Kadijken*, the original soil profile was intact. At two locations, a sample was taken for a micromorphological analysis. The black colour of the A-horizon was caused by repeated burning of the vegetation. The charcoal in the soil horizon was comprised mainly of epidermis of grasses and sedges, but also vascular tissue of trees. After the abandonment of the settlement site, renewed sedimentation took place. At first, the regular burning of the vegetation was continued. Distinct layers of charcoal particles alternate with very small silt particles. After a while, the sedimentation took place in a back swamp environment, uninterrupted by burning activities. The sediment in this back swamp consists of a diatomite clay which is characteristic for shallow, crystal clear, freshwater (Pronk in prep.). No peat growth occurred at this location.

Bovenkarspel-Het Valkje[62] is a well known Bronze Age settlement site excavated in the seventies (IJzereef 1981). During the excavation several mollusc samples were taken from house ditches and terp ditches and analyzed. The results of the analyses have been partly published in several publications. Within this research project the original 139 samples have been reanalyzed. The relative depth of the sampled ditches turned out to be comparable. The analysis indicates a different environment within the two types of ditches (Mink 2016, 66-72). House ditches provide a mollusc fauna indicating dry periods during the entire year. Terp ditches provide a mollusc fauna indicating these ditches contained water throughout the entire year by the presence of *Anisus vorticulus* and *Planorbarius corneus* and the absence of *Aplexa hypnorum* (Mink 2016, 72). The result of this reanalysis is presented in more detail in § 4.4.1.

Medemblik-Schepenwijk[63] is a settlement site situated on a small 110 meter wide creek ridge (Schurmans 2010). The site dates from the Middle and Late Bronze Age (1450-800 BC). Features and pottery dating between 1100 and 900 BC seem to be absent. In the Middle Bronze Age, the fish remains indicate a full freshwater environment with mostly *Esox lucius*, *Cyprinidae* (*Abramis brama*, *Abramis bjoerkna*, *Rutilus rutilus*, *Rutilus erytrophthalmus*) and several other species. From the Late Bronze Age, a few remains of *Pleuronectidae* and *Mugilidae* are present, indicating at least a connection with a marine environment. Apart from domestic animals, remains of *Alces alces*, *Cervus elaphus*, *Sus scrofa*, *Vulpes vulpes, Castor fiber* and *Anser* spec. are present in the Middle Bronze Age. In the Late Bronze age *Anas crecca/querquedula*, *Cygnus cygnus*, *Corvus corone/frugilegus*, *Felis silvestris*, *Bubo bubo* and *Lutra lutra* are also present. Palynological research has been carried out on samples from water wells, ditches, ard marks and coprolites. The pollen samples all indicate an open, almost treeless landscape, which is no

61 The bone assemblage was analyzed by J.T. Zeiler (Archaeobone), I. van der Jagt (Leiden University) and D.C. Brinkhuizen (Groningen University). Pollen, spores and macrobotanical remains were analyzed by M.T.I.J. Bouwman, C. Moolhuizen, J.A.A. Bos (all ADC-ArcheoProjecten) and E.E. van Hees (Leiden University). The micromorphological analysis was carried out by K. van Kappel (ADC-ArcheoProjecten), R.P. Exaltus (ArcheoPro) and M. Pronk (VU University Amsterdam). The physical geographical research and sampling was carried out by W.K. van Zijverden (ADC-ArcheoProjecten).

62 The molluscs have been analyzed by W.J. Kuijper (Leiden University) and N. Mink (Saxion University for Applied Sciences).

63 The bone assemblage has been analyzed by B. Beerenhout (Archaeo-Zoo) and M. Groot (VU University Amsterdam). Pollen, macrobotanical remains and wood has been analyzed by L.I. Kooistra. The physical geographical research and sampling was carried out by G.L. Boreel (VU University Amsterdam).

surprise considering the locations that were sampled. In the samples from the ard marks, *Alnus* makes up to 25 % of the sample. The coprolites from dogs lack any indicators for brackish environments and water plants. Pollen and macro-remains from arable fields and freshwater swamps were present in the coprolites, as well as a relatively high percentage (7 %) of *Salix*, which is a poor pollinator. The macrobotanical remains dating from the Middle Bronze Age represent different habitats ranging from dry fertile arable land to marshy grasslands. In the macrobotanical remains *Puccinellia distans* and *Salicornia europaea* are present. These plants indicate the presence of a brackish or marine environment in the vicinity of the site. This is in contradiction with all other proxies. Poorly preserved wood from oak, alder and willow was only present in features dating from the Late Bronze Age.

3.6. A new palaeogeographical map of West-Frisia

In order to describe a new palaeogeographical model, the presented data is discussed for three sub regions. The first sub region is the Vecht basin, the area east of Medemblik and Enkhuizen. The second sub region is eastern West-Frisia, the area between Hoogwoud, Medemblik and Enkhuizen. The third sub region is western West-Frisia the area between the Bergen tidal inlet and Hoogwoud.

3.6.1. Vecht basin

Based on the *Emmeloord J97* site, a brief period with a clear marine influence can be dated between *c.* 2170 and *c.* 2130 cal BC. After *c.* 1760 cal BC the levees of the gully were abandoned and the area became part of a freshwater lake. This site fits well in the reconstruction of the *P14* site as described by Ten Anscher (Gotjé 1993; Ten Anscher 2012). Ten Anscher presents a thorough description of the different facies present in the excavated area and interprets the different facies into lithostratigraphical units. In his study, Ten Anscher evaluates the date of these lithostratigraphical units in detail. At the location of *P14* a residual gully is present, however, a reliable date for the start of the infill is absent. Ten Anscher estimates the origination of the gully to be after *c.* 1950 cal BC.[64] This date is based on a dating of charcoal (*Alnus*) from a hearth in the underlying stratigraphical unit. The last marine sedimentation in the gully is dated by Ten Anscher at *c.* 1750 cal BC.[65] The top of the infill of the residual gully represents probably a freshwater fauna and can be estimated at *c.* 1700 cal BC (Ten Anscher 2012, 305). Ten Anscher presents a few dates from other locations to argue this date. Although the fauna represents a freshwater environment, Ten Anscher suggests infrequent brackish influence in this freshwater environment, based on the presence of jarosite stains. After *c.* 1700 cal BC the environment changes into a freshwater lake. Based on the thorough analysis of these two sites, *P14* and *Emmeloord J97*, a disconnection between the Bergen tidal basin and the Vecht basin has to be dated at *c.* 1750 cal BC. This is 350 years later than previously thought.

A connection between the Vecht basin and Flevomeer area is thought to be already present in the Atlantic. This connection does not coincide with the origination of the Vliestroom as is described by Vos (2015, 115). Previously, the Vecht basin was thought to debouch through the Bergen inlet and the Flevomeer area through the Oer-IJ estuary. The residual gully which is thought to represent the connection between both basins was investigated at *Nieuwe Land Site VII*. The channel fill at the base of the gully was dated in the Atlantic pollenzone. A more specific date is unfortunately not available. The top of the channel fill is dated in the early part of the Subatlantic pollenzone. Marine indicators in the channel fill are completely absent. Two other sites, *Nieuwe Land Site IX* and the well-dated site of *De Slaper* provided marine indicators. The marine influence at the first site is dated in the Subatlantic, probably Middle Iron Age. At the second site, *De Slaper*, this influence is dated from 490 cal BC onwards. The marine influence at *De Slaper* more or less coincides with a severe drainage of the peat at the site *Hattemerbroek,* which is dated after *c.* 600 cal BC. Based on these dates an opening of the Vliestroom is suggested at *c.* 500 cal BC and a connection between the Vecht basin and Flevomeer area in the Atlantic.

3.6.2. Eastern West-Frisia

The data from *Noorderboekert* give a clear indication of the nature of the landscape in the Late Neolithic and Early Bronze Age. The landscape in this area was apparently dominated by creeks and fossil creek ridges

64 Appendix 1, date 36: UtC-2511 3570 ± 80 BP.

65 Appendix 1, date 37-38: UtC-1932 3480 ± 50 BP; UtC-1931 3430 ± 50 BP.

with pronounced levees and crevasse splays. These levees and splays were stable units dissecting a vast dynamic wetland, characterized by large basin areas. The basin areas were fed by tidal creeks, rain water and the river Vecht and its tributaries. The basin areas changed in character from time to time and from place to place. Water depth, water dynamics, water quality and thus vegetation and fauna were constantly changing, in contrast with the stable levees, splays and fossil creek ridges. The botanic and faunal data from Late Neolithic sites like *Keinsmerbrug*, *Zeewijk* and *Mienakker* fit this description very well. The change towards a classic tidal flat-tidal marsh landscape, comparable to the present day landscape of "*De Slufter*" and "*Het Verdronken Land van Saefthinge*", took place after *c.* 1950 cal BC and before *c.* 1700 cal BC. This change of the nature of the landscape in eastern West-Frisia coincides apparently with the disconnection of the Vecht basin. Apparently the reduction of the Bergen tidal basin surface area by 85% combined with a reduction of only one third of the tidal channel length resulted in an imbalance in the sediment distribution within the tidal basin. It caused a raise of the MHW in eastern West-Frisia and subsequent high sedimentation rates and levels as described by Van der Spek (1994, 169-180).

After 1700 cal BC the landscape of eastern West-Frisia was inhabited by man. At the lowest areas like *Klokkeweel* and the *Enkhuizen-Omringdijk* lakes developed. During the Bronze Age these lakes expanded gradually. At different locations a different succession took place. For example in *Hoogwoud-Church* the lake developed into a *Carex* peat, birch carr and eventually into a *Sphagnum* peat. At the *Klokkeweel* site the peat developed into a mesotrophic birch carr, but never became a genuine peat bog. At *De Rikkert* an alder carr developed which drowned and became part of a lake. The start of peat growth in eastern West-Frisa varies. This variation is possibly partly caused by the use of the conventional radiocarbon method. However newly obtained dates confirm various dates for the start of peat growth.

During the Middle and Late Bronze Age, sites like *Medemblik-Schepenwijk*, *Bovenkarspel-Het Valkje* and *Enkhuizen-Kadijken* are characterized by a freshwater environment. The fish species indicate that the freshwater lakes were connected with the sea. However, the sea was at such a distance that there is no evidence for brackish or salt intrusions during the Middle and Late Bronze Age, with the exception of some macrobotanical remains from *Medemblik-Schepenwijk*. The fauna of both sites indicate the presence of a wide variety of woodlands. It is unclear where these woodlands were situated. This topic will be dealt with in chapter 4. The site of *Hoogwoud* differs from the sites in eastern West-Frisia. This site shows clear indications for marine and brackish environments in the direct vicinity of the settlement site. These indications are present in the botanic, faunal and fish remains. Furthermore this site was abandoned at the end of the Middle Bronze Age. Therefore, it is reckoned to western West-Frisia.

At the end of the Bronze Age the environment in eastern West-Frisia becomes wetter. The evidence for these wetter circumstances is omnipresent in eastern West-Frisia. For example, there are fewer indicators for seepage in the macrobotanical remains dating to the Late Bronze Age at the site *Enkhuizen-Kadijken* compared to the Middle Bronze Age. The micromorphological research from *Enkhuizen-Kadijken* indicates regular flooding of the former inhabited area. The pollen analysis of the *Klokkeweel* site presents a decrease of *Alnus* and an increase of *Salix* during the Late Bronze Age. It possibly indicates an increase of fluctuations in the water level of the peat area or at least an enlargement of the surface covered with a lake. The peat remnant of the *Enkhuizen-Omringdijk* as well as the *De Spuiter* present lake sediments on top of the Middle Bronze Age cultural layer, indicating an enlargement of the lakes. Especially the high *Pinus* and *Sphagnum* values at the *Enkhuizen-Omringdijk* site indicate erosion of peat and a connection to a larger lake, probably the Vecht basin. Fish remains excavated in *Enkhuizen-Kadijken* and *Medemblik-Schepenwijk* present an enlargement of the species indicative for stagnant flow and open water, in combination with a decrease of the species indicative for rivers. There is also an increase in species with a low salinity tolerance during this phase (Van Amerongen 2014, 84). A last, clear indication for a wetter environment in the Late Bronze Age is established at the site *Bovenkarspel-Het Valkje*. Based on a thorough analysis of 139 mollusc samples (Mink, 2016) it could be established that the ditches at this site contained water during the entire year during the Late Bronze Age, contrary to ditches dating to the Middle Bronze Age.

The wetter environment in the Late Bronze Age is expressed by the character of the settlement sites by the presence of small terp mounds surrounded by several deep (1-1,5 m) and wide (up to 2-3 m) ditches. The construction of terp mounds is only common in areas with more or less regular (seasonal) flooding events. For instance, terp mounds dating to the Iron Age are known from the coastal areas of the provinces of Zeeland, Friesland and Groningen. In the Rhine-Meuse delta terp mounds are known from the early medieval period onwards (Berendsen 2005, 197; 115). High groundwater levels are known from a variety of landscapes and periods all over the coastal area and in the Rhine-Meuse delta, but never in combination with terp mound construction. So what is the explanation for this terp phase?

It has been suggested that the terp phase is induced by a period with higher precipitation and lower evaporation rates (Van Geel *et al.* 1997). Rainfall induces soil surface sealing, especially in uncovered soils like arable land. Soil surface sealing leads to stagnation of rainwater at the surface. In eastern West-Frisia surface runoff is limited due to the absence of a good natural drainage pattern. Therefore an artificial drainage system is indispensable. Settlement sites dating to the Middle Bronze Age are characterized by such an artificial drainage system. Higher precipitation and lower evaporation rates could have worsened the limited surface runoff and therefore caused adjustments to the existing artificial drainage system, like terp mounds and ditches. However, this climatic change is dated approximately 800 BC and therefore could not have been the cause for the terp phase, which started at least 100 to 150 years earlier (Roessingh in prep.).

An alternative explanation can be found in the connection of the river Vecht-Angstel with the Flevomeer area. This connection is dated approximately at 1050 BC (Bos 2010, 54-55). Approximately 900 BC the Vecht-Angstel had a mature channel belt and reached its maximum discharge. This connection has a well-recorded and recognizable influence in the Oer-IJ estuary (Kok 2008). The Vecht-Angstel river is part of the Rhine system and has therefore a strongly fluctuating discharge with peaks in late autumn/winter (rainfall) and spring (snowmelt) (Glaser and Stangl 2003). This will have raised the seasonal water level fluctuations in the Flevomeer area. As has been previously argued, the Flevomeer area and Vecht basin were connected in this period. Therefore higher water levels in the Flevomeer area will have obstructed the discharge of the Vecht basin and therefore also have caused raised water levels in the Vecht basin.

Based on the presented data the conclusion can be drawn that raised lake levels in combination with seasonal changing water levels within the lakes, may have resulted in seasonal flooding events which could explain the construction of terp mounds. Higher precipitation rates and lower evaporation rates could have been the proverbial straw that broke the camel's back and forced people out of West-Frisia after 800 cal BC. This hypothesis needs to be tested with new research on the genesis of the cultural layer and peat remnants within the study area.

A last interesting change in peat development occurs at *Klokkeweel*. After 780 cal BC there is a strong indication for a lowering of the local groundwater level. This is also the case in the *Omringdijk* site, however this event is dated prior to 220 cal BC. At the location *De Spuiter* a change from a lake into an alder carr is dated at *c.* 610 cal BC. It seems that in the Middle Iron Age a lowering of the regional groundwater table occurred. However not as clear as dated in the Vecht basin, an explanation could be found in the origination of the Vliestroom and the consecutive drainage of the Vecht basin approximately 500 BC.

3.6.3. Western West-Frisia

The landscape and habitation history of western West-Frisia is quite different from eastern West-Frisia. Sites dating to the Bronze Age are scarce. This is partly due to the stratigraphy and research history. The few known Bronze Age sites are covered with sediments up to one meter. Therefore, the discovery probability is relatively poor. Furthermore the soil surveys and land consolidation projects were carried out relatively shortly after World War II, in a period without a focus on archaeology as discussed in chapter 2. The character of the four known sites is unclear, with the exception of *Hoogwoud*. This well excavated settlement site shows a completely different environment compared to eastern West-Frisia. This site and *Schagen-De Hoep/De Nes* and *Geestmerambacht-De Druppels* illustrate environments characterized by the availability of marine, brackish and freshwater at a short distance with an open access to the sea. This situation continued at least until 1100 BC, the end date of *Hoogwoud*. A late date (after *c.* 1600 BC) for the closure of the Bergen tidal inlet was already suggested by De Mulder and Bosch (1982), but rejected by Roep and Van Regteren Altena (1988) as discussed in § 2.5.1. Even when dates confirming a later date for a closure of the tidal inlet become available, these were easily set aside by Vos (2015, 308-309). The OSL dates of *Geestmerambacht-De Druppels* and *Schagen-De Nes* indicate marine sedimentation until at least after 1200 BC, which is in agreement with the dates of the settlement site of *Hoogwoud*. Therefore in the period 1700 BC – 1100 BC western West-Frisia can be characterized as a "*Slufter* landscape" as defined by Vos and Van Heeringen (1997, 28) after Van Rummelen (1972, 60): "*…deposits formed in a micro-tidal basin, situated in between the coastal dune area and the higher coastal peat area…*".

The sedimentation history after 1100 BC is unclear. At several locations peat develops. Furthermore tidal marsh deposits occur, which can be linked to the activity of two tidal gullies: the Zijpe in the north and De Rekere in the south of western West-Frisia (figure 3.2). In western West-Frisia several settlement sites dating from the Middle Iron Age onwards are known, situated on top of these tidal marsh deposits. The Bergen inlet closed prior to the origination of these two gullies. The most likely date for the closure of the inlet is after the abandonment of the *Hoogwoud* site. Although, a proper date is unavailable. In eastern West-Frisia a small gully, the Leek (figure 3.2), is thought to be present from the Iron Age onwards draining the peat area. It is suggested that due to the presence of this gully habitation could continue uninterrupted into the Middle Ages.

3.6.4. The palaeogeographical map

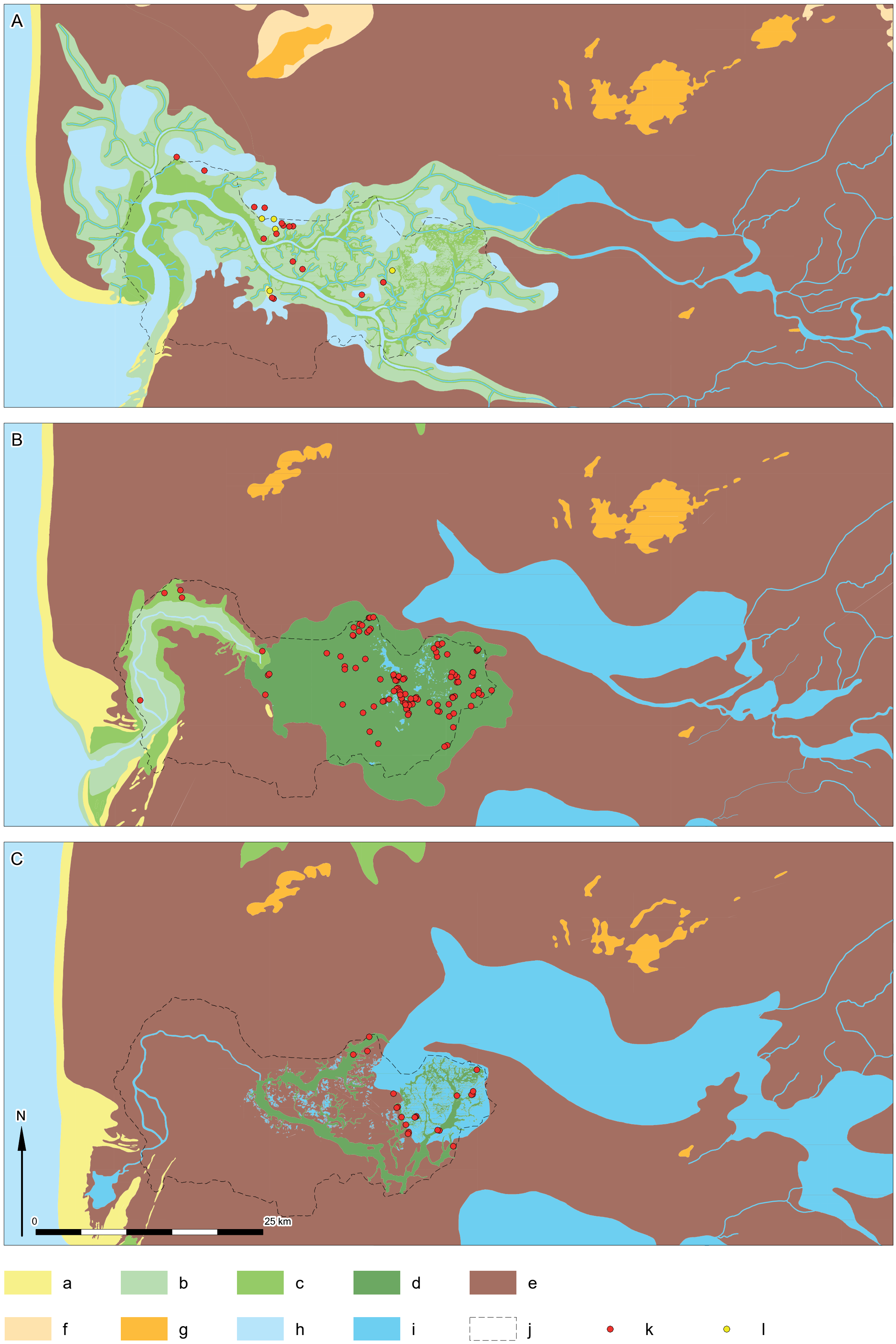
Based on the previous analyses, in figure 3.12 new palaeogeographical maps are presented for the time slices 2850 BC, 1500 BC and 900 BC. The new palaeogeographical maps are primarily based on the available soil maps, the palaeogeographical reconstructions for The Netherlands, an evaluation of the available absolute dates (Appendix 1) and the archaeological site distribution as stated in § 3.4. Furthermore LIDAR-data and the geomorphological map have been used. The key sites as presented in the previous paragraph are used to interpret the mapped soil units into environments.

The drainage pattern for the Late Neolithic palaeogeographical map is copied from the 2850 BC palaeogeographical map of the Netherlands (Vos 2015). The drainage pattern has been slightly adjusted for known sites based on the available soil maps as presented in chapter 2. The sandy soil units have been selected from the available soil maps. For the built up environment and unmapped areas the LIDAR-image has been used in combination with the geomorphological map (scale 1:50.000), in order to complete the image of the sandy soils. The drainage pattern has been buffered to create an evenly distributed small zone of sandy sediments along the channels.

The drainage pattern for western West-Frisia and the Vecht basin for the Middle Bronze Age is copied from the 1500 BC palaeogeographical map of The Netherlands (Vos 2015). For western West-Frisia the tidal marshes and tidal flats have been copied from the palaeogeographical map of The Netherlands (Vos 2015). For eastern West-Frisia peat and extremely humic soils from the available soil maps have been represented as lakes. A new legend unit has been introduced, the former tidal marsh. This area has been formed as a tidal marsh but is outside the reach of storm surges and therefore became a freshwater landscape.

The drainage pattern for western West-Frisia and the Vecht basin for the Late Bronze Age is copied from the 1500 and 500 BC palaeogeographical map of The Netherlands (Vos 2015). In the area directly behind the former inlet a lake has been created. For eastern West-Frisia the former tidal marshes are the sandy soil units from the available soil maps. For the built environment and unmapped areas these units are drawn using the LIDAR-image in combination with the geomorphological map (scale 1:50.000). The "mucky layer" from the soil map of Ente (1963) has been used to construct the lake in eastern West-Frisia. The other soil maps of West-Frisia lack such a unit. Therefore in this area some lakes have been drawn more or less arbitrarily.

An important difference from the previously published palaeogeographical maps is the nature of the environment in the Late Neolithic. Previously it has been mapped as an environment characterized by tidal channels, tidal flats and tidal marshes. Although based on the presented data, it should be interpreted as an environment characterized by tidal creeks and floodbasins. The essential difference between these two landscapes is sketched in figure 3.13 for the Late Neolithic (landscape with creeks and floodbasins) and Early Bronze Age (landscape with tidal flats and tidal marshes). Both environments result in comparable soil conditions. In figure 3.13 this has been illustrated with a simplified detail of the soil map of Ente (1963). In the reconstruction of the environment an abandoned channel and an active channel are depicted for the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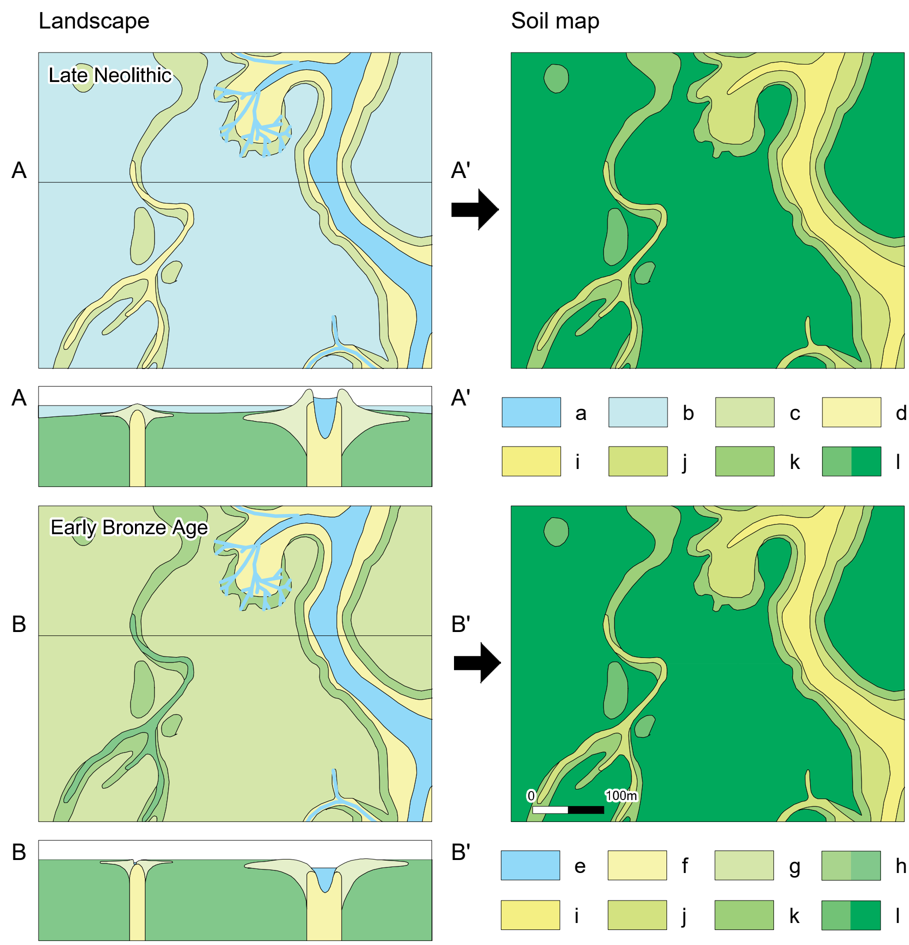


Figure 3.13: The relation between the former landscape and the present day soil map of eastern West-Frisia. Legend: a salt to brackish water, b brackish to freshwater and or reed swamps, c irregularly flooded levees and creekridges, d regularly flooded flats, splays and residual gullies, e salt to brackish water, f tidal flats, g irregularly flooded tidal marsh, h regularly flooded tidal marsh and former gully, i loamy sand to sandy loam, j sandy loam to loam, k (silty) clay loam with intercalated layers of loamy sand or sandy loam, l (silty) clay loam.

creek-floodbasin environment and the tidal flat-tidal marsh environment. A distinction between these two landscapes can only be made by a thorough evaluation of the age and microfossil content of sediments. Even at a site like *Noorderboekert* with a straightforward stratigraphy the change in environment could not be attested by lithological characteristics in the field. Therefore the new palaeogeographical maps are not adjusted by an evaluation of the available coring databases. Furthermore it is important to note that in the available soil maps no distinction has been and can be made between clay and sand deposited in the different environments. The implication is that the drainage pattern in the palaeogeographical map is a palimpsest, a mixture of drainage elements from both environments.

Figure 3.12 (previous page): West-Frisia approximately 2100 BC (A), 1500 BC (B) and 900 BC (C). Legend: a dunes and beach ridges, b tidal flats, c tidal marshes and levees, d former tidal marsh, e peat, f Pleistocene sand areas, g ice pushed ridges, h mainly brackish and salt water, i mainly freshwater, j West-Frisia, k excavation, l survey.

3.7. Concluding remarks

Although every study stresses the relation between the different tidal basins and their inlets, the development of these basins have not been studied in relation to each other. Changes in tidal basin morphology determine the sedimentation rate within the basins, tidal ranges, mean high water level and mean water level. The groundwater levels in eastern West-Frisia from the Middle Bronze Age onwards are therefore highly influenced by changes in the tidal ranges and the floodbasin effect in the Flevomeer area. The attested strong rise in the groundwater level in the Late Bronze Age can be easily explained by these kinds of changes in the Flevomeer area. Habitation in the Middle Iron Age in the eastern part of West-Frisia can be explained by a change of the mean high water level and mean water level in the Flevomeer area due to the origination of the Vliestroom. In the western part of West-Frisia this change can be linked to the activity of the Rekere and Zijpe.

	Bergen inlet	Oer-IJ estuary	Vliestroom
3850-1800 BC	Tidal basin characterized by large tidal channels with high levees accompanied by marine crevasse splays and vast open basin areas. There is a light brackish to freshwater transition from west to east in the Vecht basin. Short periods of marine phases occur in this basin probably due to storm surges.	Stable marine environment, in the hinterland an oligotrophic peat develops.	
	Seasonal exploitation of levees, splay deposits. Permanent exploitation of Pleistocene outcrops and creek ridges.	Seasonal exploitation of levees and splay deposits.	
1800 BC	Disconnection Bergen tidal basin area and Vecht basin.	Raised peat bogs are flooded due to an enlargement of the discharge from the hinterland *c.* 1700 BC.	
1800-1700 BC	Silting up of eastern West-Frisia in tidal marsh environment. Large areas in the Vecht basin are transformed into freshwater lakes.		
	Seasonal exploitation of levees, tidal marsh deposits and Pleistocene outcrops. First farmsteads occur at beach barriers. In tidal marsh areas burial mounds are erected and arable fields are present.	Seasonal exploitation of levees and tidal marsh deposits. First farmsteads occur at beach barriers.	
1700 BC	Partial closure of the inlet. Start of peat growth in eastern West-Frisia. Marine sedimentation continues in western West-Frisia.	The stream bed of the Oer-IJ-gully enlarges significantly *c.* 1700 BC due to an increased marine activity within the estuary.	
1700-1100 BC	In the western part of West-Frisia basin clay is deposited in a *Slufter* environment. In the eastern part of West-Frisa no sedimentation takes place. In the Vecht basin the freshwater lakes enlarge and are connected with Flevomeer area by narrow corridors.	Formation of tidal marshes in a marine environment.	
	Permanent habitation of former tidal marsh deposits and tidal creek deposits in eastern part of West-Frisia. In western part of West-Frisia seasonal exploitation of levees and tidal marsh deposits occurs.	Seasonal exploitation of levees and tidal marsh deposits. Farmsteads occur at beach barriers.	
1100 BC	Closure of the Bergen inlet. Seasonal flooding in eastern part of West-Frisia. Start of peat growth in western part of West-Frisia	1050 BC start of the Vecht-Angstel river system.	
1100-900 BC	Rise of the groundwater level leading to continuous peat growth in western West-Frisia and an enlargement of the lakes in eastern West-Frisia and Vecht basin. The fish population still shows an open connection to the coast probably through Vecht basin-Flevomeer-Oer-IJ estuary.	Relatively stable period with peat growth. The water quality within the estuary can be characterized as light brackish to freshwater due to the influence of the Vecht-Angstel river system.	
	Settlement sites at former tidal marsh deposits and tidal creek deposits occur in the eastern part of West-Frisia. Between 1000 and 900 cal BC habitation seem to be absent. Sites dating in this period are unknown in the western part of West-Frisia.	Sites dating in this period are unknown.	
900-500 BC	Peat growth in western West-Frisia. Enlargement of lakes and peat growth in the eastern part of West-Frisia. Further enlargement of the freshwater lakes in Vecht basin.	Short period with an increased marine influence enlargement of the freshwater discharge caused by land clearances enlarging the tidal range	
	Habitation of former tidal marshes continues at least until 800 BC on terp mounds in the eastern part of West-Frisia. Locally habitation is probably continuous (a.o. *Opperdoes*). Sites dating in this period are unknown in the western part of West-Frisia	Sites dating in this period are unknown.	
500 BC	Start of sedimentation along Zijpe/Rekere and Leek. Distinctive lowering of the groundwater level and peat oxidation in lower reach of IJssel valley, Flevomeer and peat remnants in eastern West-Frisia. First marine indicators in lower reach of Ijssel valley and Flecomeer area.	The gullies in the estuary start to fill in	Opening of the Vliestroom.

Table 3.1: Overview of events and gradual development of the landscape and exploitation of West-Frisia in relation to the Bergen inlet, Oer-IJ estuary and Vliestroom.

In table 3.1 an overview is given for habitation, environmental events and long-term environmental developments for the tidal inlets and the accompanying tidal basins which influence West-Frisia. For example, a change towards a more freshwater environment in the Bergen tidal basin between 1700 and 1100 cal BC seems to coincide with a more brackish environment in the Oer-IJ estuary. A larger freshwater input in the Oer-IJ estuary between 1100 and 900 cal BC coincides with a rise of the groundwater level in the eastern part of West-Frisia. In other words, an event in one basin has its influence on the other basins almost like communicating vessels.

Man seems to react to these changes by grasping the new opportunities and changing the ways of exploitation of the landscape. In the Flevomeer area a change in water quality results in a change from fishing with fykes and weirs to only fishing with weirs at the *Emmeloord J97* site (Bulten *et al.* 2002). In eastern West-Frisia a rise in the groundwater level is responded to by building raised mounds for their houses. Abrupt changes in the environment of Middle Bronze Age West-Frisia seem to be limited. Only the sedimentation at the *Hoogkarspel-Watertoren* site and an indication for sedimentation at the *Enkhuizen-Kadijken* site in the Middle Bronze Age indicate the occurrence of flooding events. There is no indication that these events had a major impact on the settlements or environment. Apparently these kinds of events are part of living in a wetland and don't have any influence on the habitation pattern.

In this chapter the changing nature of the environment in terms of subsoil, lithogenesis, hydrology and water quality were the central issues. A general picture of the palaeogeography has been outlined and seems to fit the archaeological database. However, the presented data also raises questions like: if woodlands were present what was the nature of these woodlands? Where were these woodlands situated? What was the influence of man on the natural vegetation? Where did people catch their fish? In the next chapter a method will be presented in order to answer these kinds of questions for a small part of West-Frisia, the land consolidation area Westwoud.

4 Reconstructing the surroundings of a Bronze Age farmstead in a wetland environment

4.1. Introduction

In the previous chapter a palaeogeographical reconstruction for West-Frisia has been presented for three time frames on a small map scale. These reconstructions explain the long term changes in the (in)habitability and general geography of West-Frisia. Questions like: "Which parts of the environment were suitable for arable land or pastures?" or "Where and what kind of forests and timberland were present in the environment?" could not be answered with these reconstructions. Therefore, these reconstructions fail to present information about the appearance and exploitation possibilities of the area which has been exploited on a daily basis, the catchment area. For this purpose, palaeogeographical reconstructions on a large map scale of the environment of settlement sites are necessary. In this chapter a method for the construction of this kind of palaeogeographical map will be presented. First a short overview of palaeogeographical reconstructions of wetland sites on a large map scale is presented and the elements needed for a reconstruction and the principles are discussed. These will be applied to the land consolidation area of Westwoud (figure 4.5), resulting in a palaeogeographical map which presents the appearance of the landscape during the Middle and Late Bronze Age.

4.2. Palaeogeographical reconstructions of wetland sites: an overview

Many palaeogeographical reconstructions have been made within the framework of archaeological projects in the Netherlands. Only few reconstructions concern the catchment area of a wetland. Different approaches have been used in these maps to reconstruct the palaeogeography of wetlands at a specific moment in time. The publication of Thoen *et al.* (2013) incorporates a number of recent case studies of coastal wetlands in relation to human exploitation of the North Sea basin. This publication focuses on the influence of man in the past on the development of coastal landscapes in this region (Thoen *et al.* 2013). In this publication a concise overview of published palaeogeographical maps for the southwestern coast of the North Sea basin is presented by Weerts (2013, 45-176).

This overview and the previously mentioned reconstructions have been the starting point for the exploration of methods for the making of palaeogeographical reconstructions, together with the publications of Vos *et al.* (2011) and Vos (2015). In table 4.1. an overview of the reconstructions used is presented. In the palaeogeographical studies presented in the overview, the subsurface is mostly represented by geomorphological units like creeks, creek ridges, salt marshes,

Toponym	Publication	Units legend								Area (ha)
		Relief	Topographic	Geomorphologic	Lithologic	Lithogenetic	Environment	Vegetation	Soil	
De Bogen (NL)	Van Zijverden 2002b; Van Dinter and Van Zijverden 2010	x	x	x						±225 ha
De Bruin (NL)	Mol 2001b	x	x	x			x			±100 ha
De Horden (NL)	Steenbeek 1990	x			x	x				± 30 ha
Dithmarshen (D)	Meier 2004		x	x	x				x	±90.000 ha
Dodewaard-Hiensche Veld (NL)	Steenbeek 1990	x			x	x				± 30 ha
Eigenblok (NL)	Van Zijverden 2002a; Van Beurden 2008	x			x	x		x		±400 ha
Hattemerbroek (NL)	Lohof *et al.* 2011	x		x	x	x				±300 ha
Huis Malburg (NL)	Van Dinter 2000					x				±100 ha
IJzer valley (B)	Baeteman and Declercq 2002			x						±20.000 ha
Jade Busen (D)	Behre 1999		x	x						±20.000 ha
Katwijk-Zanderij (NL)	Van Dinter 2013	x	x	x		x				±8000 ha
Kesteren-De Woerd (NL)	Van Dinter 2002a; Van Dinter and Van Zijverden 2010	x	x	x						±100 ha
Lage Blok (NL)	Van Zijverden 2002c		x	x		x				±100 ha
Leidschendam-Voorburg (NL)	De Kort and Raczynski-Henk 2014		x	x						±600 ha
Lienden-Woonwagenkamp (NL)	Van Dinter 2002b; Van Dinter and Van Zijverden 2010	x	x	x						±100 ha
Linge-Steenen Kamer (NL)	Van Dinter 2005		x	x			x			±100 ha
Molenaarsgraaf (NL)	Van der Woude 1987			x				x		±400 ha
Peins (NL)	Bazelmans *et al.* 1999		x	x						±7500 ha
Polderweg (NL)	Mol 2001a	x	x	x			x			±100 ha
Romney Marsh (UK)	Waller *et al.* 2007	x					x			±30.000 ha
Serooskerke (NL)	Bos and Zuidhoff 2011			x						±600 ha
Severn (UK)	Rippon 2000		x				x			±1600 ha
Swifterbant (NL)	Desscher and Raemaekers 2010		x	x						±1600 ha
Texel (NL)	Woltering 1997	x				x				±50.000 ha
Vergulde Hand (NL)	Eijskoot *et al.* 2011; Vos 2015		x	x		x	x			±40 ha
Wijk bij Duurstede (NL)	Vos *et al.* 2011		x	x						±2500 ha
Yangtze harbour (NL)	Vos 2015	x		x			x			±10 ha
Zijderveld (NL)	Van Beurden 2008	x			x	x		x		±400 ha

Table 4.1: Overview of palaeogeographical reconstructions of wetlands at a large map scale.

floodplains, tidal flats and so on. Apart from geomorphological units, lithogenetical, lithological and soil units are used to describe the nature of the subsurface. Different types of units are often combined. For example in the reconstruction of the site *Eigenblok* the geomorphological unit floodplain is subdivided, based on lithological characteristics into a floodplain with humic clay and a floodplain with clay (Van Beurden 2008). Often the geomorphological unit peatland is subdivided into lithogenetical units to distinguish different types of peatland (Lohof *et al.* 2011; Van Dinter 2013; Vos 2015). Alongside the subsurface most palaeogeographical maps present topographical elements like settlement sites, roads, allotments and so on. Often relief units are added to distinguish relatively low and high parts of for example tidal marshes, levees, crevasses, etcetera. Relief is also used to differentiate Pleistocene outcrops or dunes in these coastal landscapes.

The palaeogeographical map of the Severn (UK) is a rare exception in the presented overview. This map does not present information on the subsoil at all but presents solely environmental units like fen sedge and marsh (Rippon 2000). Surprisingly, only less than half of the reconstructions present some sort of information on the environment or vegetation. This is rather odd considering the purpose of the construction of these maps. For example, a differentiation into freshwater, brackish water and salt water environments would be relevant

Figure 4.1: Three types of floodbasins in the Danube delta, Romania (Photos: Farmers of the Coast).

for coastal environments. The only reconstruction in this overview with such a differentiation is the reconstruction of the site *Vergulde Hand* (Eijskoot *et al. 2*011; Vos 2015). Only a few reconstructions in the overview provide detailed information on vegetation units (Van Beurden 2008; Van der Woude 1987). For example, the reconstruction of *Eigenblok* presents vegetation classes like wet grassland and willow shrub, herbs and grasses, alluvial hardwood forest and alder carr (Van Beurden 2008).

Apparently the appearance of the landscape at a specific moment in time is reconstructable in abiotic, geomorphological elements like creeks, levees and so on. These units are helpful in understanding the landscape in terms of possibilities for transportation and so on. But do these palaeogeographical maps provide answers to the questions previously asked? For example the geomorphological unit floodbasin can represent environments with obvious distinct exploitation possibilities (figure 4.1). Floodbasin A provides reed, which can be used amongst others for roofing. Floodbasin B is an ideal location for fowling. Floodbasin C is ideal for fishing with weirs and fykes. Therefore lithogenetic or geomorphogenetic units seem to be more appropriate for presenting such information. For example floodbasin A can be represented by peaty floodbasin deposits, B by humic floodbasin deposits and C by clayey floodbasin deposits.

The palaeogeographical map of the site *Vergulde Hand* is a good illustration of a palaeogeographical map with lithogenetical units (Eijskoot *et al.* 2011; Vos 2015). Figure 4.2 presents the palaeogeography of this site around approximately 250 BC. The reconstruction displays two lithogenetical units, eutrophic peat (reed-sedge peat) and oligotrophic peat (mosaic of *Sphagnum* and heather). The location of creeks and settlements are also depicted in this palaeogeographical map. In the map description it is explained that during the exploitation of this area there is no active peat formation around 250 BC, but that the substrate consists of peat which has been formed within a fen or bog. According to the description, the research area became inhabitable just before 250 BC as a result of extensive drainage. This lithogenetic

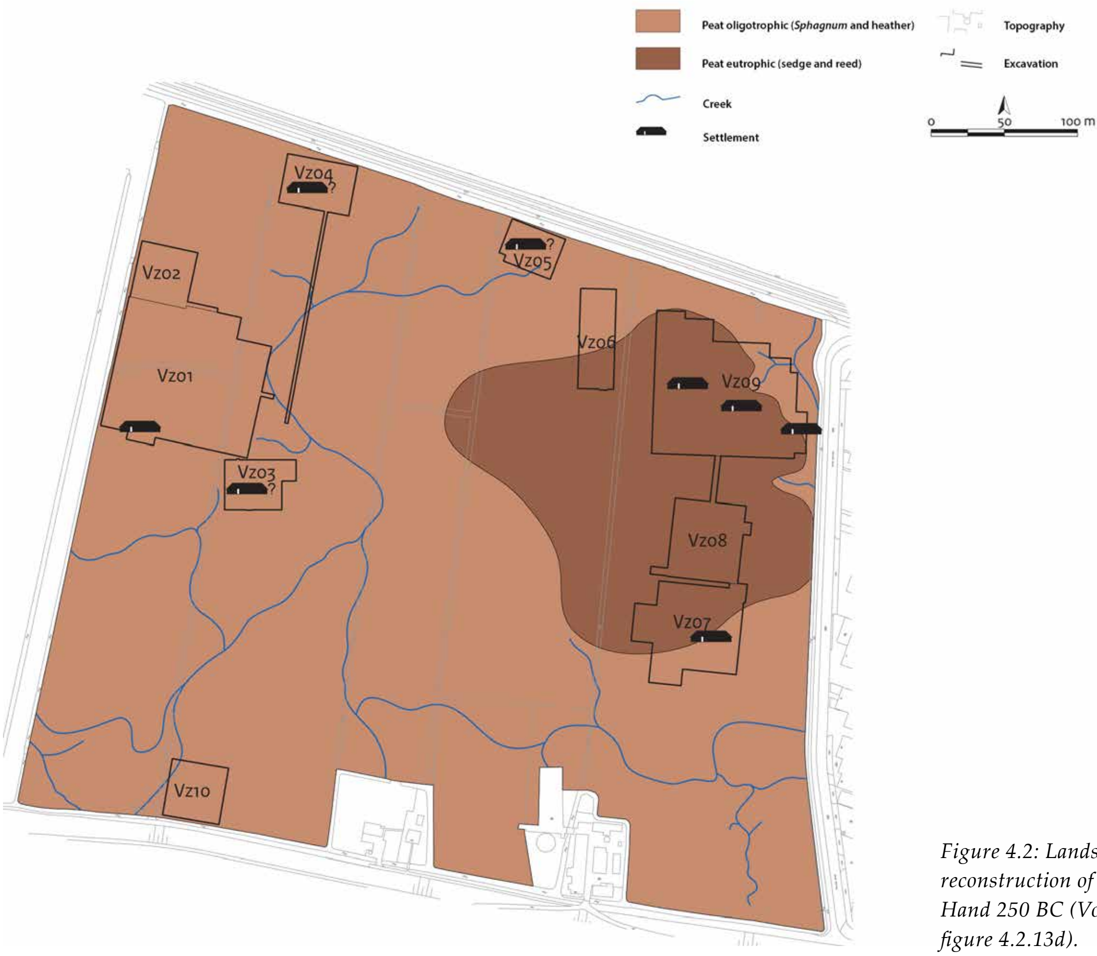


Figure 4.2: Landscape reconstruction of Vergulde Hand 250 BC (Vos 2015, 285, figure 4.2.13d).

information is very useful to understand the origin of this specific landscape. However, questions regarding the suitability for agricultural use or the location of forests and shrubs cannot be answered using these lithogenetic units in a palaeogeographical map. In this specific reconstruction, knowledge of the palaeohydrology is essential to understand the possible development of the vegetation and the exploitation possibilities in this area.

The abiotic environment as presented in the analyzed palaeogeographical reconstructions, is relevant to some extent. But it has been the vegetation that was noted by and mattered to prehistoric communities (Arnoldussen 2008, 48). Therefore, insight into the appearance of the landscape including vegetation is crucial to understand the different possibilities and use of the landscape around settlement sites. The elements needed for a reconstruction of such a palaeogeographical map at this scale are: topography, relief, information of the subsurface and hydrology.

4.3. Methods

In upland environments the aforementioned elements: relief, information of the subsurface, hydrology and vegetation, are relatively "easily" obtained (figure 4.3). Sources like LIDAR-data, soil maps and historic maps usually provide the necessary ingredients for a reconstruction of the subsurface, relief and hydrology. The vegetation in uplands is commonly reconstructed by using palynological data. A problem with vegetation reconstructions in upland environments is the overrepresentation of wet contexts (Gaillard *et al.* 2008; Groenewoudt *et al.* 2008). The study by Gaillard *et al.* (2008) presents promising results to overcome this problem. In wetland environments palynological data is easily obtained and can be completed with macrobotanical remains, but the other sources are not sufficient. Weerts (2013) notes several problems that hinder an easy application of these sources. First of all, the reconstruction of the groundwater level is not only influenced by the sea level rise, but also by the estuary effect, floodbasin effect, river gradient effect and avulsion effect (Weerts 2013, 157-159). Secondly, periods of erosion, sedimentation and non-sedimentation alternate in wetlands through space and time (Weerts 2013, 166). LIDAR-data, soil maps and historical maps only represent the result of these processes and are therefore not applicable. Thirdly, wetland environments are liable to differential subsidence (Weerts 2013, 166). The present day height differences as shown in LIDAR-data are therefore not applicable. Due to these three factors (water dynamics, sedimentation history and differential subsidence), the aforementioned sources are of limited use in palaeogeographical reconstructions of wetlands. In the following paragraph an alternative method will be presented in order to obtain the necessary elements for a palaeogeographical reconstruction of a wetland.

4.3.1. Hydrology

In order to obtain information about changes in hydrology over time, three types of indicators are usually used: sediment, botanic remains (pollen, spores and macrobotanical remains) and archaeological features (water pits and ditches). Sediments indicate changes in water conditions by the presence of several organisms. Organisms like diatoms, ostracods, forams, amoeba and molluscs present detailed information on water depth, salinity, stream velocity, temperature and so on. Combined with micromorphological analyses, a well-argued typification of the environment at a specific location at a specific time can be made. Botanical remains like pollen, spores and macrobotanical remains preserved in mires and moors can deliver information on general changes in water conditions over time (Lowe and Walker 2003, chapter 4). It is important to note that short events are sometimes not registered by these proxies due to the relatively long reaction time of plant communities (e.g. § 3.5.3). Archaeological features related to water management like canals, ditches and water pits can provide information about changes in the local hydrology. Remains of organisms from the infill of these features, for example molluscs, can provide information about the groundwater level and fluctuation at a specific moment in time. Furthermore it is thought that the depth of these features is related to the groundwater level (Buurman 1996, 187).

4.3.2. The subsurface

The properties of the first 50 centimeters of a soil are for most plants one of the determining factors if they will be able to grow at a specific location, besides the climatological conditions (De Bakker and Locher 1990, 218). Therefore a map presenting the soil properties to a depth of at least 50 centimeters is needed. Ellenberg (1979) describes the soil preferences for phytosociological vegetation classes by the following soil characteristics: acidity (pH), nutrient availability, moisture content and salinity. If these soil characteristics are known for a specific location, the natural vegetation that will develop and the different succession stages can be more or less predicted. The suitability of a soil for agricultural use is usually described by a different set of soil characteristics: natural drainage, field capacity, crumbling and

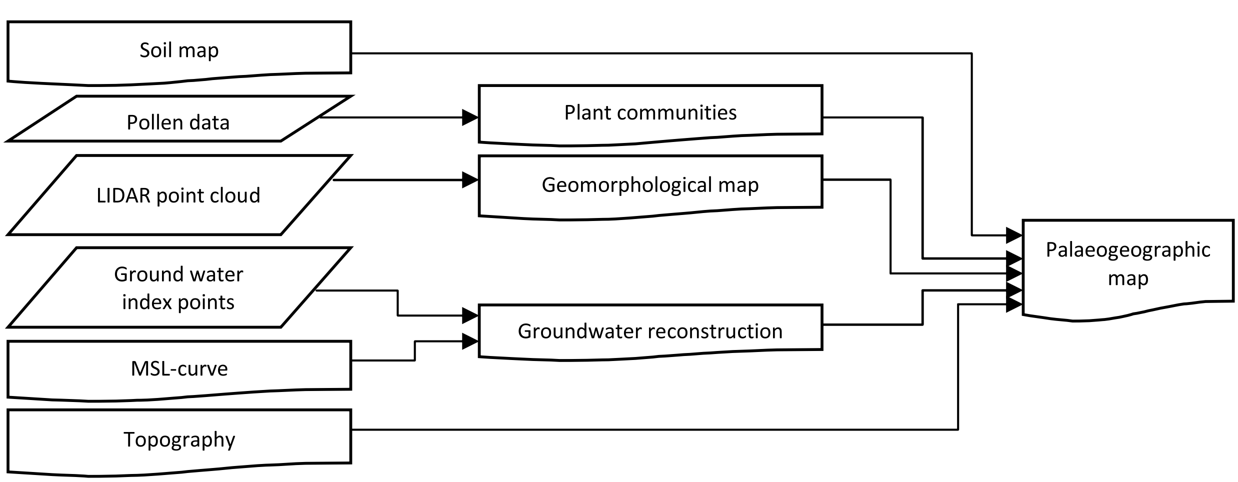


Figure 4.3: Flow chart for a conventional palaeogeographical reconstruction for an upland location.

sensitivity for slaking and aeolian erosion (De Bakker and Locher 1990, 216). These characteristics, needed to make an estimate of the vegetation and soil suitability for agricultural purposes, are relatively easy to obtain by manual corings and it can often be deduced from coring databases.

For instance, the soil suitability for agricultural purposes depends heavily on the lithology. Soils with a lutum content smaller than 8% are sensitive to aeolian erosion and are susceptible to drying (De Bakker and Locher 1990, 218). Drying can be prevented to a certain extent by enlarging the organic matter content. Soils with a lutum content smaller than 25% are susceptible to slaking, but do have a high capillary fringe and are therefore less susceptible to drying (De Bakker and Locher 1990, 220). Slaking can also be prevented by enlarging the organic matter content. Soils with a lutum content larger than 25 % do have a low capillary fringe and are difficult to work due to a low crumbling rate (De Bakker and Locher 1990, 219). The crumbling rate can also be enlarged by adding organic matter. Soils with a lutum content larger than 25% are not susceptible to slaking or drying. From an agricultural point of view, the crop failure risk is smallest in the 8-25% and highest in the <8% lutum zone. The suitability for crop cultivation of the different soil types depends largely on the groundwater level. Soils with a groundwater depth less than 15 cm during winter season are thought to be unsuitable for arable land (De Bakker and Locher 1990, 218).

The soil characteristics used in vegetation research can also be partly deduced from these coring databases. The acidity of a soil is usually expressed in pH-values however it can also be roughly estimated from the $CaCO^3$-content. Since 1966 $CaCO^3$-content has been estimated with a 10% HCl solution as a standard during soil surveys in the Netherlands (De Bakker and Schelling 1966). This standard has been used in all available databases for West-Frisia as presented in table 2.1. The availability of nutrients is usually expressed by the C/N-ratio, $CaCO^3$-content and P-value. A high $CaCO^3$-content often coincides with a good C/N-ratio and P-value. The reverse is untrue, for example an oxidized peat usually has a high C/N-ratio but a low $CaCO^3$-content. Moisture content and salinity are difficult to obtain. The moisture content depends on the groundwater level and capillary fringe and thus lithology and hydrology as described before. The salinity of soils at a certain moment in time is difficult to estimate due to the mobility of salt in a soil. The original salinity can be obtained by an analysis of fossil organisms like molluscs, ostracods, forams and diatoms (Lowe and Walker 2003, chapter 4). Pollen and macrobotany can be used to describe the salinity of an environment at a specific moment in time in general terms (Lowe and Walker 2003, chapter 4).

4.3.3. Relief

The original morphology of a wetland is difficult to reconstruct due to differential subsidence, erosion and sedimentation. Soils exploited during a specific period in the past are, when non erosively covered, often well visible in wetlands. For example the dark fossil A-horizons representing the surface of the landscape during a specific period (figure 5.20) of sites like *Noorderboekert* and *De Rikkert* can be traced over extensive areas. The relief of these horizons can be mapped easily using hand coring equipment or digital coring databases. The mapped relief of these horizons can be represented with a digital elevation model (DEM). This mapped relief differs from the original relief due to differential subsidence. Several methods have been applied in the past in order to create an educated guess for the original relief. A first method which has been used by many authors is a correction based on the thickness of sand bodies (Van der Woude 1987; Steenbeek 1990; Van Dinter 2002a; 2002b; Van Dinter and Van Zijverden 2010). In this method the amount of sand present in a soil section is used to estimate the compression factor. A second method is the measurable compressibility of the subsoil. This type of correction is only possible for locations with detailed and reliable knowledge of local soil properties and compressibility of the sediments (Koster *et al.* 2012). This kind of information is often available in a high density from cone penetration tests for construction sites, railway-tracks and highways. Although, outside the perimeters of the actual construction sites little to no information on compressibility is available. A third approach is the use of modern analogies. A DEM of the surface can be corrected with a well-considered compression factor based on maximal height differences in an analogy.

4.3.4. Vegetation

In order to reconstruct the vegetation at a specific location and moment in time archaeobotanists use several proxies. Palynological data (pollen and spores), macrobotanical data (seeds, leafs and stems) and analysis of wood are widely used for this purpose. Traditionally palynological research is used to gain insight into the wider environment of archaeological sites and changes over time in these environments. This type of research has been criticized in the past two decades. Studies, especially of the relevant source area of pollen (RSAP), prove that traditional archaeological contexts like water pits and ditches are often too small to gain insight into the wider environment (Sugita 1994; Sugita *et al.* 1999; Groenewoudt *et al.* 2008; Van Beurden 2008; Lohof *et al.* 2011, 437). Furthermore wet contexts are overrepresented due to their relatively good preservation conditions. The frequent analysis of these wet contexts and on-site contexts resulted in a biased image of the natural vegetation in the past (Groenewoudt *et al.* 2008; Schepers 2014). Samples obtained from intensively used areas like settlement sites and arable fields present almost a reverse image of the environment which has been exploited by man (Van Amerongen 2016, 17). Finally palynological data represent vegetations of the past, but quite different vegetations can result in strikingly similar palynological records (Vera 1997, 73). The interpretation of these records is a specialism and sometimes leads to heated debates (Louwe Kooijmans 2012).

Analyses of macrobotanical remains are often used to gain insight into the use of domesticated and gathered plants by communities in the past. Furthermore, these are also used to gain insight into the biotopes represented by these plants. In this way the study of macrobotanical remains contributes to the analyses of the environment outside the settlement, for example distinctions are made between different types of pastures and meadows. Macrobotanical remains from natural contexts have not been used in order to reconstruct the palaeovegetation with the exception of the study by Schepers (2014). A special class of macrobotanical remains is wood. Wood from archeological sites is often used for obtaining dendrochronological dates. It is rarely used to obtain information on woodland types in the vicinity of sites. A few studies in Dutch archaeology of large samples of wood provide information about the composition and maintenance of woodlands in the past (Koot and Vermeeren 1993; Bulten *et al.* 2002; Van Dinter 2013). Contexts with well preserved sub-fossil woodlands are rare, but provide detailed information about the composition of woodlands in the past (Kooistra *et al.* 2006; Bouma 2011).

Schepers (2014, 30-33) distinguishes two research strategies for the reconstruction of plant communities of the past. Plants can be differentiated into ecological groups, groups with more or less similar demands to pH, nutrient availability, light, salinity and so on. Secondly plants can be differentiated into syntaxonomic groups, that is to say, groups of plants which form a plant community under certain

Figure 4.4: Yard of a house in Letea (Romania) showing straw for cattle, reed for roofing, assembled wood for fire, wood for timber and locally grown pumpkins.

preconditions. Every plant community is represented by one or more indicator species, which is typical for this plant community. Based on the presence of indicator species in a macrobotanical analysis the presence of specific plant communities can be deduced. For example, *Calamagrostis Canescens*, *Ribes nigrum* and *Carex elongata* are the indicator species of a specific type of alder carr. One or more of these indicator species in combinations with remnants of *Alnus glutinosa* indicate the presence of this type of woodland. The combination of these types exclude other types of alder carr. The principle of actualism is an important condition for the application of both approaches. Schepers (2014) uses in his study samples from channel lags and other remains assembled in natural secondary contexts. Based on an analysis of indicator species he presents a plausible vegetation reconstruction of the wider environment. This idea should also be applicable to macrobotanical and zoological remains from settlement sites. Man assembled material in his catchment area. The finds on-site are therefore a representation of the exploited off-site environment and the on-site environment, which is well-illustrated in figure 4.4.

4.3.5. A method for the reconstruction of a wetland environment

In order to create a reconstruction of the environment, information on the subsurface is needed regarding lithology, organic matter content and $CaCO^3$-content of the upper 50 centimeters of the surface. Furthermore a reliable set of groundwater index points is needed in combination with a reliable DEM of the former surface. For reconstructions in (near-) coastal environments information on the salinity of surface water is needed. The palaeovegetation can be reconstructed using these characteristics, because plants arrange themselves in plant communities based on the previously mentioned characteristics. Plant communities and the succession of plant communities are therefore more or less predictable in composition and structural appearance.

A man-made selection of macrobotanical remains is available at every excavated site. This selection is not at all a complete representation of the exploited environments but more or less a jig saw puzzle with lots of missing pieces although the individual species can be organized in plant communities based on the indicator species which are present in the samples. These plant communities can be compared with the based on the soil properties predicted plant communities. If there is a match the communities can be distributed in space based on their preferred habitat. Information derived from remains of wild fauna can be used to complete the environmental picture but can also be used to evaluate the reconstruction.

4.4. Case-study Westwoud

Westwoud is a land consolidation project situated in West-Frisia (figure 4.5). The Westwoud land consolidation project was carried out in the mid-eighties preceded by a soil survey (Bles and Rutten 1972). The original 1360 core descriptions from the soil survey could be obtained for this study from Wageningen University.[66] The surface height measurements of the original survey were not available. To create a valid reconstruction of the surface level for the seventies a set of 4047 height measurements dating from 1971 has been used.[67] In advance of the land consolidation project an extensive archaeological field survey was carried out. The original data and finds from this survey could be obtained for this study from the Provincial Archaeological Depot Noord-Holland.[68] Based on the results of the soil survey and the archaeological field survey, four small-excavations were carried out (figure 4.5: site 1-4). Since 1984 several small-scale excavations have been carried out within the Westwoud land consolidation area (figure 4.5: site 5-7). Recently, in advance of the construction of a road, several small scale excavations were conducted (figure 4.5: site 8 and 9). Just outside the borders of the land consolidation area the large scale excavations of *Hoogkarspel* were carried out as well as a small scale excavation (figure 4.5: site 10-12).

The landscape in the Middle Bronze Age of the Westwoud land consolidation area can be characterized as a former tidal marsh area. The subsurface is therefore characterized by the presence of tidal marsh deposits, creek deposits and peat. In the top of the tidal marsh deposits a distinct A-horizon of 10-15 centimeters has developed. This A-horizon is

66 Thanks to Fokke Brouwer for making available the original data (Alterra Wageningen UR) and Renate de Boer (Leiden University) for digitizing the data.

67 The vertical datum used is the Amsterdam Ordnance Datum (NAP).

68 Thanks to Martin Veen and Jean Roefstra (Provincial Archaeological Depot) and Esther Eilering (Saxion University) for digitizing the data.

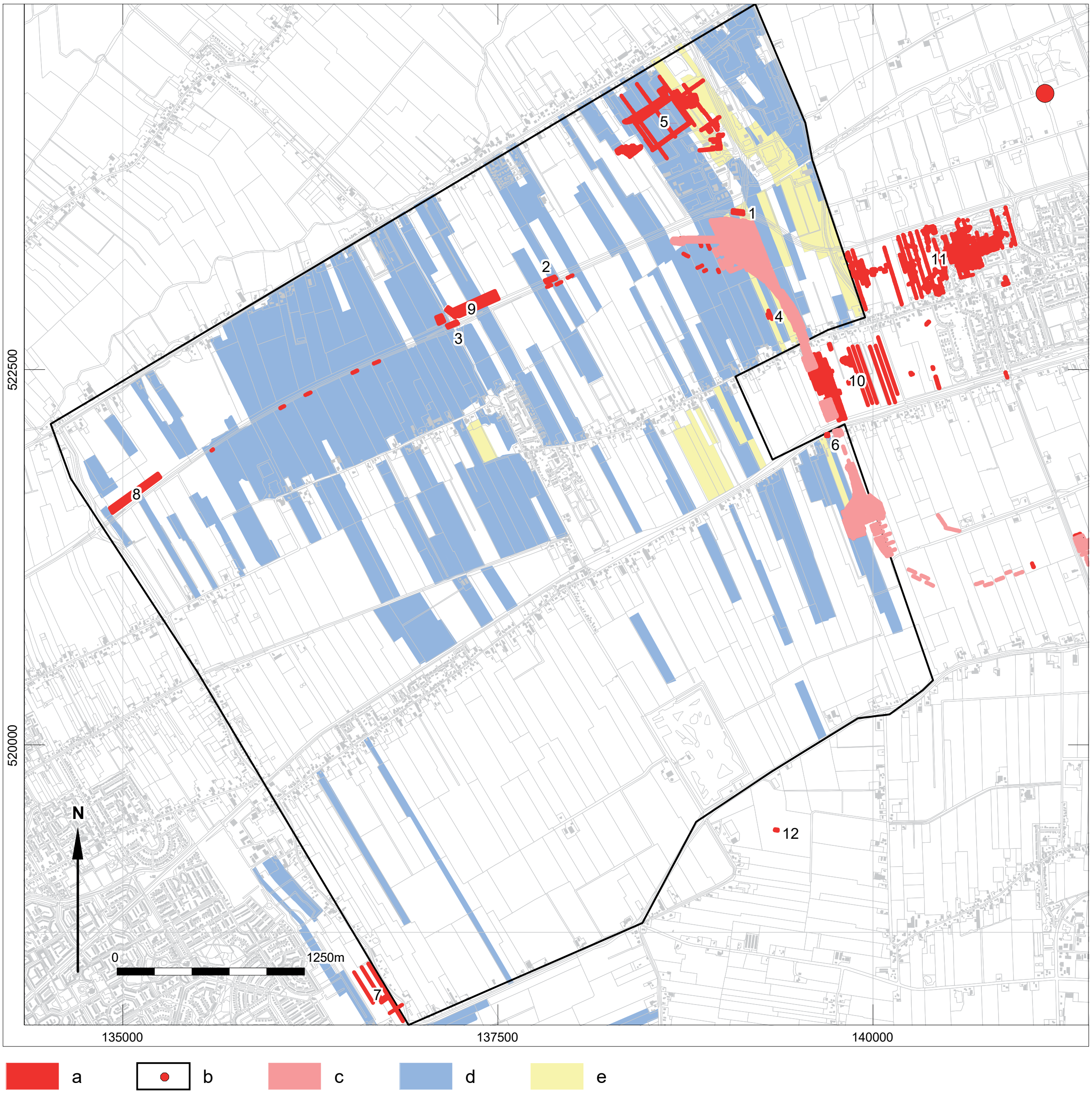


Figure 4.5: Excavations and field survey within the Westwoud land consolidation area. Legend: a sites: 1 Westwoud I, 2 Westwoud II, 3 Westwoud III, 4 Westwoud IV, 5 Zwaagdijk-Oost, 6 Binnenwijzend 100, 7 Zuiderdracht, 8 Rijweg, 9 Noorderboekert, 10 Hoogkarspel-Tolhuis, 11 Hoogkarspel-Watertoren and Tumuli, 12 Blokdijk, b Klokkeweel, c Excavations in advance of construction works N23, d parcels included in field survey without finds dating to the Middle or Late Bronze Age, e parcels included in field survey with finds dating to the Middle or Late Bronze Age.

covered with a thin layer of younger sediments dating after approximately *c.* 750 BC (Buurman 1996, 112). The A-horizon was mostly still present during the soil survey carried out between June 1970 and March 1971 (Bles and Rutten 1972).

4.4.1. Construction of the subsurface model

The original top of the Bronze Age surface is well visible due to a distinct dark colored A-horizon. In the set core descriptions, dating from the seventies, this A-horizon is easily identified. The lithology is described in centimeters below the surface level. In order to reconstruct the Bronze Age relief the depth

Figure 4.6: Reconstruction of the relief and soil properties.
A. Palaeorelief, a 4.00-3.25 m-OD, b 3.25-2.50 m-OD, c 2.50-1.75 m-OD, d 1.75-1.00 m-OD.
B. Adjusted palaeorelief, a 1.25-1.50 m-OD, b 1.50-1.75 m-OD, c 1.75-1.00 m-OD.
C. Soil properties, e 8-25% lutum in top and subsoil, f >25% lutum in top soil and 8-25% in subsoil, g 8-25% lutum in top soil and >25% in subsoil, h >25% lutum in top and subsoil.

of the soil horizon in centimeters O.D. was calculated with a DEM based on a set of height measurements dating from the seventies (figure 4.6A). The height differences within this A-horizon are approximately 3 meters. This is a high relief difference which is unlikely for this type of landscape. Modern analogies like "*Het Verdronken Land van Saefthinge*" and "*De Slufter*" show maximal height differences of approximately 75 centimeters. Therefore the DEM has been adjusted in proportion to this maximum difference (figure 4.6B).

To reconstruct the soil properties, the lutum content of the distinct A-horizon and the first layer beneath this horizon have been mapped resulting in four lithological classes: 8-25% lutum in top and subsoil, >25% lutum in top soil and 8-25% in subsoil, 8-25% lutum in top soil and >25% in subsoil and >25% lutum in top and subsoil. Apparently a class vulnerable to aeolian erosion and susceptible to drying is absent within this particular area. In addition a distribution map of the CaCO^3-content has been made as well as a distribution map of the organic matter. Within this research area these factors show little to no variation. Therefore these classes are not incorporated in the subsurface map. Peat is absent in the upper 50 centimeters within the research area. All factors are presented in a soil suitability map (figure 4.6C).

In order to obtain an idea of the rise of the groundwater level, an analysis of features like pits, water pits and ditches from sites in the region has been conducted. Comparing these features in relation to the original top soil, a clear trend is visible (figure 4.7A). Water pits become shallower over time, indicating a rising groundwater level as expected. Although the function of the pits is unknown these also tend to become shallower over time. Within the category ditches, a difference between house ditches (ditches surrounding a house plan) and terp ditches (ditches surrounding a terp mound) has been made. The terp ditches dating to the Late Bronze Age are clearly deeper compared to the house ditches dating to the Middle Bronze Age.

A confusing image arises when the depth of the previously mentioned features is compared in meters O.D. (figure 4.7B). The house ditches of *Hoogkarspel* are approximately 1 meter less deep compared to the house ditches of *Andijk* and *Enkhuizen*. If these ditches have been dug into or close to the groundwater level, these ditches should have a different depth with respect to the Bronze Age surface, which is obviously not true (figure 4.7A). More confusing is the depth of the terp ditches. The terp ditches of *Hoogkarspel* are slightly deeper compared to the

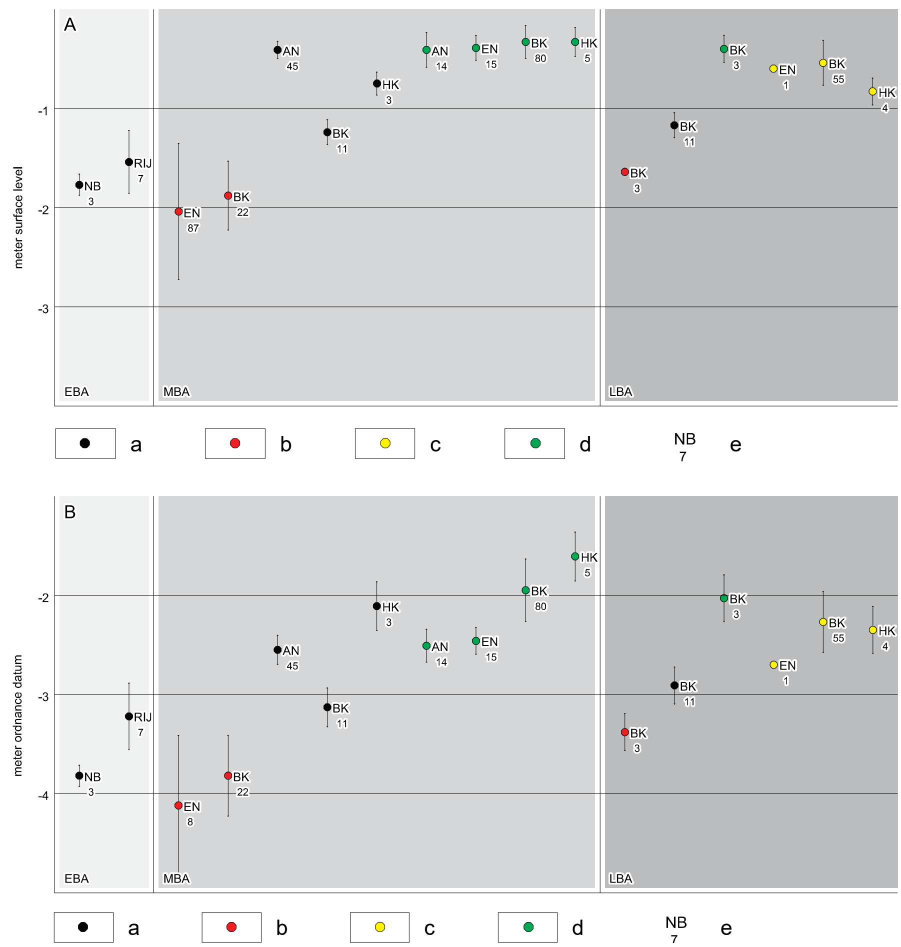


Figure 4.7: Mean depth of features with variation. Legend: a pits, b water pits, c terp ditches, d house ditches, e site name and number of features: NB Noorderboekert, RIJ Rijweg, EN Enkhuizen-Kadijken, BK Bovenkarspel-Het Valkje, AN Andijk, HK Hoogkarspel.

ditches of *Bovenkarspel-Het Valkje* (figure 4.7A), but do reach to the same depth in meters O.D. This is to be expected when these ditches have been dug into or close to the groundwater level. But why does the terp ditch of *Enkhuizen-Kadijken* reach deeper into the subsurface? The sites *Bovenkarspel-Het Valkje* and *Hoogkarspel* are both thought to be situated on top of a thick sandy creek ridge and *Enkhuizen-Kadijken* on top of a more clayey tidal marsh deposit. Therefore, the groundwater level of *Enkhuizen-Kadijken* in the Bronze Age is expected to be relatively shallow compared to *Bovenkarspel-Het Valkje* and *Hoogkarspel*. Hence the terp ditch should have been shallower in meters O.D. Because of this uncertainty and inexplicable differences in the relative depth of the different archaeological features, these are not used for the reconstruction of the groundwater level.

The site *Bovenkarspel-Het Valkje* is situated on top of a thick sandy creek ridge and is not vulnerable to compaction (Roep and Van Regteren Altena 1988). At the site *Bovenkarspel-Het Valkje* a thorough analysis of 139 mollusc samples from terp as well as house ditches has been conducted. The analysis at this site indicates a different environment within the two types of ditches (Mink 2016, 66-72). House ditches provide a mollusc fauna indicating dry periods during the entire year. Terp ditches provide a mollusc fauna indicating that these ditches contained water throughout the entire year, by the presence of *Anisus vorticulus* and *Planorbarius corneus* and the absence of *Aplexa hypnorum* (Mink 2016, 72). The shallowest terp ditches reach to 200 cm -O.D. The average depth of these ditches is 60 cm. Therefore, the groundwater level in the Late Bronze Age is estimated to approximately 150 cm -O.D. The Bronze Age surface level at this site varies between 90 and 160 cm -O.D. Therefore, the lowest areas of the site will have been regularly flooded which is in agreement with the observation of the local sedimentation of very fine sediments in the Late Bronze Age at for example the nearby site of *Enkhuizen-Kadijken* (Roessingh and Lohof 2011, 46).

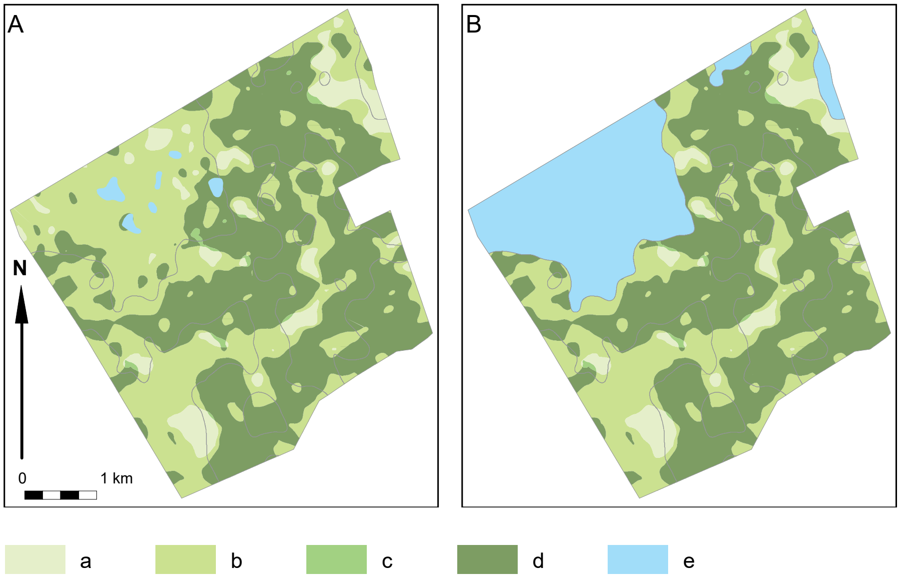


Figure 4.8: Reconstruction of soil properties for the Middle Bronze Age (A) and Late Bronze Age (B). a 8-25% lutum in top and subsoil, b >25% lutum in top soil and 8-25% in subsoil, c 8-25% lutum in top soil and >25% in subsoil, d >25% lutum in top and subsoil, e freshwater lake.

On top of the relatively high groundwater level there are also indications for a change in surface water dynamics. An analysis of pollen and macrobotanical remains indicates a significant decrease of *Alnus* and an increase of *Salix* and *Phragmites australis* (Pals *et al.* 1980). This change is dated to around 1000 BC (GrN-7912 2860 ± 30 BP). According to Wolf *et al.* (2001) *Alnus* allows fluctuations in the surface water level up to 30 cm. When fluctuations exceed this value regularly, *Alnus* is replaced by *Salix* and *Phragmites*. Van Beurden (2008, 28) interprets a comparable change in the river area as an enlargement of peak discharges. This explanation of Van Beurden is possibly applicable to the situation in West-Frisia. The idea of larger surface water fluctuations is supported by the erection of small terp mounds, the occurrence of local sedimentation of very fine sediments in the Late Bronze Age at the site *Enkhuizen-Kadijken* and the origination of the Vecht-Angstel system (§ 3.2.2). In figure 4.8B the average water level for the Late Bronze Age is depicted on top of the soil suitability map.

The average MSL-rise for the period Middle Bronze Age to Late Bronze Age is approximately 100 cm per 1000 years (Van der Plassche *et al.* 2010). Therefore the groundwater level for the Middle Bronze Age is estimated at 225 cm -O.D. This value suits very well the observed habitat of molluscs in house ditches, a mollusc fauna indicating dry periods during the entire year (Mink 2016, 66-72). An analysis of fish remains illustrates the presence of open water in this part of West-Frisia (Van Amerongen 2014). Therefore, within the area shallow lakes should have been present. The reconstructed surface level however exceeds the value of the reconstructed groundwater level in the entire area. Due to the absence of a natural drainage pattern and an expected surplus of precipitation, stagnation will occur at the lower locations with a low permeability. Therefore, lakes are depicted in the reconstruction at locations with a low permeability (a lutum percentage of 35 and up) in the lowest relief class (figure 4.8A).

4.4.2. Furnishing of the environment

In the previous paragraph the indicator values for phytosocial vegetation classes have been reconstructed for two specific moments in time: approximately 1500 BC and 800 BC. Using the reconstructed indicator values it is possible to predict the succession in phytosocial vegetation classes and, if possible, plant associations, for a specific place and moment in time (figure 4.9). During the Middle Bronze Age habitats with a high morphodynamic are absent. In the lowest areas with stagnant water, a groundwater level almost reaching the surface and a eutrophic environment, a forest of the class Alnetea glutinosae, will develop within several years. Within this class, two associations can develop: Thelypterido-Alnetum, an alder carr with an undergrowth characterized by ferns and a permanent groundwater level less than 20 cm below the surface, or Carici elongatae-Alnetum, an alder carr with an undergrowth characterized by sedges (Stortelder *et al.* 2008). In pollen spectra from the sites within the Westwoud land consolidation area, spores of ferns are rare. Remnants of ferns are

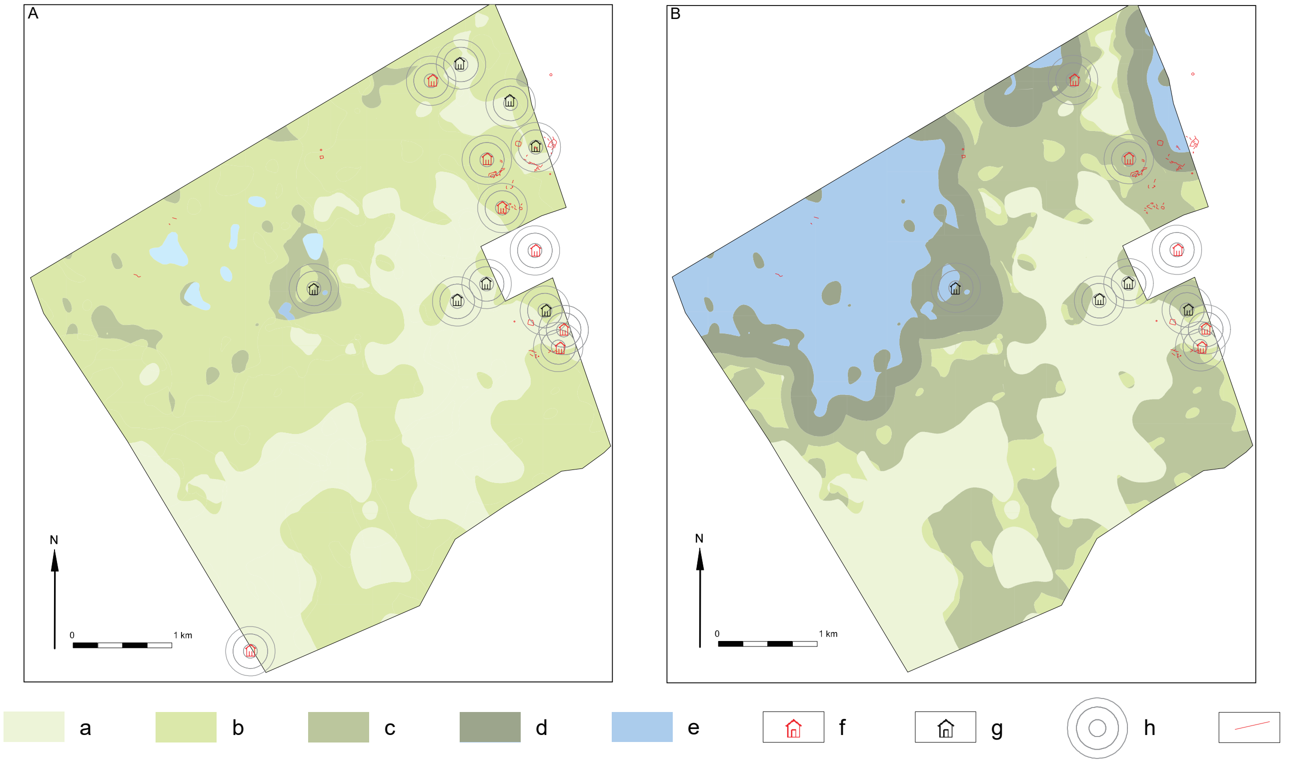


Figure 4.9A: Palaeogeographical reconstruction of the Westwoud land consolidation area for the Middle Bronze Age (ca. 1500 BC. a Molinio-Arrhenatheretea, b Fraxino-Ulmetum, c Alnetea glutinosae, d Artemisio-Salicetum albae, e open water and or, f settlement site excavation, g settlement site field survey, h vegetation influenced by man Salsolion ruthenicae, Fumario-Euphorbion and/or Polygonion avicularis, i Bronze Age structures from photographs.

Figure 4.9B: Palaeogeographical reconstruction of the Westwoud land consolidation area for the Late Bronze Age (ca. 800 BC). a Molinio-Arrhenatheretea, b Fraxino-Ulmetum, c Alnetea glutinosae, d Artemisio-Salicetum albae, e open water and or, f settlement site excavation, g settlement site field survey, h vegetation influenced by man Salsolion ruthenicae, Fumario-Euphorbion and/or Polygonion avicularis, i Bronze Age structures from photographs.

absent in the macrobotanical samples. Pollen and macrobotanical remains of sedges are, in contrast to ferns, abundant. However, the indicator species *Carex elongata* is absent. Therefore, a more specific subdivision is not possible.

At the drier surfaces a forest of the class Querco-Fagetea could develop. Within this class, a subdivision in orders and alliances is made, based on, amongst others, the nutrient availability of the soil. Due to the local high groundwater level and high calcium carbonate content, a forest of the Alno-Padion alliance is expected. Species belonging to this alliance, like ash (*Fraxinus excelsior*) and elm (*Ulmus*) in the pollen data suggest the presence of a hardwood alluvial forest of the Alno-Padion.

At the driest soils, a forest from the class Querco Fagetea can also be expected. Based on the nutrient availability of the soil and deep groundwater level, a forest of the Carpinion betuli alliance would be expected. However, some important indicator species like lime (*Tilia cordata*) are absent in the macrobotanical data. Lime shows low values in the pollen spectra. Indicator species of the expected associated edges of the forest (class Rhamno-Prunetea) like sloe (*Prunus spinosa*) are absent. Especially the stones of sloe plums are usually widely found in Bronze Age settlements (RADAR 2010). Within the rich botanic data these stones should be present, if the sloe plum has been collected. Indicator species for outer edges and clearances of the class Gallio-Urticetea are present, although common nettle (*Urtica dioica*) and cleavers (*Galium aparine*) are also very common in settlement areas. Where woody vegetation has disappeared completely the class Molinio-Arrhenatheretea is considered to be present. Indicator species of this class are clearly visible in the macrobotanical data, like *Ranunculus acris, Rumex acetosa, Prunella vulgaris, Taraxacum* *officinale* and *Phleum pratense pratense*. Apparently the grazing pressure was high and prevented the succession to woodland. Finally, the influence of man is clearly visible in the presence of indicator species of the ruderal biotopes like Artemisietea vulgaris, arable biotopes like Stellarietea mediae and medium nutrient rich grasslands like Plantaginetea majori.

By the Late Bronze Age the groundwater level had gradually increased by approximately 1 meter compared to the Middle Bronze Age. Apart from this gradual rise of the groundwater level, the seasonal fluctuation of the surface water level had strongly increased as well. These two factors caused a gradual change in the biotopes within the study area. In the enlarged surface of the shallow lakes a reed swamp (Phragmitetea) of the order Sparganio- Glycerion and/or Oenanthion aquaticae developed. Along the borders of the lakes a soft wood willow shrub (Salicetea purpureae) developed. For both biotopes the indicator species are present in high numbers (Appendix 2). The other biotopes are still present in the study area, but at different locations compared to the Middle Bronze Age.

Cronau (2016) used a comparable strategy to reconstruct the appearance of the landscape of West-Frisia in the Middle Bronze Age by an analysis of zoological remains. An important premise in his analysis is the idea that all zoological remains found during excavations represent species which were present in the environment surrounding the settlement sites. Therefore, Cronau deliberately uses the counts of species, instead of the counts of individuals. He argues that all species represent healthy reproducing populations. With the zoological database of the sites of eastern West-Frisia, Cronau calculates different surfaces of preferred vegetation for all species. He also takes the surface used by man and his domestic animals into account, based on an estimated value by Van Amerongen (2016). Cronau concludes that the carrying capacity of the eastern West-Frisian landscape has been sufficient for healthy reproducing populations of game, man and his domestic animals. He also concludes that the grazing pressure was high, which probably affected the vegetation at the richest soils, resulting in a more parkland like vegetation. Based on his analysis he expects the following types of woodland present during the Middle Bronze Age: Fago-Quercetum, Thelypterido-Alnetum, Carici elongatae-Alnetum and Artemisio-Salicetum albae, which corresponds very well with the previously presented results.

4.4.3. Topography

A last element which has to be added to the palaeogeographical reconstruction is the topography (figure 4.9). Settlement sites are represented based on the results of excavations and a field survey. Locations where a (part of a) house plan or terp ditches have been excavated are represented as settlement sites. Interpretation of the results of the field survey is less simple. During the eighties a field survey was carried out (De Vries-Metz 1993). During this survey many finds dating to the Bronze Age were found. The pottery is divided into Hoogkarspel Oud (Middle Bronze Age) and Hoogkarspel Jong (Late Bronze Age). The pottery dating to the Middle Bronze Age has a coarse temper and is vulnerable to mechanical weathering, contrary to the pottery dating to the Late Bronze Age. Therefore it is thought that Late Bronze Age pottery is overrepresented in field surveys (Roessingh in prep.; IJzereef and Van Regteren Altena 1991, 65). It appears that finds of Late Bronze Age pottery always coincide with Late and Middle Bronze Age features contrary to the reverse (IJzereef and Van Regteren Altena 1991; Roessingh in prep.). Clusters of Late Bronze Age pottery are therefore mapped as settlement sites in the 1500 and 800 BC reconstruction. Clusters of Middle Bronze Age pottery are only represented in the 1500 BC reconstruction. Loose finds are plotted on the map as well. It is very important to note that the numbers of finds are highly dependent on local visibility of archeological remains. Furthermore it is important to note that the field survey of the northern part was far more detailed compared to the southern part of the land consolidation area (figure 4.5).

Extensive ditch systems are known from all excavations. The detail of these systems is too much to present at this map scale. Sometimes these field systems are visible in aerial photographs. During the period of the land consolidation projects aerial photos were taken by Willy Metz (1993). She kindly gave access to her extensive photo archive with over 4000 (!) analogue photographs of the eastern part of West-Frisia.[69] These photographs are a great resource for the recognition of field systems, burial mounds and even a few settlement sites in the land consolidation area *De Streek*. There were two problems, however, in using the photographs. First the topography

69 Thanks to Carla Soonius, the community archaeologist for West-Frisia, all photographs have been made digitally available.

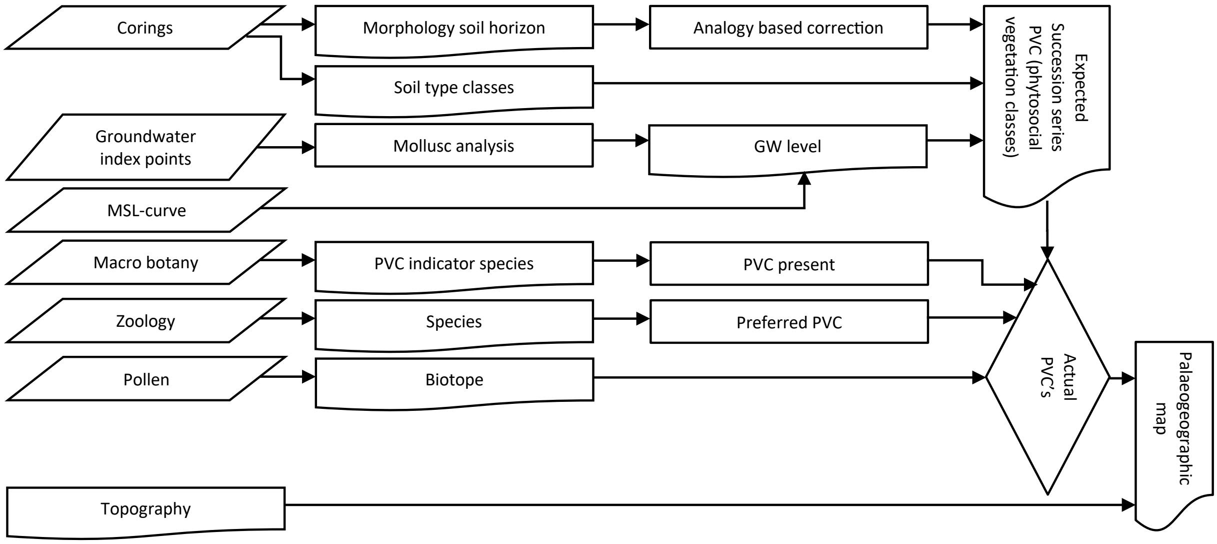


Figure 4.10: Flow chart for the palaeogeographical reconstruction of Westwoud.

has greatly changed (see figure 2.4), therefore it is difficult to georeference the photos. Second, all photographs are oblique and therefore difficult to use in a GIS. With a lot of effort all available photos (26) for the land consolidation area *Westwoud* have been incorporated in a GIS.[70] All visible ditch systems have been depicted in figure 4.9.

West-Frisia was a vast tidal marsh in the Early Bronze Age. Such marshes should be (based on modern analogies) intersected by creeks. Therefore, the absence of residual gullies is remarkable. During excavations in the recent decades, only at two settlement sites dating to the Bronze Age in eastern West-Frisia was a residual gully found, *Bovenkarspel-Het Valkje* and *Noorderboekert*. At both locations the gully was active in the Late Neolithic and had been silted up completely at the start of the Middle Bronze Age. In the aerial photos residual gullies are absent within the Westwoud land consolidation area. In the excavated areas the farm yards are surrounded by arable fields. In the palaeogeographical reconstruction the settlement sites are surrounded by arable fields and pastures. It is thought that the arable fields can be expected on the rich soils, the same part of the landscape which apparently had a high grazing pressure preventing the succession of Fagetalia sylvaticae. Van Amerongen (2016) estimated a surface needed for a single farm for a sustainable production of crops, pastures and woodland. The area needed for arable fields and pastures is represented by a circle of *c.* 19 hectares around the settlement sites.

4.5. Concluding remarks

Constructing a palaeogeographical map for a wetland is always a laborious task (figure 4.10). Each project has its own challenges. The construction of a reliable subsurface model is difficult and the quality depends largely on the distribution and quality of the available or collectable data. The conversion from lithological information to meaningful soil type classes in order to predict the succession of plant communities is relatively easy.

The reconstruction of the palaeorelief of a wetland is an educated guess independent of the chosen method. The drainage situation of the subsoil at the start of the exploitation and changes of the drainage situation over time are unknown factors. The influence of man on this process is an unpredictable factor, even for prehistoric times. For example, it is known that artificial drainage of peat and clay soils in Walcheren (the Netherlands) caused subsidence leading to a large impact of floods at the end of the Iron Age and in the Early Roman period (Vos and Van Heeringen 1997). The amount and depth of the ditches in Bronze Age West-Frisia will certainly have contributed to local subsidence. Due to the variation in lithology and unknown parameters for the starting

70 With many thanks for the accurate processing and georeferencing of the photos by Esther Eilering.

point, it is impossible to estimate the actual impact. Subsidence of clayey soils due to artificial drainage can reach a substantial part of its original volume (De Bakker and Locher 1990, 312-316). Historic and modern water resource management combined with lithological variation influence the local subsidence rate and can cause large differences in the relief of former landscapes (Borger 1975, 74).

Traditional groundwater index points are hard to obtain in a wetland area due to compaction and local influences as noted by Weerts (2013, 166-167). Feature-depths of water pits and/or ditches are unsuitable for constructing reliable groundwater index points. In the case of Westwoud an estimation of the groundwater level could be made using molluscs sampled from features. Not only molluscs but all kind of water organisms like ostracods, diatoms and forams can be useful in the construction of groundwater index points. During excavations one should be aware of the importance of obtaining high quality samples from suitable locations in order to provide reliable groundwater index points.

With the combination of soil suitability classes, a relief model and a groundwater model, a natural succession can be predicted for each unit. An analysis of on-site assembled macrobotanical remains on indicator species unveils the presence of different phytosocial vegetation classes within the catchment area. In this way the classes can be placed in geographical space. The influence of man, which blurs most vegetation reconstructions based on (on site) pollen analysis, can be evaded this way. In a similar way zoological data can be used to evaluate the reconstruction (Cronau 2016).

5 Site location: local variation or uniformity?

5.1. Introduction

In chapter 3 and 4 palaeogeographical reconstructions were presented at different map scales. The maps presented in chapter 3 are useful to understand the general geography of West-Frisia and changes in its appearance over time. It also explains changes in exploitability in general terms and main routes of transportation. The maps presented in chapter 4 show information about the exploitability of the environment surrounding settlement sites and changes over time. In this chapter the focus lies on the local variation in the subsurface of the site locations, in order to understand which parts of the landscape were favoured for settlement sites.

In 1991 IJzereef and Van Regteren Altena suggested a close relationship between relief and settlement layout for the Middle Bronze Age of West-Frisia. In their publication, the authors suggest that all settlement sites were situated at creek ridges or at least in close proximity to these ridges (IJzereef and Van Regteren Altena 1991, 67). In their opinion, the first houses were built on the higher parts of the flanks of the creek ridges. During the habitation in the Middle Bronze Age, the houses were displaced to the lower parts of the flanks of the creek ridges. In the Late Bronze Age, the houses moved to small terp mounds situated at the higher parts of the ridges (figure 5.1). Since the excavation of *Enkhuizen-Kadijken* it is clear this is not true for all sites (Roessingh and Lohof 2011, 299).

In order to get a grip on the relation between the nature of the subsurface and site location, the key sites of the *"Farmers of the Coast"* research project, are evaluated for information on the subsoil. This evaluation should result in a general idea on site location. These ideas about site location will be tested in the case-study of *De Rikkert*.

Figure 5.1: Habitation model according to IJzereef and Van Regteren Altena (1991). From left to right the situation at the start of the Middle Bronze Age, the end of the Middle Bronze Age and the Late Bronze Age. Legend: a marsh area, b flanks of creekridge, c creek ridge, d house, e house situated on a terp mound bordered by a terp ditch.

Figure 5.2: Ditches of the site Hoogkarspel-Watertoren plotted on the map of Ente (1963) (After: Bakker et al. 1977, 194, figure 7). Legend: a ditches, b loamy sand to sandy loam, c sandy loam to loam, d sandy loam to loam overlying (silty) clay loam, e deeply humose soils induced by man.

5.2. The model

As early as 1959 a relation between the nature of the subsoil and the location of a burial mound was attested by Bakker (1959, 173). Bakker used the then unpublished soil map of Ente (1963) to understand the location of *Tumulus I* of the site *Hoogkarspel* (Bakker 1959, 183). In a later publication he plotted all excavated features uncovered during the subsequent excavations of the *Hoogkarspel* sites on this soil map (Bakker *et al.* 1977, 192). He observed: "*The ditch density displays a striking relation to Ente's soil map.*" and "*In the North, one can see a compromise between the current*[71] *rectangular ditch system and the desire to include a loam ridge running diagonal to this system: the enclosures thus have a diamond shape*" (Bakker *et al.* 1977, 192; figure 5.2). In other words, it is thought that relief and soil types were meaningful to the inhabitants in relation to the settlement location and layout. Not only at the *Hoogkarspel* site was this relationship presumed. IJzereef and Van Regteren Altena (1991, 67) suggest for the site *Bovenkarspel-Het Valkje* that the orientation of the individual houses was determined by the orientation of the "sandy" creek ridge during the entire period of habitation. Just like Bakker *et al.* (1977), IJzereef and Van Regteren Altena (1991, 66) depict the soil map of Ente (1963) underneath the maps with the layout of the excavation to emphasize their argument.

Two critical remarks can be made about these observations, interpretations and use of Ente's soil map. First of all, the map of Ente (1963) is a soil map with a complex section type legend. The soil map describes the successive lithological units to a depth of 125 cm below the surface. The successive lithological units are described in four classes: *deeply humose soils*, *"kiek" clay*, *"knik" or "pik" layer* and *westfrisian marine clay soils*. The first class, *deeply humose soils,* is the result of drainage and tillage by man of former peat lands. In general this layer is dated to the Middle Ages and later. The second layer, *"kiek" clay*, is related to the enlargement of the lakes in the Flevomeer area. The third layer, *"knik" or "pik" layer*, refers to the (cultivated) Bronze Age top soil. The last layer refers to, as the name suggests, the marine deposits in the Bergen tidal basin. All layers are subdivided based on organic matter content and grain size distribution. The map definitely does not reflect geomorphological elements like levees, creek ridges or relief classes. Although Ente (1963, 67) mentions that creek ridges often consist of relatively sandy soils, he specifically mentions that this is not always the case. Therefore the simple translation of sandy soils into creek ridges and clayey soils into tidal marshes or floodbasins, used in many archaeological publications, is incorrect.

Secondly the map is published on a scale of 1:20.000 and based on an average of 6 corings per hectare. Ente (1963, 4) specifically states that the map units cannot **and** do not reflect the actual detail

71 Middle Bronze Age.

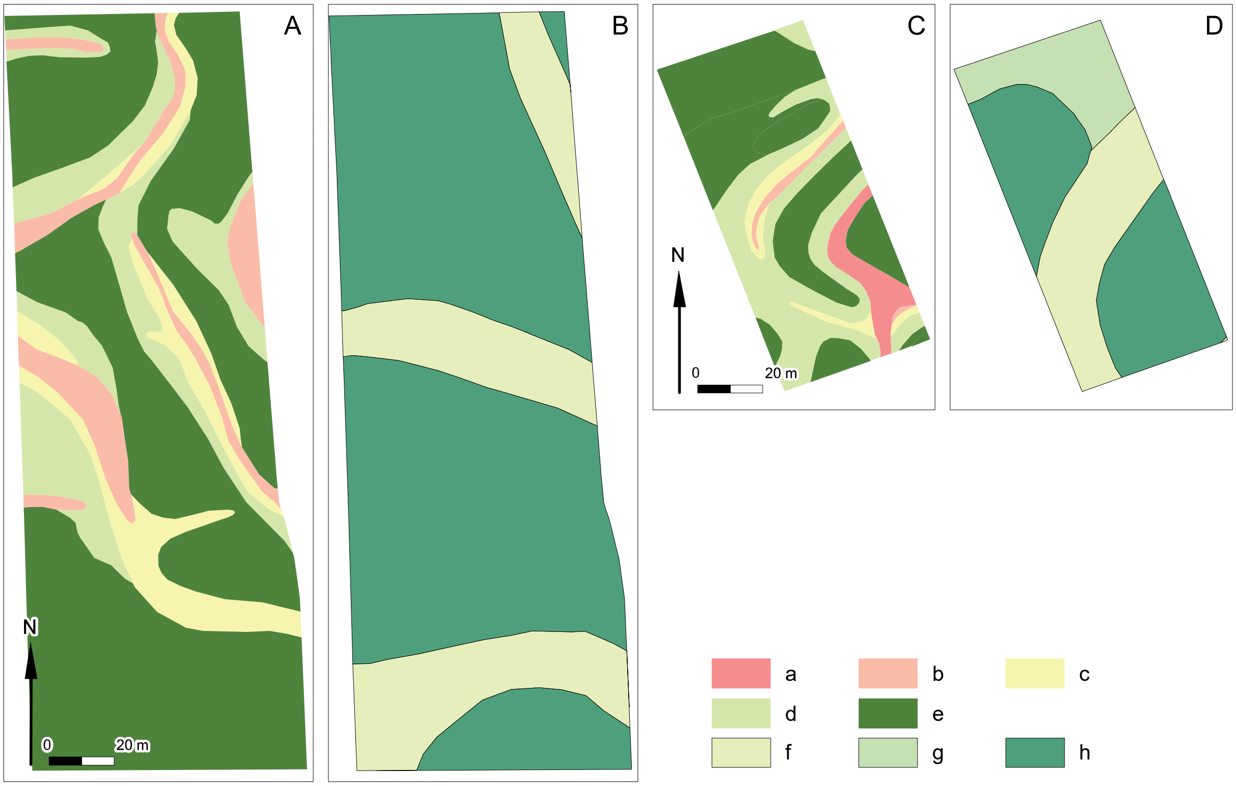


Figure 5.3: A Detailed soil map of a parcel in Andijk presenting the 'westfrisian marine clay soils' based on c. 100 corings/hectare (After: Ente 1963, 4, figure 3A). B The same parcel and soil units at the soil map of Ente (1963) based on c. 6 corings/hectare. C Detailed map of a parcel in Hout presenting the 'westfrisian marine clay soils' based on c. 100 corings/hectare (simplified after: Ente 1963, 14, figure 5A) D The same parcel and soil units at the soil map of Ente (1963) based on c. 6 corings/hectare. Legend: a loamy sand to sandy loam over (sandy) loam b sandy loam, c (sandy) loam over (silty) clay loam, d (silty) clay loam over (sandy) loam, e (silty) clay loam, f sandy loam to loam, g sandy loam to loam overlying (silty) clay loam, h (silty) clay loam.

present in the landscape. He illustrates this problem with two detailed maps of a parcel in Andijk (Ente 1963, 4; figure 5.3A) and a parcel in Hout (Ente 1963, 14; figure 5.3C) with a density up to an average of 100 corings per hectare (Ente 1963, 14). Obviously there is only a slight resemblance between both maps. For archaeological purposes the detail of figure 5.3A and 5.3C is needed. In the absence of such detailed maps, the map of Ente is often magnified ten times or more (for example Bakker *et al.* 1977 or Hakvoort and Jansen 2012). One should bear in mind that the map is not designed for such uncritical use.

5.3. An uniform description

In every archaeological project at least one or more soil sections are described. In the field of archaeology there is consensus on the necessity of the documentation of the local stratigraphy by analysis of one or more soil sections. The description method of these soil sections is always subject to debate. In general several elements are included: colour, lithology, archaeological features, soil formation, lithostratigraphy, lithogenesis and sedimentary characteristics. Only for the description of the lithology is the use of a standard common practice. In the Netherlands different standards for the description of the lithology (grain size distribution, organic matter content and $CaCO^3$-content) have been in use. These standards are known as "Stiboka", "Verbraeck" and "NEN5104" (resp.: De Bakker and Schelling 1966; Verbraeck 1984; Nederlands Normalistatie Instituut 1989). In 1997 a committee of archaeologists and earth scientists developed a standardized method for the documentation of soil sections and corings in which NEN5104 was chosen as the standard for the description of the lithology (Projectgroep Archeologie HSL 2001). Despite the consensus on the necessity of standardisation, standardisation of the description method of soil sections is not an issue in the Dutch Archaeology Quality Standard (CCvD

2013). Depending on education and experience, archaeologists describe sections in more or less detail and quality and certainly not in a standardized way, with the exception of the grain size distribution, organic matter content and $CaCO^3$-content.

In order to compare the information on the subsoil of the different sites (§ 5.4), the original documentation on sections has been consulted, including photographs and technical reports. The lithological units have been transposed into USDA soil taxonomy terminology following the example of Van der Veer (2006, Appendix I). For each excavation a representative cross-section is selected and described. Furthermore, information retrieved from soil samples is summarized.

5.4. A selection of sites

In West-Frisia over 90 excavations revealed features dating to the Bronze Age (Roessingh in prep.). Many of these sites have not or only partly been published. Within the *"Farmers of the Coast"* research project, the excavation results of the sites *Hoogkarspel*, *Andijk*, *Bovenkarspel-Het Valkje*, *Medemblik-Schepenwijk* and *Enkhuizen-Kadijken* are selected for an analysis of settlement sites. These five sites have been chosen, because they cover relatively large areas and are thought to be representative for Bronze Age settlement sites in West-Frisia. The first three sites were excavated in advance of or during the period of land consolidation projects. These sites have not been published in full. The documentation of these sites was available in an analogue format and had to be digitized. The last two sites were excavated more recently in advance of housing development projects. These sites have been published in full and all documents are digitally available.

5.4.1. Hoogkarspel

During the soil survey, Ente and his co-workers mapped several barrows close to the water tower in the village of Hoogkarspel. In 1958 one of those barrows was partly levelled by the owner of the parcel. A rescue excavation was undertaken by the archaeological institute of the University of Amsterdam (Bakker 1959). This excavation is the first of a series of excavations in the municipality of Hoogkarspel. In successive years between 1965 and 1979 large parts were excavated with test trenches and trenches. Three excavated units can be distinguished, *Hoogkarspel-Watertoren*, *Hoogkarspel-Tumuli* and *Hoogkarspel-Tolhuis* (figure 5.4). The last unit, *Hoogkarspel-Tolhuis*, is also referred to collectively as *Hoogkarspel-Tolhek*, *Medemblikker-Tolhuis*, *Medemblikker-Tolhek* or simply *Tolhek*, *Tolhuis* or *Tolweg* in the literature. The unit *Hoogkarspel-Tolhuis* is further subdivided into smaller units A to F. The barrows have been excavated separately and are referred to as *Tumulus,* followed by a number and a letter. All excavations have been carried out by the archaeological institute of the University of Amsterdam with the exception of *Tumulus I A*, which was excavated by the archaeological institute of Leiden University (Modderman 1974). In this chapter this complex of excavations is referred to by the name *Hoogkarspel*.

The first use of the *Hoogkarspel* site is dated to the Early Bronze Age, based on the presence of a pit with Barbed Wire pottery. The location of this pit is unclear. Brandt (1988, 217) places this pit in the western part of the *Watertoren* excavation. Bakker (2004, 98) places this pit in the north-eastern part of the excavation. Based on an analysis of the excavation data Roessingh suggests for the entire complex a date in the Middle and Late Bronze Age between 1500 and 800 BC with an emphasis on the periods 1400-1200 and 900-800 BC for the use as settlement site (Roessingh in prep.). According to Roessingh (in prep.) the tumuli have to be dated in the Middle Bronze Age. All dates have to be used with some reservation due to the lack of a solid dated framework for this site (Roessingh in prep.).

During the excavations many sections have been documented by archaeologists. In their descriptions of the sections they focus on the stratigraphy of features. Therefore, most of the sections have been described with great detail to features. The sampling for pollen, macrobotanical remains and molluscs was also mainly focused on the features. In contrast to these often detailed descriptions of archaeological stratigraphy and sampling, the nature of the subsoil is described in a very general way. In the technical report it is mentioned that the subsoil in some areas is more clayey compared to other areas within the excavation. Very little information on sedimentary characteristics is available. In the technical reports sampling of the subsoil for diatoms, pollen and molluscs is mentioned.[72] These analyses are briefly

72 The molluscs have been analyzed by W.J. Kuijper, the diatoms by M.J. Jansma and the pollen and spores by B. van Geel and C.C. Bakels.

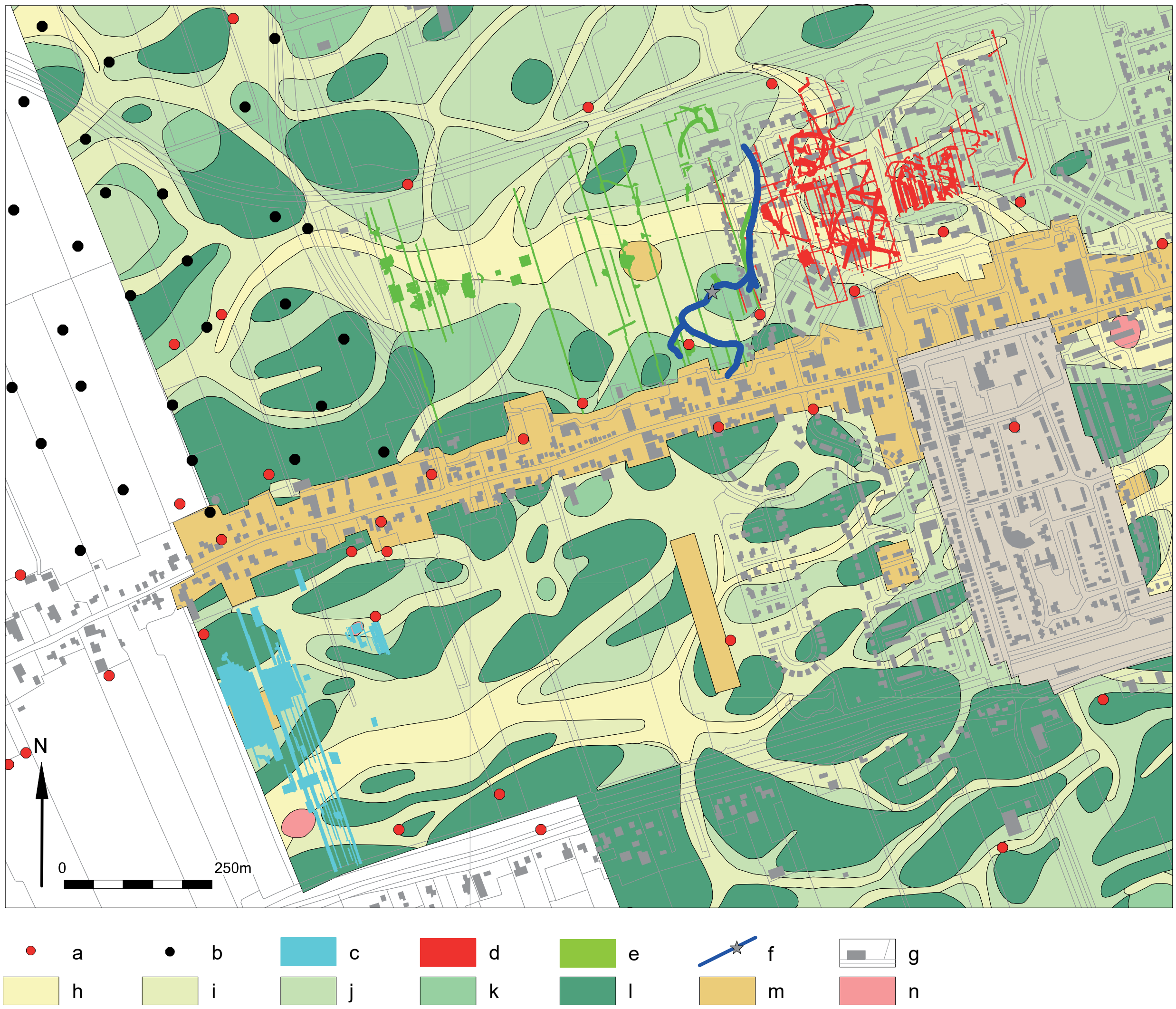


Figure 5.4: Overview of archaeological research of Hoogkarspel plotted on the soil map of Ente (1963). Legend: a coring (DINO-Loket), b coring Stiboka, c trenches excavation Hoogkarspel-Tolhuis, d trenches excavation Hoogkarspel-Watertoren, e trenches excavation Hoogkarspel-Tumuli, f "breakthrough" gully and location section figure 5.5, g modern topography, h loamy sand to sandy loam, i sandy loam to loam, j sandy loam to loam overlying (silty) clay loam, k thick (25-60 cm) (silty) clay loam soils overlying (20-30 cm) sandy loam to loam, sometimes underlain by (silty) clay loam, l (silty) clay loam, m deeply humose soils induced by man, n ancient settlement soils.

reported by Bakker *et al.* (1977, 197-204). In the technical reports several visits of Ente (Stiboka), De Jong (Geological Survey) and a visit of Zagwijn (Geological Survey) are reported. In two sentences the visit of these soil scientists are summarized: "*… het profiel…en het horizontale vlak … met zoden zijn typisch voor kwelderzoden. Zijn (Ente) indruk is dat het kwelderstadium zeer snel verlopen is.*"[73] Any arguments for this interpretation are absent.

Detailed information on the landscape is mainly provided by Bakker in Bakker *et al.* (1977, 192-196). In this publication he gives a lot of thought on the relief in relation to the subsoil. During the *Hoogkarspel* excavations, a relief difference of 100 cm was attested between the highest and the lowest part of the settlement sites. The higher parts are characterized by a sandy subsoil, whereas the lower parts are characterized by a clayey subsoil. According to Bakker the *Hoogkarspel* site is situated at two parallel oriented sandy stretches which probably represent tidal gullies (figure 5.4). Bakker discusses the nature of the sediment flanking these gullies.

73 "The soil in the section and excavation floor are typical for a tidal marsh environment with a high sedimentation rate." Technical report 17-08-1965.

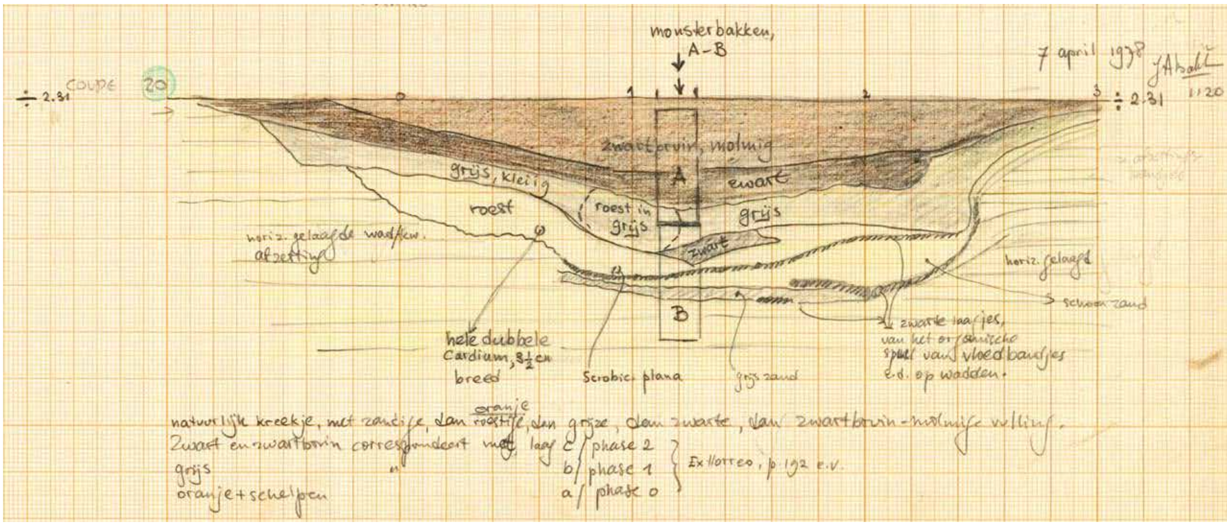


Figure 5.5: Cross-section of the breakthrough gully drawn by Bakker. The position of the section is indicated in figure 5.4 (Source: Digital Production Centre University of Amsterdam).

Two contradicting interpretations are presented, salt marshes and tidal flats. Bakker refers to personal communication with Ente over an interpretation as tidal flat. Bakker is aware that this interpretation needs an explanation for the drying of these tidal flats and relief inversion accounting for the current differences in the relief. Bakker refers to "other specialists" for the interpretation as a high salt marsh. He concludes the discussion with the observation that: "*a generally accepted geomorphological model is not yet available*" (Bakker *et al.* 1977, 196).

Interesting in the publication of the site *Hoogkarspel-Watertoren* by Bakker is the description of a gully that cuts through the northern sand stretch at a right angle (figure 5.4). This gully is described by Bakker as a breakthrough gully in analogy to the breakthrough gullies described by Louwe Kooijmans in the central river area (Louwe Kooijmans 1974, 102). This type of gully is caused by different surface water levels in the basins on either side of a ridge. The water breaches the ridge causing a small channel and levelling the surface water in both basins. Characteristic for these channels are the fan shaped splays in the basins on either side of the ridge at the mouth of the gully. In figure 5.5 one of the scarce well-documented cross-sections of the gully is depicted. The drawing clearly shows the lack of lateral displacement of the gully. The channel deposits consist of fine sand and contain doublets of molluscs like *Scrobicularia plana* and *Cerastoderma* (in figure 5.5 noted as: *Cardium*). The subsoil shows a distinct horizontal bedding which is thinning upwards. The note "*wad/kw. afzettingen*" illustrates the questioning of the nature of the subsoil. The diatom samples taken from the subsoil indicate a marine to marine-brackish environment (Bakker *et al.* 1977, 197) The mollusc samples taken from the channel deposits of the gully indicate a shallow brackish environment by the high numbers of *Peringia ulvae*, *Littorina saxatilis saxatilis*, *Hydrobia stagnorum* and *Cerastoderma glaucum*. The other species present are *Ovatella myosotis*, *Mytilus edulis*, *Cerastoderma edule edule* and *Macoma balthica* (Bakker *et al.* 1977, 198-199). This population is representative for a shallow, vegetated brackish environment intersected by creeks. Probably there were higher grounds or salt marshes in the immediate vicinity. Pollen in the subsoil was severely corroded and therefore not informative (Bakker *et al.* 1977, 197-198).

A proper date of the gully is not provided. The absence of archaeological material in the channel deposits is striking. The gully has been excavated over a length of approximately 500 meters. One should expect some archaeological material like pottery and bone to be present as channel lag deposit in these channel deposits. Therefore an early date for this gully is suggested. Furthermore mollusc analysis of features represent an exclusively freshwater environment for the Middle and Late Bronze Age (Bakker *et al.* 1977, 198). This is supported by the analysis of spores and macrobotanical remains of features dating to the Middle Bronze Age and later (resp. Bakker *et al.* 1977, 197-198 and 200-204). The chronology of events at

Figure 5.6: Gully cutting the creek ridge at the site Noorderboekert. The surface with ard marks dates to the Late Neolithic and Early Bronze Age (Photo: ArchOL BV).

the *Hoogkarspel* site shows some resemblance to the *Noorderboekert* and *Rijweg* sites. These sites were exploited in the Late Neolithic and Early Bronze Age (§ 3.5.6). After the Early Bronze Age sedimentation took place and gullies, cutting the creekridge at a right angle, were formed (figure 5.6). These sediments represent comparable environments with the breakthrough gully of *Hoogkarspel* (§ 3.5.6). Based on the resemblance in environment, stratigraphy and morphology it is reasonable to place this breakthrough gully in this short sedimentation phase.

Based on the presented data, the lithology at the site of *Hoogkarspel* can be described as follows. The base of the sediments consists of a calcareous sandy loam to loam. This sandy loam to loam is, as far as it has been described, horizontally bedded and thinning upwards. In the north eastern part of the *Hoogkarspel* site, a small gully, the previously described "breakthroughgully", cuts through the top of this layer. The top of the sediment is decalcified and enriched with organic matter by soil formation. The archaeological features are visible underneath the A-horizon. This horizon is also visible underneath the tumuli. The A-horizon varies in colour. In the more sandy subsurface and underneath the tumuli the soil has a greyish colour. At other locations the horizon is almost black. Locally the A-horizon is covered with a thin layer of sandy loam or loam. In the top of this layer a second A-horizon has developed. Features are present under both A-horizons. Based on the distribution and appearance of this layer, an artificial origin is suggested.[74] The top of this Bronze Age landscape is covered by a brown layer, which is interpreted as dredging mud. The top of this mud is incorporated in the modern plough layer.

5.4.2. Andijk

The excavation of the well-preserved *Hoogkarspel* sites made archaeologists of the Dutch State Archaeological Service (ROB) aware of the upcoming destruction of this well-preserved prehistoric landscape by the planned land consolidation project. Based on a large scale field survey of the land consolidation area *De Streek*, north and south of the village of Andijk test trenches were dug. These excavations are known as *Andijk-Noord* and *Andijk-Zuid* (IJzereef and Van Regteren Altena 1991, 61). In this publication is referred to these two sites as *Andijk*. In figure 5.7 an overview of the trenches is presented. Based on an evaluation of the available data, amongst others the absence of Hoogkarspel Jong pottery, the site is dated to the Middle Bronze Age. A more exact date is not possible (Roessingh in prep.). Both sites will be published in full by Roessingh (in prep.).

74 Technical reports 13-03-1967, 21-04-1967 and 27-04-1967; drawing of soil section trench 12, November 1966.

Figure 5.7: Overview of archaeological research of Andijk plotted on the soil map of Ente (1963). Legend: a coring (DINO-Loket), b trenches excavation Andijk-Noord, c trenches excavation Andijk-Zuid, d location section, e loamy sand to sandy loam, f sandy loam to loam, g sandy loam to loam overlying (silty) clay loam, h (silty) clay loam, i "kiek"clay, j deeply humose soils induced by man, k modern topography.

Very little is known of the stratigraphy of these two sites. A sketch of the stratigraphy and a poorly documented soil section (figure 5.8) is all that is left on the stratigraphy in the documentation of this excavation. The technical reports of the excavations are lost. The soil map of *De Streek* (Ente 1963) suggests a relatively clayey subsoil. The few coring descriptions available in the DINO-database support this description. Remarkable is the absence of a sand body in all coring descriptions. Although every description presents a layer of sandy (clay) loam of 20 to 80 cm within the first 120 cm.

Based on the corings and the few notes on the drawings, the base of the section can be described as a calcareous sandy (clay) loam. The top is enriched with organic matter and is decalcified. Underneath the top features dating to the Middle Bronze Age are present including ard marks. The top is covered with an oxidized layer of peat. The nature of this peat is unknown. The peat is non erosive covered with clay. The top of this clay is incorporated in the modern plough zone.

5.4.3. Bovenkarspel-Het Valkje

Based on the previously mentioned survey and the experience during the excavation in Andijk, the Dutch State Archaeological Service (ROB) decided to excavate an area of approximately 18 hectares in Bovenkarspel. This excavation is known as *Bovenkarspel-Het Valkje*. Only the bone assemblage of this site has been published in full by IJzereef (1981). The botanical data has been published by Buurman (1996) and Van Amerongen (2016). An adjacent area of 61 hectares south of the excavated area has been preserved for future research (IJzereef and Van Regteren Altena 1991, 61-62). This area is known as *Bovenkarspel-Monument*. In this area three small-scale excavations have been conducted in the period of the land consolidation project. In 2002 a fourth excavation, known as *Bovenkarspel-De Geerling* was carried out. The four excavations were published in 2004 (Van Heeringen *et al.* 2004). In figure 5.9 an overview of the trenches is presented. The site is dated in the Middle and Late Bronze Age between 1600 and 800 BC according to Roessingh (in prep.).

From the Bovenkarspel sites a large number of soil sections has been documented in detail, amounting to a total of almost 4 km length. Little information

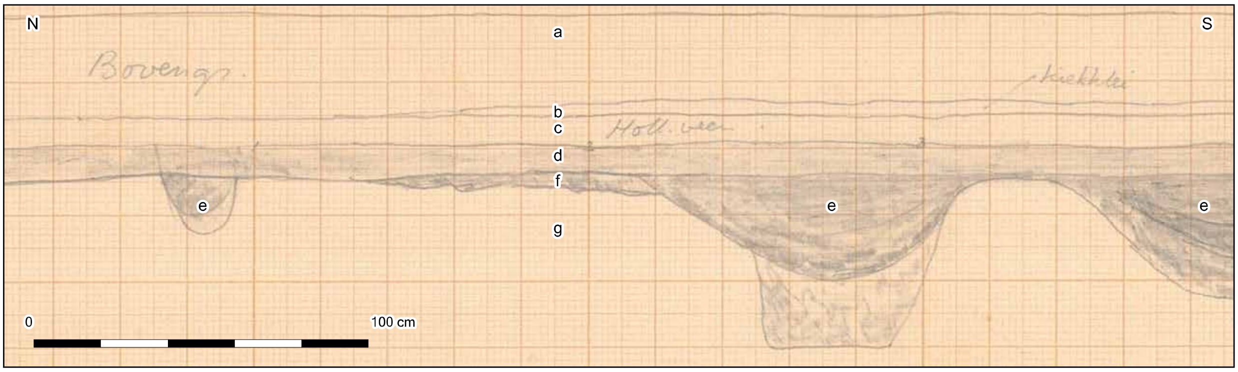


Figure 5.8: Detail of soil section Andijk-Noord (Source: Provinciaal depot voor archeologie Noord-Holland). Legend: a modern plough zone, b "kiek" clay, c oxidized peat, d decalcified humic (clay) loam, e feature Middle Bronze Age, f feature ard marks, g calcareous sandy loam.

has been written on the drawings of the sections. Although a large number of samples were taken during the excavation for a wide variety of research (mollusc analysis, macrobotanical analysis, pollen analysis, phosphate analysis and so on), little of this research has actually been realized. Interesting is the schematic drawing of the bedding in a large number of sections. Based on these sketches the impression of the environment is quite different to the environment of *Andijk*, *Hoogkarspel*, *Medemblik* and *Enkhuizen*. In these excavations the natural sediment is characterized by a planar lamination. At the site of Bovenkarspel the natural sediment is characterized by a cross stratification. The first is, amongst others, common in tidal marsh deposits, the second in channel deposits.

During the excavation several sections were discussed with Ente (Stiboka) and De Jong (Geological Survey). In the technical reports of the excavation the information from these earth scientists is shortly summarized. According to these notes, the base of the sections consists of tidal flat deposits gradually changing into tidal marsh deposits. Ente questions the interpretation as tidal marsh deposits, whereas De Jong has no doubts. The discussion focuses on the planar lamination of the top of the natural sediments, which is typical for a tidal marsh according to De Jong. Ente reasons that such stratification is also possible in mud flats. Due to the close proximity of a tidal channel he suggests that an interpretation as mudflat should be taken into account. In the top of the marsh deposits a soil has developed. Little attention is given to the nature and genesis of this horizon by both earth scientists. Based on the drawings, the nature of the A-horizon varies in the excavation in stratigraphy, lithology, organic matter content and colour. Locally the horizon is covered by a thin peat layer and/or "kiek" clay. Remarkable is the absence of peat in the drawings of the sections. In most sections a brown layer interpreted as "baggerdek" (dredging mud), covers the soil horizon. In figure 5.10 a detail of a section is depicted.

The researchers divided the soil horizon into two stratigraphical layers. The lower unit is dated to the Middle Bronze Age, the upper unit to the Late Bronze Age. In the excavation reports this is simply stated as a fact. No additional research has been carried out for a better understanding of this division. Not one section contains sediment between the supposed Middle and Late Bronze Age layer, contrary to the sections of *Hoogkarspel*. Therefore a sedimentation phase in between the Middle and Late Bronze Age can be excluded at this site. Two explanations can be given for this division. First, the soil formation conditions have been changed during the Bronze Age. For example, a substantial change in the groundwater depth and fluctuation can lead to a different breakdown process of organic matter, explaining the difference in colour and lithology of the upper layer, compared to the lower layer. Second, gradual sedimentation has taken place from the Late Bronze Age onwards for example during seasonal flooding. At the time of the excavation these kinds of ideas could have been tested with micromorphology. Since the project leader of the excavation was well acquainted with this kind of technique, this has apparently not been an issue.

Two deep (up to 3 meters) sections have been documented at a right angle to the supposed tidal channel (cross-sections trench 200-201 and 250, figure 5.9-5.12). The cross-sections present a classic section of a silted up channel with distinct levees. A

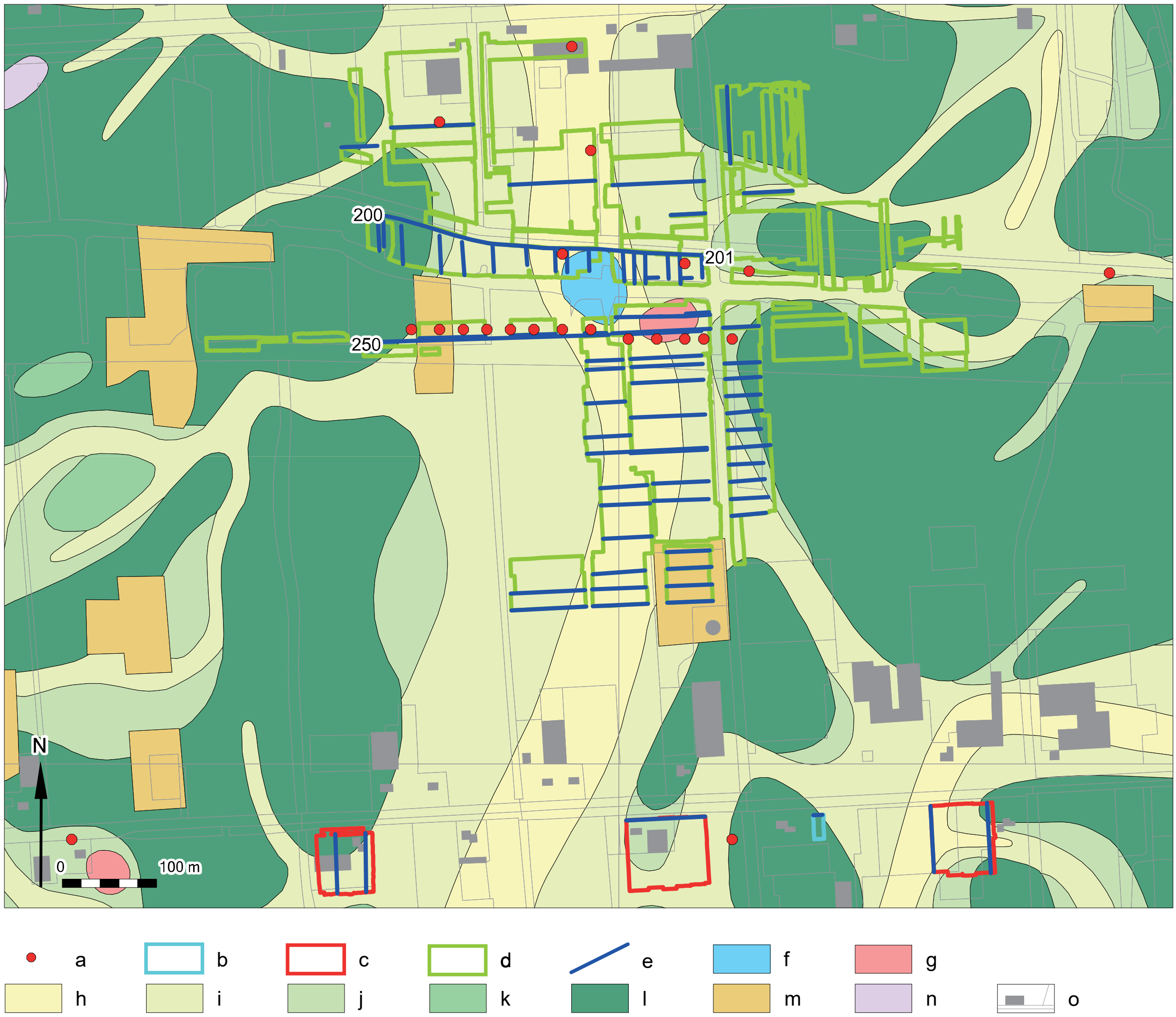


Figure 5.9: Overview of archaeological research of Bovenkarspel plotted on the soil map of Ente (1963). Legend: a coring (DINO-Loket), b trenches excavation Bovenkarspel-De Geerling, c trenches excavation Bovenkarspel-Monument, d trenches excavation Bovenkarspel-Het Valkje, e location section, f, water, g ancient settlement soils, h loamy sand to sandy loam, i sandy loam to loam, j sandy loam to loam overlying (silty) clay loam, k thick (25-60 cm) (silty) clay loam soils overlying (20-30 cm) sandy loam to loam, sometimes underlain by (silty) clay loam, l (silty) clay loam, m deeply humose soils induced by man, n peat, o modern topography.

clear residual gully was present in the centre of these sections (figure 5.11). This residual gully was silted up completely at the start of the habitation in the Middle Bronze Age. A sedimentological description of both cross-sections has been published by Roep and Van Regteren Altena (1988). One of the sections (250) has been completed with corings down to the Pleistocene subsoil. According to this description the sections contain two superimposed channel systems. Off-centre of the channel deposits, the systems are separated by a peaty clay representing a lagoonal phase. The youngest channel system contains thick layers with climbing ripples indicating a rapid accumulation. The changes in stratification from bottom to top indicate decreasing flow velocities over time. The levees present mostly sharp laminations of sand and clay. Only towards the top is the typical crinkly bedding indicative of vegetated levees present. The same is attested for the tidal marsh deposits accompanying the levees. At the base of the tidal marsh deposits a distinct layer of *Scrobicularia plana* is present. The top of the levees and tidal marshes is relatively sandy. In the top of the tidal marsh deposits small and shallow channel fills occur. These observations also indicate high sedimentation rates. Roep and Van Regteren Altena (1988) suggest the

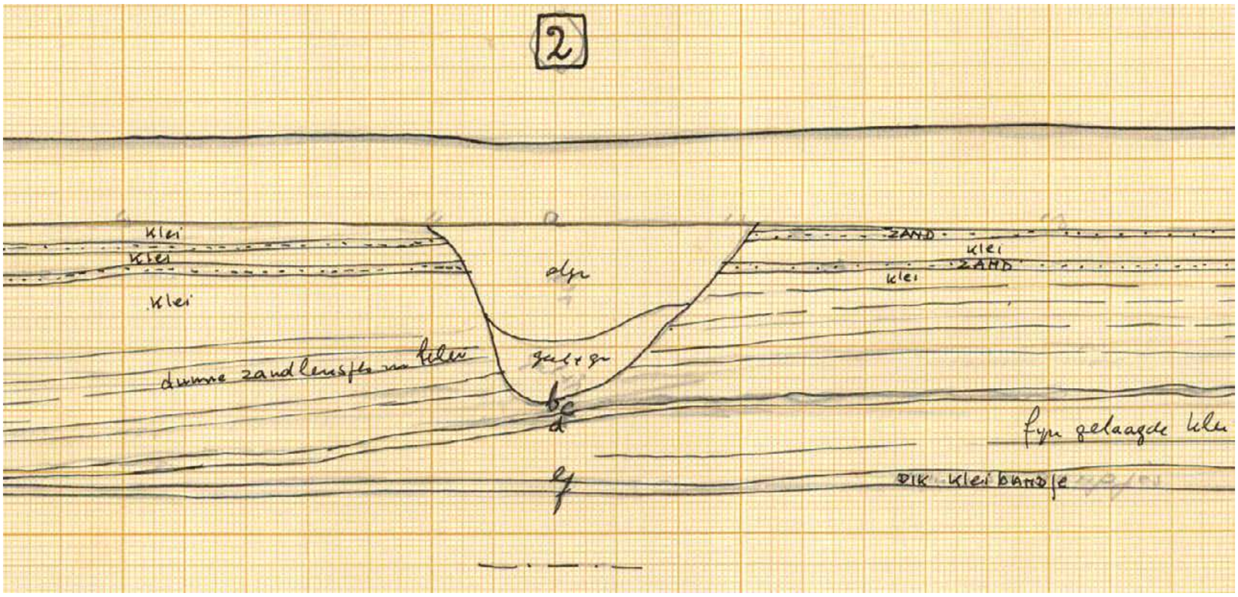


Figure 5.10: Detail of a soil section Bovenkarspel-Monument (Source: Provinciaal depot voor archeologie Noord-Holland). Legend: a plough zone, b feature, c crinkled layering sand and clay, d Scrobicularia plana, e fine layers of clay, f massive clay.

Figure 5.11: Detail of a cross-section of the residual gully at Bovenkarspel-Het Valkje (Source: Provinciaal depot voor archeologie Noord-Holland).

rapid sedimentation as a result of storm enhanced currents.

Roep and Van Regteren Altena (1988) suggest that compaction of the levees and tidal marsh deposits had already taken place at the start of the Middle Bronze Age. In their opinion the compaction led to inversion of the relief. However, in § 2.5.1. and 4.5 it is argued that the compaction only partly took place in the Middle Bronze Age and relief inversion did not occur. The largest part of the compaction occurred from the Middle Ages onwards as a result of an artificial lowering of the groundwater level, a process which still continues. Roessingh (in prep.) calculates a height difference of 120 cm in the Bronze Age top soil. He uses surface height measurements and height measurements of the top of the trench floors for his computation. This calculated height difference is not corrected for differential subsidence and reflects the present day height difference in the Bronze Age surface. Therefore it is reasonable to expect that the height difference in the Middle Bronze Age was smaller than the computed 120 cm

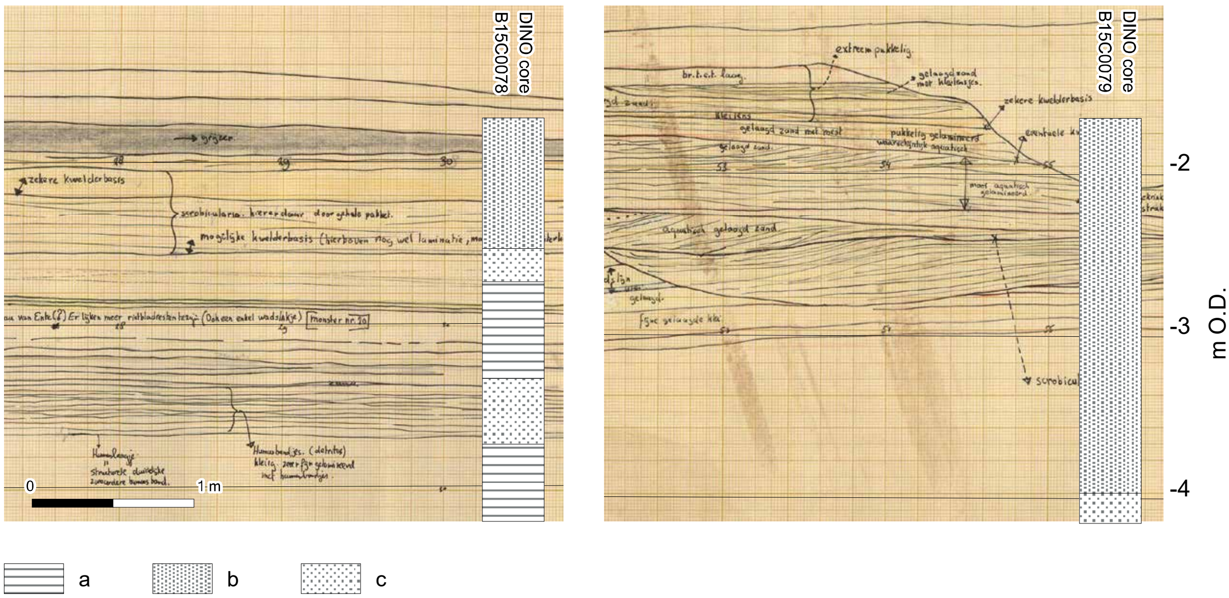


Figure 5.12: Details of cross-section 250 and DINO-coring with tidal marsh deposits (left) and channel deposits (right) (Source: Provinciaal depot voor archeologie Noord-Holland). Legend: a clay loam, b loamy sand, c sand.

and that the site of *Bovenkarspel* was situated at a slightly elevated ridge in the Bronze Age landscape. Probably the well-drained sandy top soil was more meaningful to the inhabitants than the slightly higher elevation. The distribution of the houses, orientation of the settlement site and the ditch system suggest the first over the latter (Roessingh in prep.), a situation which was also observed by Bakker *et al.* (1977, 192) for the *Hoogkarspel* site.

5.4.4. Medemblik-Schepenwijk and Schuitenvoerderslaan

Medemblik is a small town in West-Frisia. The first historical sources date to the 9th century AD (Besteman 1979, 210). The research into the early medieval history of Medemblik by the University of Amsterdam led coincidentally to the discovery of two Bronze Age settlement sites (Besteman 1977, 257; Besteman 1979, 217-218). Between 1967 and 1969 part of a settlement site was excavated at a construction plot (De Boer 2013). This site is known as *Medemblik-Schuitenvoerderslaan*. In 1996 in advance of the development of a residential area named *Schepenwijk*, in a plot next to the area excavated in the sixties, a desktop study combined with an assessment with manual corings was conducted (De Rooij and Soonius 1997). In 1997 test-trenching was conducted (De Rooij and Thanos 1997), during this assessment features dating to the Middle and Late Bronze Age were found. A follow-up with a full excavation was not achievable at that time. In 2006 the second part of the construction plot was once again subject to desk top study research and assessment with manual corings (Buitenhuis and Mulder 2006). An assessment with test-trenches was conducted in 2006 and followed by an excavation in 2007 (Van Benthem 2007; Schurmans 2010). Figure 5.13 presents an overview of the research and the location of documented soil sections. The site is dated to the Middle and Late Bronze Age between 1450 and 1100 BC and 900 and 800 BC (Schurmans 2010, 144-146).

During the excavations in the sixties almost every section was documented. The section depicted in figure 5.13 was published by Besteman (1977) for its completeness of the stratigraphy. Part of the original drawing is depicted in figure 5.14. During the excavation of 2007 only one section was documented. The location of this section is also depicted in figure 5.13. Although the description of both sections is detailed when it comes to archaeological phenomena, the information on the subsoil is poor. The lithological descriptions of the subsoil in the available corings from archaeological projects are not helpful at all for clarifying the stratigraphy, due to the poor quality of the descriptions and the shallow depth. Most corings end in fine sand within 120 cm below the surface level. The few corings which have been placed into deeper levels, present clay underneath the sand body of the supposed creek ridge.

Figure 5.13: Overview of archaeological research of Medemblik-Schepenwijk and Schuitenvoerderslaan plotted on the soil map of Du Burck and Dekker (1975). Legend: a coring (DINO-Loket), b coring Stiboka, c coring (De Rooij and Soonius 1997), d coring (Buitenhuis and Mulder 2006), e coring with (loamy) sand, f trenches excavation Medemblik-Schuitenvoerderslaan (De Boer 2006), g test trenches (De Rooij and Thanos 1997), h test trenches (Van Benthem 2007), i excavated area (Schurmans 2010), j location of soil sections, k modern topography, l loamy sand to sand, m sandy loam to loamy sand, n loam to sandy loam, o kiekclay (20-40 cm) on loamy sand to sand, p soil with alternating lithology with or without (20-40 cm) kiekclay cover, q lake deposits (>80 cm).

In the documented sections, the base is characterized by calcareous, sandy clay loam to very or extremely fine sand. All photographs and descriptions of the sections present a clear planar stratification in this sediment. The sediment is fining upwards. The top of the sand body is decalcified and enriched with organic matter and can be interpreted as an A-horizon. In this horizon pottery dating to the Middle and Late Bronze Age is incorporated. Underneath the horizon, features dating to the Middle and Late Bronze Age are present. The horizon is erosively covered with a thin layer of clayey peat to very humic clay or (clay) loam. In the descriptions of the depicted section in figure 5.14 it is suggested that this sediment originated as a gyttja (Besteman 1977, 255). The organic matter is strongly oxidized and was not investigated in the sixties or during the excavation of 2007. This peaty layer is covered with several layers of clay. The oldest layer consists of decalcified clay, contains charcoal and gradually develops into a second layer of clay, which is characterized by a large amount of burned clay, charcoal and some pottery dating to the Medieval period. Features dating to the Medieval period are present in and underneath this layer. The layer is covered with a third layer of decalcified clay. In this layer charcoal and small particles of burned clay are present. The entire section is covered with a very humic clay. In this layer medieval and prehistoric pottery appear, which suggests that these finds are in a secondary position. The top of this layer is incorporated in the modern plough layer.

Based on the excavations, it is thought that the sites *Schuitenvoerderslaan* and *Schepenwijk* were situated at a small creek ridge. This interpretation is based on the height differences in the Bronze Age surface level within the excavated area. The interpretation is understandable given the available data. For example Schurmans (2010, 17) noted a height difference in the top of the Bronze Age surface of almost one meter (-1.30 m O.D. to -2.20 m O.D.). Furthermore in the low southeast corner of the excavation the top of the Bronze Age surface is far more clayey compared to the higher parts. The available soil map also suggests a southwest-northeast oriented stretch with sandier sediments (figure 5.13). Although this interpretation is understandable given these observations and the available habitation model, two observations should have led to a critical evaluation of this interpretation:

- Where are the outer limits of the sites/cultivated landscape?
- How to explain the distribution of sand (figure 5.13) in relation to the "small creek ridge"?

As described in chapter 4, differential subsidence due to changes in hydrology and sedimentation are of great influence on height differences in the present day landscape. Therefore the present day height differences do not reflect the height differences of the landscape of the past. Therefore, the question arises whether the creek ridges, as they are observed in the present day landscape, were an equally recognizable geomorphological unit in the Bronze Age landscape. Apart from that the used soil map is a section type map, which reflects the successive lithological units of the first 120 cm below the present day surface in a generalized way. It does not reflect geomorphological or geomorphogenetic units and therefore cannot be used as such. A comparison of the soil map with the distribution of corings with a sandy subsoil (figure 5.13 unit e) presents, not surprisingly, a partially contradicting image. Apparently, outside the borders of the sandy stretch, sand bodies occur. An analysis of the sand depth of all the sand bodies shows that the highest sand elevations occur outside the excavated areas. Despite the presence of sand bodies outside the sandy stretch, during the coring campaigns no archaeological finds appeared to be present in this area. The soil section of *Schuitenvoerderslaan* explains partially why archaeological finds were absent in the coring campaigns (figure 5.14). When the top of the Bronze Age surface is incorporated in the modern plough zone, the chance of finding indications for settlement sites, like charcoal, pottery and burned clay in a core are very small.

The follow-up of the coring campaigns with small and widely distributed trenches is not suitable for tracing settlement sites, as is argued by Roessingh (in prep.). In addition, the large amount of modern disturbances in the test trenches of the 2007 excavation are grounds for questioning the validity of the conclusion that the area is no part of the settlement site (Van Benthem 2007). Although the conclusions of the survey are questionable due to the small trenches and large surface with disturbances, the design of the survey is way better compared to the design of the test trenches carried out in 1997. During this survey the trenches were focused on locations with a positive result in the coring campaign. Locations with absence of archaeological finds have not been trenched at all!

This "sloppy" research process makes the excavation results of the *Medemblik* sites less useful for a site location analysis. The usefulness of these sites is hampered by the lack of additional information on the genesis of the subsoil and a relation between characteristics of the subsoil and archaeological features. Based on the presented data, the interpretation as settlement sites situated at a small creek ridge is questionable. With the presented data, an interpretation as a former tidal marsh is a likely possibility. A proper geoarchaeological assessment in the early phase of the research process possibly could have improved the interpretation. In chapter 6 the topic of the need for proper geoarchaeological assessments is discussed in more detail.

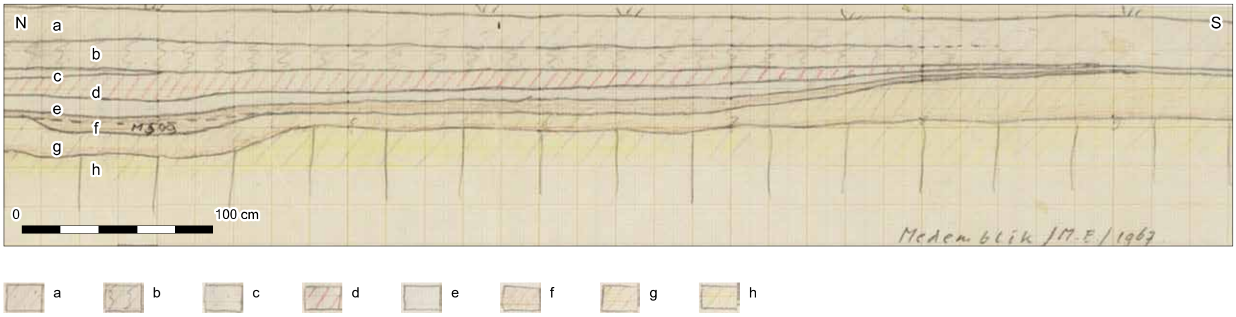


Figure 5.14: Detail of soil section Medemblik-Schuitenvoerderslaan (Source: Digital Production Centre University of Amsterdam). Legend: a modern plough zone, b decalcified very humic clay, c decalcified clay with particles of charcoal and burned clay, d decalcified very humic clay with medieval pottery, large amounts of burned clay and charcoal, e decalcified clay with small particles of charcoal, f oxidized peaty clay, g very humic clay or (clay) loam, h calcareous sandy loam.

5.4.5. Enkhuizen-Kadijken[75]

Enkhuizen-Kadijken is a construction plot northeast of the city of Enkhuizen. In 2006 a desktop study was published (Lohof 2006). Lohof (2006, 6) argues that the chances for a Bronze Age settlement site are high, due to a few finds of Bronze Age pottery during a field survey in 1954 at the plot. The presence of a burial mound just outside the perimeters of the plot strengthens his expectation (Lohof 2006, 6). During the land consolidation project the site was levelled. Therefore, Lohof advised an assessment of the completeness of the stratigraphy with hand coring equipment. This assessment was carried out shortly after the desktop study (Van Zijverden 2006). Large parts of the plot appeared to be intact and an assessment with test trenches was conducted (Roessingh and Van Zijverden 2007). It appeared to be a settlement site dating to the Middle and possibly Late Bronze Age. A small part of the plot (5A) was excavated due to the progress of the building activities (Roessingh and Lohof 2011). In 2009 the central part of the plot (5B) was excavated (Roessingh and Lohof 2011). In 2008 and 2010 an assessment with test trenches was conducted in the western part of the construction plot (Roessingh 2009; Roessingh 2010). Although the stratigraphy at this part of the plot was less well preserved, the features of a settlement site were well visible. A small stretch was excavated in 2011 (Roessingh and Vermue 2011). The last part of the construction plot was excavated in 2012 (Van der Linde and Hamburg 2014). Figure 5.15 presents an overview of the research and the location of documented soil sections. The site is dated to the Middle and Late Bronze Age between 1500 and 800 BC (Roessingh in prep.).

The base of the soil section consists of calcareous (silty) clay loam. In this clay some marine molluscs are present. The clay is only partially consolidated and any indications for soil formation are absent. The clay is abruptly covered with peat. The peat can be characterized as a *Carex* peat based on macrobotanical remains (figure 5.16). Towards the top the peat transforms gradually into a clayey peat or peaty clay. The top of the peat is eroded and covered by calcareous fining upwards sandy loam to (silty) clay loam. The sediment is characterized by a thinning upwards planar lamination. At the base of this unit many marine molluscs, like for example *Macoma balthica*, are present in a secondary context. The only molluscs in living position in this unit are exclusively *Scrobicularia plana*. In the top of this unit a soil horizon has developed, which is characterized by a slight decalcification and enrichment with organic matter. In this A-horizon, successive rows of small particles of charcoal (probably grasses) were observed in a thin section analysis (Roessingh and Lohof 2011, 391). Probably the grassy vegetation has been burned repeatedly. There are however, no additional indications for the presence of man. This unit is interpreted as a tidal marsh deposit.

The top of this unit is locally eroded and covered by a second unit of calcareous fining upwards sandy

75 The analysis of macrobotanical remains was carried out by C. Moolhuizen (ADC-ArcheoProjecten), the analysis of molluscs by W.J. Kuijper (Leiden University), the thin section analysis by R.P. Exaltus (ArcheoPro), K. van Kappel (ADC-ArcheoProjecten) and M. Pronk (VU University Amsterdam), the analysis of diatoms by H. de Wolf (WMC Kwartair Consultants). The physical geographical research and sampling was carried out by W.K. van Zijverden (ADC-ArcheoProjecten).

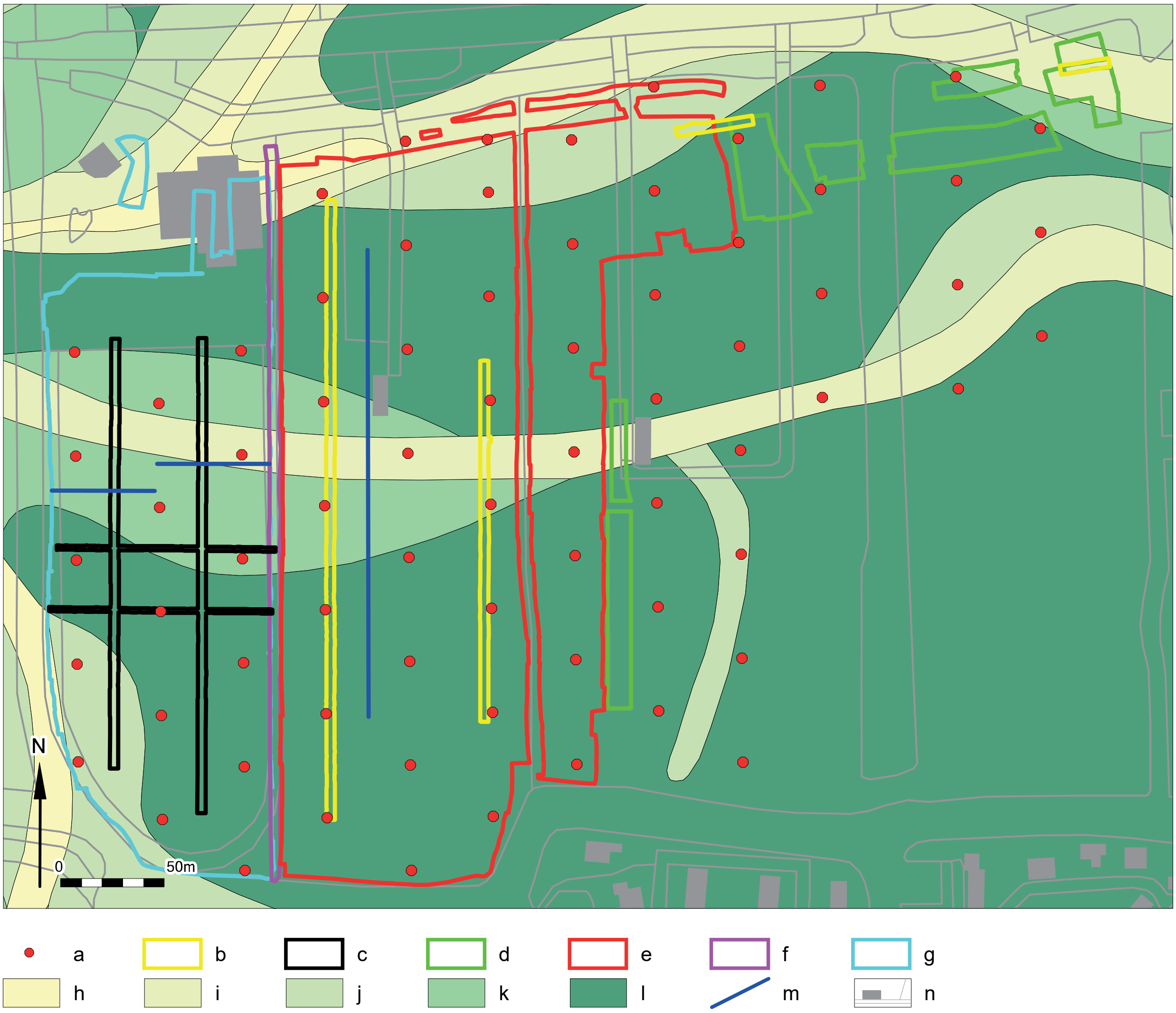


Figure 5.15: Overview of archaeological research of Enkhuizen-Kadijken plotted on the soil map of Ente (1963). Legend: a coring (Van Zijverden 2006), b test trenches (Roessingh and Van Zijverden 2007), c test trenches (Roessingh 2009; Roessingh 2010) d excavated area 5A (Roessingh and Lohof 2011), e excavated area 5 b (Roessingh and Lohof 2011), f excavated area (Roessingh and Vermue 2011), g excavated area (Van der Linde and Hamburg 2014), h loamy sand to sandy loam, i sandy loam to loam, j sandy loam to loam overlying (silty) clay loam, k thick (25-60 cm) (silty) clay loam soils overlying (20-30 cm) sandy loam to loam, sometimes underlain by (silty) clay loam, l (silty) clay loam, m location of soil sections, n modern topography.

loam to (silty) clay loam. The sediment is characterized by a thinning upwards planar stratification. In the center of the section the sediment is characterized by cross-stratification. The diatoms and molluscs indicate the presence of a small gully in a salt to brackish environment. The small gully has eroded the older underlying tidal marsh and peat deposits. The unit has been interpreted as a tidal marsh deposit. In the top of this unit a soil horizon has developed. This A-horizon consists of a very humic (silty) clay, which is decalcified. It is the top of this unit which represents the surface during the Bronze Age. In the northern part of the excavated area, a small area of this Bronze Age surface is covered with a thin (30 cm) layer of calcareous clay loam. Based on a diatom analysis and a thin section analysis this layer has probably originated within a very short time span, probably a single event (Lohof and Roessingh *et al.* 2011, 46). The diatoms indicate a brackish to freshwater environment. In the top of this unit an A-horizon has developed, which has been exploited in the Bronze Age. Therefore the event that caused this layer has to be placed in the Bronze Age. A more exact date could not be provided. Based on a thin section

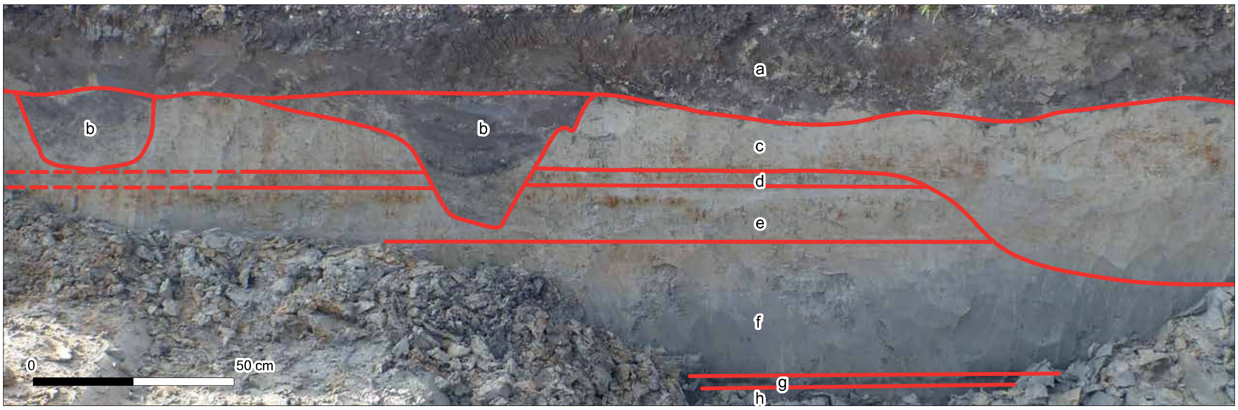


Figure 5.16: Soil section Enkhuizen-Kadijken (Photo: ArchOL BV). Legend: a modern plough zone, b features, c channel deposits, d soil horizon, e tidal marsh deposits, f tidal flat deposits, g clayey peat, h Carex peat.

analysis the soil became waterlogged over time and a diatomite clay developed, which represents a shallow freshwater lake (Pronk in prep.). The diatomite clay slowly developed into a regular non-calcareous clay. This unit is, based on the thin section analysis, interpreted as a back swamp environment. The top of this unit is incorporated in the present day plough zone.

5.4.6. A preliminary conclusion

After this evaluation of available information for the selected sites, which are supposed to be representative for Bronze Age settlement sites in West-Frisia, a generalized model can be drawn for each of the sites. In figure 5.17 a schematic sketch of the stratigraphy for each site location is presented (figure 5.17). The base of the section is formed by the fluvial sediments of the river Rhine and/or Vecht. These sediments are covered with a thin layer of cover sand. This landscape, dating to the Late Weichselian, is covered by a 10 to 13 meter thick cover of marine sands and clays alternating with peat layers. In the top of these sediments, channel deposits and levee deposits are present. These sediments have been formed before approximately 1800 BC. The silted up channels and their accompanying levee deposits formed larger or smaller creek ridges during the Late Neolithic and Early Bronze Age, depending on the compressibility of the subsoil, the age of the channel belt and the channel width. This landscape is covered by tidal flat and tidal marsh deposits. It is nearly impossible to distinguish tidal flat from tidal marsh deposits in the available dataset, due to the lack of information on the genesis of these deposits. In this layer channel deposits of former small creeks are present.

The tidal flat and marsh deposits have been draped over the previous landscape, leveling the former height differences in the Early Bronze Age landscape. For example at the *Noorderboekert* site, a cover of 250 cm in the lower parts of the previous landscape and less than 50 cm on the highest part of the previous landscape was present in the Middle Bronze Age. Therefore the former creek ridge of *Noorderboekert* was hardly visible in the landscape in the Middle Bronze Age. Contrary to the *Noorderboekert* site, the former creek ridge at the *Bovenkarspel* site has not been covered with tidal flat and/or tidal marsh deposits. In the Middle Bronze Age this former creek ridge was probably visible as a slight elevation in the landscape. The sites of *Andijk*, *Enkhuizen* and *Medemblik* are situated on top of tidal marsh deposits, distinct channel deposits are almost absent. At these sites probably little or no relief differences were present in the Middle Bronze Age. The same goes for a large part of the *Hoogkarspel* site. In the (probably) north-eastern part of the site, probably, a small channel belt dating to the Early Bronze Age is present. It would explain the presence of some Barbed Wire Pottery in this part of the site and channel deposits described by Bakker *et al.* 1977 as breakthrough gully.

Although any evidence is absent, it is likely that the large amount of Bronze Age ditches has contributed to differential subsidence of the top of the clayey and organic rich deposits to some extent. After all drainage of this type of sediments always results in subsidence.

This subsidence caused by man will have contributed to the natural subsidence. In the Late Bronze Age the relief difference will have been more pronounced compared to the Middle Bronze Age. The erection of small terp mounds at the sites of *Bovenkarspel* and *Hoogkarspel* in the Late Bronze Age points to recurring seasonal flooding (§ 3.6.2). Therefore small relief differences will have been of larger significance in the Late Bronze Age compared to the Middle Bronze Age. With this in mind, the present day height difference in the Bronze Age top soil of *Bovenkarspel* (110-240 cm -O.D.), *Andijk* (180-235 cm -O.D.), *Hoogkarspel* (80-170 cm -O.D.), *Medemblik-Schepenwijk* (165-245 cm -O.D.) and *Enkhuizen-Kadijken* (175-205 cm -O.D.) should be several centimeters or at the most a few decimeters, but not over a meter as is the case. Therefore, the present day height variation of the Bronze Age top soil is not representative for the situation in the Bronze Age as was also argued in § 4.3.3.

These small height differences will also have influenced the development of the landscape in and after the Late Bronze Age. At locations where the original top soil is intact, the top of the Middle Bronze Age surface is covered with diatomite, very fine clay and/or peat. It is important to realize that this selection of locations is not an a-select sample. This is due to the simple fact that the upper clay layer protects the underlying sediments from mechanical erosion by historic and modern land use. This layer is only present in originally lower parts of the landscape, therefore originally low lying areas are overrepresented. Despite the small and hampered dataset, apparently very different environments were simultaneously present in eastern West-Frisia at the end of the Late Bronze Age or shortly after this period. The simple statement that West-Frisia was covered by oligotrophic peat (Pons 1992, 48) at the end of the Late Bronze Age or shortly after is certainly not defendable. Oligotrophic peat has been locally present in West-Frisia and dates to various periods in and after the Bronze Age (§ 3.5.4; 3.5.5, 3.5.7 and 3.5.8). Most peats in West-Frisia however, start as gyttja or other eutrophic peat and stay eutrophic long after the Late Bronze Age (§ 3.5.4-10).

Summarizing: in the Middle and Late Bronze Age slightly higher areas in the landscape appear at three locations (figure 5.17):

1. Locations with channel deposits of creeks in the tidal flat and marsh deposits.
2. Locations where Neolithic and or Early Bronze Age channel deposits occur at the surface.
3. Locations where Neolithic and or Early Bronze Age channel deposits are covered with a thin layer of tidal marsh deposits.

Concluding: there is a relationship between landscape and settlement site location, as was previously suggested. Small height differences have been of influence as suggested by IJzereef and Van Regteren Altena (1991, 67), especially in the Late Bronze Age. These slightly higher locations cannot be characterized morphogenetically as creek ridges, with the exception of the *Bovenkarspel* site. There is definitely no relation between the units in the soil map of Ente (1963) or Du Burck and Dekker (1975) and the presence of settlement sites. This is clearly visible in the figures presented for each assessment of the local landscape (figure 5.3, 5.7, 5.9, 5.13 and 5.15). For each assessment features are present in all soil units, with the exception of the unit "peat". This unit is absent in all assessments. Apparently there is a relationship between the occurrence of boundaries between soil units and the layout plan of the settlement sites, especially for boundaries between sandy and clayey soils. It appears that boundaries between sand and clay are of influence on the parceling (Bakker *et al.* 1977; Schurmans 2010; Roessingh in prep.). It is important to state that this boundary between map units is strictly lithological and does not necessarily coincide with morphological or morphogenetic units.

5.5. The test: De Rikkert

Large parts of the land consolidation areas *De Streek* and *Westwoud* were surveyed in advance of and during the land consolidation projects, resulting in numerous finds of Bronze Age pottery. The Bronze Age finds of these surveys have never been properly analysed. In order to put survey finds in perspective, fieldwork was conducted in four successive years (2012-2015) at several parcels situated north of De Rikkert in Oosterdijk (figure 5.18). This fieldwork also provided an opportunity to conduct a small geoarchaeological assessment.

The first archaeological features at *De Rikkert* were found in 1935 when the landowner levelled a burial mound and found parts of a skeleton (Lehman 1963). In 1960 a small excavation of another burial mound was conducted at an adjacent parcel (Lehman 1963). In the period 1972-1975 a large scale field survey was

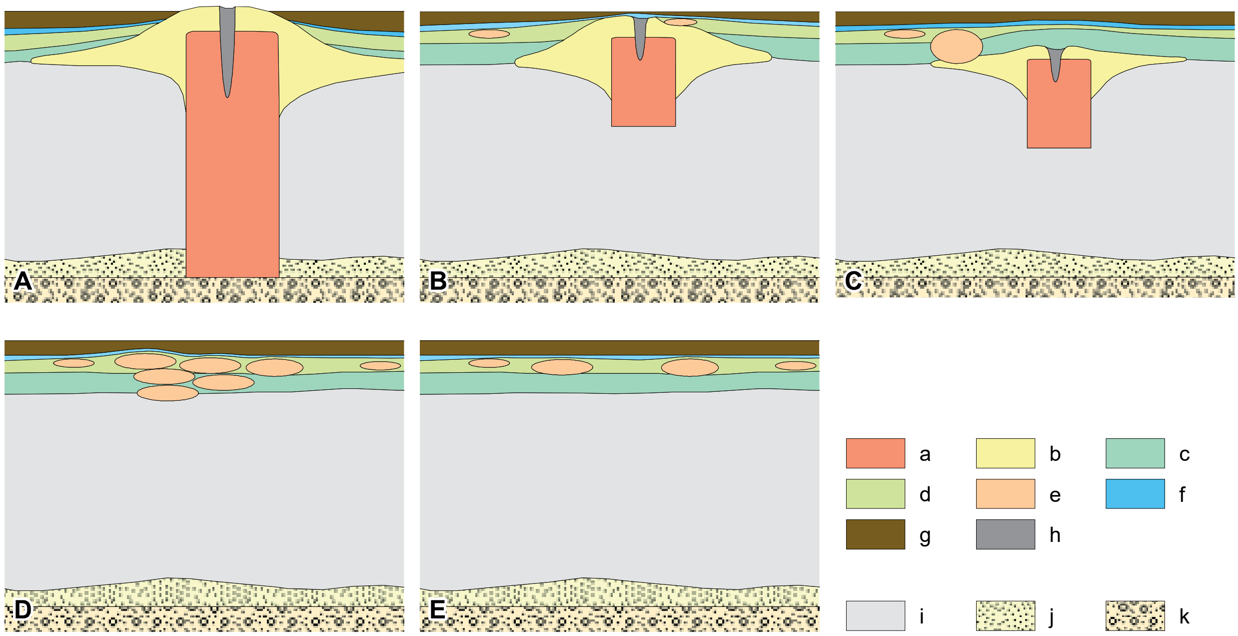


Figure 5.17: Schematic sketch of the landscape of Bovenkarspel (A), Hoogkarspel (B), Noorderboekert (C), De Rikkert (D) and Enkhuizen-Kadijken (E). Legend: a channel deposits, b levee deposits, c tidal flat deposits, d tidal marsh deposits, e small channel deposits, f lake deposits, g peat and/or clay, h residual gully deposits, I older marine deposits and/or peat, j cover sand, k fluvial deposits.

carried out in *De Streek* (Roessingh and Valentijn in prep.). During this survey several finds dating to the Bronze Age were found at *De Rikkert*. In addition to the survey, aerial photographs were analyzed revealing two possible burial mounds (De Vries-Metz 1993). This was the situation in 2012 when the Faculty of Archaeology of Leiden University organised a field survey for MA-students at *De Rikkert* (figure 5.18). During the survey, several corings were conducted in order to understand the lithogenesis. Based on the survey and a few additional corings, the stratigraphy was thought to be largely intact at one parcel. This parcel was selected for a small scale excavation, which was carried out by the *"Farmers of the Coast"* project group and students in 2013.

The excavation proved that a complete stratigraphy, including sediments dating after the Bronze Age was present. A sample of this complete stratigraphy was taken for micromorphologic, pollen, phytolith and macrobotanical research.[76] After the excavation a part of the parcel was investigated with geophysical methods (electric conductivity).[77] Later that year a second field survey and additional corings were carried out. In 2014 the adjacent parcel was investigated with small trenches and an additional geophysical research was conducted. In 2015 two series of small pits (1 m^2) were dug manually in order to test different field methods for prospection in West-Frisia. During this fieldwork, additional geophysical research was conducted (electrical conductivity and magnetometer).[78]

The base of the cross-section (figure 5.19) consists of a small peat layer, probably reed peat. This layer is covered by calcareous clay loam. In this sediment various small molluscs like *Scrobicularia plana* and juvenile *Cardium edule edule* are present. The sediment is slightly fining upwards and the lamination is thinning upwards. Based on these characteristics the layer is interpreted as tidal flat and tidal marsh deposits. A distinct division between these two lithogenetical units could not be made in the field. In the centre of the section a small body with channel deposits is present at the base of this layer. In the southern part

76 Micromorphology carried out by C. French (Cambridge University), pollen by M. Doorenbosch (Leiden University), Phytoliths by W. Out (Universität Kiel), Macrobotanical remains by E. van Hees (Leiden University).

77 Geophysical research carried out by W. Verschoof (RAAP BV).

78 Geophysical research carried out by W. Verschoof (RAAP BV) and a team of the Römisch-Germanische Kommission of the Deutschen Archäologischen Institut in Frankfurt.

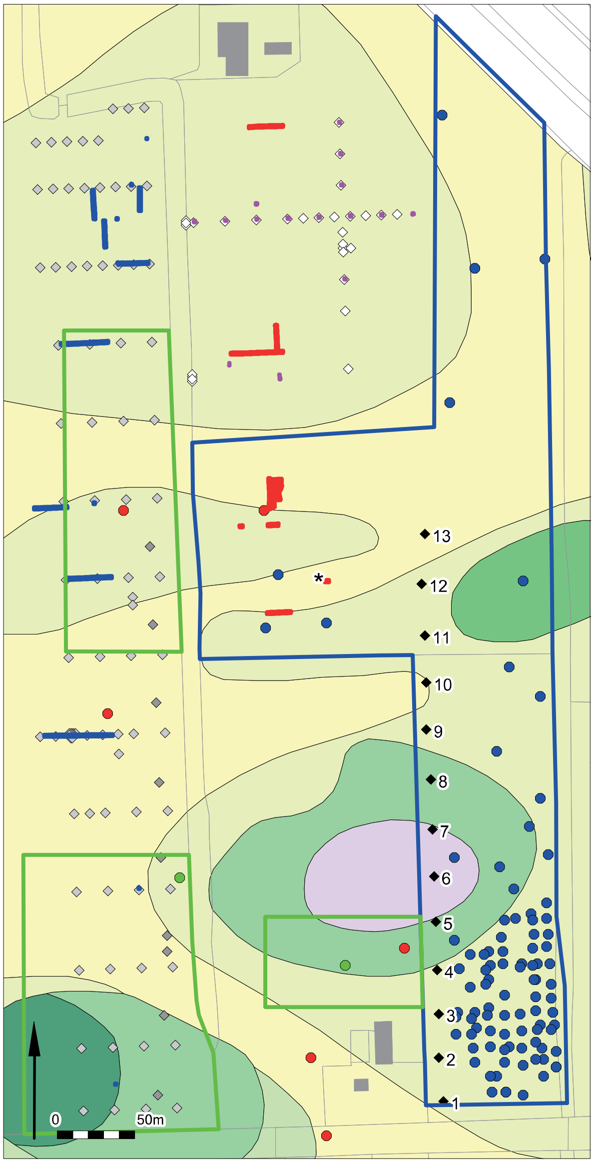
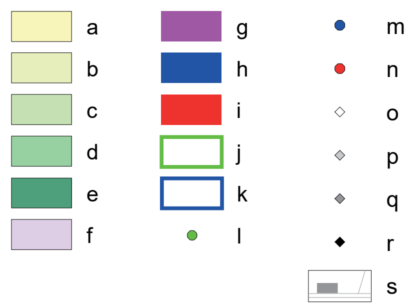


*Figure 5.18: Overview of archaeological research De Rikkert plotted on the soil map of Ente (1963). Legend: a loamy sand to sandy loam, b sandy loam to loam, c sandy loam to loam overlying (silty) clay loam, d thick (25-60 cm) (silty) clay loam soils overlying (20-30 cm) sandy loam to loam, sometimes underlain by (silty) clay loam e (silty) clay loam, f peat, g trench 2015, h trench 2014, i trench 2013, j surveyed in 2013, k surveyed in 2012, l Bronze Age finds survey 2013, m Bronze Age finds survey 2012, n Bronze Age finds survey 1972-1975, o corings 2015, p corings 2014, q corings 2013, r corings 2012, s modern topography. The location of the soil sample depicted in figure 5.20 is indicated by an *.*



a second body with channel deposits is present in the top of the layer. The top of the tidal marsh deposits and channel deposits is decalcified and enriched with organic matter. This zone represents a former top soil. The layer is covered with a layer of calcareous clay loam. The sediment is fining upwards and the lamination is thinning upwards. In the southern part of the section channel deposits are present which cut through the underlying layer. The top of this layer is decalcified, homogenized and enriched with organic matter due to soil formation. In the southern part this soil horizon is completely incorporated in the modern plough zone. In the northern half of the section only the top of the soil horizon is incorporated in the modern plough zone.

Two observations on this cross-section are of interest. First, in the top of coring 6 and 7 a peat layer was expected based on the soil map by Ente (1963). This peat layer is absent in these corings and finds are present in the top of this soil unit. Furthermore, peat is actually present more to the north in the area investigated by trenches in 2013. Second, the present day surface in the southern part is slightly higher compared to the central and northern part of the section. Due to levelling by modern land use, the height difference is nowadays 20 centimeters at the most, but probably was a little larger originally. The height differences are caused by the presence of the channel deposits in the subsurface. It is important to note that the relief differences are caused by stacked bodies of channel deposits (see coring 2, 3 and 4) and not single bodies of channel deposits. A comparable observation has been made in detailed cross-sections of a crevasse complex in the river area in the central part of The Netherlands (Van Zijverden 2002). This crevasse complex showed a complex morphology of superimposed crevasse channel deposits. The detailed cross-sections made clear that the elevations were not representing single crevasse channels but elevations caused by stacked bodies of channel deposits. This idea is apparently also applicable to some elevations in West-Frisia, which are traditionally interpreted as creek ridges.

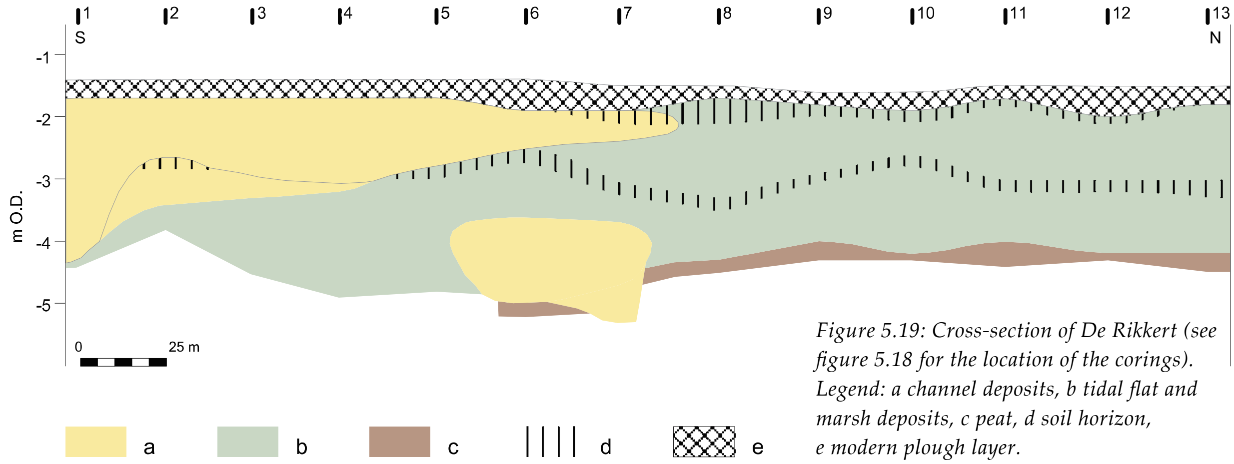


Figure 5.19: Cross-section of De Rikkert (see figure 5.18 for the location of the corings). Legend: a channel deposits, b tidal flat and marsh deposits, c peat, d soil horizon, e modern plough layer.

In 2013 several small trenches revealed a complete stratigraphy of the Bronze Age soil and later sediments (figure 5.20). The soil horizon was homogenized due to ploughing in the Bronze Age. Clear ard marks were present under the A-horizon. The micromorphological research by French (Roessingh and Valentijn in prep.) confirmed that the layer has been ploughed. Macrobotanical remains were not preserved at all and pollen was poorly preserved in this layer. The pollen grains that could be identified by Doorenbosch (Roessingh and Valentijn in prep.) represented pollen which are to be expected in arable land, like *Triticum*, *Hordeum*, Chenopodiaceae and *Plantago lanceolata*. The high numbers of pollen of *Alnus* and *Corylus* point to the presence of alder carr and hazel shrubs in the surroundings. These pollen types are also present in almost identical percentages in the lowest part of the overlying peat. Based on the almost identical pollen content of the base of the peat and the top of the A-horizon, it is suggested by Doorenbosch (Roessingh and Valentijn in prep.) that the pollen probably represent the base of the peat. The horizon contained phytolits, which are considerably weathered according to Out (Roessingh and Valentijn in prep.). The assemblage indicates the presence, in particular, of grasses and further some sedges and a modest presence of dicots (herbs and woody plants). Grasses of the *Pooideae* grass subfamily were present in the sample. This subfamily includes wild grasses but also wheat (*Triticum* sp.) and barley (*Hordeum* sp.). Part of the assemblage has a black discoloration, which may well have resulted from the burning of vegetation.

The overlying peat contained large particles of charcoal. Based on the micromorphological analysis and micro charcoal particles content in the pollen slides, it is suggested that the charcoal is only present at the base of the peat. Several particles were selected for an AMS-date, which resulted in a date in the Late Roman or Early Medieval period.[79] In the micromorphological research the presence of small layers of very fine sand and silt crusts were observed. These indicate that the peat has been flooded irregularly and fell dry. Based on the pollen analysis the peat can be characterized as a eutrophic peat, probably an alder carr. Pollen of cereals are present all through the peat layer, indicating that farming continued in this area.

The peat layer is covered by clay. According to the micromorphological analysis by French (Roessingh and Valentijn in prep.) this clay represents an environment with a variable stream velocity. Probably the landscape fell dry irregularly. This layer has not been investigated by other means.

5.6. Concluding remarks

At the start of the *"Farmers of the Coast"* research project, it was known that settlement sites were not only limited to the creek ridges, as was previously thought. Based on the excavation results of *Enkhuizen-Kadijken* it was clear that this type of site also occurred at tidal marsh deposits outside the perimeters of creek ridges. Based on the available publications on Bronze Age settlement sites in West-Frisia, the location of this site was thought to be an exception. The analysis of several large scale excavations presented in this chapter, shows that this situation is by no means an exception and far more complex.

79 Appendix 1, date 199: Suerc-51347 1608 ± 32 BP.

Figure 5.20: Soil section and position of the investigated sample at De Rikkert (Photo: "Farmers of the Coast").

In chapter 3 it was argued that the landscape of the Late Neolithic and Early Bronze Age was characterized by the presence of tidal creeks and basins, a landscape with considerable height differences and pronounced creek ridges. Between 1800 and 1700 BC a tidal marsh deposit was draped almost completely over the top of this landscape, levelling the distinct height differences of the former landscape (figure 5.21). Former creek ridges were sometimes present in this newly formed landscape as slightly elevated areas at locations like *Bovenkarspel* or the northeastern part of *Hoogkarspel*. At other locations like *Noorderboekert*, these creek ridges were buried beneath tidal marsh deposits, or simply absent at locations like *Enkhuizen-Kadijken* and *De Rikkert*. But these (partly) covered and uncovered former creek ridges were not the only elevated areas in the newly formed landscape. In a tidal marsh small creeks can be present resulting in small zones with channel deposits. Due to differential subsidence, these zones result in slightly elevated areas, like the small sandy stretch of *Enkhuizen-Kadijken*. To complete this more complex image, the case-study of *De Rikkert* shows that elevations also occur at locations with stacked bodies of channel deposits. Elevations in the landscape of the Middle Bronze Age are therefore not always the result of one single channel belt nor have a comparable genesis. The concept of either tidal marsh or creek ridge oversimplifies the complex reality.

The presence of settlement sites on top of tidal marsh deposits like *Enkhuizen-Kadijken* and parts of *De Rikkert* and *Hoogkarspel*, implies that the inhabitable area in the Bronze Age is far larger than previously expected. During the "*Farmers of the Coast*" research project the vastness of the Bronze Age cultural landscape was often questioned. If the creek ridges, or better, natural elevations, are not the structuring element of settlement sites, what else is? The results of the excavations at *Hoogkarspel*, *Medemblik* and *Bovenkarspel* suggest that changes in lithology (sand to clay) of the subsurface played a role in the structuring of the settlement sites. Apparently these changes in lithology were meaningful to the Bronze Age inhabitants (Bakker *et al.* 1977; Schurmans 2010; Roessingh in prep.). Although a structuring element, these lithological boundaries still do not explain the outer boundaries of the inhabited area.

This analysis of the local sites also demonstrates the difficulties in using detailed soil maps like the map of Ente (1963). For instance, the analysis implies that in the landscape of the Middle Bronze Age palimpsests of the previous periods were present. The detailed soil maps of West-Frisia only represent the clay, loam, sand and organic matter content of the subsoil in a strongly generalized way. One should bear in mind that the drawing is based on an oversimplified development model. Neither the genesis nor morphology is taken into account.

These maps cannot and should not be translated into geomorphological, geomorphogenetical or lithogenetical terms as is common use for predictive modelling (for example De Boer and Molenaar 2006; Molenaar and Van Berkel 2013). These soil maps should be used for what they are designed for, the distribution of clay, loam, sand and organic matter. If the soil maps cannot be used in this way a different approach is needed for predictive modelling in West-Frisia. This will be the topic of chapter 6.

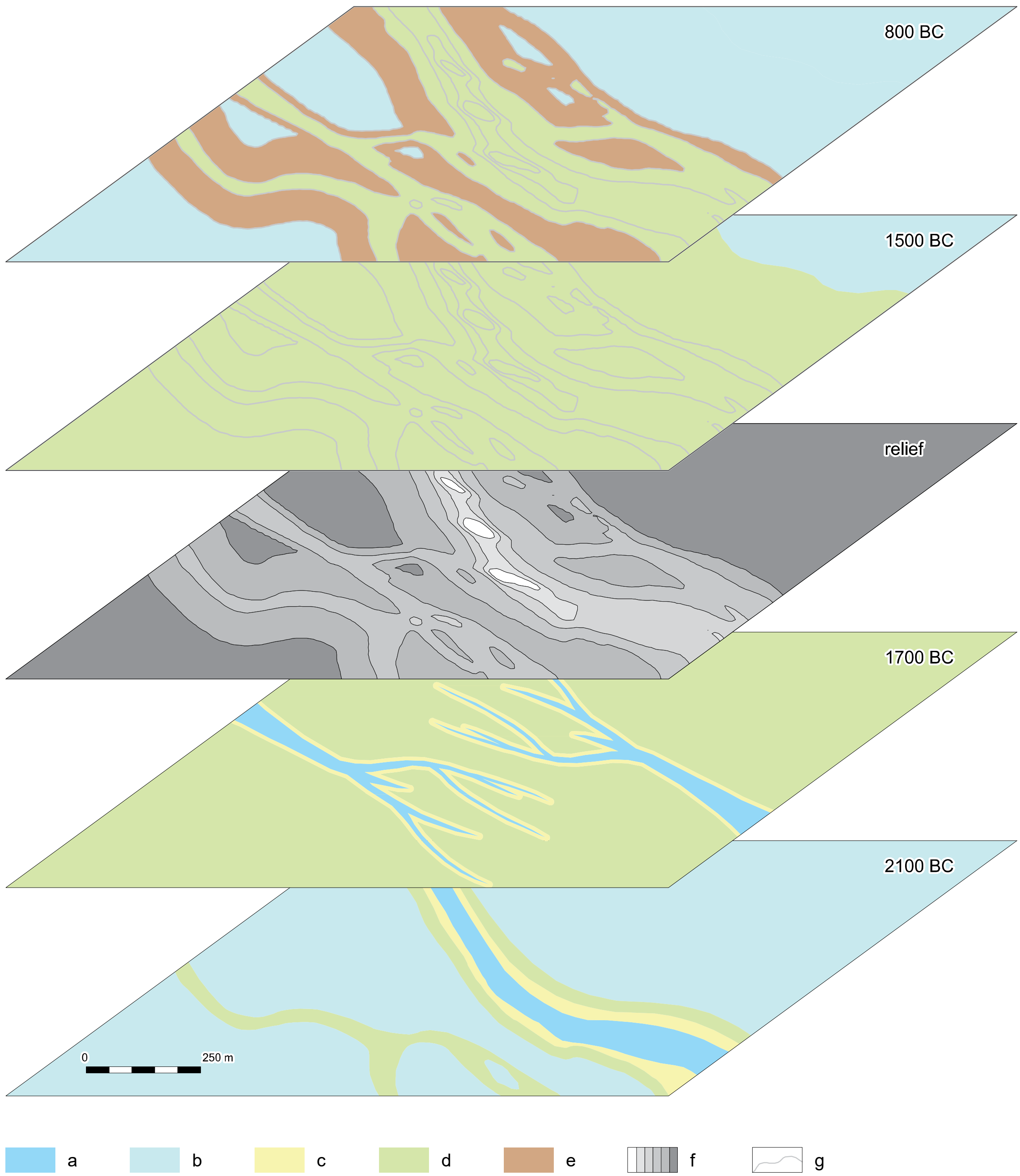


Figure 5.21: Successive stages in the development of the landscape of West-Frisia. Legend: a salt-brackish water, b light-brackish to freshwater, c regular flooded, d vegetated area, e peat area, f relief classes from high (left) to low (right), g isohypse.

6 Bronze Age sites are everywhere! Predictive modelling in eastern West-Frisia

6.1. Introduction

In the previous chapter it was argued that the natural landscape is more complex than previously thought. The geomorphogenesis of local heights turned out to differ in time-depth and genesis. Furthermore, Late Neolithic, Early Bronze Age and Middle to Late Bronze Age sites can occur in one, two or three stratigraphical layers, depending on the geomorphogenesis (§ 3.5.6). In chapter 4 it was argued that factors like hydrology, relief and soil properties and their influence on vegetation are thought to be of importance during the different archaeological periods. In chapter 5 it was argued that sites dating to the Late Neolithic and Early Bronze Age do have a strong relationship with the relief of the natural landscape. These sites appear to be situated on high levees and creek ridges in close proximity to tidal creeks. Contrary to these two periods, sites dating to the Middle Bronze Age seem to have no relationship with the natural relief at all, but appear to have a relationship with the lithology of the subsoil as was demonstrated in chapter 4 and 5. In the same chapters it was argued that in the Late Bronze Age sites probably show a relationship between relief and site-location, although this relationship cannot be attested due to differential subsidence, as was discussed in chapter 4.

A geomorphogenetical model combined with site-location factors, such as described above, can be used for predictive modelling in eastern West-Frisia. Not only these site-location factors have to be taken into account but also historic and modern land-use are of importance. In this chapter these factors are the subject of research. First the standing practice of predictive modelling in the Netherlands and in particular West-Frisia is introduced.

6.2. Archaeology in the Netherlands

In the past, archaeological research was often carried out in research led projects in order to answer a wide variety of research questions (§ 2.8). Sometimes excavations led coincidentally to unexpected finds. This is for example well illustrated by the excavation *Medemblik-Schuitenvoerderslaan,* which was carried out to learn more about the development of this small town in the Early Medieval period (Besteman 1977; De Boer 2013). During the excavation it turned out that the remains of a Middle Bronze Age settlement site were present in the subsurface (§ 5.4.4). Nowadays, most archaeological research is carried out in development led projects in advance of spatial planning projects (§ 2.8). The archaeological research, carried out in these development led projects, is structured conform the

Dutch Archaeology Quality Standard, KNA (Willems and Brandt 2004). Each project follows, in theory, the same route, starting with a desk-based assessment. This research process will be described in § 6.2.1.

Predictive modelling plays an important role in this research process. The first step in predictive modelling is to consult the indicative map of archaeological values (IKAW) and, if available, a local predictive model. The first is described in detail in § 6.2.2, the second for eastern West-Frisia is described in detail in § 6.2.3. The second step, the actual prospecting of sites in the Netherlands and West-Frisia in particular, is described in § 6.2.4. In § 6.2.5 the process of predictive modelling for West-Frisia is evaluated.

6.2.1. The AMZ cycle and the Dutch Archaeology Quality Standard (KNA)

Willems (1997, 4) introduced the Archaeological Heritage Management cycle ("AMZ-cyclus") in Dutch archaeology (figure 6.1). This simple scheme visualizes the archaeological research process and its relation to the public and legislation. In 1997 the Dutch government ratified the Valletta treaty, which led to a new Archaeological Heritage Management Act (WAMZ) in 2007 (Keers *et al.* 2011, 3). The main goal of the new legislation is to preserve archaeological remains *in situ*. When *in situ* preservation is not possible the site has to be investigated, valued and if necessary preserved or as a last resource excavated. The developer is charged for the costs of the archaeological research including the report(s), filing and stabilization of the finds and data. Only certified organizations are allowed to perform this archaeological research. The research has to be executed conform the Dutch Archaeology Quality Standard. A research brief for the archaeological research is written by a certified organization and has to be authorized by local authorities. Local authorities are responsible for laying down and maintaining a policy on archaeological heritage (Keers *et al.* 2011, 4). Since 2007 municipalities are obliged to develop a policy on archaeological heritage management, which is often based on a local or regional predictive model. In 2011 slightly less than half of the municipalities had developed such a framework (Keers *et al.* 2011). In areas lacking such a framework, provincial predictive models or the national model (IKAW) are used. Smaller municipalities joint forces in regional organizations to develop and maintain a predictive model and policy. Several of these organizations are

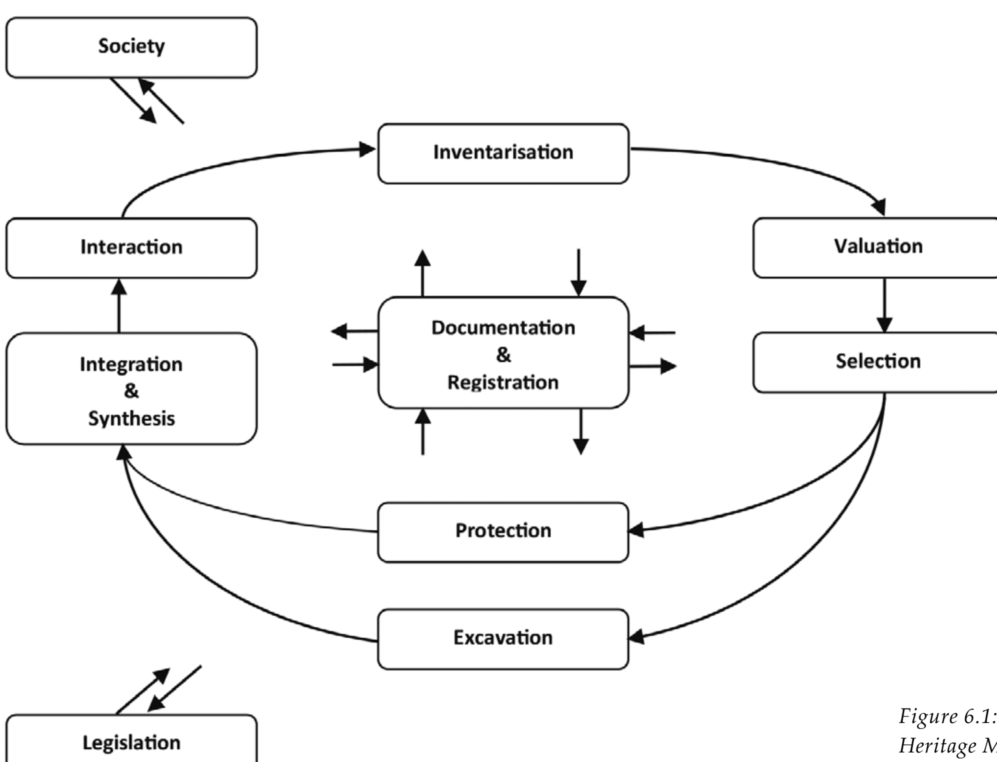


Figure 6.1: The Archaeological Heritage Management cycle (Willems 1997, 4, figure 1).

also certified to perform archaeological research like *Archeologie West-Friesland*, which at the moment represents the municipalities of Drechterland, Enkhuizen, Hoorn, Koggenland, Medemblik, Opmeer and Stede Broec. Besides regulation, policy and sometimes research, these organizations are also involved in public outreach.

The Archaeological Heritage Management cycle is elaborated in the archaeological research process, as described in the Dutch Archaeology Quality Standard, KNA (figure 6.2). According to the KNA all archaeological research starts with a desk-based assessment. The objective of such an assessment is to acquire information, using existing sources, concerning known or expected archaeological values within a defined area (Willems and Brandt 2004, 27). The result of the assessment is a specified and substantiated predictive model of the expected archaeological values, based on existing archaeological, landscape and historical information. This existing information is combined with newly acquired information (including earth science data) concerning the defined area (Willems and Brandt 2004, 35). The assessment results in a report which contains recommendations, in accordance with the prevailing policy, for the follow-up process.

Often a desk-based assessment is followed by an archaeological field evaluation. The objective of the archaeological field evaluation is to supplement and verify the specified predictive model that resulted from the desk-based assessment (Willems and Brandt 2004, 45). During the field evaluation a distinction is made into three successive phases, an exploratory, a mapping and an evaluation phase. The objective of the exploratory phase is to gain insight into the geomorphology in relation to location factors in order to distinguish between high- and low-potential zones. In the mapping phase the area is systematically mapped for archaeological finds and/or features. During the evaluation phase the nature, size, conservation and relative quality of sites are investigated.

The methods used during the archaeological field evaluation depend on the local conditions and the phase in the evaluation process. In the exploratory phase coring, often in section lines or grids, is widely used as a research method in Dutch archaeology.

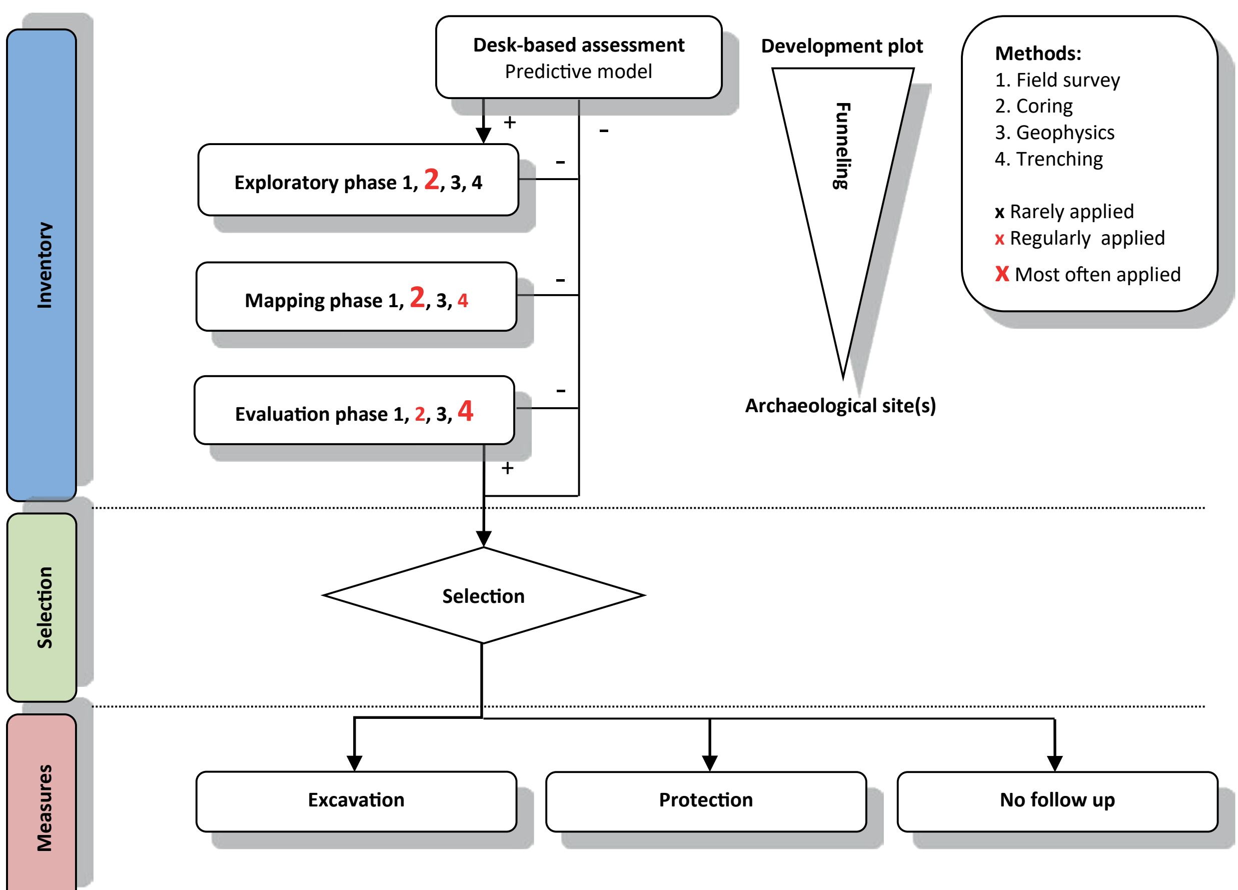


Figure 6.2: Archaeological research process according to the Dutch Archaeology Quality Standard.

During the mapping phase, coring in grids is most often applied in the Netherlands especially for sites in or covered by Holocene sediments. There has been a lively debate about the effectiveness of this method (Tol *et al.* 2004; Fokkens 2007; Wilbers 2007; Tol 2008). The outcome of this debate is a guideline for coring (Tol *et al.* 2006; Tol *et al.* 2012) and a guideline for trenching methods (Borsboom and Verhagen 2009; Borsboom *et al.* 2012). Contrary to other countries in North-Western Europe, field surveys are rarely used in the Netherlands during the mapping and evaluation phase and never during the exploratory phase. This is partly due to the small time windows with suitable conditions for field survey caused by the intensive and varied use of the fields. Geophysical methods are also seldom used during archaeological field evaluation in the Netherlands, despite the positive results in various studies (Kattenberg 2008). Recently a study on the prospection methods for Mesolithic sites with a Holocene cover has been published (Hamburg *et al.* 2014). This study proved a greater value for geophysical methods over corings in the exploratory phase. Studies by Verschoof-Van der Vaart (in prep.) in West-Frisia demonstrate the great value of geophysical research during the mapping phase (§ 6.4.4). Although in other European countries the use of geophysical methods is routine, in Dutch Archaeology these techniques are still experimental (Hamburg *et al.* 2013, 57). Anticipating a changed attitude towards geophysical methods the "*Guidelines geophysical survey in archaeological field evaluation*" of English Heritage have been made available for Dutch archaeologists (Kattenberg and Hessing 2013).

Several comments have to be made on this archaeological research process. Depending on the results of each step in the research process the next step(s) can be skipped. For example, if during the desk-based assessment absence of archaeological remains in the defined area can be argued, the defined area can be deselected for further archeological research by the local authorities. Furthermore, it is important to note that the area under investigation tends to become smaller and smaller during the research process. In the desk-based assessment the complete development area is subject to research. Based on this desk-based assessment often part(s) of the development area is (are) deselected. The exploratory phase is explicitly designed for selecting low- and high-potential zones. It is good practice to do a follow-up with a mapping phase solely in the high-potential zones. During the next phase in the research process it is also good practice to valuate only the locations mapped as an archaeological site. This process of studying progressively smaller areas with increasing research intensity is called funneling (Gehasse 2009, 59). Funneling can easily lead to tunnel vision. In addition, predictive models determine the used field methods. The risk of a self fulfilling prophecy is great with this combination of funneling and selection of methods, especially when the validity of the selection is not randomly tested, which is often not imposed by legislation.

6.2.2. Indicative map of archaeological values (IKAW)

In the field of predictive modelling it is widely accepted that there is a relationship between the natural landscape and locations for specific human activities (Verhagen 2007, 13). The nature of these relationships depends on the landscape characteristics and its use for man. This relationship can be studied in two ways, inductive or deductive. This dichotomy is also described as data-driven or theory-driven (Wheatley and Gillings 2002, 149), though it is not always as clear as is often thought. The data used in data-driven models is often (partially) assembled in a theoretical context and therefore theory-laden (Wheatley and Gillings 2002, 149). Conversely it is also true that theories are often (partially) based on empirical observations. In the Netherlands there is a strong data-driven tradition in predictive modelling (Verhagen 2007, 18-19). In 1997 a data-driven map at a national scale was published. This map presented the relationship between the nature of the soil and the presence of archaeological sites (Deeben *et al.* 1997). This indicative map of archaeological values (IKAW) was developed for use in spatial planning projects in order to obtain a basic idea of the possible presence of archaeological sites.

The first edition of the IKAW is a classic example of a data-driven approach. The first IKAW presented a simple relationship between soil units, groundwater classes and the number of sites in the national database for archaeological finds (ArchIS). Each archaeo-region, a region with more or less comparable archaeological and environmental characteristics, was analyzed for the available data (soil map 1:50.000 and ArchIS). Based on these analyses, for each region three classes were defined: a low, middle high and high indicative value (Deeben *et al.* 2002, 12). Therefore the boundaries between the different classes are not uniform across the map. For example, the boundary between a low and middle high indicative value in one region can be defined on 3 finds per km^2 of a certain soil unit, whereas in another region this boundary is defined by 1 find per km^2 of the same soil unit.

During the compilation of this map, the authors were well aware of the limited depth of the soil units (Deeben 2008, 8). Therefore, the map is not applicable for sites at deeper levels in the Holocene parts of the Netherlands. Furthermore, the authors observed different correlations with soil units for different types of sites. For example, the correlation between the preferred soil unit for Late Neolithic barrows is not the same as for Late Neolithic settlement sites (Van Zijverden and De Moor 2014, 136). A last important observation is that sites dating to different periods sometimes correlate with different soil units. Apparently this goes especially for Late Palaeolithic sites, because sites dating to this period occur mostly in units with a low indicative value on the IKAW. What has not been taken into account are the post-depositional and research processes, which are of large influence on the 'map formation processes' as it is called by Fokkens (1998). Fokkens (1998, 57-60) argues that, amongst others, site visibility, research strategy and the interest of local archaeologists are of great influence on the site distribution. In the explanation of the third edition of the IKAW (Deeben 2009, 6) this problem is explicitly mentioned.

The second and third edition of the IKAW are not solely based on the previously described simple data-driven relationship. Parts of the map have been adjusted with theory-driven models. For example the second edition of the IKAW has been adjusted for the central river area (Deeben *et al.* 2002). For this part of the IKAW the map of meander belts (Berendsen and Stouthamer 2001, addendum 1) and the available geological maps (1:50.000) have been used. In order to comprise the levees and larger parts of the crevasse splays into the IKAW as areas with a high indicative value, a buffer zone along the meander belts has been used (Deeben *et al.* 2002, 25). The idea behind this adjustment is that stream ridges, levees and crevasse splays have been attractive to man, whereas basin areas have been less attractive to man. This adjustment has many implications. In this part of the IKAW there is no established relationship between the map units and the number of known sites. Furthermore, the depth of the map is considerably increased, although it must be noted that the core density used to map the older meander belts is considerably less compared to the core density used to map younger meander belts (Berendsen and Stouthamer 2001). Therefore the older units are mapped with less accuracy compared to the younger units, which implies a difference in reliability of the presented units.

The process of the compilation of the IKAW and its use in spatial planning were and are criticized and debated (Verhagen 2007, 18-19; Van Zijverden and De Moor 2014, 136-139). Nevertheless, the impact of this map and the developed methods for predictive modelling has been of great influence on the present day predictive modelling practice in Dutch archaeology.

6.2.3. The policy document for eastern West-Frisia

The changed legislation after the Valletta Treaty led to the development of detailed maps for heritage management and policy documents by municipalities. In West-Frisia, several municipalities joined forces to develop their own map of archaeological values and a policy document (De Boer and Molenaar 2006). The methodology used in this publication combines a data-driven and theory-driven strategy, like the previously described IKAW.

The starting-point for the construction of the map is the idea that soil and geological characteristics have been important location factors for man in the past. It is thought that, especially farmers, chose locations based on specific soil properties like fertility and available water capacity (De Boer and Molenaar 2006, 42). They argue that the soil map of Ente (1963) not only represents the soil properties for the Bronze Age landscape very well, but also presents information on the morphogenesis. They discuss the relationship between soil classes, site location and site visibility at length. Based on this discussion, they present an important constraint on the analysis of find patterns in relation to the soil map. They state that sites covered by later sediments are less visible during field surveys and therefore under represented in the site database of their inventory, which contains a considerable number of sites found during field surveys. Despite this constraint De Boer and Molenaar (2006) present the number of sites per soil unit and compute the gain for each soil unit by subtracting the relative surface area of each soil unit from the relative number of

Soil unit	ha	%	N sites	% sites	gain	Archaeological value
Sandy loam to loam soils	1.480	23,9	137	38,4	14,4	high
Loamy sand to sandy loam soils	377	6,1	51	14,3	8,2	high
Ancient settlement soils	10	0,2	11	3,1	2,9	high
Thin (silty) clay loam soils overlying loam to loamy sand	41	0,7	6	1,7	1,0	middle
Sandy loam to loam soils mostly overlying (silty) clay loam	805	13,0	44	12,3	-0,7	middle
Thick clay loam soils overlying sandy loam to loam.	360	5,8	17	4,8	-1,1	middle
Transitional soils	99	1,6	0	0	-1,6	middle
Deeply humose soils	225	3,6	8	2,2	-1,4	low
Peat soils	230	3,7	3	0,8	-2,9	low
"Kiek clay"	330	5,3	0	0	-5,3	low
(Silty) clay loam soils	2.047	33,1	76	21,3	-11,8	low
Water	31	0,5	1	0,3	-0,2	none
Raised soils	29	0,5	1	0,3	-0,2	-
No data	119	1,9	2	0,6	-1,4	-

Table 6.1: Archaeological value per soil unit (After: De Boer and Molenaar 2006, 45-46).

sites (table 6.1).[80] Based on the gain the soil units are classified in three classes regarding the archaeological value analogous to the classification of the IKAW: high, medium high and low. Remarkable is the classification of the deeply humose soils as the class with low archaeological values. These soils represent Medieval settlement sites and are supposedly heavily worked (De Boer and Molenaar 2006, 47). Although not explicitly described by De Boer and Molenaar (2006) it is often thought that this land use resulted in destruction of Bronze Age sites, this is probably the reason for this classification.

For each of the archaeological value classes a policy advice is presented by De Boer and Molenaar (2006). For the high and middle high classes archaeological research in advance of disturbance of the soil should be obligatory in their opinion. During the desk top phase and inventory phase for these classes it is advised to focus on disturbances of the subsoil caused by modern land use, like levelling. It is advised to exclude locations which are heavily influenced by this type of modern land use from further archaeological research. At locations with a low archaeological value it is recommended to do some additional coring in order to check the validity of the used soil map. For development projects of 2500 m^2 and upwards it is advised to execute a watching brief during excavation work. This last advice is specifically added in order to prevent a self-fulfilling prophecy for the class "low archaeological value".

De Boer and Molenaar (2006) end their publication of the policy document with three important notes. First they state that the find layer of most of the Bronze Age sites in West-Frisia is characterized by a very small density of finds (De Boer and Molenaar 2006, 54). Furthermore the find layers are often incorporated in the plough zone (De Boer and Molenaar 2006, 54). Therefore these sites are difficult to map with coring, the standard method for exploring sites in the Netherlands. Second they state that the model is solely based on a relation between known sites and soil classes (De Boer and Molenaar 2006, 57). Besides the soil many other site location factors may have mattered to the Bronze Age inhabitants, not in the least social factors, which have not been taken into account in the model (De Boer and Molenaar 2006, 57). Third the model is only based on settlement sites and therefore not applicable to sanctuaries, burials and other types of sites. These notes restrict the applicability of the presented model by De Boer and Molenaar (2006) to a considerable degree; solely settlement sites with a proven positive

80 An evaluation of different methods of the computation of the gain is given by Verhagen (2009, 76). The gain can be used for choosing high and low probability classes (Verhagen 2009, 81).

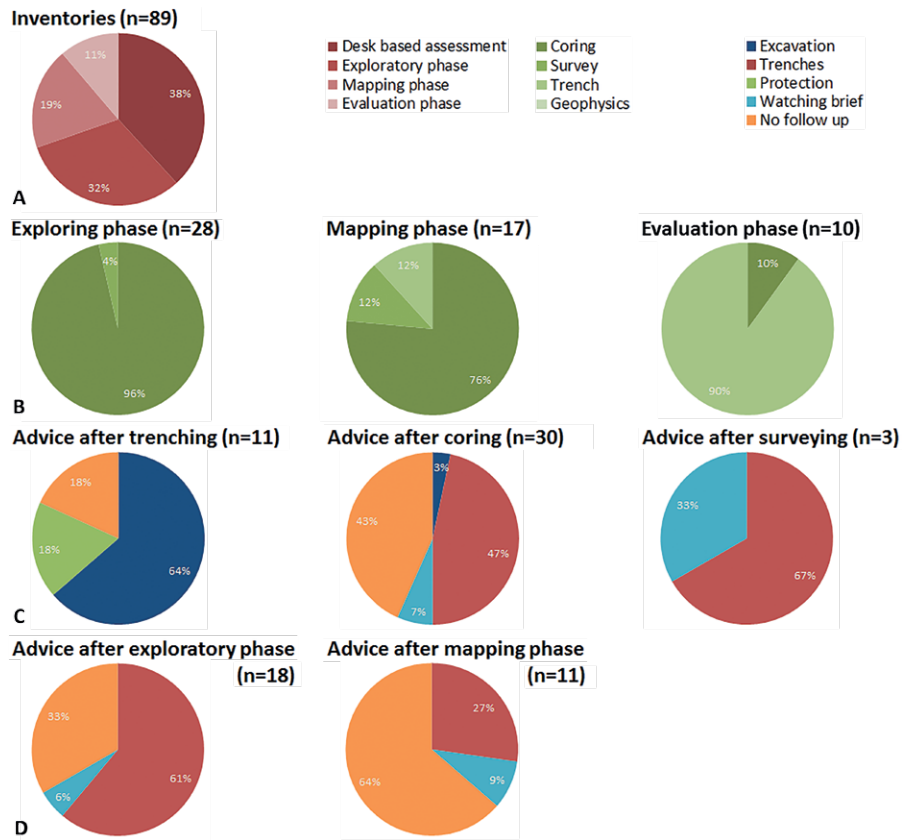


Figure 6.3: Result of an analysis of 89 reports on inventories for Bronze Age sites in eastern West-Frisia. A Number of inventories per phase, B Used methods per phase, C Advice for method per phase, D Advice for method per phase after coring (see appendix 3 for an overview of all used reports).

relationship to several soil units of the soil map of Ente (1963).

6.2.4. Predictive modelling: theory and practice

Since the publication of the policy document for eastern West-Frisia in 2006, many reports on inventories concerning development sites have been published. In the digital database EDNA (Electronic Depot for Archaeology in the Netherlands) 54 publications on inventories of possible Bronze Age sites are available,[81] dating to the period after the publication of this policy document. These 54 publications cover 89 reports on different inventory phases. It is important to note that the EDNA database is, despite the obligation of uploading the publications in the KNA, far from complete. An analysis of these uploaded publications is presented below.

The process of funneling is clearly visible in the amount of reports for the different phases in the inventory process (figure 6.3A). The number of investigations decreases during the process, at the same time the research intensity increases. Thirty-four desk-based assessments were published since the publication of this policy document in 2006. In the same period eight recommendations for an excavation, three recommendations for a watching brief and two recommendations for preservation were given. The methods used in the different phases of the inventory (figure 6.3B) show a focus on coring during the exploratory and mapping phase. Trenching is the main method used during the evaluation phase. Geophysical methods are not applied at all. Surveying is only used during the mapping phase. According to the local policy document, mapping of Bronze Age settlement sites is nearly impossible with coring. Therefore the focus on coring as the main technique during the mapping phase is, at the least, remarkable.

Interesting is the advice given in the publications in relation to the used techniques (figure 6.3C). Surveying and trenching lead to different types of advice. With a few exceptions, both types of research always lead to a follow up. After trenching often an excavation or protection is advised. After a field survey trenching or a watching brief is advised. The

81 Checked at April 25th, 2016.

differences in advice can be explained by the phase in the inventory process in which these techniques have been used. Trenches are mostly used during the evaluation phase and surveys during the mapping phase, which logically leads to a different advice during the next phase of the inventory. The small number of surveys hinders a generalization of this conclusion. Coring leads in almost 50 % of the cases to a negative advice for a follow up (figure 6.3B). This is remarkable given the reservations by De Boer and Molenaar (2006, 57) on the applicability of coring as a method for mapping Bronze Age sites in this area.

Given the results and the applicability of coring as a method in the mapping phase it is interesting to have a better look at the advice after inventories based on corings. In figure 6.3C an overview of the given advice after an inventory based on corings, is presented per phase. For the negative advice after coring in the exploratory and mapping phase, three different motives or a combination of motives have been used:

1. During the inventory finds were absent (n=10).
2. The top soil dating to the Bronze Age is no longer intact (n=7).
3. The subsoil is unsuitable for habitation (n=2).

It is obvious that the first motive is invalid, the soil horizon dating to the Middle Bronze Age contains very little archaeological indicators, like charcoal, bone, burned clay, pottery and so on. This is even the case in settlement sites (De Boer and Molenaar 2006, 57; Van Zijverden 2006, 8). The absence of finds in this horizon during an inventory with coring equipment cannot be used as an argument for the absence of archaeological remains dating to the Bronze Age. The second motive is questionable. A natural top soil (A-horizon) in this type of sediments varies in thickness between several centimeters and 15 centimeters. The soil sections of Bronze Age settlement sites, as presented in the previous chapter, prove that the absence of such a top soil is not at all an indication for the absence of a settlement site! Therefore, if the top soil is incorporated in the modern plough zone it does not imply that features are absent. It definitely means that the information value of a site is smaller. Of course it is possible that only the deeper features like water pits are present when the top soil is absent, but this information cannot be derived from corings. The third motive is also dubious. In one case it is noted that man only lived at the sandy creek ridges. Due to the absence of such a creek ridge at the investigated plot, habitation in the Bronze Age has been impossible (Warning 2006, 6). Based on the results of sites like *Enkhuizen-Kadijken* this argument is obvious invalid. In the second case it is noted that the soil is not consolidated and therefore unsuitable for exploitation (Brokke 2008), which is a reasonable argument.

In conclusion: despite the well-argued methodology for the prospection of settlement sites by De Boer and Molenaar (2006), despite a well-informed and well-organized local government (Archeologie West-Friesland) and despite a plain policy document, this analysis demonstrates that since the introduction of this policy in 2006 at over 50% of the investigated locations this policy is not put into practice. The implication is that Bronze Age sites are probably destroyed unseen despite the good intentions and effort of archaeological companies and the local government. This is quite clearly illustrated by several watching briefs carried out by Archeologie West-Friesland, where features of Bronze Age settlement sites were found at locations with a low archaeological expectation, based on an inventory (mapping phase) carried out with hand auger equipment (Gerritsen 2014).

6.2.5. Asking the right question

In addition to this discouraging practice in eastern West-Frisia, one should bear in mind that the document of De Boer and Molenaar (2006, 48) explicitly states that their model is developed for the prospection of Bronze Age settlement sites. Are settlement sites the only types of sites the archaeological community wants to explore? For example, West-Frisia is not only known for its well preserved settlement sites, but also for a large number of well-preserved burials and burial mounds (Steffens 2013). Steffens (2013, 100) demonstrates that burial mounds are located differently compared to settlement sites in respect to soil units of the soil map of Ente (1963). A focus on locations preferred for settlement sites will lead to an under representation of burial sites. Furthermore, we now believe that hunting, fishing and gathering still played a significant role in Bronze Age West-Frisia (Van Amerongen 2014, 92). The find of a fyke in the settlement site of *Enkhuizen-Kadijken* demonstrates the actual existence of fishing spots. The absence of sites with weirs and fykes forms a contrast to the large number of settlement sites and burial mounds.[82] We also do know there has been contact with communities in other areas of the Netherlands for the exchange of cattle and goat/sheep (Brusgaard 2014, 64). Distances which probably have been bridged by boat or canoe. Given the wet environment, boats or canoes must have been important for transport in West-Frisia. Apart from the find of one paddle in a settlement site and a blade of a paddle in a residual gully, any finds associated with transport by water are absent (Roessingh in prep.; Cordfunke 1972, 18).

The current policy is focused on the selection of locations favored for Bronze Age settlement sites. Based on the existing model, it is thought that these sites are situated at the relatively high and sandy creek ridges. Therefore, research is focused on these ridges. Focusing on these ridges implies you will have little chance finding a canoe, fishing camp and so on. Based on the previous, a series of important question arises: "Should predictive modelling in Bronze Age West-Frisia solely focus on settlement sites or are these other types also relevant to investigate? What are the "right" questions to ask? And in addition: What is the "right" methodology in order to answer these questions? Which techniques are applicable in West-Frisia? What kind of results are achievable?

These questions are not easy to answer. In the next paragraph, the research carried out at *De Rikkert* is presented as a case-study for the possibilities in predictive modelling in eastern West-Frisia.

6.3. Predictive modelling: De Rikkert

It is believed that Bronze Age settlement sites in West-Frisia are represented by surface finds, as is described in the policy document for the municipality of Enkhuizen.[83] The reverse is also thought to be true. The absence of surface finds indicates the absence of settlement sites (IJzereef and Van Regteren Altena 1991, 65). Several excavations prove that this is, at least partly, untrue. For example, during the survey in the seventies only three sherds of Bronze Age pottery were found close to the northern border of the development plot *Enkhuizen-Kadijken* (Lohof 2006, 5). Therefore, it was a surprise that the entire development plot (over 13 hectares) turned out to be part of a Bronze Age settlement site (Roessingh and Lohof 2011). During the same survey a large number of Late Bronze Age pottery was found, which led to the excavation in Andijk in 1973 (IJzereef and Van Regteren Altena 1991, 61). During the excavation only features dating to the Middle Bronze Age were found (Roessingh in prep.). Both examples illustrate that the distribution map of finds cannot be the only source for the mapping of Bronze Age sites in West-Frisia. Therefore additional prospection techniques are needed. For each technique additional knowledge is needed about the influence of factors like soil type, (pre)historic land use and so on. Questions like: what determines the presence of archaeological remains at the surface of arable land and when is the absence of these remains an indication for the absence of features in the subsoil? have to be answered. This was the starting point for the research at *De Rikkert*.

The research at *De Rikkert* (see also § 5.5) was carried out within the scope of a field school in surveying techniques for MA-students in Field Archaeology of Leiden University. Great was the disappointment of the students that only in a small part of the surveyed area, material dating to the Bronze Age was present at the surface. Did this imply that only in this small part a settlement site was situated and the remaining surveyed area was "empty"? During the successive field campaigns, the *De Rikkert* project focused on these "empty" areas. Various prospection techniques were tested at these supposedly "empty" areas. The results of the different techniques used are presented and discussed below.

6.3.1. Desk-based assessment

In figures 6.4 and 6.5 an overview is presented of the available archaeological information for the location of *De Rikkert*. An inventory of the information in ArchIS resulted in three find locations with Bronze Age finds, discovered during the survey in the seventies. At two locations flint sickles were found. Flint sickles, especially complete ones, are rarely found in settlement sites (Schinning 2012, 39). A third location yielded 6 fragments of Middle Bronze Age pottery. Despite the number of pottery fragments, this location is not indicated as a settlement site. According to the available information on the survey,

82 Roessingh and Van Zijverden (2011, 123) estimated the area covered by settlement sites in eastern West-Frisia at at least 730 hectares. Steffens (2013, 38) incorporated 176 burial mounds in his database of Westfrisian burial mounds.

83 Molenaar and Van Berkel 2013, 49 *"Over het algemeen wordt er vanuit gegaan dat de ligging en verspreiding van het archeologisch vondstmateriaal een weerspiegeling vormen van de eertijdse bewoningslocaties." Which can be translated like: "It is generally accepted that the location and distribution of archaeological finds represent the location of former settlement sites."*

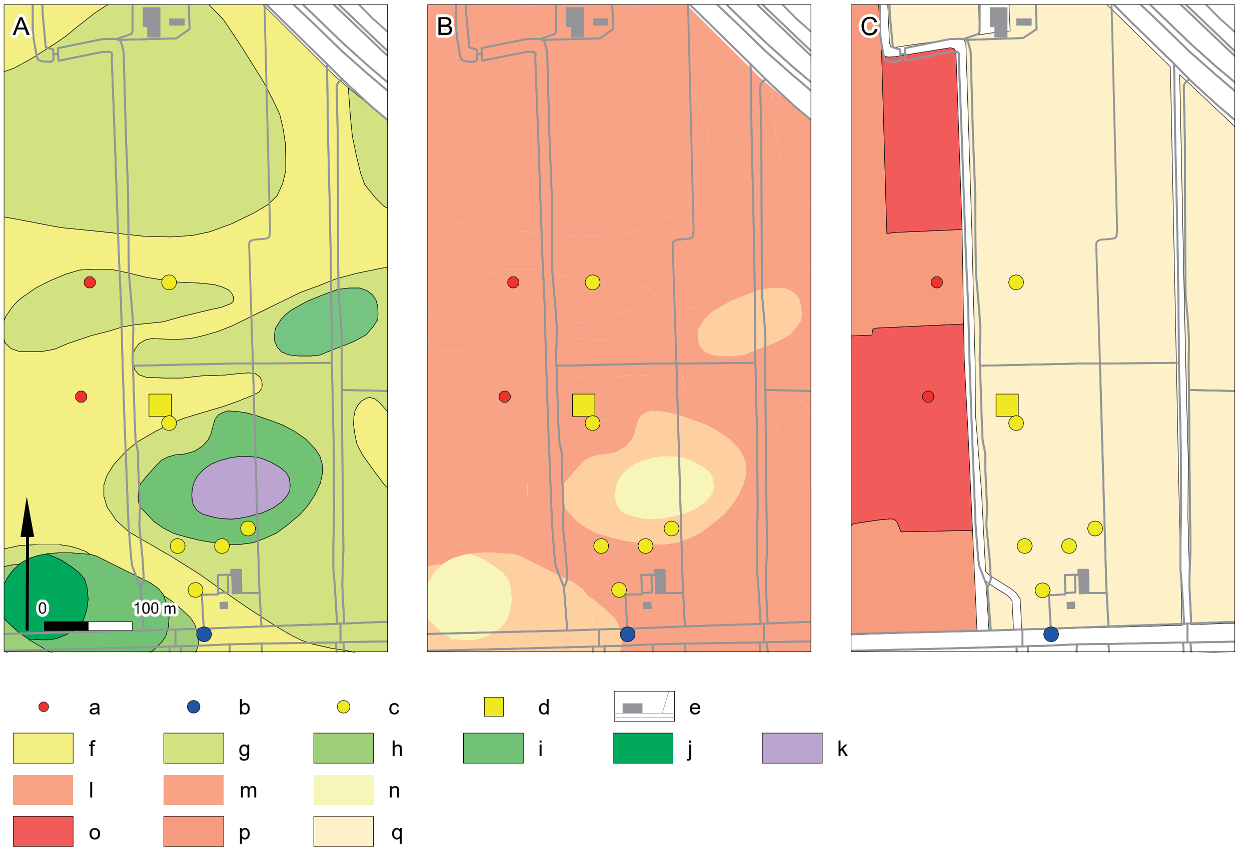


Figure 6.4: Archaeological finds and soil map (A), indicative archaeological values (B) and soil improvement measures (C) for research area De Rikkert. Legend: a flint sickle, b 6 fragments MBA pottery, c burial mound, d burial mound excavated by Lehman, e modern topography, f loamy sand to sandy loam, g sandy loam to loam, h sandy loam to loam overlying (silty) clay loam, i thick (25-60 cm) (silty) clay loam soils overlying (20-30 cm) sandy loam to loam, sometimes underlain by (silty) clay loam, j (silty) clay loam, k peat, l high archaeological value, m medium high archaeological value, n low archaeological value, o 80 cm ploughed, p 50 cm ploughed, q lightly ploughed.

the surveyed area was in use as an arable field. Based on this information it is assumed that the visibility during the survey of the seventies was average to good. In addition to these finds several burial mounds were recognized during the field survey in the seventies, based on small height differences. One of these mounds has been excavated by Lehman (1963).

In figure 6.4A the research location of *De Rikkert* is plotted on top of the detailed soil map of Ente (1963). Based on the analysis by De Boer and Molenaar (2006) the study area includes locations with a high, medium high and low archaeological value (figure 6.4B and table 6.1). An important source of information on the distortion degree of the top soil is the map of the planned soil improvements for the land consolidation projects.[84] This map shows three different zones with different soil improvement methods for *De Rikkert* (figure 6.4C). The western part of the research area had to be ploughed to a depth of 50 or even 80 centimeters. The eastern part of the research area had to be ploughed only lightly. It is assumed that these instructions have been followed. It is unknown in which way the fields have been worked by the farmers after the land consolidation projects.

A digital elevation model (DEM) based on a set of height measurements dating prior to the land consolidation project shows height differences of up to 80 cm with much variation (figure 6.5A).

84 These maps are available at the regional archives (Westfries Archief) but not yet registered. The following information is written on the map: Grontmij 1974, Bestek I, R.V.K. Het Grootslag, Blok 75, Blad II, Situatie wegen, waterlopen en kunstwerken.

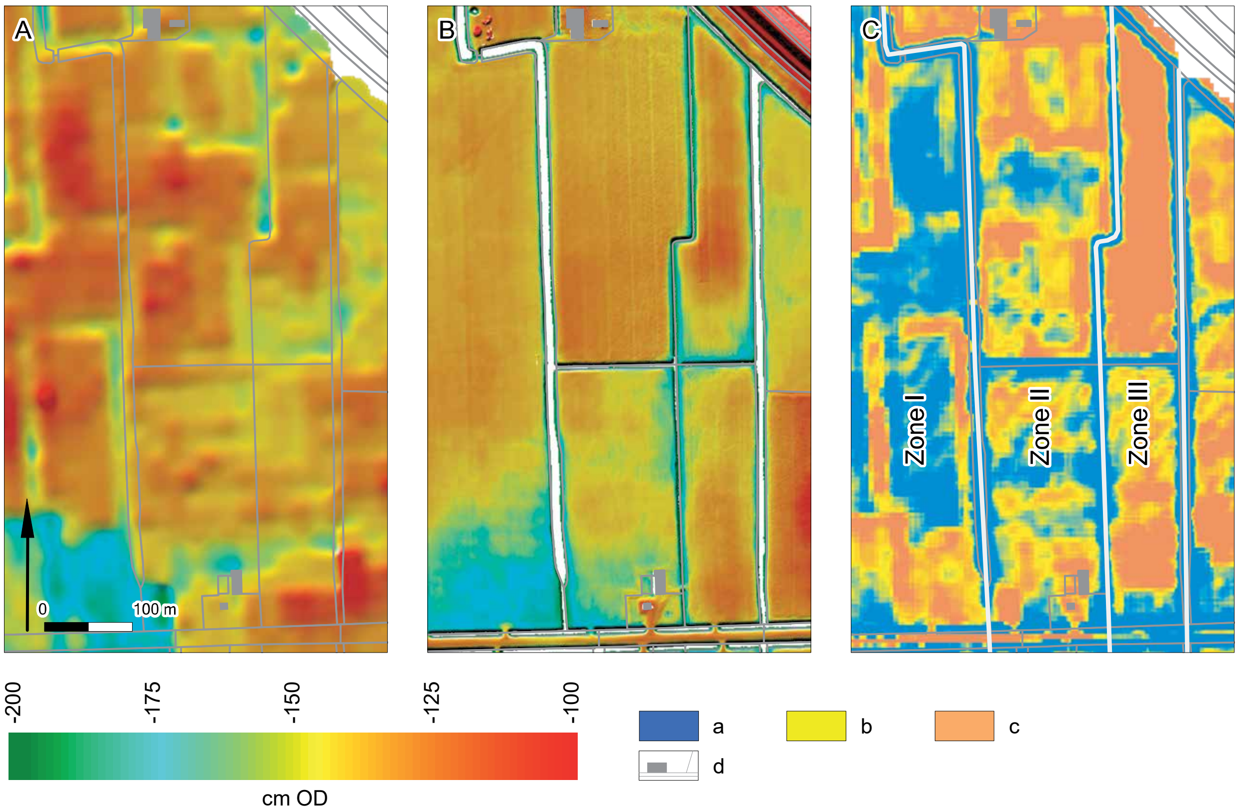


Figure 6.5: Comparison (C) of the relief of the surface before the land consolidation project (A) and the present day relief (B). Legend: a lowered, b unchanged, c raised, d modern topography.

The available LIDAR-image also displays relief differences up to 80 centimeters (figure 6.5B). In contrast with the DEM there is very little variation, which is characteristic for levelled fields. The burial mounds which have been mapped in the field, based on relief differences, are not visible as a raised area in the LIDAR-image and DEM nor in the field. A subtraction of this DEM from the LIDAR-image gives a rough estimation of the change in relief over time (figure 6.5C).

Based on the presented data *De Rikkert* can be divided into three zones (figure 6.5C). It can be argued that the top soil of the western parcel (zone I) is at least damaged and possibly completely disturbed. This parcel has probably been ploughed to a considerable depth (50-80 cm) and apparently part of the top soil has been removed. The eastern parcel (zone III) is considered to be well-preserved. This parcel has only been ploughed lightly and the parcel has been raised. The central parcels (zone II) have been ploughed lightly and are partly raised and partly lowered. Therefore the preservation of the top soil will differ from place to place in this zone. Archaeological finds correlate well with the expected archaeological values. Finds are absent in the areas with a low indicative archaeological value and only present in areas with a medium high and high archaeological value. It is important to note that the find complexes concern mainly burial monuments and not settlement sites for which the map has been developed. Based on the presence of burial mounds, the find of two complete sickles and the almost complete absence of pottery, the location probably cannot be characterized as a settlement site.

6.3.2. Exploratory phase

As described in § 6.2 the objective of the exploratory phase is to gain insight into the geomorphology in relation to location factors, in order to distinguish between high- and low-potential zones. In order to understand the nature of the subsoil, several corings were carried out. These corings have been used for the construction of figure 6.6. In this figure the nature of the topsoil, subsoil and the relief are displayed using the method presented in chapter 4. The entire research area is apparently suitable for habitation. In

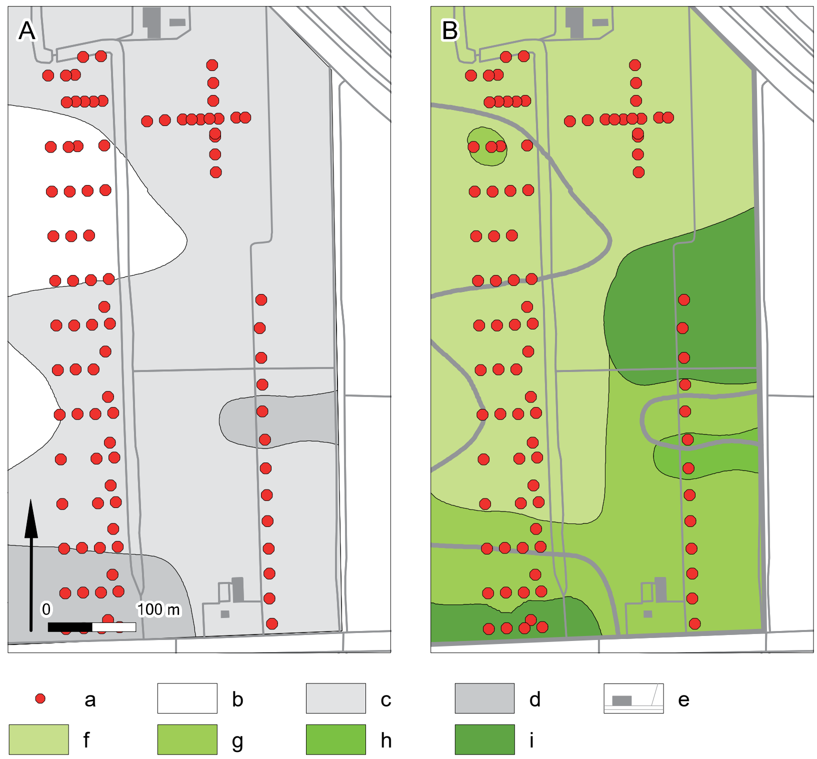


Figure 6.6: Reconstruction of relief (A) and the top soil and subsoil (B) of De Rikkert. Legend: a coring, b 160-120 cm -O.D., c 200- 160 cm -O.D., d 200-240 cm -O.D., e modern topography, f 8-25% lutum in top and subsoil, g >25% lutum in top soil and 8-25% in subsoil, h 8-25% lutum in top soil and >25% in subsoil, i >25% lutum in top and subsoil.

the south-eastern part the soil is slightly more clayey and the Bronze Age surface is a little lower compared to the northern part of *De Rikkert*. In addition to the nature of the soil the intactness of the stratigraphy is also the subject of research during the exploratory phase. In figure 6.7 the distribution of locations with a (partially) intact soil horizon dating to the Bronze Age is shown. It appears there is no relation between the plough depth and the (partial) intactness of the Bronze Age soil (figure 6.7A). Especially in the northern part of zone I the Bronze Age top soil is remarkably well-preserved in light of the plough depth. The reverse is true in the southern part of zone III. The Bronze Age top soil in this zone is poorly preserved despite the shallow plough depth. Apparently there is also no obvious relationship between the intactness of the Bronze Age soil horizon and former relief nor the lowering or raising of the sampled locations (figure 6.7B and 6.7C).

6.3.3. Mapping phase

The objective of the mapping phase is a systematic mapping of the research area for archaeological finds and/or features. Based on the previously presented data it is assumed that the Bronze Age top soil is only partly intact and therefore the find layer should be incorporated in the modern plough zone. Most parcels in the area are in use as arable land and therefore suitable for an archaeological survey. Therefore a field survey is suggested as the ideal strategy for mapping settlement sites at *De Rikkert*.

For part of the research area a field survey was carried out, assembling material in squares of 100 m^2 and partly in squares of 400 m^2. The squares have been walked in lines with a distance of approximately 5 m in between (Roessing and Valentijn inprep.). Some parts have been surveyed twice. The success of field surveys depends for a large part on the circumstances during the survey. During the 2012 field survey the circumstances were ideal. The weather was good, the fields were easily walkable and the parcels were recently ploughed. Therefore, the visibility at the parcels was very good. During the field survey in 2013 it was rainy, the fields were difficult to walk and although the crops had been harvested, the fields were not yet ploughed. Therefore the visibility on the parcels was considered to be poor.

Several indicators can be used for an estimation of the visibility: the relative number of finds, the fragmentation degree and the distribution of find categories (Verhagen 2007, 103-104). The number of finds in both field surveys is comparable, 253 finds per hectare in 2012 and 334 finds per hectare in 2013 (table 6.2; figure 6.8). The fragmentation degree

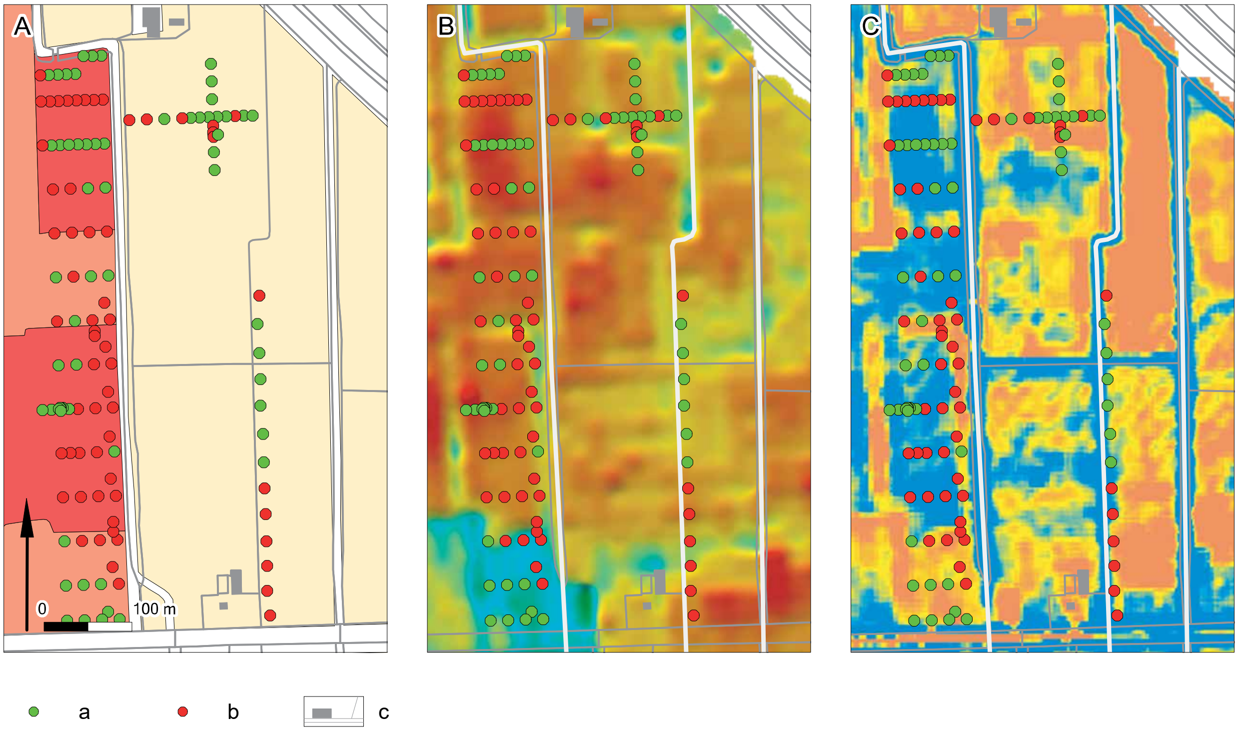


Figure 6.7: Intactness of Bronze Age soils in relation to plough depth (A), relief (B) and change in relief (C). Legend: a Bronze Age soil (partially) intact, b Bronze Age soil disturbed, c modern topography; see further figure 6.4 and 6.5.

is more or less comparable for both surveys. Late Bronze Age pottery has a higher fragmentation grade compared to Middle Bronze Age pottery. Therefore, Late Bronze Age pottery is apparently better visible compared to Middle Bronze Age pottery. The fact that only relatively large fragments of Late Bronze Age pottery were found in the 2013 field survey suggests a poor visibility, although the total number of finds of Bronze Age pottery is very low and therefore not significant. Only the relatively high number of pottery dating to the Late Medieval and modern times (30% in 2012 versus 70% in 2013) is an indicator for a poor visibility. Due to the red colour and glaze of this pottery, it is easily spotted during a field survey compared to the grayish Bronze Age pottery, bone, stone and flint. In conclusion, the expected poor visibility in the 2013 field survey is not clearly reflected in the analysis of the finds.

The distribution of the different find classes shows a comparable pattern. A large number of Bronze Age pottery finds cluster in the southern part of zone III (figure 6.8C). The other classes like stone, flint and bone show a comparable distribution pattern (a.o. figure 6.8B). Zone I shows very few finds compared to zone II and III. Based on the assumed disturbance of the top soil the highest number of surface finds would have been expected in zone I if *De Rikkert* has a homogeneous archaeological expectation. Based on this field survey zone II and III are expected to be part of a settlement site. Zone I is categorized as an "off site" location, an interpretation which is in agreement with the find of the two flint sickles in the past.

Although the suggested ideal mapping technique is a field survey, the most popular technique for the mapping of settlement sites in the Netherlands and West-Frisia is coring. Despite the poor results with coring in West-Frisia during the mapping phase, a large number of corings were executed in order to test the possibilities of coring during the mapping phase. In 50% of the corings the Bronze Age top soil was found (partially) intact. Despite this relatively well-preserved Bronze Age landscape, the mapping phase resulted in only one single archaeological indicator (pottery) on a total number of 136 corings. This result is comparable to the number of finds in the exploratory phase of the settlement site of *Enkhuizen-Kadijken* (Van Zijverden 2006). This minimal number of finds compared to the large number of finds during the field survey demonstrates once again

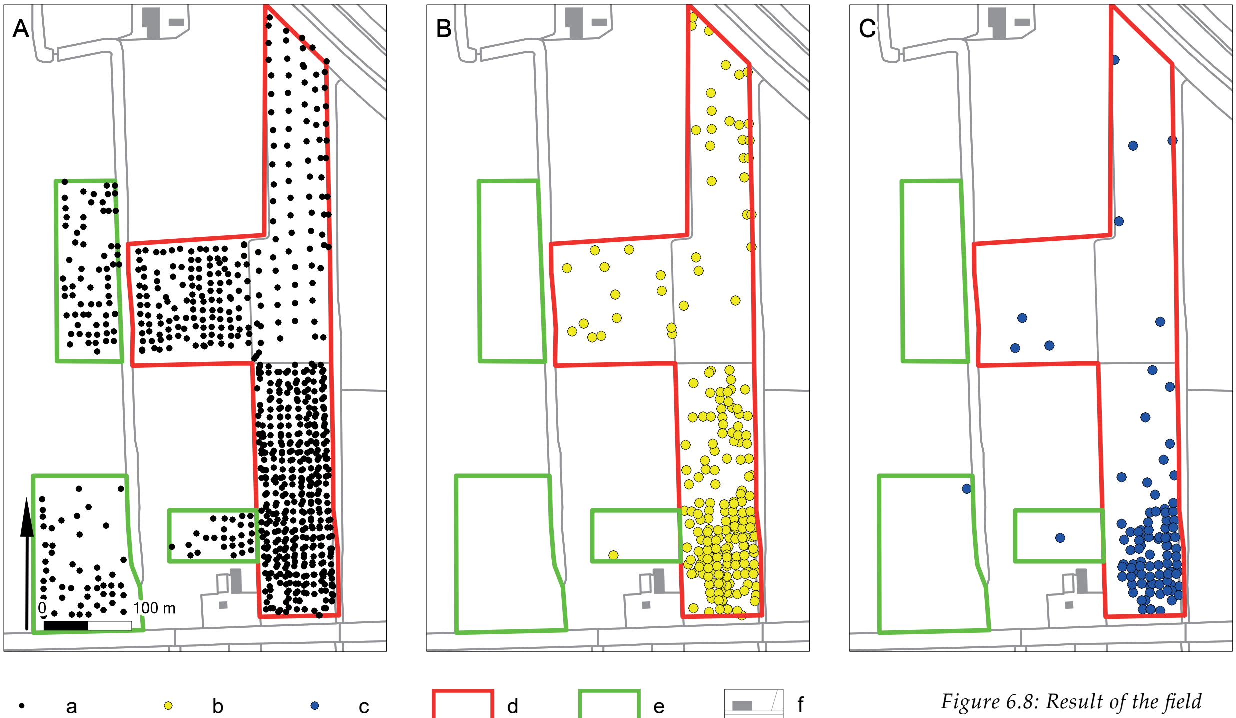


Figure 6.8: Result of the field surveys at De Rikkert. Legend: a finds, b bone, c Bronze Age pottery, d field survey 2012, e field survey 2013, f modern topography.

Field survey 2012 (7,4 ha)	N	Weight (gr)	Fragmentation (gr/N)	% (N)	% (gr)
MBA pottery	5	34,4	6,9	0,3	0,2
LBA pottery	84	191,4	2,3	4,6	1,0
Flint	159	2901,0	18,2	8,7	14,6
Stone	545	10646,4	19,5	29,7	53,5
Bone	528	2359,7	4,5	28,8	11,9
Medieval and modern pottery	562	3751,4	6,7	30,7	18,9

Field survey 2013 (4,0 ha)	N	Weight (gr)	Fragmentation (gr/N)	% (N)	% (gr)
MBA pottery	0	0,0	-	-	-
LBA pottery	3	24,8	8,3	0,2	0,2
Flint	107	1452,3	13,6	8,0	9,5
Stone	275	9141,9	33,2	20,4	59,7
Bone	20	85,9	4,3	1,5	0,6
Medieval and modern pottery	940	4601,0	4,9	69,9	30,1

Table 6.2: Summarized results of the field surveys at De Rikkert of 2012 and 2013.

the inadequacy of this method for mapping sites in West-Frisia.

In addition to the field surveys and corings, "*sondages*" have been used as a mapping method (figure 6.9). A *sondage* is a small test trench of one to four square meters. The advantage of *sondages* over corings is on the one hand the substantial amount of material for sieving for small finds like microdebitage, pottery fragments and small bones. On the other hand it is possible to study the soil section in much greater detail compared to a core. This method was developed in the late seventies amongst others for the construction of a 3D-model of the layered multi-period site of *De Horden* in the Dutch central river area (Hessing and Steenbeek 1990, 9). At this 14 ha site, 350 of these *sondages* have been carried out, which helped to understand the stratigraphy of the site in detail in advance of an excavation. In West-Frisia this mapping method is easy to apply due to the

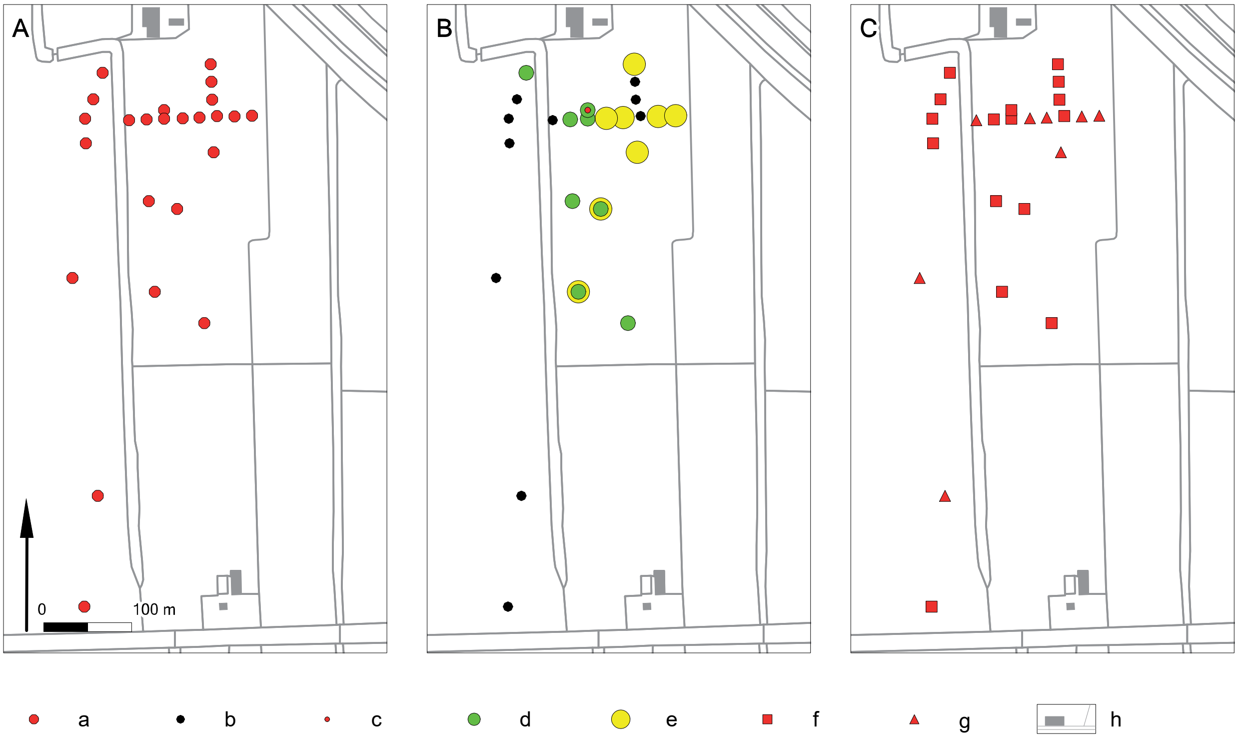


Figure 6.9: Result of the sondages at De Rikkert. Legend: a sondages, b no features, c Bronze Age pit, d Bronze Age ard marks, e Bronze Age ditch, f Bronze Age top soil (partially) intact, g Bronze Age top soil disturbed, h modern topography.

relatively shallow depth of the occurrence of Bronze Age remains. The *sondages* can even been dug by hand.

In three successive years, *sondages* have been made in the research area of *De Rikkert*. During the first (2013) and second (2014) field period a mini excavator was used for digging *sondages* and small test trenches. In the 2015 field period the *sondages* were dug by hand. An overview of the *sondages* is presented in figure 6.9A. For every *sondage* the interpretation of the archaeological features, post holes, ard marks and ditches are schematically presented (figure 6.9B). Next to the presence of archaeological features the intactness of the Bronze Age top soil could be attested also (figure 6.9C). Based on the *sondages* the variability in the intactness of the Bronze Age top soil derived from the corings could be confirmed. Locations with a Bronze Age ditch in the subsoil were, during the corings, often interpreted as a disturbed Bronze Age topsoil. Most of the *sondages* in zone I turned out to be "empty" as expected, based on the results of the field survey. The features in the *sondages* of zone II, mainly ditches which are characteristic for settlement sites, confirmed the interpretation as settlement site.

In addition to the research by *sondages*, a geophysical survey was conducted (figure 6.10). This type of method is not often used in the Netherlands (§ 6.2.1). In this project electrical conductivity was measured (Verschoof-Van der Vaart in prep.), using a RM15-D resistance meter with a PA20 frame in a Twin Probe configuration (0,75 m mobile probe separation). Electrical conductivity reveals contrasts in resistivity or conductivity of the soil. These contrasts are largely dependent on the moisture retaining properties of the soil. Grain size and organic matter content mainly define the moisture retaining properties of a soil. Soils with a high moisture content show a smaller resistivity compared to soils with a low moisture content (Kattenberg 2008, 56). The idea by Verschoof-Van der Vaart (in prep.) is that ditches contain a more clayey material and have a higher organic matter content compared to the surrounding natural landscape. Verschoof-Van der Vaart (in prep.) was indeed successful in mapping ditches, revealing amongst others the location of the circular ditch of a burial mound (figure 6.10B). The images of zone I and zone II reveal ditch systems with a pattern comparable to the ditch patterns of Bronze Age settlement sites like *Enkhuizen-Kadijken*, *Hoogkarspel*, *Medemblik-*

Figure 6.10: Interpretation of the geophysical images of the research carried out by Verschoof-Van der Vaart (in prep.). Legend: a sondages, b trenches, c geophysical research 2013, d geophysical research 2014, e geophysical research 2015, f supposed Bronze Age ditch systems, g modern topography.

Schepenwijk, etcetera (figure 6.10B). The quality and patterns in the images produced by Verschoof-Van der Vaart (in prep.) are very consistent over the years (2014-2015). The method used by Verschoof-Van der Vaart (in prep.) is very promising when it comes to mapping the outlines of the parcelled landscape of the Bronze Age and also the Medieval and modern period. In combination with well-chosen *sondages* the geophysical image produced, can be valuated with little effort. The combination of *sondages* with a geophysical survey changed the interpretation for the northern part of zone I from an offsite location into a settlement site. Zone II can also be characterized as a settlement site by the combination of these two methods, an interpretation that fits with the results of the field survey. The presence of at least one burial mound, which is nowadays hardly visible in the field, in zone II could be confirmed with the results of the geophysical survey.

The final used method in the mapping phase was trenching. Trenching is a technique which is often used for a combination of mapping and evaluating in development-led projects. In the Netherlands a guideline is available for the design of an excavating plan in this particular research phase (Borsboom and Verhagen 2009). Usually trenching of 10 % of the entire surface is recommended for the mapping of a site (Borsboom and Verhagen 2009, 42). For an optimal strategy it is advised to use a grid (Borsboom and Verhagen 2009, 37). The advice for such a grid is entirely based on a statistical model and valuated by several simulations (Borsboom and Verhagen 2009, 26-31). An important precondition for the design of a plan for surveying with trenches is expert knowledge on the expected feature density and distribution (Borsboom and Verhagen 2009, 53-54). Based on these characteristics the optimal grid can be established. The authors of the guideline explicitly define a site as a clustering of features (Borsboom and Verhagen 2009, 14). Due to this focus on clusters of features in the mapping phase, it is often forgotten that archaeologists study the cultural landscape and not only clusters of features (Fokkens 2007, 60). A nice example of a broader strategy designed for mapping the cultural landscape is the trenching strategy developed by Brandt and Bakker for the site of *Hoogkarspel*. They developed a trenching strategy for mapping the Bronze Age field system of this complex and later on the burial landscape (Bakker *et al.* 1977, 189).

At *De Rikkert* the mapping phase with trenches (figure 6.11) was focussed on characterizing the nature of the site. Based on the absence of finds in the survey and the find of two complete flint sickles in the

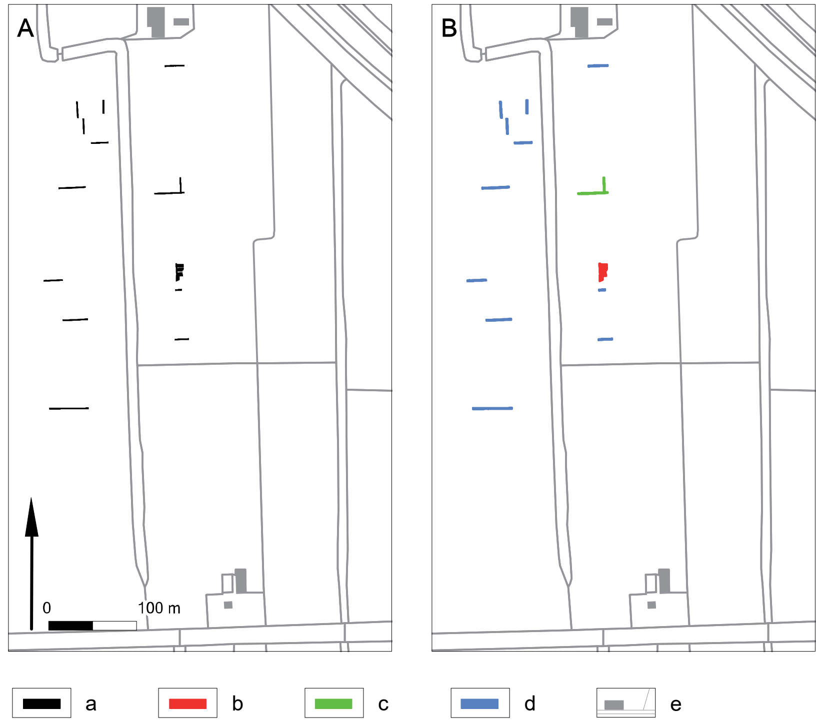


Figure 6.11: Result of the trenches at De Rikkert. Legend: a trenches, b burial mound, c house plan, d features common for settlement sites like pits, postholes, post circles, ard marks, ring ditches and ditches.

past, zone I was characterized as an off-site location. The *sondages* did not contradict this interpretation. The geophysical survey on the other hand revealed in the northern part of this zone a pattern of ditches, which is typical for Bronze Age settlement sites. Test trenches in this part of zone I were planned using the results of the geophysical research. The results of these test trenches were in line with the results of the geophysical survey. Features like ditches, pits, postholes and ard marks led to an interpretation as a settlement site! The features in the other trenches in zone I do not differ from the ditches in the northern part. Therefore the entire zone I is interpreted as settlement site (figure 6.11B). In all trenches features dating to the Middle Bronze Age are present. Only the southernmost trench contained also features dating to the Late Bronze Age.

Zone II contains at least one burial mound and possibly more according to the desk-based assessment. Based on the number and type of finds in the field survey this zone could be interpreted as a settlement site. In the central part of zone II a very small part of a burial mound and part of the accompanying ring ditch were excavated. The ring ditch is clearly visible in the geophysical image. All other trenches contained features like ditches, pits, postholes and ard marks which are typical for settlement sites. Even a part of a house plan could be recognized in one of the trenches (figure 6.11B). Therefore zone II is also interpreted as part of a settlement site. A total of 0,05 ha was excavated in a research area of approximately 22 ha, which is 0.2%.

6.3.4. Evaluation phase

The objective of the evaluation phase is to investigate the nature, size, conservation and relative quality of a site. Based on the previously presented information the entire research area can be characterized as a Bronze Age settlement site. Despite the supposed destructive soil improvement techniques, the site turned out to be well-preserved. Based on an analysis of pollen, macrobotanical remains, phytoliths and a thin section presented in § 5.5, the conservation of the site is comparable with recently excavated sites like *Enkhuizen-Kadijken* and *Medemblik-Schepenwijk*.

6.3.5. Lessons learned

As was presented in the previous chapter (§ 5.5), the genesis of the landscape at *De Rikkert* is, in general, comparable to sites like *Hoogkarspel*, *Enkhuizen-Kadijken* and *Andijk*. Therefore the location of *De Rikkert* is representative for Bronze Age sites in West-Frisia. A difference with these sites is the presence of all soil units distinguished by Ente (1963), according to his soil map. Therefore, this research area is ideal for testing the hypotheses on low, medium high and high indicative archaeological values presented in the publication by De Boer and Molenaar (2006). The research area was also ideal for a study on the effects of the supposedly different applied soil improvement techniques during the land consolidation project and by individual farmers after the period of land consolidation projects. The large difference in numbers of finds in the field surveys made it also possible to test general hypotheses on the value and interpretation of surface finds as described by Molenaar and Van Berkel (2013).

Several conclusions can be drawn based on this case-study:

- The analysis of the top soil and subsoil based on corings, *sondages* and trenches, using the method described in chapter 4, shows that the entire area was suitable for habitation during the Bronze Age. This analysis can be easily done with corings.

- Bronze Age ditches are usually not recognized in corings and are often interpreted as a disturbance of the Bronze Age top soil.

- Although the land consolidation projects have changed the appearance of the landscape drastically, the soil at this specific location is not disturbed to the degree as was supposed in advance of the project. The case of *De Rikkert* shows that corings and *sondages* can be used to check if a top soil is intact or not. These methods cannot be applied for estimating the degree of disturbance. The degree of disturbance can only be checked with trenches and not by coring, which is a regular practice in West-Frisia (§ 6.2.4). *Sondages* are not that useful for this purpose due to the small number of features present in the *sondages*.

- The geophysical research turned out to be extremely valuable. With this method it is possible to map larger ditches revealing the outlines of the cultural landscape. This information was very useful for the strategic planning of trenches for evaluation purposes. It is important to note that at this moment, with this type of equipment, it is not possible to identify individual features like post holes or structures like house plans. However, burial mounds with a ring ditch can be mapped very well.[85]

- The results of field surveys are difficult to interpret. The absence of finds does not mean anything with regard to the presence of settlement sites. This is not only the case at locations where the soil is intact and therefore finds in the modern plough zone are absent but also at locations where the Bronze Age top soil is incorporated in the present day plough zone. Surprisingly the distribution pattern of bone matches the distribution pattern of pottery. Due to the high numbers of bone, it reflects the presence of a settlement site possibly better.

After the analysis of settlement sites in chapter 5 and this case-study one conclusion is obvious: there is no relationship between the presence of archaeological sites and the soil units on the available detailed soil maps. The use of these maps puts one on the wrong track, therefore one ***should not use*** the map of Ente (or any other detailed soil map) in any way in a predictive model for West-Frisia.

6.4. A new policy document?

Based on the analysis in the previous chapters it is clear that the theory of relief inversion is not applicable in West-Frisia (§ 2.5.1) and the genesis of the landscape is far more complex than previously thought (§ 5.4.6). Therefore, the generally accepted relationship between the natural landscape, translated into soil units of detailed soil maps, and the location of settlement sites in West-Frisia is untrue. This implicates that the existing policy document, which is based on these relationships, is useless. In this last paragraph a new predictive model is described, a suggestion for the use of prospection techniques is given and a new idea for a policy document is suggested.

6.4.1. Predictive model

Site locations dating to the Late Neolithic and Early Bronze Age are strongly related to creeks and creek ridges. Not only settlement sites are to be expected

85 See also unpublished results by Van der Heijden and Feiken for the burial mounds of the site *De Eendenkooi* in Wervershoof and the unpublished results by Verschoof-Van der Vaart of the same site.

in close proximity to these geomorphogenetical units, but also special activity areas like fishing and fowling sites. Little is known about the location and depth of these types of units. The focus in inventories and especially during the exploratory phase for sites dating to this period should be the mapping of these units. Sites like *Noorderboekert* and *Rijweg* prove that these types of sites are not only present in western West-Frisia, but also present in eastern West-Frisia (Knippenberg in prep.).

All known settlement sites dating to the Middle Bronze Age are situated on top of tidal marsh deposits or creek deposits. These sites do have a relationship with the lithology. Settlement sites as well as burial sites are situated on top of consolidated clay, loam or sand surfaces. These types of sites are not situated on top of (partly) unconsolidated sediments or peat. The region covered by tidal marsh deposits in West-Frisia is a well-known, but intimidatingly vast area. Although the strong wish to differentiate within this vast area is understandable, it is hard to achieve. The method presented in chapter 4 can be applied easily on large uniformly described coring databases like the databases of STIBOKA and RAAP, but is of limited use in small development plots. Other types of sites like fishing and fowling sites may be expected in close proximity to creeks and lakes. Probably sites like *De Druppels*, *De Hoep* and *Emmeloord J97* can be interpreted in this way. Little or no research has been done on this type of landscape due to the focus on burial and settlement sites.

Late Bronze Age settlement sites are thought to be situated at the higher parts of the former tidal marsh landscape and creek ridges. Due to differential subsidence it is not possible to identify these higher parts in the present landscape. Only the large (Neolithic/Early Bronze Age) creek ridges of *Bovenkarspel* and *Opperdoes* have been, without any doubt, relatively high locations during this period.

6.4.2. Prospection techniques

The inventory process always starts with a desk-based assessment. Three questions are central in a desk-based assessment. These questions concern the intactness of the (Bronze Age) surface, the presence of finds and sites and the palaeogeographical development of the landscape.

The soil improvement map of the period of land consolidation projects is thought to be a valuable document to solve the first question. Also the use of old height measurements in relation to modern LIDAR-data are thought to be helpful in understanding the intactness of the landscape. The research at *De Rikkert* proved otherwise. It is important to note this research concerns only a relatively small (22 hectares) case and therefore cannot be uncritically extrapolated to the entire region of West-Frisia. The second question, concerning the presence of finds and sites in the research area, can be answered with information from the national archaeological database (ArchIS), the results of the surveys from the seventies and available databases with aerial photographs (for example the databases of Metz and the Water Board). It appears that the presence of archaeological finds is evidence for the presence of archaeological remains. The analysis of *De Rikkert* proves the reverse to be incorrect. Interpretation of this archaeological data in terms of archaeological expectations appears to be difficult. For example the ideas on the occurrence of the distribution of complete flint sickles outside settlement sites (Schinning 2012, 39) did not apply for the site of *De Rikkert*. The third question is usually answered with the use of detailed soil maps. Enough is said about this practice. It would be wise to use uniform described coring databases for this purpose if available.

The exploratory phase focuses on two questions: is the landscape as intact as suggested in the desk-based assessment and which geomorphogenetic units are present within the research area? The first question is usually thought to be answered by the use of corings. The research at *De Rikkert* confirmed the reservations about this technique by Archeologie West-Friesland (Gerritsen 2014, 35). Sondages and particularly small trenches provided good results concerning this question at *De Rikkert*. Corings are a good technique for answering the second question. Although experience with the description methods of sediments and a considerable depth (3-4 m) of the corings are defining for the success of this method.

The mapping phase focuses on the question: what type of sites at which location are present in the research area? The field survey at *De Rikkert* was a great success, with regard to the high numbers of finds. However, the location and nature of the site could not be established. Coring in West-Frisia is a technique that does not provide no answers to this question and needs no more explication. Sondages and trenches are useful to a certain extent. The same disadvantage of a field survey applies to trenching, absence of features cannot be translated into the absence of a site unless the sample is large enough, approximately 10 % of the surface (Borsboom and Verhagen 2009, 42). The only technique which provided consistent information in three successive years was the geophysical research. This method in combination with small trenches for ground truthing turned out to be a very powerful technique at *De Rikkert*. It is thought that this combination of methods is applicable in large parts of West-Frisia. Several tests at known sites in West-Frisia by Verschoof-Van der Vaart appeared to be successful.[86]

During the evaluation phase the nature, size, conservation and relative quality of sites are investigated. Trenching is the method of choice for answering these topics (figure 3.6). For example, at *De Rikkert,* trenching in the evaluation phase could have been focused on the nature, conservation and date of the burial mound. Topics for which samples and a clear section are needed. The geophysical data can be used to find the location of the burial mound and formulate an idea on the structure of the mound prior to trenching. This information can be used during the trenching in order to decrease the minimum surface area which is necessary for answering the research questions.

6.4.3. Policy document

The change in focus from research-led excavations into development-led excavations in the recent past resulted in finds of sites at unexpected locations. For Bronze Age West-Frisia it resulted, amongst others, in the observation that settlement sites are apparently not restricted to creek ridges (Van Zijverden 2013, 168). In relation to the formulation of a policy document this is an "awkward" observation. It implies that the familiar framework is no longer applicable and has to be adjusted. In the Dutch system these policy documents are usually developed for a 10 years period (Wro-article 3.1-2).[87] The idea of the settlement sites situated on creek ridges and use of the detailed soil maps, turns out to be incorrect. New sources are needed to build a new framework. What are these sources and how can these be incorporated into a new policy document for eastern West-Frisia and most importantly, should it be presented as a fixed map?

Four sources of information can be obtained and used easily. First of all information on the type and quality of the subsurface can be obtained relatively easily from large uniformly described databases, like the STIBOKA and RAAP databases. A second source is the large database with aerial photographs by De Vries-Metz (1993). This formidable database is only a useful start compared with the promising archived dataset of the Water Board. Soil marks and crop marks are directly related to land use and well-preserved sites. Important to note is that site locations with a (thin) sediment cover are not visible with this method. Therefore aerial pictures can only be used for a positive identification of archaeological sites and not for the absence of sites. A third source are the available results of field surveys in West-Frisia. This source is highly influenced by land use, surveying circumstances and research history. This last point is clearly visible in figure 4.5. A fourth source of information is the ArchIS database with known and sometimes valuated sites.

This type of information, corings, aerial pictures, field surveys and known sites is easily stored, labeled and kept up-to date in a GIS. New data and sources can easily be incorporated. Different layers for different periods are also easy to add. In the Netherlands this type of information is usually obtained from soil maps and the ArchIS database and translated into a fixed map of archaeological values. A disadvantage in this process is the lack of information on the quality and detail of the used data. In Bergen (Norway) a completely different strategy is used for determining the archaeological value. In the World Heritage site of Bryggen, a flexible GIS is used for determining the archaeological value of development sites (De Beer *et al.* 2011). In this GIS-model amongst others hydrological information is incorporated and can be used to provide detailed information on the conservation within this World Heritage site. A great advantage of this approach is that the reliability of the expected value can be visualized by the density and quality of records used to determine the expected value. Furthermore new subsurface data can be added easily and influences the expected value. For the Westwoud land consolidation area a dataset with the previously mentioned data is compiled and incorporated in a GIS and translated into maps for different purposes (chapter 4). For each mapped unit the data density and quality can be visualized in a manner comparable to the Bryggen GIS. It would be a challenge to develop this GIS for a larger part of West-Frisia in the future.

86 Amongst others research at Wervershoof Eendenkooi, personal communication.

87 Wro is the Dutch law on spatial planning.

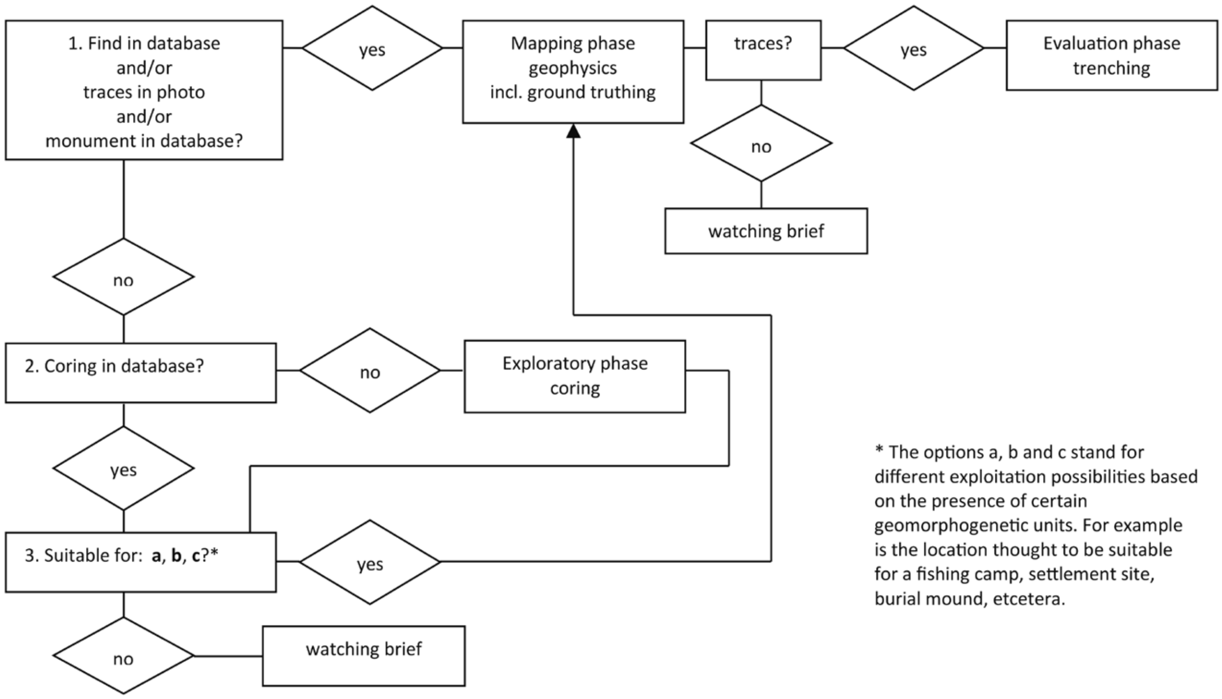


Figure 6.12: Suggested flow chart for archaeological inventories for Bronze Age sites in eastern West-Frisia.

The last ingredient needed for a policy map besides a predictive model and a "map" of archaeological values, is a policy for research. Based on the results of *De Rikkert* an ideal flow chart for research in eastern West-Frisia is designed (figure 6.12). In this chart the suggestion by De Boer and Molenaar (2006) for a systematic check of deselected locations, is formalized. This check is important in order to validate the assumptions constantly and keep the model up to date. In the chart geophysical researchs play an important role. This choice has been made, based on the consistent results in successive years at *De Rikkert* and comparable results at other site locations in West-Frisia, for example at *Wervershoof Eendenkooi*.

6.4.4. New legislation

The proposed model, with a flexible digital information system for archaeological values, fits very well with the new legislation (*Omgevingswet*) which will be effectuated from 2018 onwards. At this moment the policy map in combination with a map of archaeological values is used by municipalities to fill a zoning map with do's and don'ts regarding archaeology. These zones are usually defined for a period of 10 years. After 10 years a new zoning map is defined for a new period of ten years. Under the current legislation each new spatial initiative is assessed by the municipality for its influence in the particular zone. This way of regulation results in a fixed policy with little or no flexibility, a policy that can only be evaluated and changed every 10 years. New insights in archaeological values regarding preservation, site location and so on cannot be implemented during this 10 year period. The new legislation (*Omgevingswet*) is based on co-creation with more responsibility for citizens and enterprises and a more transparent local government. This way of spatial planning will result in more freedom of action for both the developer(s) and council. In order to realize this new way of spatial planning, up-to-date and transparent information is needed which cannot be realized in a traditional zoning map. A flexible GIS with a compact transparent flow chart as sketched in figure 6.12 can be a helpful tool in the realization of this new legislation.

6.5. Concluding remarks

Since the introduction of development-led archaeology in the Netherlands, a number of publications have been written on the topic of predictive modelling. These publications culminated in guides for best practices, as described in § 6.2.1. These guidelines are uncritically applied in West-Frisia. After the publication of the policy document for eastern West-Frisia by De Boer and Molenaar (2006) this situation did not change, despite the clear, well-argued guidelines and constraints presented by the authors. Large areas have been deselected through incorrect argumentation (for example Gerritsen 2014, 9-11). In the policy document by De Boer and Molenaar (2006), choices have been made which were in line with the ideas on habitation and settlement sites of West-Frisia and ideas on the way predictive maps should be made in that period. In this respect it is probably one of the best substantiated maps. Shortly after the publication of this document the settlement site of *Enkhuizen-Kadijken* was discovered at a location with a low archaeological value. The find of this site led to the "*Farmers of the Coast*" project and eventually to the research at *De Rikkert*.

The project of *De Rikkert* was fun, a playground for testing different prospection techniques.[88] In Dutch archaeology there are little opportunities for this type of research. Nevertheless this kind of research is important to understand the often experienced mismatch between archaeological expectation and archaeological reality. The proposed flexible digital information system for archaeological values works manually very well within the study area of Westwoud. Within the scope of the "*Farmers of the Coast*" project there was simply not enough time to develop this idea into a fully automated prototype. The changing legislation will probably stimulate other archaeologists to explore this idea (and probably many other ideas) into a policy document 2.0.

88 It was only possible to write this chapter based on the fieldwork carried out by Richard Jansen, Wouter Roessingh, Patrick Valentijn, Renate de Boer, Bastiaan Steffens, Wouter Verschoof-Van der Vaart (RAAP), Kees Kiestra (volunteer) and a large number of students. The project *De Rikkert* was only possible through the efforts of Carla Soonius (Archeologie West-Friesland), Liesbeth Theunissen (RCE) and of course the land owner J. Hovenier.

7 Conclusions

7.1. Introduction

In 2006, while prospecting the site of *Enkhuizen-Kadijken*, I never expected to rewrite the landscape development model of West-Frisia in the near future. I was a believer in the relief inversion model and did not question the closure history of the Bergen Inlet. Why would I? It was an elegant and simple model and it seemed to fit the archaeological data. I doubted the model presented by Van Geel *et al.* (1997) and wrote an article on that topic together with Peter Jongste (Jongste and Van Zijverden 2008). Today, ten years later, I reject the landscape development model and present a new palaeogeographical model. I embrace the ideas of Van Geel *et al.* (1997) partially. I reject their idea when it comes to a gradual change to a wetter environment induced by a change in solar activity. Although I do believe that the climatic event described by Van Geel *et al.* (1997) was the proverbial straw that broke the camels back and possibly dislocated the social structure of Bronze Age society. In this last chapter I will present a coherent model that provides answers to the questions formulated in the research proposal.

The aim of the project "*Farmers of the Coast*" is to create a new and coherent picture of farming communities in the coastal area of the North Sea. There is hardly a better area imaginable that is suitable for this study than West-Frisia. This area contains a well preserved Bronze Age landscape which is well-researched. There is an overwhelming amount of data available, which is, unfortunately, poorly published. Four sub-projects have been formulated within this project concerning the physical environment, settlements, farming practices and the cultural identity of coastal communities and their place in communication networks. This thesis deals with the physical environment and has to provide the necessary information on the physical environment for the other three sub-projects. This information has been studied and presented at three different scale levels. Three research questions were formulated in the research proposal for this study on the physical environment of the Westfrisian coastal wetlands (Fokkens 2011) as guidelines for this research:

1. How was the physical landscape of West-Frisia structured and how did it develop between 2000 and 800 cal BC?
2. Which parts were favoured for settlement?
3. What restraints and opportunities did it offer people?

In chapter 2 the history of the landscape research in West-Frisia as well as the current landscape development and habitation model have been discussed. In chapter 3 a new model for the development of West-Frisia has been described at a small map scale. In chapter 4 a new method for the construction of palaeogeographical reconstructions at an intermediate scale has been presented; the scale of an catchment area defined as the area which has been exploited on a daily basis. This new method has been applied at the land consolidation area Westwoud. In chapter 5 the variation of the subsoil of a selection of excavated settlements was analysed. Based on this evaluation the ideas formulated in chapter 3 were evaluated. This evaluation resulted in an overview of different geomorphogenetic models for site locations in West-Frisia. In chapter 6 the newly formulated ideas on the relation between the nature of the subsoil and locations favoured for settlement sites have been tested and applied to the research location *De Rikkert*. This test resulted in general recommendations for future research in eastern West-Frisia. In this last chapter these results are summarized and the research questions are answered.

7.2. The structure and development of the West-Frisian landscape

In the Late Neolithic and Early Bronze Age, West-Frisia is characterized by large tidal creeks in a vast basin area. In this basin area, creeks in different stages of development are present. Especially the creeks in their end-phase, with high levees, flanked by full grown splays and creeks which have been abandoned but still form high corridors in the basin area (the so-called creek ridges) are attractive locations to man. At the levees, splays and ridges people grow crops. In the more dynamic environments people gather, hunt, fish and fowl. In this varied landscape many environmental gradients are present. Gradients in water quality, water depth, flow velocity and flooding frequency. This variety results in a landscape with a high ecological diversity. This high ecological diversity is for example reflected in excavations like *Zeewijk*, *Mienakker* and *Keinsmerbrug*. Indications for salt, brackish and freshwater are found at each single site. Also indications for open, tidal marsh-like landscapes and different types of woodlands are present at each site. The time-depth of these sites is too large to understand the dynamic environment in the surroundings of these sites. Therefore, the struggle with the interpretation of these sites is understandable. Locations like *Noorderboekert* and *Wervershoof* fill in what is missing at these stable archaeological sites. Especially *Noorderboekert* presents on one hand a stable landscape which has been continuously in use for a relatively long period. A site, which is, with regard to this aspect, comparable to the three previously mentioned sites. On the other hand at less than 150 meters distance the biological record presents, simultaneously, a change from salt water, to brackish to almost fresh to brackish water again. In the same period the water depth, water movement and flooding frequency varies. But this is the reality for man in the Late Neolithic, exploiting stable locations surrounded by a highly dynamic environment with a great variety in ecological zones, or in the words of Hogestijn: an ecological paradise (Van Ginkel and Hogestijn 1997, 24).

This idyll is shattered *c.* 1800 BC when a deluge takes place in the Bergen tidal basin. For a short period, marine conditions reach as far as Emmeloord and probably even further east into the lower reach of the river Vecht. Due to little detailed environmental research and a lack of a firm set of dates in the Vecht basin, it is not possible to pinpoint this change to a single event. *Emmeloord J97* is the only site that shows a glimpse of the length of this environmental change. It is short and does not affect the use of this fishing spot. A storm surge is the most likely explanation for this event. It results in a blockade of the connection between the Vecht-river and the Bergen tidal inlet and affects the entire Bergen tidal basin to a large extent. After *c.* 1800 BC the landscape in eastern West-Frisia changes rapidly into a regular tidal marsh and silts up above mean high water (MHW). Meanwhile, the Vecht basin changes into a freshwater basin area. Only in western West-Frisia a small *Slufter*-like marine landscape remains. This change takes place within a hundred year period. In this pristine landscape, *c.* 1700 BC the first ditches are dug in eastern West-Frisia by the first settlers. This is the start of a new period of continuous exploitation of the landscape of West-Frisia.

From *c.* 1700 BC onwards eastern West-Frisia is best characterized as a flat and vast landscape with a poor natural drainage. Height differences are small and meaningless. In the lowest parts of the landscape water assembles and crystal clear lakes develop. Forests develop, but not on the nutrient rich and well-drained soils. At these locations grasslands of the class Molinio-Arrhenatheretea develop, probably as a result of a high grazing pressure. It results in a park like landscape with lakes, marshes and different types of woodlands alternating with open grassy areas. A landscape with great fishing waters, which is like a playground for wildlife. This landscape offered great opportunities for farming communities. Next to farming the landscape offered plenty of resources for hunting, fishing, fowling and gathering. At the same time in western West-Frisia, a *Slufter*-like landscape existed, which was flooded regularly by the sea through a smaller but still open Bergen tidal inlet. Though few sites are known in this area, this landscape was still exploited by man. Sediments and peat of later date hide probably well-preserved sites at greater depths than the length of a standard Edelman auger.

Approximately 1100 BC a new phase of landscape development starts. Probably the Bergen tidal inlet is closed from this moment onwards. The period is marked by extensive peat growth in western West-Frisia and the only known settlement site in this part of West-Frisia, *Hoogwoud*, is abandoned. In eastern West-Frisia the number of settlement sites seems to decrease. A decrease which is not only limited to eastern West-Frisia, but is a common phenomenon in The Netherlands as a whole. The landscape of eastern West-Frisia starts to change. The landscape becomes wetter and the lakes expand. On one hand this is caused by the ongoing rise of the sea level. On the other hand it is caused by the formation of the river Vecht-Angstel. This river is one of the main courses of the river Rhine and debouches in the Flevomeer area. This new river, with a rain induced peak discharge in winter, causes increasing seasonal fluctuations of the water level in the Flevomeer area and thus in the Vecht basin. At *c*. 900 BC the Vecht-Angstel is a mature river and reaches its maximum discharge. From this date onwards there are several indications for larger and more areas with stagnant freshwater: lakes. This date coincides with the erection of small terp mounds and a change in peat development. Terp mounds are mostly known from areas that experience regular flooding. The impact of the seasonal fluctuation is relatively large due to the small differences in surface heights in eastern West-Frisia. Presumably man used the natural higher spots in the landscape for settlement sites, although this is impossible to prove due to post Bronze Age differential subsidence. Apparently after *c*. 800 BC eastern West-Frisia was abandoned completely. Was it the changed climate, the suggested cloudier, colder and high precipitation rates suggested by Van Geel *et al.* (1997)? This will be hard to prove, but heavy rainfall could have been the proverbial straw that broke the camel's back.

Within a period of less than 300 years West-Frisia again became an attractive location for man. In western West-Frisia it was caused by origination of the tidal gullies of De Rekere and De Zijpe and the sedimentation along these tidal gullies. In eastern West-Frisia the opening of the Vliestroom *c*. 500 BC played an important role in the habitability of this area.

7.3. Site location and predictive modelling

The nature of the landscape and the location of sites are connected to each other. In the late Neolithic and Early Bronze Age the splays and levees of tidal creeks in their end phase and creek ridges were favored as site locations. In theory this type of location is easy to find, although in practice these sites are rarely found in regular inventories. The locations are characterized by a well-developed body of channel deposits. Often there is a well-developed dark A-horizon/find layer present in the sites. Outside the site locations, these horizons are light grayish and therefore difficult to recognize or even absent, depending on the dynamics in the former landscape. At some places these site locations are situated at a relatively shallow depth, within reach of the standard Edelman hand auger. However, large parts of this landscape are situated deeper than 120 centimeters below the present day surface level. This implies that the creek ridges, splays and levees from this period are poorly mapped and often not visible in LIDAR-images. For example, the substantial creek ridge of the *Noorderboekert* site is not visible in the LIDAR-image, not visible in the soil map and only recognizable in a few corings from the DINO-database. The top soil dating to the Late Neolithic and Early Bronze Age of this site can be recognized in some of the corings in the STIBOKA database (Knippenberg in prep.). Due to the small number of available observations it is not possible to reconstruct the location of this nevertheless pronounced ridge. For example, the few Late Neolithic sherds from field surveys in this area do not relate to the known locations with channel deposits from both databases or a clear ridge in a LIDAR-image. In order to create a better view of this landscape, corings have to be carried out to a greater depth in a denser pattern. An alternative is mapping the channel deposits geophysically. Research by Hamburg *et al.* (2014) shows it is relatively easy to map sand bodies (read channel deposits) by geophysical research with a magnetometer. After the landscape has been mapped properly, mapping sites is relatively easy and can be done by coring.

The relationship between sites and the landscape and prospection techniques for settlement sites dating to the Middle Bronze Age differs from the previous period. The landscape of the Middle Bronze age can be characterized as a former tidal marsh. At some locations the creek ridges dating to the Late Neolithic and Early Bronze Age were present at the surface as rudiments of the previous landscape. Middle Bronze Age settlement sites are mainly situated on top of the tidal marsh deposits, but also on these rudiments. Sites like *Enkhuizen-Kadijken*, *Andijk*, *Medemblik-Schepenwijk* and *De Rikkert* are situated at the first kind of location. The site of *Bovenkarspel-Het Valkje* is a good example of this last kind of location. In conclusion, contrary to the idea in the old model, Middle Bronze Age settlement sites are not solely situated at creek ridges and these ridges are definitely not the result of relief inversion. Other types of sites, like for example fishing sites, are expected to be present at the border of former lakes and especially along tidal gullies in western West-Frisia.

Settlement sites dating to the Middle Bronze Age are difficult to map. The case-study of *De Rikkert* showed that electrical conductivity followed by ground truthing with small trenches was the only consistent method in three successive years of research. This method was also successful at other Westfrisian sites dating to this period (Verschoof-Van der Vaart in prep.). Coring as a tracing method is useless, it does not reveal the degree of disturbance as is often thought and it is not possible to map settlement sites by finds. Field surveying is also not useful for mapping sites. The presence of surface finds seems to represent sites, but the reverse, absence of finds means absence of sites, is not true. Sondages can be useful for researching specific questions, for example the presence of ard marks. The nature of the landscape can be studied in much greater detail in sondages compared to corings, though sondages show the same type of limitation as corings in the mapping phase, no features does not mean no site.

Late Bronze Age sites are situated at the higher parts of the same landscape that was exploited in the Middle Bronze Age. Due to differential subsidence it is difficult to locate these higher parts. For example, Late Bronze Age features at the site of *Bovenkarspel-Het Valkje* are nowadays situated up to 75 cm higher compared to the same type of features at *Enkhuizen-Kadijken*. These sites are situated only 800 meters apart from each other. One would expect comparable heights in these sites at such short distances, when flooding occurred seasonally and obviously had to be faced. There is only one type of location which can easily be identified as a relatively high spot in the Late Bronze Age, the rudiments of the landscape of the Late Neolithic and Early Bronze Age.

7.4. Restraints and opportunities of the environment

When it comes to the three periods, the exploitation possibilities and restraints offered by the landscape are very different. Important in this respect is the changing position of West-Frisia in a transport-geographical sense. In the Late Neolithic and Early Bronze Age it was possible to navigate through the Bergen tidal inlet into Germany and the reverse. It is important to understand that navigation in this landscape and especially the crossing of the Vecht basin was not an easy task. Navigation skills and local knowledge of sailing routes were needed to traverse this area successfully. After the deluge between *c.* 1800 and 1700 BC, it was no longer possible to navigate across West-Frisia by boat into Germany. In the Middle Bronze Age lakes were present, but not necessarily connected to each other. Crossing West-Frisia by boat was probably a comparable experience to a modern canoe trip in Värmland (southern Sweden), a lot of land crossings. Eastern West-Frisia was connected to the east by the Vecht and Vecht basin and to the west by the Bergen tidal inlet. It was also possible to reach the coast through the Flevomeer area and the Oer-IJ estuary. In the Late Bronze Age, after the closure of the Bergen inlet, the coast could only be reached by boat through the Flevomeer-Oer-IJ estuary route.

In the Late Neolithic and Early Bronze Age the largest part of the Bergen tidal basin was covered with lakes, swamps and peats. The creeks and creek ridges formed narrow, but long stretches of stable, partially wooded, strips of land. At some places these strips of stable land were broader due to the presence of splay deposits. The creek ridges and locations with splays were attractive locations for settlement sites. The soil at these spots is rich in carbonates and has a high capillary fringe, therefore organic matter of a good quality can be expected at these locations. These soils were easy to work with an ard or hoe. Fishing was possible in creeks and basin areas. Fowling will have taken place at open (not wooded) locations in this area, for example at active splays. Sites like *Emmeloord J97* and *Keinsmerbrug* are good examples of what this type of site can look like.

In the Middle Bronze Age, western West-Frisia can be characterized as an active tidal marsh area. Tidal creeks may have been used for fishing and the marshes were ideal for fowling and herding cattle. Sites like *Schagen-De Hoep* illustrate this type of use of the landscape. In this area locations with arable land probably will have been absent or at least scarce. Settlement sites are not known from this area, which does not mean they are absent. In eastern West-Frisia the topsoil differs from clay to loamy sand ranging from a low to a high capillary fringe. The top soil contains a high proportion of calcium carbonates, which led to organic matter of a good quality. In other words, the landscape was ideal for arable land. Especially the clayey soils in this area are hard to work. Depending on the specific circumstances the soil has be worked with an ard and possibly burning techniques have been used to prepare the lutum rich arable land for sowing (Van Amerongen 2016, 186). Settlement sites can be literally expected almost everywhere in this landscape, but foremost at locations with grasslands of the class of Molinio-Arrhenatheretea. These grasslands developed probably due to a high grazing pressure and prevented the development of forests of the class Querco Fagetea (alliance Carpinion betuli). Fishing will have taken place in the omnipresent lakes.

In the Late Bronze Age the landscape became wetter. The lakes enlarged and the lower part of the landscape was seasonally flooded. This resulted in a smaller area suitable for arable land. Settlement sites were situated at the higher parts of the landscape. The composition of the vegetation did not change, compared to the Middle Bronze Age. The surface areas covered by lakes and wetter vegetation like Alnetea glutinosae and Artemisio-Salicetum albae enlarged at the expense of the area covered by drier vegetation like Fraxino-Ulmetum and Molinio-Arrhenatheretea.

7.5. Epilogue

When the last tunes of the Reuvensnight concert died away, FA walks up with ES to the exit of the concert-room. “Your lecture on the landscape of West-Frisia was quite unnerving” said FA. “So creek ridges are not always creek ridges even if they look like them, relief inversion is gibberish, the theory of Van Geel *et al.* (1997) is probably true but not the cause of the wetter circumstances in the Late Bronze Age of West-Frisia and the Bergen inlet was open during a large part of the Bronze Age? “Yup” mumbled ES. “But why are you sulking? It gives quite a different view on the exploitation possibilities of West-Frisia in the Bronze Age!” “How so?”, asked ES. “Well, for instance, if people lived on top of former tidal marsh deposits, Bronze Age settlement sites can be everywhere. If there have been forests the area must have been full of a diverse wildlife. Maybe farmers harvested plants and hunted game in these forests, just as your colleague what’s her name, presented in her lecture. And don’t forget the possibilities for fowling and fishing in this area!” “Yes, yes it’s all in the new model” said ES, “but if they have been fowling, fishing and hunting, where are the traps, the weirs, the fykes and so on? You don’t think people were fishing in these omnipresent ditches, don’t you?” “No of course not”, answered FA, “that is not possible. It must have been in the lakes and gullies”, “And what about boats and canoes? If the main way of transportation to and from West-Frisia was by boat and we do know these guys lived on a kind of island trading cows and sheep with people in the eastern parts of the Netherlands and flint sickles with the Danes and bronzes with the French and English, where are their means of transport?” ES cried out in frustration. “Well, we have the fyke from *Enkhuizen-Kadijken*, the paddle from *Houterpolder*, the bling bling of *Markerwaardweg* and the sickles of *De Rikkert*.” FA summed up the most recent finds in West-Frisia. “You just wait and we will find the first boat or canoe some time soon,” FA said. “Will you?”, ES asked. “The whole damn predictive modelling industry is focused on settlement sites.” “Yeah that’s true, but these other types of sites are so hard to find, so who’s to blame?” FA replied. “Yes indeed”, sighed ES, “it is always difficult to find something you’re not explicitly looking for, but it doesn’t mean you shouldn’t at least try. It’s Popper’s swans or the invisible gorillas!” “Yeah those times in college were great when you had time to think about stuff like that. But we ain’t no longer in that ivory tower are we?” FA replied. “Come on let’s go and grab some beers. Did I tell you about the new dig in Opperdoes next week? Maybe we’ll find one of your swans or gorillas!” And off they went for another memorable adventure.

Samenvatting

Na de vloed, een paleogeografische reconstructie van West-Friesland in de Bronstijd (2000-800 voor Chr.)

Introductie

Ik ben opgegroeid in Medemblik in de periode van de ruilverkavelingen (figuur 2.5). Deze maakten op mij als kind niet heel veel indruk. Mijn ouders klaagden vooral over de gladheid op de wegen door de grote hoeveelheid modder. Wat mij het meest is bijgebleven van de ruilverkavelingen is de opening van de McDonalds bij Hoorn in 1978. Veel meer herinner ik mij hier niet van. Achteraf gezien hebben de ingrepen in het landschap in deze periode een zeer grote impact gehad op de economie, het natuur- en cultuurlandschap (figuur 2.4), de biodiversiteit en het cultureel erfgoed. Met betrekking tot het cultureel erfgoed kan in positieve zin worden opgemerkt dat in deze periode de kennis over de ontstaanswijze van het landschap en haar bewoningsgeschiedenis sterk is toegenomen. In negatieve zin kan worden geconcludeerd dat een groot deel van dit cultureel erfgoed ongezien is vernietigd door grootschalig grondverzet en diepe ontwatering. Deze kennis heeft geleid tot een algemeen geaccepteerd beeld over de landschaps- en bewoningsgeschiedenis van West-Friesland in de Bronstijd (Van Geel *et al.* 1982; 1997; IJzereef en Van Regteren Altena 1993). In dit proefschrift wordt op basis van archeologisch en aardkundig onderzoek uit de ruilverkavelingsperiode en recent gepubliceerd onderzoek een nieuw beeld geschetst van de landschappelijke ontwikkeling van West-Friesland in de Bronstijd (2000-800 v. Chr.).

Een eerste studie naar de ontwikeling van het landschap van West-Friesland is gepubliceerd door Pons en Wiggers (1959;1960). Deze publicatie is gebaseerd op de aardkundige kennis die is vergaard ten tijde van de bodemkarteringen voorafgaand aan de ruilverkavelingsprojecten. In 1982 verscheen een studie waarin de paleogeografische ontwikkeling van West-Friesland schetsmatig is weergegeven (De Mulder en Bosch 1982; figuur 2.6), ondersteund door een groot aantal koolstofdateringen. In datzelfde jaar werd ook een aansprekend en elegant bewoningsmodel (figuur 2.9) gepubliceerd door Van Geel *et al.* (1982). In 1993 is dit bewoningsmodel verder ingevuld (figuur 5.1) door IJzereef en Van Regteren Altena (1993). Als sluitstuk publiceerden Van Geel *et al.* (1997) een overtuigend artikel waarin een plotselinge klimaatomslag de oorzaak is van het einde van de bewoning van West-Friesland. Dit bewoningsmodel komt samengevat op het volgende neer:

Het Westfriese landschap is ontstaan als een wad-/kwelderlandschap. Door de sluiting van het zeegat van Bergen rond 1570 voor Chr. ontstond een landschap dat grote aantrekkingskracht uitoefende op de toenmalige bewoners van het Nederlandse kustgebied. Als gevolg van reliëfinversie vormden de voormalige wadgeulen hoge ruggen in het landschap. De mens nam deze hoge ruggen in gebruik, vrijwel direct nadat deze beschikbaar kwamen voor bewoning. Het landschap had een open karakter en was nagenoeg boomloos. Als gevolg van een stijgende zeespiegel werd het oppervlak dat geschikt was voor bewoning in de loop van de Bronstijd steeds kleiner. Uiteindelijk werd de wateroverlast zo groot dat men kleine huisterpen opwierp. Tenslotte vond een omslag in het klimaat plaats waardoor een snelle vernatting plaatsvond en bewoning in dit gebied niet langer meer mogelijk was. Men verliet West-Friesland en kort daarna raakte het gebied overdekt met een enkele meters dik pakket veen.

Vanaf 2005 vonden enkele opgravingen plaats in West-Friesland die leidden tot vragen met betrekking tot het hierboven beschreven bewoningsmodel van West-Friesland (Van Zijverden 2013). Vooral de opgraving van *Enkhuizen-Kadijken* (Roessingh en Lohof 2011) paste niet in het hierboven geschetste beeld. Deze vindplaats was niet gesitueerd op een kreekrug maar op kwelderafzettingen en was niet afgedekt met veen. Daarnaast werden verschillende aanwijzingen voor de aanwezigheid van bossen in de nabije omgeving van de vindplaats aangetroffen. Deze discrepantie en het feit dat er weinig tot niets van het grootschalige archeologisch onderzoek uit de ruilverkavelingsperiode was gepubliceerd, inspireerde Harry Fokkens tot het opstellen van het onderzoeksproject "*Farmers of the Coast*".

Onderzoekskader en -vragen

Het project "*Farmers of the Coast*" draait om de these dat tijdens de Bronstijd de agrarische gemeenschappen in het kustgebied een centrale positie innamen in communicatienetwerken en dat deze gemeenschappen een eigen culturele identiteit bezaten (Fokkens 2011). West-Friesland is bij uitstek de plaats in noordwest Europa om dit te onderzoeken vanwege de goede conservering en de grote, goed gedocumenteerde archeologische en geologische dataset. In vier deelprojecten is deze these vanuit verschillende gezichtspunten onderzocht. Dit proefschrift heeft de ontwikkeling van de fysieke leefomgeving en de bewoningsmogelijkheden als onderwerp. Het onderzoek biedt het landschappelijk kader voor de andere drie deelprojecten: de analyse van de nederzettingen (Roessingh in prep.), de landbouwpraktijken (Van Amerongen 2016) en de plaats van de kustgemeenschappen in communicatienetwerken (Valentijn in prep.). Voor elk van deze studies is het landschap op een verschillend schaalniveau bestudeerd: de vindplaats, de *catchment area* en het getijdenbekken van Bergen. De volgende drie vragen staan centraal in dit onderzoek van de fysieke omgeving van de Westfriese kust (Fokkens 2011):

1. Hoe is het fysieke landschap van West-Friesland ontstaan en hoe ontwikkelde dit landschap zich tussen 2000 en 800 voor Chr.?
2. Welke delen van het landschap waren geschikt voor bewoning?
3. Welke kansen en beperkingen bood het landschap de mens?

Geschiedenis van het landschappelijk onderzoek

De totstandkoming van de dataset en de daarop gebaseerde modellen is het onderwerp van hoofdstuk 2. In dit hoofdstuk wordt een kort overzicht gegeven van de ontwikkeling van het aardwetenschappelijk onderzoek in de negentiende eeuw en het begin van de twintigste eeuw. Een belangrijke stimulans voor het aardwetenschappelijke onderzoek in de twintigste eeuw is de ruilverkavelingswet van 1924. Voor het herverdelen en verbeteren van landbouwgrond waren namelijk kleinschalige gedetailleerde bodemkaarten onontbeerlijk. De toenmalige Landbouwhogeschool in Wageningen speelde een belangrijke rol bij het ontwikkelen van karteringsmethoden en -technieken voor dit doel. Na de Tweede Wereldoorlog nam het aantal en de omvang van de ruilverkavelingen sterk toe. In opdracht van de rijksoverheid werd door Stiboka (Stichting voor Bodemkartering) een bodemkaart vervaardigd van Nederland op schaal 1:50.000. Daarnaast werden voor de Landinrichtingsdienst gedetailleerde bodemkaarten (schaal 1:20.000) vervaardigd ten behoeve van ruilverkavelingen. De data van de Nederlandse ondergrond die in dat kader is verzameld vormt in belangrijke mate de basis voor studies naar de ontwikkeling van het landschap, zo ook in het onderhavige onderzoek.

Hoewel voorafgaand aan de ruilverkavelingen in West-Friesland al bekend was dat dicht onder de bouwvoor vindplaatsen uit de Bronstijd aanwezig zijn (Van Giffen 1944; Ente 1963), werd de volle omvang pas duidelijk tijdens de eerste grootschalige grondwerkzaamheden in ruilverkavelingsgebied *Het Grootslag* (IJzereef and Van Regteren Altena 1991, 61). Dit leidde tot grootschalige onderzoeken van het Instituut voor Prae- en Protohistorie (IPP), de Rijksdienst voor het Oudheidkundig Bodemonderzoek (ROB) en het Biologisch-Archeologisch Instituut (BAI). De opgraving van de vindplaats *Opperdoes-Markerwaardweg* in 1985 vormde het sluitstuk van de toenmalige opgravingen van Bronstijdnederzettingen in West-Friesland. Algemeen werd gedacht dat als gevolg van de ruilverkavelingen het bodemarchief zodanig zou zijn aangetast dat met uitzondering van *Bovenkarspel-Monument* weinig resten uit de Bronstijd bewaard zijn gebleven.

Na de millenniumwisseling vonden in het kader van nieuwe wetgeving opnieuw onderzoeken plaats. Dit zogenaamde Malta-onderzoek, leidde tot een hernieuwde belangstelling voor Bronstijdvindplaatsen in West-Friesland. Met name de opgravingen *Hoogwoud* (Lohof en Vaars 2005), *Medemblik-Schepenwijk* (Schurmans 2011) en *Enkhuizen-Kadijken* (Roessingh en Lohof 2011) illustreren dat de vernietiging van het bodemarchief niet zo volledig is als algemeen werd aangenomen. Daarnaast illustreert dit onderzoek dat het bestaande bewoningsmodel en het landschapsontwikkelingsmodel op een aantal punten moet worden bijgesteld.

In de jaren '90 heeft een uitgebreide studie plaatsgevonden naar de landschapsontwikkeling van West-Friesland in het kader van het project Kustgenese van de Rijks Geologische Dienst (Van der Spek 1994). In dit proefschrift wordt afstand genomen van het tot dan toe gangbare transgressie-regressie kustontwikkelingsmodel en een alternatief ontwikkelingsmodel gepresenteerd. In dit model speelt naast de bodemdaling en zeespiegelstijging de vorm van het getijdenbekken een belangrijke rol. Van der Spek (1994) past dit model toe op de ontwikkeling van het getijdenbekken van Bergen. Dit en andere nieuwe inzichten in de landschapsgenese van Nederland vroegen om een nieuw paleogeografisch overzicht van Nederland. In 2011 verscheen dit overzicht in een prachtige uitgave voor een breed publiek (Vos *et al.* 2011). De paleogeografische kaart die de situatie rondom 1500 voor Chr. weergeeft (figuur 2.10) is echter overduidelijk onjuist, immers geen enkele van de vindplaatsen die op deze kaart is afgebeeld is gesitueerd op veen. Een aangepaste kaart verscheen in 2015 (Vos 2015). Ook deze kaart geeft de situatie onjuist weer, de vindplaats *Bovenkarspel-Het Valkj*e is bijvoorbeeld niet gesitueerd op of langs een actieve wadgeul of kreek.

Aan het einde van hoofdstuk 2 kan worden geconcludeerd dat ondanks de intensieve samenwerking tussen aardwetenschappers en archeologen en de grote dataset, het destijds gepresenteerde bewoningsmodel en het paleogeografische model niet op elkaar aansluiten. Daarnaast passen de nieuwste opgravingsgegevens niet in de gepresenteerde modellen. In de volgende drie hoofdstukken wordt op drie schaalniveaus (getijdenbekken van Bergen, de *catchment area* en de vindplaats) het landschapsontwikkelingsmodel geëvalueerd.

Het getijdenbekken van Bergen

De waterstand in West-Friesland wordt beïnvloed door drie kustopeningen en de bijbehorende bekkens, het zeegat van Bergen, het Oer-IJ en de Vliestroom (figuur 3.2). De ontwikkeling van deze drie bekkens wordt in hoofdstuk 3 kort beschreven aan de hand van de beschikbare literatuur. De drie bekkens zijn in het recente verleden in meer of mindere mate van detail bestudeerd (De Mulder en Bosch 1982; Lenselink en Koopstra 1994, Kok 2008, Ten Anscher 2012, Vos 2015). Echter, de bekkens zijn niet eerder in onderlinge samenhang bestudeerd.

Het Bergen getijdenbekken is het langst geleden onderzocht (De Mulder en Bosch 1982). Een aantal van de door De Mulder en Bosch (1982) gepresenteerde dateringen kunnen op basis van de huidige kennis over dateringsmethoden en -technieken terzijde worden geschoven als minder betrouwbaar. In Appendix I wordt een waarderingssystematiek gepresenteerd om de beschikbare dateringsgegevens uit alle drie de datasets met elkaar te kunnen vergelijken. In het derde hoofdstuk worden vervolgens 29 locaties gepresenteerd die in detail informatie geven over de ontwikkeling van het landschap in het getijdenbekken van Bergen in de loop van de tijd. Op basis van deze informatie is een nieuw paleogeografisch beeld opgesteld (figuur 3.12). Deze analyse wijzigt op een aantal belangrijke punten het paleogeografische beeld van de ontwikkeling van West-Friesland.

Voorafgaand aan de Bronstijd is sprake van een grote kustopening ter plaatse van het huidige Bergen. Vanuit deze opening slingert een zich vertakkende getijdengeul diep landinwaarts tot in het merengebied ter plaatse van het huidige IJsselmeer. Voorafgaand aan de Bronstijd is dit geen onderwatergeul maar een geul die wordt geflankeerd door ruim boven gemiddeld hoogwater opgeslibde oevers die worden geflankeerd door splays en uitgestrekte komgebieden. Deze komgebieden zijn verschillend van aard. Afhankelijk van de diepte, overstromingsfrequentie en waterkwaliteit kunnen deze kommen worden gekarakteriseerd als open watervlaktes, rietmoerassen en soms slikken. Het milieu in de komgebieden wisselt regelmatig terwijl de oevers en splays een min of meer stabiel milieu kennen. Op deze locaties kunnen dan ook bossen en bosschages tot ontwikkeling komen. Dit zijn de plaatsen in het landschap die aantrekkelijk zijn geweest voor de mens getuige sporen van akkerbouw en bewoning. Aan de oostzijde van het huidige IJsselmeergebied wordt het merengebied gevoed door de Overijsselsche Vecht. In deze periode is het mogelijk vanuit het Duitse achterland in één keer door te varen naar de Noordzee en vice versa.

Tussen 1800 en 1700 voor Chr. vindt in dit systeem een grote omslag plaats. Deze omslag is zichtbaar door het kortstondig voorkomen van brakwatercondities tot in Emmeloord. Als verklaring wordt gedacht aan een desastreuze stormvloed. Vlak na dit event is er geen enkele indicatie meer voor een verbinding tussen het merengebied en de Noordzee. Kennelijk is de getijdengeul als gevolg van dit event geblokkeerd. Door deze blokkade verkleint de accommodatieruimte van het getijdenbekken met circa tweederde van het oorspronkelijke oppervlak. Tegelijkertijd verkleint de lengte van de getijdengeul slechts met een derde van de oorspronkelijke lengte. Dit zorgt voor een disbalans in het getijdenbekken. Als gevolg hiervan verandert het landschap in West-Friesland volledig van karakter. In oostelijk West-Friesland ontstaat een wad-/kweldergebied waarbij het sediment hoog opslibt terwijl in westelijk West-Friesland deze opslibbing veel geringer is. Wanneer het evenwicht rond 1700 voor Chr. weer is hersteld blijft in westelijk West-Friesland een kleine opening in de kust bestaan met een Slufter-achtig landschap dat zich uitstrekt tot aan Hoogwoud. Oostelijk West-Friesland is dan opgeslibd tot buiten het bereik van de zee en kan worden gekarakteriseerd als een voormalig kweldergebied, een grote platte pannenkoek met een slechte natuurlijke drainage. Dit landschap verzoet vanaf 1700 voor Chr. in hoog tempo. De afvoer van de Overijsselsche Vecht vindt nadien plaats via het zuidelijk gelegen merengebied (het Flevomeer) en het Oer-IJ naar de Noordzee.

Het zeegat van Bergen is open gedurende de bewoning van de vindplaats *Hoogwoud*. De bewoning op deze vindplaats eindigt circa 1100 voor Chr. Het is goed mogelijk dat de beëindiging van de bewoning op deze vindplaats samenhangt met de sluiting van het zeegat. Een latere datering voor de sluiting van het zeegat kan echter niet worden uitgesloten. In oostelijk West-Friesland wordt gedurende de hele Midden en Late Bronstijd gewoond en gewerkt. Net als in andere regio's in Nederland lijkt tussen 1100 en 1000 voor Chr. sprake te zijn van een korte onderbreking. Het is onduidelijk wat hiervan de oorzaak is. Als gevolg van een geleidelijk stijgende zeespiegel worden de condities in oostelijk West-Friesland in de loop van de Bronstijd steeds natter. Dit leidt tot veenvorming en uitbreiding van de in het landschap aanwezige meren. Het is echter niet alleen deze zeespiegelstijging die voor een verdere vernatting verantwoordelijk is. Het zijn vooral toegenomen fluctuaties van het waterpeil in het merengebied die van invloed zijn op de grond- en oppervlaktewaterstand in oostelijk West-Friesland. Rond 1050 v.Chr. vindt de Vecht-Angstel aansluiting op het Flevomeer (Bos 2010, 54-55). Deze rivier vormt rond 900 v.Chr. een volwassen rivierarm en voert dan circa eenderde van de totale afvoer van de Rijn af. De Rijn kent een afvoerregime met hoogwaters in de late winter en het vroege voorjaar. Deze schommelingen zullen effect hebben gehad op de seizoensmatige fluctuaties in de waterstanden in het merengebied. Op verschillende plaatsen is vastgesteld dat rond deze tijd veranderingen optreden in de Westfriese waterhuishouding. Daarnaast worden in deze periode de eerste huisterpen opgeworpen, een maatregel die goed past bij het optreden van seizoensmatige wateroverlast. Het is goed mogelijk dat de door Van Geel *et al.* (1997) geconstateerde klimaatsverandering de spreekwoordelijke druppel is geweest die de emmer deed overlopen en de oorzaak is van de beëindiging van de bewoning.

Rond 500 voor Chr. ontstaan nieuwe geulen in westelijk West-Friesland, de Zijpe en de Rekere. Dit zorgt voor een verbetering van de drainage van westelijk West-Friesland en heeft tot gevolg dat het aanwezige veen gedeeltelijk oxideert. Op de afzettingen langs deze geulen en op het geoxideerde veen ontstaan nieuwe nederzettingen. Ook in oostelijk West-Friesland wordt het veen gedraineerd en ontstaan nieuwe mogelijkheden voor bewoning. De drainage in oostelijk West-Friesland wordt veroorzaakt door het ontstaan van de Vliestroom. Hierdoor daalt het waterpeil in het merengebied. Indirect versnelt dit ook de sluiting van het Oer-IJ. Dit verhaal valt echter buiten de scope van het onderhavige onderzoek.

Catchment area

In hoofdstuk 4 wordt een methode gepresenteerd om inzicht te krijgen in de paleogeografie van het dagelijks geëxploiteerde landschap. Twee studies liggen ten grondslag aan deze methode. De eerste studie is die van Van Beurden (2008), de tweede die van Schepers (2014). Van Beurden (2008) beredeneert de vegetatie vanuit standplaatsfactoren. Wanneer de standplaatsfactoren op een geografische locatie bekend zijn, is de natuurlijke successie op deze locatie in grote mate voorspelbaar. Voor het bepalen van de standplaatsfactoren maakt zij gebruik van een ondergrondmodel waarin reliëf, waterbeweging, waterkwaliteit en bodemkwaliteit zijn opgenomen. De invloed van de mens op de vegetatie blijft in haar benadering min of meer buiten beschouwing. Schepers (2014) maakt in zijn studie gebruik van kensoorten in onder meer *channel lag deposits*, min of meer toevallig bijeen gespoelde plantenresten. Op basis van de kensoorten die in deze afzettingen aanwezig zijn, kan Schepers (2014) met enige zekerheid aangeven welke plantengemeenschappen in de directe omgeving daadwerkelijk aanwezig moeten zijn geweest. Een groot gemis in het model van Schepers(2014) is dat het met deze methode niet mogelijk is de geografische plaats van deze vegetaties te bepalen. Door de twee methoden te combineren is in hoofdstuk 4 geprobeerd een reconstructie te maken voor het ruilverkavelingsgebied *Westwoud* (figuur 4.9). Enkele gebieden in dit gereconstrueerde landschap zijn minder geschikt voor bewoning. Aan de hand van een grootschalige veldverkenning en luchtfoto's (De Vries-Metz 1993) kon worden gecontroleerd of in deze gebieden sporen van bewoning afwezig zijn. Tenslotte vonden er tijdens het onderzoek voor het onderhavige proefschrift diverse onderzoeken plaats binnen dit ruilverkavelingsgebied die konden worden gebruikt ter controle van de opgestelde reconstructie (figuur 4.5).

Het ondergrondmodel is vervaardigd op basis van boorgegevens die voorafgaand aan de ruilverkaveling zijn verzameld door Stiboka. Voor het hoogtemodel is gebruik gemaakt van een gedigitaliseerd hoogtepuntenbestand uit de ruilverkavelingsperiode. Voor het grondwatermodel is gebruik gemaakt van een uitgebreide herwaardering van 139 molluskenmonsters die in het verleden zijn uitgewerkt door Wim Kuijper (Mink 2016). Op basis van het ondergrondmodel werd een successie voorspeld voor de verschillende eenheden van het ondergrondmodel, analoog aan de methode van Van Beurden (2008). Vervolgens zijn uit een groslijst van alle beschikbare botanische data uit opgravingen in het ruilverkavelingsgebied de kensoorten voor verschillende plantengemeenschappen geselecteerd. Opmerkelijk is dat slechts één van de verwachtte plantengemeenschappen, het Carpinion-Betuli, afwezig moet zijn geweest op basis van de afwezigheid van de bij deze plantengemeenschap behorende kensoorten. Voor deze vegetatie typerende soorten als de linde (*Tilia cordata*) lijken lokaal niet te hebben gegroeid. Ook de bijbehorende rompgemeenschap waarin een soort als sleepruim (*Prunus spinosa*) een belangrijke plaats inneemt is afwezig. Kensoorten uit de voedselrijke graslanden (Molinio-Arrhenatheretea) die voorafgaan aan de ontwikkling van het bovengenoemde bostype zijn daarentegen zeer duidelijk aanwezig. Als verklaring voor de afwezigheid van dit bostype met bijbehorende rompgemeeschap wordt gedacht aan een grote graasdruk op de rijkere, droge gronden waardoor dit bostype binnen het onderzoeksgebied niet tot ontwikkeling is gekomen.

De vindplaats

In hoofdstuk 5 staat het landschap in en rondom de nederzetting centraal. In de literatuur over nederzettingen in West-Friesland neemt de kreekrug een belangrijke plaats in (figuur 5.1). In hoofdstuk 2 is aangegeven dat landschapsinversie niet van toepassing is op het ontstaan deze ruggen zoals Havinga aantoont in een artikel met de suggestieve titel: "*Op dwaalwegen met de theorie van de omkering van het bodemreliëf*". In hoofdstuk 5 wordt de relatie tussen nederzettingen en de aard van de ondergrond geanalyseerd aan de hand van enkele grootschalige opgravingen: *Medemblik-Schepenwijk*, *Andijk*, *Hoogkarspel*, *Bovenkarspel-Het Valkje* en *Enkhuizen-Kadijken*. Op basis van een analyse van de opgravingsgegevens en beschikbare boorgegevens wordt geconstateerd dat de vindplaatsen met uitzondering van *Bovenkarspel-Het Valkje* niet op een kreekrug zijn gelegen maar op kwelderafzettingen. Desalniettemin is binnen sommige vindplaatsen sprake van duidelijk hoger gelegen plekken, bijvoorbeeld in de vindplaats *Hoogkarspel*. De genese van deze hogere plaatsen is complex en niet eenduidig toe te wijzen aan een specifieke kreek. In figuur 5.17 is dit schematisch weergegeven. In figuur 5.21 is sterk vereenvoudigd uitgewerkt op welke wijze de kreekruggen uit het Laat-Neolithicum samen met de beddingafzettingen van kreken uit het wad-/kwelder landschap uit de Vroege Bronstijd resulteren in een licht geaccidenteerd landschap. Een landschap waarin individuele kreekruggen niet meer als zodanig herkenbaar zijn. Daarnaast is sterk vereenvoudigd weergegeven hoe dit reliëf van invloed is op de exploiteerbaarheid van het landschap in de Midden en Late Bronstijd.

Twee belangrijke conclusies kunnen worden getrokken op basis van deze analyse. Ten eerste beperkt de bewoning in oostelijk West-Friesland zich beslist niet tot de huidige hogere plaatsen in het landschap. Het uitgevoerde onderzoek op *De Rikkert* toont aan dat zelfs in de eenheid veen op de kaart van Ente (1963) nederzettingssporen uit de Bronstijd kunnen voorkomen. Dat wil niet zeggen dat de aard van de ondergrond niet van invloed is geweest op de inrichting van het landschap. Zoals Bakker (Bakker *et al.* 1977) al constateerde, speelden lithologische overgangen een rol bij de inrichting van het landschap (figuur 5.2). Een tweede conclusie betreft het gebruik van de bodemkaart van Ente (1963) en andere gedetailleerde bodemkaarten. Deze kaarten geven een sterk gegeneraliseerd beeld van de opbouw van de ondergrond (figuur 5.3). De kaarten kunnen en mogen niet worden vertaald in geomorfologische, lithogenetische of geomorfogenetische eenheden zoals gebruikelijk is binnen het archeologische werkveld. De kaarten moeten worden gebruikt waarvoor deze zijn gemaakt: de verspreiding en opeenvolging van zand, zavel, klei en veen.

Predictive modelling

De bodemkaarten van Stiboka, zoals de kaart van Ente (1963), spelen in West-Friesland een belangrijke rol bij het voorspellen waar vindplaatsen aanwezig zouden kunnen zijn. Dat niet alleen, deze kaarten worden ook toegepast als onderlegger voor het lokale beleid (De Boer en Molenaar 2006). De beleidsadvieskaart voor oostelijk West-Friesland is op dit punt bijzonder goed onderbouwd (tabel 6.1). Op basis van een analyse van de bodemkaart van Ente (1963) in relatie tot de verspreiding van vondsten worden verschillende eenheden onderscheiden met een verschillende archeologische verwachtingswaarde. Voor elk van deze eenheden is een beleidsadvies opgesteld. Een belangrijke constatering in dit document is dat grondboringen niet geschikt zijn als prospectiemiddel voor nederzettingsterreinen in West-Friesland. Op basis van een analyse van alle uitgevoerde onderzoeken die zijn opgenomen in het E-depot voor de Nederlandse archeologie (EDNA) in de eerste 10 jaar sinds de publicatie van dit beleidsdocument, blijkt deze richtlijn slechts in beperkte mate te worden opgevolgd (figuur 6.3). Dit is opmerkelijk gezien het feit dat de lokale overheden in deze regio intensief samenwerken op het gebied van archeologie in de vorm van de goed geoutilleerde organisatie, Archeologie West-Friesland.

Om antwoord te krijgen op de vraag welke prospectiemethoden en -technieken dan wel werken voor het opsporen van Bronstijdnederzettingen in oostelijk West-Friesland, is tijdens het onderzoeksproject "*Farmers of the Coast*" in opeenvolgende jaren veldwerk verricht aan De Rikkert in Oosterdijk (figuur 6.4-6.11). Op basis van dit veldwerk is een stroomdiagram opgesteld waarin het optimale proces voor een prospectief onderzoek voor deze regio is weergegeven binnen de kaders van de vigerende versie van de Kwaliteitsnorm Nederlandse Archeologie (figuur 6.12). Electrische weerstandsmetingen (Verschoof-Van der Vaart in prep.) in combinatie met *ground-truthing* door middel van sondages en proefsleufjes met minimale afmetingen, bleek de meest betrouwbare en consistente methode.

In hoofdstuk 5 is duidelijk aangetoond dat de bodemkaarten van Stiboka niet gebruikt kunnen worden als onderlegger voor archeologische beleidsadviesdocumenten. De vraag is: wat dan wel? Binnen de kaders van het onderhavige onderzoek was het niet mogelijk hiervoor een nieuwe tool te ontwikkelen. Een *GIS-based* beleidsadvieskaart zoals deze is ontwikkeld voor de site Bryggen in Noorwegen (De Beer *et al.* 2011) lijkt een zeer bruikbaar middel dat bovendien goed aansluit bij de nieuwe Omgevingswet die vanaf 2018 van toepassing wordt voor het Nederlandse archeologische werkveld.

Tot besluit

Tot besluit wordt in hoofdstuk 7 een antwoord geformuleerd op de vragen die in de inleiding zijn gesteld. Kort samengevat kan West-Friesland in het Laat-Neolithicum worden gekenmerkt als een kreken-kommen landschap. In dit landschap woonde en werkte de mens op oevers en splays van de (verlande) kreken. Deze plaatsen vormden stabiele plekken in een verder zeer dynamisch landschap. In de kommen wisselde de waterkwaliteit en -diepte met enige regelmaat. In deze periode was het mogelijk om per boot vanuit Duitsland via West-Friesland de Noordzee te bereiken en vice versa. Rond 1800 voor Chr. vindt hierin een drastische verandering plaats, mogelijk als gevolg van een stormvloed. De verbinding tussen de Overijsselsche Vecht en de Noordzee verloopt nadien via het Flevomeer en het Oer-IJ. In West-Friesland ontstaat in zeer korte tijd een wad-/kwelderlandschap. Door de disbalans in het systeem raakt oostelijk West-Friesland hoog opgeslibd en ligt rond 1700 voor Chr. buiten bereik van de zee. Het is vanaf dit moment niet meer mogelijk per boot West-Friesland te doorkruisen. In westelijk West-Friesland bestaat dan een Slufter-achtig landschap dat in ieder geval tot 1100 voor Chr. blijft bestaan. De voormalige kweldergronden in oostelijk West-Friesland zijn zonder uitzondering geschikt voor bewoning. In de loop van de Bronstijd stijgt de grond- en oppervlaktewaterspiegel. Relatieve hoogten in het landschap worden daardoor een aantrekkelijker vestigingslocatie. De huidige hoogtes in het landschap corresponderen als gevolg van differentiële klink slechts ten dele met de toenmalige hoge plaatsen in het landschap. Het ontstaan van de Vecht-Angstel leidt tot een toename van de waterfluctuaties in het merengebied en daarmee tot een toenemende seizoensmatige wateroverlast in de periode 1050-900 v.Chr. Dit is dan ook de periode waarin men begint met de aanleg van huisterpen. Het is goed mogelijk dat de door Van Geel *et al.* (1997) veronderstelde klimaatsomslag rond 800 voor Chr. de bewoners van West-Friesland de das omdeed. Veenvorming heeft nadien beslist niet overal in West-Friesland plaatsgevonden. Ook is er nadien zeer beslist geen sprake van een aaneensluitend hoogveendek geweest. Nat was het zeker wel. Gedacht moet worden aan een afwisselend landschap met meren, laagvenen en een enkel hoogveenkussen. Vanaf 500 voor Chr. wordt dit landschap gedraineerd als gevolg van het ontstaan van de Zijpe en de Rekere in westelijk West-Friesland en de Vliestroom tussen Vlieland en Terschelling. Dit valt echter buiten de scope van het onderhavige onderzoek.

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Appendix 1: Dates

For the writing of this thesis an overview of available dates was needed. The last overviews of dates from West-Frisia were published by De Mulder and Bosch (1982) and Westerhof *et al.* (1987). Since these publications the available number of dates has expanded. Not only the number of dates has increased but also the number of available dating techniques like AMS and OSL. The AMS technique became available in the nineties and is nowadays the standard technique for ^{14}C-dating in the field of archaeology. In 2000 the OSL technique was introduced into Dutch archaeology at the site of *Emmeloord J97*. Since then OSL is used in archaeology for dating pottery and sandy or silty sediments with varying success. Not only are new methods introduced but the methods have also improved. The possibilities and quality of dendrochronological dates have strongly improved. Nowadays dendrochronological dates can be obtained from different types of wood and the databases for references are significantly larger and the dating results therefore better. The overviews of De Mulder and Bosch (1982) and Westerhof *et al.* (1987) contain solely radiocarbon dates performed by the laboratory in Groningen. Nowadays numerous laboratories perform radiocarbon dates, OSL dates and even dendrochronological dates. This change hampers retrieval and comparison of dates.

			Rank method			
Material	Code table A.3	Rank material	AMS	Conventional	OSL	Dendrochronology
Mollusc bivalve (specified)	Sbs	7	3	2		
Mollusc valve (specified)	Svs	4	3	2		
Mollusc (unspecified)	Su	1	3	2		
Bone apatite	Ba	7	3	2		
Bone collagen	Bc	7	3	2		
Bone unknown	Bu	1	3	2		
Macrobotanical remains specified	Ms	7	3	2		
Macrobotanical remains unspecified	Mu	1	3	2		
Wood specified	Ws	7	2	1		3
Wood unspecified	Wu	1	3	2		
Peat specified	Ps	7	3	2		
Peat with clay component	Pc	1	3	2		
Peat gyttja	Pg	1	3	2		
Peat unspecified	Pu	1	3	2		
Silt or sand particles	Qp	7			3	
Humic acids	Ha	7	3			
Charcoal specified	Cs	7	3	2		
Charcoal unspecified	Cu	1	3	2		

Table A.1: Ranking of material classes and dating methods.

194: GrN-8337 2520 ± 30 BP			
What kind of material has been dated? (wattlework => Ws)			7
Which method is used? (conventional)			1
Combined rank			8
	y	n	u
Does the sample contain other ^{14}C than solely acquainted by CO^2 assimilation?		x	
Is the sample susceptible to the reservoir effect?		x	
Is the sample susceptible to the hard water effect?		x	
Is the sample susceptible to mechanical contamination?		x	
Is the sample susceptible to a slow accumulation rate?		x	
Value:			8

189: UtC-11881 3018 ± 35 BP			
What kind of material has been dated? (mollusc marine shell single valve=> Svs)			4
Which method is used? (AMS)			3
Combined rank			7
	y	n	u
Does the sample contain other ^{14}C than solely acquainted by CO^2 assimilation?	3		
Is the sample susceptible to the reservoir effect?	3		
Is the sample susceptible to the hard water effect?	3		
Is the sample susceptible to mechanical contamination?		x	
Is the sample susceptible to a slow accumulation rate?		x	
Value:			-2

Table A.2: Two examples for the calculation of a rating value.

In order to handle the large amount of available dates a column with a rating value is added to the overview. In this rating, the dating technique, the sampled material and the context of the sample are taken into account. Rating a date is difficult. It is obvious that dendrochronology provides the best date for an oak pole with intact cambium. The choice for an AMS date on terrestrial seeds extracted from a gyttja over a conventional date of the same gyttja is easily made. But is an AMS date of a mollusc to be preferred over a conventional date of a human bone from the same context? And is an AMS date of a mollusc from a core to be preferred over a sample of an AMS date of a mollusc from a soil section? In order to rate the dates a simple rubric has been constructed. In this rubric the three elements technique, sample and context are rated separately. In order to rate the context possible ageing effects, as described in chapter 3, are taken into account. It is important to note that the outcome of the rubric does not give a definitive answer for the quality of an individual date! It is a simple qualification tool for the expressiveness of a date in order to organize a large database of dates assembled over a long period of time with different techniques.

The material used for the dates in the database has been categorized in classes. In table A.1 an overview of these classes is presented. Each class is rated for the relative expressiveness of the obtained date. The dating techniques are also ranked in relation to the material. The rating value is calculated by adding the rank of the material to the rank of the method. This results in a number between 1 and 10. The rank of the context is substracted from this number. In formula: $R^{total} = R^{material} + R^{method} - R^{context}$ In table A.2 the rating value is calculated for two examples. Total rankings with a score smaller than 0 are indicated by the value 0 in table A.3.

The overview (table A.3) contains for each date the same information. It does not contain all assembled information although it does provide the necessary information to find the original publication, the laboratory code and sample number which makes it possible to retrieve the original data. Every date is numbered. These numbers are used in references in this thesis. Most dates are associated with a location which is known by a toponym which is incorporated in the overview. The laboratory and number of the date as well as the original date are incorporated. The calibrated two sigma interval is presented

id	name	lab.	number	date	σ	cal AD 2σ	median	mat.	x-co	y-co	references	R
Bergen Inlet												
Disconnection Vecht basin and Bergen tidal basin												
1	Emmeloord J97	GrN	26503	3850	20	-2456\-2208	-2318	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
2	Emmeloord J97	GrN	26500	3840	35	-2458\-2202	-2302	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
3	Emmeloord J97	GrN	26502	3830	20	-2385\-2202	-2265	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
4	Emmeloord J97	GrN	26495	3830	20	-2397\-2202	-2265	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
5	Emmeloord J97	GrN	26501	3830	40	-2458\-2148	-2286	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
6	Emmeloord J97	GrN	26511	3770	20	-2284\-2135	-2180	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
7	Emmeloord J97	GrN	26510	3800	35	-2429\-2064	-2239	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
8	Emmeloord J97	GrN	26484	3760	35	-2288\-2041	-2174	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
9	Emmeloord J97	GrN	26458	3730	20	-2200\-2040	-2134	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
10	Emmeloord J97	GrN	26509	3700	20	-2190\-2029	-2086	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
11	Emmeloord J97	GrN	23327	3700	25	-2195\-1985	-2088	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
12	Emmeloord J97	GrN	26483	3710	40	-2269\-1977	-2098	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
13	Emmeloord J97	GrN	25464	3680	25	-2141\-1977	-2080	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
14	Emmeloord J97	GrN	26508	3660	20	-2133\-1957	-2033	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
15	Emmeloord J97	GrN	25513	3600	20	-2022\-896	-1955	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
16	Emmeloord J97	GrN	26499	3660	40	-2189\-1925	-2037	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
17	Emmeloord J97	GrN	25506	3530	20	-1930\-1772	-1844	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
18	Emmeloord J97	GrN	25507	3530	20	-1930\-1772	-1844	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
19	Emmeloord J97	GrN	25512	3510	20	-1894\-1758	-1826	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
20	Emmeloord J97	GrN	26515	3490	20	-1882\-1751	-1817	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
21	Emmeloord J97	GrN	26504	3480	20	-1881\-1745	-1812	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
22	Emmeloord J97	GrN	26492	3480	20	-1881\-1745	-1812	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
23	Emmeloord J97	GrN	26493	3470	20	-1879\-1700	-1804	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
24	Emmeloord J97	GrN	26514	3460	20	-1878\-1694	-1774	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
25	Emmeloord J97	GrN	26490	3460	20	-1878\-1694	-1774	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
26	Emmeloord J97	GrN	26505	3450	25	-1878\-1689	-1760	Ws	*179230*	*522090*	Bulten *et al.* 2002	8
27	Emmeloord J97	GrA	18857	5410	60	-4355\-4055	-4264	Ms	*179230*	*522090*	Bulten *et al.* 2002	10
28	Emmeloord J97	GrA	18852	5340	60	-4329\-4005	-4172	Ms	*179230*	*522090*	Bulten *et al.* 2002	10
29	Emmeloord J97	GrA	18757	4870	70	-3895\-3384	-3663	Ms	*179230*	*522090*	Bulten *et al.* 2002	10
30	Emmeloord J97	GrA	18855	4830	60	-3759\-3381	-3599	Ms	*179230*	*522090*	Bulten *et al.* 2002	10
31	Emmeloord J97	GrA	18856	4840	60	-3765\-3384	-3631	Ms	*179230*	*522090*	Bulten *et al.* 2002	10
32	Emmeloord J97	GrA	18854	4500	60	-3368\-2944	-3203	Ms	*179230*	*522090*	Bulten *et al.* 2002	10
33	Noorderboekert	GrA	63737	3715	35	-2205\-1982	-2102	Ms	*137200*	*522800*	Unpublished	10
34	Noorderboekert	GrA	63736	3600	35	-2116\-1881	-1959	Ms	*137200*	*522800*	Unpublished	10
35	Noorderboekert	GrA	63741	3425	35	-1876\-1632	-1727	Ms	*137200*	*522800*	Unpublished	10
36	P14	UtC	2511	3570	80	-2138\-1694	-1919	Cs	*181540*	*517980*	Ten Anscher 2012	10
37	P14	UtC	1932	3480	50	-1931\-1669	-1806	Ms	*181540*	*517980*	Ten Anscher 2012	10
38	P14	UtC	1931	3430	50	-1881\-1628	-1739	Ms	*181540*	*517980*	Ten Anscher 2012	10
Habitation												
39	Andijk	GrN	11975	3265	30	-1619\-1457	-1547	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6
40	Andijk	GrN	11973	3240	30	-1610\-1440	-1511	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6
41	Andijk	GrN	11974	3230	30	-1607\-1432	-1498	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6
42	Andijk	GrN	11972	3205	45	-1610\-1405	-1478	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6
43	Andijk	GrN	12368	3100	25	-1427\-1294	-1355	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6
44	Andijk	GrN	12366	3070	30	-1414\-1235	-1338	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6

Table A.3: Overview of dates.

id	name	lab.	number	date	σ	cal AD 2σ	median	mat.	x-co	y-co	references	R
45	Andijk	GrN	11971	3055	30	-1406\-1230	-1321	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6
46	Andijk	GrN	12367	3020	80	-1435\-1023	-1257	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6
47	Andijk	GrN	12369	2980	80	-1416\-980	-1201	Bc	*142550*	*528560*	Lanting & Van der Plicht 2003	6
48	BVK-Het Valkje	GrN	7472	3275	35	-1630\-1456	-1557	Cs	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	9
49	BVK-Het Valkje	GrN	11976	3165	30	-1502\-1328	-1443	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
50	BVK-Het Valkje	GrN	11978	3145	30	-1497\-1309	-1423	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
51	BVK-Het Valkje	GrN	11979	3095	30	-1428\-1280	-1350	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
52	BVK-Het Valkje	GrN	11977	3080	25	-1414\-1276	-1343	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
53	BVK-Het Valkje	GrN	11980	3040	25	-1393\-1220	-1296	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
54	BVK-Het Valkje	GrN	12437	3045	30	-1398\-1221	-1305	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
55	BVK-Het Valkje	GrN	12435	3030	25	-1391\-1211	-1280	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
56	BVK-Het Valkje	GrN	8560	3035	30	-1397\-1210	-1289	Ms	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	9
57	BVK-Het Valkje	GrN	12438	3025	25	-1390\-1136	-1272	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
58	BVK-Het Valkje	GrN	12370	3020	25	-1387\-1134	-1265	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
59	BVK-Het Valkje	GrN	7510	3025	35	-1396\-1131	-1275	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
60	BVK-Het Valkje	GrN	7512	3000	25	-1373\-1128	-1237	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
61	BVK-Het Valkje	GrN	8559	3020	40	-1396\-1128	-1267	Ms	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	9
62	BVK-Het Valkje	GrN	7511	2990	40	-1386\-1059	-1220	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
63	BVK-Het Valkje	GrN	12434	2975	30	-1367\-1059	-1196	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
64	BVK-Het Valkje	GrN	7473	2980	35	-1373\-1058	-1203	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1979	3
65	BVK-Het Valkje	GrN	12436	2980	35	-1373\-1058	-1203	Bc	*145050*	*525600*	Lanting & Van der Plicht 2003	6
66	BVK-Het Valkje	GrN	7474	2925	35	-1221\-1013	-1123	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980	3
67	BVK-Het Valkje	GrN	8558	2860	25	-1114\-935	-1027	Ms	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	9
68	BVK-Het Valkje	GrN	8556	2845	30	-1109\-922	-1004	Bc	*145050*	*525600*	Van Regteren Altena *et al.* 1980; IJzereef 1981; Lanting & Van der Plicht 2003	6

Table A.3: Overview of dates.

id	name	lab.	number	date	σ	cal AD 2σ	median	mat.	x-co	y-co	references	R
69	BVK-Het Valkje	GrN	8557	2845	60	-1207\-847	-1014	Ms	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	9
70	BVK-Het Valkje	GrN	7475	2760	35	-996\-829	-903	Ws	*145050*	*525600*	Van Regteren Altena *et al.* 1980	8
71	BVK-Het Valkje	GrN	7507	2745	30	-973\-819	-882	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980	3
72	BVK-Het Valkje	GrN	8561	2745	30	-973\-819	-882	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
73	BVK-Het Valkje	GrN	7508	2740	40	-976\-811	-882	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980	3
74	BVK-Het Valkje	GrN	8563	2690	25	-896\-806	-837	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
75	BVK-Het Valkje	GrN	7509	2710	35	-917\-806	-861	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
76	BVK-Het Valkje	GrN	8562	2685	30	-898\-803	-836	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
77	BVK-Het Valkje	GrN	8334	2650	30	-894\-791	-815	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
78	BVK-Het Valkje	GrN	8564	2620	20	-816\-790	-803	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1980; Lanting & Van der Plicht 2003	3
79	Enkhuizen-Kadijken	SUERC	28688	3230	35	-1609\-1430	-1500	Bc	*146750*	*525600*	Roessingh & Lohof 2011	7
80	Enkhuizen-Kadijken	SUERC	28688	3230	35	-1609\-1430	-1500	Bc	*146750*	*525600*	Roessingh & Lohof 2011	7
81	Enkhuizen-Kadijken	SUERC	28668	3140	35	-1498\-1302	-1417	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
82	Enkhuizen-Kadijken	SUERC	37158	3115	30	-1442\-1291	-1386	Ms	*146650*	*525700*	Roessingh & Vermue 2011	10
83	Enkhuizen-Kadijken	SUERC	28669	3085	35	-1429\-1261	-1344	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
84	Enkhuizen-Kadijken	SUERC	37157	3065	30	-1412\-1234	-1335	Ms	*146650*	*525700*	Roessingh & Vermue 2011	10
85	Enkhuizen-Kadijken	SUERC	28671	3065	35	-1414\-1230	-1332	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
86	Enkhuizen-Kadijken	SUERC	28683	3065	35	-1414\-1230	-1332	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
87	Enkhuizen-Kadijken	SUERC	28673	3055	35	-1409\-1224	-1319	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
88	Enkhuizen-Kadijken	SUERC	28679	3050	35	-1408\-1219	-1312	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
89	Enkhuizen-Kadijken	SUERC	28687	3050	35	-1408\-1219	-1312	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
90	Enkhuizen-Kadijken	SUERC	28660	3045	35	-1408\-1214	-1305	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
91	Enkhuizen-Kadijken	SUERC	28663	3040	35	-1409\-1208	-1297	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
92	Enkhuizen-Kadijken	SUERC	28681	3040	35	-1409\-1208	-1297	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
93	Enkhuizen-Kadijken	SUERC	28667	3035	35	-1406\-1135	-1290	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10

Table A.3: Overview of dates.

id	name	lab.	number	date	σ	cal AD 2σ	median	mat.	x-co	y-co	references	R
94	Enkhuizen-Kadijken	SUERC	31003	3035	35	-1406\-1135	-1290	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
95	Enkhuizen-Kadijken	SUERC	28662	3030	35	-1404\-1132	-1282	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
96	Enkhuizen-Kadijken	SUERC	28670	3030	35	-1404\-1132	-1282	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
97	Enkhuizen-Kadijken	SUERC	28672	3030	35	-1404\-1132	-1282	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
98	Enkhuizen-Kadijken	SUERC	26271	3025	30	-1394\-1132	-1274	Ws	*146750*	*525600*	Roessingh & Lohof 2011	9
99	Enkhuizen-Kadijken	SUERC	28677	2910	35	-1213\-1006	-1100	Bc	*146750*	*525600*	Roessingh & Lohof 2011	7
100	Enkhuizen-Kadijken	SUERC	28661	2895	35	-1208\-980	-1080	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
101	Enkhuizen-Kadijken	SUERC	37152	2895	30	-1207\-998	-1078	Ms	*146650*	*525700*	Roessingh & Vermue 2011	10
102	Enkhuizen-Kadijken	SUERC	28680	2785	35	-1011\-839	-935	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
103	Enkhuizen-Kadijken	SUERC	31002	2760	35	-996\-829	-903	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
104	Enkhuizen-Kadijken	SUERC	28678	2680	35	-900\-800	-836	Ms	*146750*	*525600*	Roessingh & Lohof 2011	10
105	Grootebroek-Tumulus	GrN	160	3000	140	-1528\-849	-1221	Cu	*143000*	*522500*	Lanting & Van der Plicht 2003	3
106	Hoogkarspel	GrN	11049	3110	30	-1437\-1288	-1377	Bc	*140570*	*523170*	Lanting & Van der Plicht 2003	6
107	Hoogkarspel	UtC	2350	3050	60	-1433\-1126	-1303	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
108	Hoogkarspel	GrN	6837	3035	55	-1418\-1124	-1286	Bc	*140640*	*523210*	Lanting & Van der Plicht 2003	6
109	Hoogkarspel	GrN	5050	3020	40	-1396\-1128	-1267	Cu	*139800*	*522500*	Lanting & Van der Plicht 2003	3
110	Hoogkarspel	UtC	2348	3030	60	-1429\-1093	-1277	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
111	Hoogkarspel	UtC	2349	2950	60	-1382\-980	-1159	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
112	Hoogkarspel	UtC	2347	2980	80	-1416\-980	-1201	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
113	Hoogkarspel	UtC	2351	2980	90	-1424\-942	-1200	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
114	Hoogkarspel	UtC	2353	2860	70	-1223\-845	-1038	Cu	*139325*	*522850*	Lanting & Van der Plicht 2003	4
115	Hoogkarspel	GrN	5048	2650	45	-902\-779	-822	Cu	*139800*	*522500*	Lanting & Van der Plicht 2003	3
116	Hoogkarspel	UtC	2356	2660	60	-975\-596	-834	Cu	*139325*	*522850*	Lanting & Van der Plicht 2003	4
117	Hoogkarspel	GrN	5051	2680	50	-928\-790	-846	Cu	*139800*	*522500*	Lanting & Van der Plicht 2003	3
118	M'blik-Schepenwijk	KIA	37075	3140	30	-1496\-1305	-1418	Bc	*135730*	*530440*	Schurmans 2010	7
119	M'blik-Schepenwijk	KIA	37076	3115	30	-1442\-1291	-1386	Bc	*135730*	*530440*	Schurmans 2010	7
120	M'blik-Schepenwijk	KIA	37077	3050	25	-1396\-1230	-1314	Ws	*135730*	*530440*	Schurmans 2010	9
121	M'blik-Schepenwijk	KIA	37073	3055	30	-1406\-1230	-1321	Bc	*135730*	*530440*	Schurmans 2010	7
122	M'blik-Schepenwijk	KIA	36979	3045	25	-1394\-1224	-1304	Ws	*135730*	*530440*	Schurmans 2010	9
123	M'blik-Schepenwijk	KIA	36980	3035	25	-1391\-1216	-1288	Ms	*135730*	*530440*	Schurmans 2010	10
124	M'blik-Schepenwijk	KIA	37074	3015	25	-1384\-1132	-1257	Bc	*135730*	*530440*	Schurmans 2010	7
125	M'blik-Schepenwijk	KIA	36981	2960	25	-1261\-1059	-1173	Ms	*135730*	*530440*	Schurmans 2010	10
126	M'blik-Schepenwijk	KIA	38009	2735	25	-924\-822	-873	Ws	*135730*	*530440*	Schurmans 2010	9
127	M'blik-Schepenwijk	KIA	37078	2715	25	-907\-813	-862	Ws	*135730*	*530440*	Schurmans 2010	9
128	M'blik-Schepenwijk	KIA	36982	2705	20	-899\-813	-851	Ms	*135730*	*530440*	Schurmans 2010	10

Table A.3: Overview of dates.

id	name	lab.	number	date	σ	cal AD 2σ	median	mat.	x-co	y-co	references	R
129	M'blik-Schuitenvoerderslaan	GrN	6333	2960	40	-1285\-1036	-1172	Cu	*135850*	*530600*	Lanting & Van der Plicht 2003	3
130	M'blik-Schuitenvoerderslaan	GrN	6335	2955	55	-1377\-1006	-1165	Cu	*135850*	*530600*	Lanting & Van der Plicht 2003	3
131	Oostwoud-De Tuithoorn	GrA	15597	3690	60	-2278\-1914	-2081	Bc	*135320*	*517400*	Lanting & Van der Plicht 2002	7
132	Oostwoud-De Tuithoorn	GrA	15598	3660	50	-2196\-1903	-2038	Bc	*135320*	*517400*	Lanting & Van der Plicht 2002	7
133	Oostwoud-De Tuithoorn	GrN	8801	3530	25	-1934\-1771	-1845	Bc	*135320*	*517400*	Lanting 1979; Runia 1987; Lanting & Van der Plicht 2002	6
134	Oostwoud-De Tuithoorn	GrN	15601	3520	60	-2018\-1692	-1844	Bc	*135320*	*517400*	Lanting 1979; Runia 1987; Lanting & Van der Plicht 2002	6
135	Oostwoud-De Tuithoorn	GrA	15602	3500	50	-1945\-1692	-1823	Bc	*135320*	*517400*	Lanting 1979; Runia 1987; Lanting & Van der Plicht 2002	7
136	Oostwoud-De Tuithoorn	GrA	17226	3450	40	-1883\-1665	-1766	Bc	*135320*	*517400*	Lanting & Van der Plicht 2003	7
137	Oostwoud-De Tuithoorn	GrA	17225	3440	40	-1881\-1646	-1750	Bc	*135320*	*517400*	Lanting & Van der Plicht 2003	7
138	Oostwoud-De Tuithoorn	GrN	797	3025	80	-1439\-1027	-1263	Wu	*135320*	*527400*	Lanting & Van der Plicht 2003	2
139	Opperdoes	GrN	10015	2210	55	-396\-116	-276	Cu	*134700*	*531250*	Buurman 1993	3
140	Twisk	GrN	10461	3350	35	-1739\-1531	-1642	Ms	*133140*	*526280*	Lanting & Van der Plicht 2003	9
141	Wervershoof-De Ark	GrN	2395	3015	55	-1414\-1088	-1257	Cu	*139470*	*525330*	Lanting & Van der Plicht 2003	3
142	Wervershoof-De Ark	GrN	2168	2965	45	-1372\-1028	-1178	Cu	*139470*	*525330*	Lanting & Van der Plicht 2003	3
143	Westwoud	UtC	2350	3050	60	-1433\-1126	-1303	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
144	Westwoud	UtC	2348	3030	60	-1429\-1093	-1277	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
145	Westwoud	UtC	2352	2980	60	-1392\-1022	-1202	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
146	Westwoud	UtC	2349	2950	60	-1382\-980	-1159	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
147	Westwoud	UtC	2347	2980	80	-1416\-980	-1201	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
148	Westwoud	UtC	2351	2980	90	-1424\-942	-1200	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
149	Westwoud	UtC	2353	2860	70	-1223\-845	-1038	Cu	*139325*	*522850*	Lanting & Van der Plicht 2003	4
150	Westwoud	UtC	2354	2880	100	-1375\-830	-1073	Cu	*139325*	*522850*	Lanting & Van der Plicht 2003	4
151	Westwoud	UtC	2355	2700	70	-1014\-773	-870	Ms	*139325*	*522850*	Lanting & Van der Plicht 2003	10
152	Westwoud	UtC	2356	2660	60	-975\-596	-834	Cu	*139325*	*522850*	Lanting & Van der Plicht 2003	4
153	Zwaagdijk	GrN	4243	3200	60	-1621\-1306	-1477	Cu	*139030*	*523850*	Lanting & Van der Plicht 2003	3
154	Zwaagdijk	GrA	25718	3130	50	-1501\-1270	-1398	Bc	*138350*	*523975*	Ufkes *et al.* 2003	7
155	Zwaagdijk	GrN	28825	3130	50	-1501\-1270	-1398	Bc	*138350*	*523975*	Ufkes *et al.* 2003	6
156	Zwaagdijk	GrN	28826	3130	50	-1501\-1270	-1398	Bc	*138350*	*523975*	Ufkes *et al.* 2003	6
157	Zwaagdijk	GrN	22823	3120	50	-1498\-1264	-1383	Bc	*138350*	*523975*	Ufkes *et al.* 2003	6
158	Zwaagdijk	GrN	22822	3110	50	-1496\-1234	-1367	Bc	*138350*	*523975*	Ufkes *et al.* 2003	6
159	Zwaagdijk	GrN	28824	2960	50	-1374\-1014	-1172	Bc	*138350*	*523975*	Ufkes *et al.* 2003	6

Table A.3: Overview of dates.

id	name	lab.	number	date	σ	cal AD 2σ	median	mat.	x-co	y-co	references	R
160	Noorderboekert	GrA	66702	3615	35	-2121\-1888	-1976	Cs	*137200*	*522800*	Unpublished	10
161	Noorderboekert	GrA	66675	3565	35	-2022\-1776	-1916	Cs	*137200*	*522800*	Unpublished	10
Closure Bergen inlet												
162	BVK-Het Valkje	GrN	7472	3275	35	-1630\-1456	-1557	Cu	*145050*	*525600*	Van Regteren Altena *et al.* 1977	3
163	Koedijk Gassleuf	GrN	6763	3360	50	-1761\-1510	-1652	Pg	**111070**	**519050**	Roep *et al.* 1979	0
164	Schoorldam	GrN	823	2950	85	-1396\-932	-1160	Pg	**109750**	**525525**	Du Burck 1960	0
165	Aartswoud	GrN	5554	3440	90	-1973\-1526	-1757	Pc	**124720**	**527700**	Vogel & Waterbolk 1972	0
166	Hoogwoud	GrN	6603	3150	35	-1501\-1305	-1428	Pc	**124390**	**525630**	Roldaan 1972	0
167	Hauwert	GrN	7782	3270	35	-1626\-1454	-1553	Pu	**135110**	**523940**	De Mulder & Bosch 1982	3
168	Wervershoof-derde keursloot	GrN	8094	3165	40	-1517\-1306	-1443	Pc	**136875**	**526530**	De Mulder & Bosch 1982	0
169	Grootslag	GrN	611	3155	110	-1682\-1123	-1417	Ps	**141525**	**526050**	Ente 1963	9
170	Enkhuizen-Omringdijk	GrN	9067	2690	60	-979\-787	-859	Ps	**147500**	**523120**	Van Geel, Hallewas & Pals 1982	9
171	Alkmaar-De Heul	GrN	5217	3140	50	-1506\-1277	-1411	Pu	**111390**	**516250**	De Jong & Van Regteren Altena 1972	3
172	Alkmaar-Van der Veldelaan	GrN	6309	3560	40	-1551\-1405	-1501	Sbs	**109800**	**516280**	Roep *et al.* 1979	0
173	Schagen-De Hoep	GrN	28921	3610	100	-2279\-1692	-1976	Bc	*115770*	*534260*	Zeiler, Brinkhuizen & Bekker 2007	6
174	Schagen-De Hoep	GrN	28922	3560	100	-2196\-1644	-1907	Cu	*115770*	*534260*	Zeiler, Brinkhuizen & Bekker 2007	3
175	Geestmerambacht-De Druppels	X	5334	3315	295	-1598 \ -1008	-1303	Qp	*133067*	*520683*	Hakvoort and Jansen 2012	10
176	Geestmerambacht-De Druppels	NCL	6212043	3900	200	-2088 \ -1688	-1888	Qp	*110750*	*522500*	Vos, Van der Heiden & Stuurman 2012	10
177	Geestmerambacht-De Druppels	NCL	6212042	3200	200	-1388 \ -988	-1188	Qp	*110750*	*522500*	Vos, Van der Heiden & Stuurman 2012	10
178	Geestmerambacht-De Druppels	NCL	8113025	3200	200	-1388 \ -988	-1188	Qp	*115894*	*534243*	Unpublished	10
179	Geestmerambacht-De Druppels	Poz	47277	3615	35	-2121\-1888	-1976	Ha	111457	**523012**	Vos 2015	3
180	Geestmerambacht-De Druppels	Poz	47275	3330	35	-1728\-1517	-1615	Ha	**111457**	**523012**	Vos 2015	3
181	Geestmerambacht-De Druppels	Poz	47276	3490	30	-1893\-1700	-1816	Ha	**111457**	**523012**	Vos 2015	3
182	Geestmerambacht-De Druppels	KiA	45558	3407	27	-1766\-1630	-1706	Bc	11450	**523014**	Vos 2015	3
183	Noorderboekert	NCL	7515055	3400		Doubtful		Qp	*137200*	*522800*	Unpublished	10
184	Noorderboekert	NCL	7515056	3400	200	-1584 \ -1184	-1384	Qp	*137200*	*522800*	Unpublished	10
End of habitation												
185	Klokkeweel	GrN	7666	3230	35	-1609\-1430	-1500	Pc	**141200**	**524400**	Pals, Van Geel & Delfos 1980	0
186	Klokkeweel	GrN	7912	2860	30	-1117\-930	-1027	Ps	**141200**	**524400**	Pals, Van Geel & Delfos 1980	9
187	Klokkeweel	GrN	7913	2735	30	-968\-814	-874	ps	**141200**	**524400**	Pals, Van Geel & Delfos 1980	9
188	Klokkeweel	GrN	7667	2590	35	-827\-570	-789	Ps	**141200**	**524400**	Pals, Van Geel & Delfos 1980	9
189	Venhuizen-Omringdijk	GrA	53538	2465	30	-764\-430	-623	Ha	**144030**	**518220**	Sassi 2012	10
190	Venhuizen-Omringdijk	GrA	53540	2450	35	-755\-411	-579	Ha	**142845**	**517515**	Sassi 2012	10
191	Venhuizen-Omringdijk	GrA	35539	1645	30	333\533	402	Pg	**143616**	**518011**	Sassi 2012	0
192	Enkhuizen-Omringdijk	GrN	10993	2800	50	-1107\-832	-955	Ps	**147455**	**523050**	Van Geel, Hallewas & Pals 1982	9

Table A.3: Overview of dates.

id	name	lab.	number	date	σ	cal AD 2σ	median	mat.	x-co	y-co	references	R
193	Enkhuizen-Omringdijk	GrN	9067	2690	60	-979\-787	-859	Ps	**147455**	**523050**	Van Geel, Hallewas & Pals 1982	9
194	Enkhuizen-Omringdijk	GrN	10994	2510	35	-793\-523	-641	Ps	**147455**	**523050**	Van Geel, Hallewas & Pals 1982	2
195	Hoogwoud	GrN	6601	2440	30	-751\-408	-537	Ps	**124390**	**525630**	Havinga & Van den Berg van Saparoea 1992	9
196	Hoogwoud	GrN	6602	2915	30	-1209\-1016	-1106	Ps	**124390**	**525630**	Havinga & Van den Berg van Saparoea 1992	9
197	Enkhuizen-Omringdijk	GrN	10995	2160	40	-360\-92	-219	Ps	**147455**	**523050**	Van Geel, Hallewas & Pals 1982	9
198	De Rikkert	Suerc	51347	1608	32	391\539	464	Cu	**147310**	**528174**	Unpublished	4
Oer-IJ estuary												
Start Oer-IJ estuary												
199	De Bonte Hen	GrN	23820	4660	80	-3639\-3114	-3451	Ps	**116030**	**49990**	Vos 1998	9
200	Uitgeest	GrN	1650	4580	60	-3516\-3096	-3315	Pu	**109780**	**503870**	Jelgersma 1961	3
201	De Bonte Hen	GrN	23819	4430	60	-3337\-2917	-3095	Pu	**116030**	**49990**	Vos 1998	3
Peat formation												
202	Uitgeest	GrN	1649	4140	70	-2892\-2497	-2725	Pu	**109780**	**503870**	Jelgersma 1961	3
203	Uitgeest	GrN	1663	3970	70	-2838\-2210	-2483	Pu	**109780**	**503870**	Jelgersma 1961	3
Increasing marine activity												
204	Broekpolder profiel	KiA	9492	3430	35	-1877\-1639	-1734	Ha	**107500**	**500650**	Vos 2000	10
205	Assendelft-Noorderweg	GrN	11630	3380	70	-1878\-1510	-1678	Pu	**110460**	500390	Westerhof *et al.* 1987	3
Decreasing marine activity and habitation												
206	PWN secundair L	UtC	11919	3180	42	-1166\-897	-1026	Svs	**103290**	**510675**	Vos *et al.* 2010	0
207	PWN secundair 5	UtC	12021	3116	36	-1050\-827	-941	Su	**103650**	**504130**	Vos *et al.* 2010	0
208	PWN WRK gebouw	UtC	11894	3060	38	-977\-792	-875	Svs	**103620**	**505040**	Vos *et al.* 2010	0
209	PWN secundair 5	UtC	11891	3030	41	-952\-772	-849	Svs	**103650**	**504130**	Vos *et al.* 2010	0
210	PWN secundair G	UtC	11897	3034	29	-926\-784	-849	Svs	**103630**	**506620**	Vos *et al.* 2010	0
211	PWN WRK gebouw	UtC	12015	3016	40	-930\-763	-837	Su	**103620**	**505040**	Vos *et al.* 2010	0
212	PWN secundair E	UtC	11881*	3018	35	-920\-769	-837	Svs	**103290**	**510675**	Vos *et al.* 2010	0
213	site Q APP	GrN	11242	2620	30	-829\-776	-803	Pu	*109110*	*497770*	Vos 1998	3
214	site Q APP	GrN	11243	2670	80	-1018\-548	-846	Pu	*109110*	*497770*	Vos 1998	3
215	Broekpolder profiel	KiA	9490	2605	50	-895\-549	-791	Ha	*107500*	*500650*	Vos 2000	10
216	site Q APP	GrN	6400	2600	50	-894\-545	-786	Ws	*109110*	*497770*	Vos 1998	8
217	site Q APP	GrN	8337	2520	30	-794\-542	-645	Ws	*109110*	*497770*	Vos 1998	8
218	site 100 APP	GrN	12099	2570	60	-839\-490	-686	Pu	**110180**	**503050**	Westerhof *et al.* 1987	3
219	Assendelft-Noorderweg	GrN	11629	2460	70	-772\-408	-597	Pu	**110460**	**500390**	Westerhof *et al.* 1987	3
220	site Q APP	GrN	8686	2465	30	-764\-430	-623	Ws	*109110*	*497770*	Vos 1998	8
Increasing marine activity												
221	Portengen-3	UtC	14584	2870	47	-1206\-918	-1046	Ms	**125711**	**465662**	Bos 2010	10
222	Broekpolder profiel	KiA	9486	2862	27	-771\-564	-700	Sbs	*107500*	*500650*	Vos 2000	1
223	Broekpolder profiel	KiA	9495	2745	26	-649\-395	-502	Sbs	*107500*	*500650*	Vos 2000	1
224	Broekpolder profiel	KiA	9487	2740	27	-645\-392	-494	Sbs	*107500*	*500650*	Vos 2000	1
225	Broekpolder profiel	KiA	9488	2608	32	-406\-211	-346	Sbs	*107500*	*500650*	Vos 2000	1
226	Broekpolder profiel	KiA	9489	2615	37	-441\-209	-352	Sbs	*107500*	*500650*	Vos 2000	1
End-phase Oer-IJ estuary												
227	PWN pomp	UtC	11886	2774	42	-716\-409	-564	Svs	**104060**	**507740**	Vos *et al.* 2010	0
228	PWN secundair D	UtC	11884	2702	37	-589\-352	-451	Svs	**103040**	**508970**	Vos *et al.* 2010	0
229	PWN pomp	UtC	11885	2678	37	-541\-339	-424	Svs	**104060**	**507740**	Vos *et al.* 2010	0
230	PWN secundair 5	NCL	313011	-477	157	-634 \ -320	-477	Qp	**103650**	**504130**	Vos *et al.* 2010	10

Table A.3: Overview of dates.

id	name	lab.	number	date	σ	cal AD 2σ	median	mat.	x-co	y-co	references	R
231	PWN secundair E	NCL	313008	-411	145	-556 \ -266	-411	Qp	**103290**	**510675**	Vos *et al.* 2010	10
232	PWN secundair 3	UtC	11881*	2564	38	-378\-183	-287	Svs	**102060**	**503970**	Vos *et al.* 2010	0
233	Site F APP	GrN	11477	2300	30	-406\-235	-383	Bc	*110820*	*500860*	Vos 1998	6
234	PWN secundair 5	UtC	11892	2296	34	-408\-212	-376	Ha	**103650**	**504130**	Vos *et al.* 2010	10
235	PWN secundair G	NCL	313013	-365	163	-528 \ -202	-365	Qp	**103630**	**506620**	Vos *et al.* 2010	10
236	PWN WRK gebouw	NCL	313006	-250	146	-396 \ -104	-250	Qp	**103620**	**505040**	Vos *et al.* 2010	10
237	PWN secundair L	NCL	313007	-239	136	-375 \ -103	-239	Qp	**103290**	**510675**	Vos *et al.* 2010	10
238	Castricum PWN	GrN	8661	2180	35	76\270	175	Sbs	**102960**	**506040**	De Jong 1987	0
239	PWN secundair D	NCL	313001	202	114	88 \ 316	202	Qp	**103040**	**508970**	Vos *et al.* 2010	10
240	Portengen-2	UtC	14583	1877	60	1\322	136	Ms	**126505**	**465671**	Cohen *et al.* 2012	10
Vliestroom												
241	HZL-Knooppunt Hattemerbroek	GrA	39304	7960	40	-7041\-6700	-6889	Ms	**199402**	**500254**	Lohof, Hamburg & Flamman 2011	10
242	HZL-Knooppunt Hattemerbroek	GrA	38090	3115	30	-1442\-1291	-1386	Ms	**199402**	**500254**	Lohof, Hamburg & Flamman 2011	10
243	HZL-Knooppunt Hattemerbroek	GrA	38093	2490	30	-781\-510	-636	Ws	**199083**	**500162**	Lohof, Hamburg & Flamman 2011	9
244	HZL-Knooppunt Hattemerbroek	GrA	38087	2455	55	-762\-411	-592	Ms	**199402**	**500254**	Lohof, Hamburg & Flamman 2011	10
245	HZL-Knooppunt Hattemerbroek	Poz	13799	2310	30	-410\-236	-388	Ms	**199300**	**500138**	Hamburg *et al.* 2006	10
246	HZL-Knooppunt Hattemerbroek	GrA	38096	1115	25	884\989	934	Ms	**199402**	**500254**	Lohof, Hamburg & Flamman 2011	10
247	HZL-Knooppunt Hattemerbroek	GrA	38091	4090	30	-2859\-2499	-2645	Ms	**199402**	**500254**	Lohof, Hamburg & Flamman 2011	10
248	HZL-De Slaper	GrA	34963	3820	40	-2456\-2142	-2268	Ms	**188908**	**505017**	Lohof, Hamburg & Flamman 2011	10
249	HZL-De Slaper	GrA	34959	2920	35	-1217\-1011	-1115	Ms	**188908**	**505017**	Lohof, Hamburg & Flamman 2011	10
250	HZL-De Slaper	GrA	35488	2415	30	-744\-401	-489	Ms	**188734**	**505352**	Lohof, Hamburg & Flamman 2011	10
251	HZL-Nieuwe Land Site IX	Ua	36473	6320	55	-5469\-5208	-5303	Ms	*173310*	*506700*	De Moor *et al.* 2009	10

*These two different dates have the same laboratory number in Vos (2015) as well as in Vos *et al.* (2010).

Table A.3: Overview of dates.

using Calib 7.10 and a median value is calculated. The dated material and context in this table are not described in detail, this information can be obtained, if available, from the different laboratories using the identification number. The coordinates refer sometimes to an exact location (bold) and sometimes to a more general location (cursive), for example the central coordinate of an excavation.

Appendix 2: Phytosociological vegetation classes

In this appendix an overview is given of the climax biotopes in phythosociological vegetation classes which are expected to be present in the environment of Westwoud during the Middle and Late Bronze Age based on the reconstructed indicator values in chapter 4. The indicator species presented for the specific biotopes are retrieved from the databases of macrobotanical remains in the Westwoud area as assembled by Van Amerongen for her PhD thesis (Van Amerongen 2016). The used phytosociological vegetation classes and indicator species are based on the five-volume publication "*De vegetatie van Nederland*" especially the volumes with regarding to wetlands, grasslands and woodlands (Schaminée *et al.* 1995; 1996; Stortelder *et al.* 1999).

Middle Bronze Age

Table A.4: Phytosocial vegetation classes and indicator species for Westwoud in the Middle Bronze Age.

Biotope	Indicator species	Biotope	Indicator species
Class: *Alnetea glutinosae* (39)			
Order: *Alnetalia glutinosae* (39A)			
Alliance: *Alnion glutinosae* (39Aa)			
Association: *Thelypterido-Alnetum* (39Aa1)	+ *Alnus glutinosa*	Association: (*Carici elongatae-Alnetum* (39Aa2)	+ *Alnus glutinosa*

Biotope	Indicator species	Biotope	Indicator species
Class: *Querco-Fagetea* (43)			
Order: *Fagetalia sylvaticae* (43A)			
Alliance: *Alno-Padion* (43Aa)			
Association: *Fraxino-Ulmetum* (43Aa2)	+ *Rumex sanguineus* + *Ulmus minor*	Association: *Violo odoratae-Ulmetum* (43Aa1)	+ *Rumex sanguineus* + *Ulmus minor*

Biotope	Indicator species	Biotope	Indicator species
Class: Querco-Fagetea (43)			
Order: *Fagetalia sylvaticae* (43A)			
Alliance: *Carpinion betuli* (43Ab)	+ No diagnostic species		
Class: *Rhamno-Prunetea* (37)	+ No diagnostic species		
Class: *Galio-Urticetea* (33)			
Order: *Glechometalia* (33A)			
Alliance: *Galio-Alliarion* (33Aa)	+ *Urtica dioica* + *Galium aparine*		
Class: *Molinio-Arrhenatheretea* (16)			
Order: *Arrhenatheretalia* (16B)			
Alliance: *Arrhenatheretum elatioris* (16Bb)		Alliance: *Cynosurion cristati* (16Bc)	+ *Ranunculus acris* + *Rumex acetosa* + *Prunella vulgaris* + *Taraxacum officinale* + *Phleum pratense *pratense*
Association: *Arrhenatheretum elatioris* (16Bb1)	+ *Ranunculus acris* + *Rumex acetosa* + *Prunella vulgaris* + *Taraxacum officinale* + *Phleum pratense *pratense*		

* subspecies

Late Bronze Age

Biotope	Indicator species	Biotope	Indicator species
Class: *Alnetea glutinosae* (39)			
Order: *Alnetalia glutinosae* (39A)			
Alliance: *Alnion glutinosae* (39Aa)			
Association: *Thelypterido-Alnetum* (39Aa1)	+ *Alnus glutinosa*	Association: *Carici elongatae-Alnetum* (39Aa2)	+ *Alnus glutinosa*

Biotope	Indicator species	Biotope	Indicator species
Class: *Querco-Fagetea* (43)			
Order: *Fagetalia sylvaticae* (43A)			
Alliance: *Alno-Padion* (43Aa)			
Association: *Fraxino-Ulmetum* (43Aa2)	+ *Rumex sanguineus* + *Ulmus minor*	Association: *Violo odoratae-Ulmetum* (43Aa1)	+ *Rumex sanguineus* + *Ulmus minor*

Biotope	Indicator species	Biotope	Indicator species
Class: *Querco-Fagetea* (43)			
Order: *Fagetalia sylvaticae* (43A)			
Alliance: *Carpinion betuli* (43Ab)	+ No diagnostic species		
Class: *Rhamno-Prunetea* (37)	+ No diagnostic species		
Class: *Galio-Urticetea* (33)			
Order: *Glechometalia* (33A)			
Alliance: *Galio-Alliarion* (33Aa)	+ *Urtica dioica* + *Galium aparine*		
Class: *Molinio-Arrhenatheretea* (16)			
Order: *Arrhenatheretalia* (16B)			
Alliance: *Arrhenatheretum elatioris* (16Bb)		Alliance: *Cynosurion cristati* (16Bc)	+ *Ranunculus acris* + *Rumex acetosa* + *Prunella vulgaris* + *Taraxacum officinale* + *Phleum pratense *pratense*
Association: *Arrhenatheretum elatioris* (16Bb1)	+ *Ranunculus acris* + *Rumex acetosa* + *Prunella vulgaris* + *Taraxacum officinale* + *Phleum pratense *pratense*		

Biotope	**Indicator species**	**Biotope**	**Indicator species**
Class: *Phragmitetea* (8)			
Order: *Nasturtio-Glycerietalia* (8A)			
Alliance: *Sparganio-Glycerion* (8Aa)	+ *Phragmitis australis* + *Rumex hydrolapathum* + *Alisma plantago-aquatica* + *Glyceria maxima* + *Sium latifolium* + *Sparganium erectum* s.l. + *Berula erecta* + *Lycopus europaeus* + *Rorippa amphibia* + *Myositis palustris* + *Iris pseudacorus* + *Phalaris arundinacea* + *Oenanthe fistulosa* + *Glyceria fluitans* + *Veronica beccabunga* + *Rorippa nasturtium-aquaticum* + *Hippuris vulgaris* + *Veronica anagallis-aquatica*	Alliance: *Oenanthion aquaticae* (8Ab)	+ *Phragmitis australis* + *Rumex hydrolapathum* + *Alisma plantago-aquatica* + *Glyceria maxima* + *Sium latifolium* + *Sparganium erectum* s.l. + *Berula erecta* + *Lycopus europaeus* + *Rorippa amphibia* + *Myositis palustris* + *Iris pseudacorus* + *Phalaris arundinacea* + *Oenanthe fistulosa* + *Glyceria fluitans* + *Oenanthe aquatica*

Biotope	**Indicator species**	**Biotope**	**Indicator species**
Class: *Salicetea purpureae* (38)			
Order: *Salicetalia* (38A)			
Alliance: *Salicion albae* (38Aa)			
Association: *Artemisio-Saliceteum albae* (38Aa1)	+ *Populus nigra*		

* subspecies

Table A.5: Phytosocial vegetation classes and indicator species for Westwoud in the Late Bronze Age.

Appendix 3: Archaeological reports eastern West-Frisia

In this appendix an overview is given of all publications used for the analysis of inventories in eastern West-Frisia in chapter 6.

No	Municipality	Year	Publication
1	Drechterland	2006	Wullink, A.J. (2006) *Een archeologisch bureau-onderzoek en inventariserend veldonderzoek (IVO) door middel van boringen, op het Bargerveld te Oosterblokker, gemeente Drechterland (N.-H.)*. Groningen: ARC bv.
2	Drechterland	2006	Soetens, L. and Hoekstra, J. (2008) *Archeologisch onderzoek distributiecentrum Zwaagdijk Bureauonderzoek*. Assen: Grontmij.
3	Drechterland	2007	Wullink, A.J. (2007) *Een archeologisch bureauonderzoek en inventariserend veldonderzoek (IVO) door middel van boringen, op plan Reigersborg V te Hoogkarspel, gemeente Drechterland (N.-H.)*. Groningen: ARC bv.
4	Drechterland	2007	Wullink, A.J. (2007) *Een archeologisch bureauonderzoek en inventariserend veldonderzoek (IVO) door middel van boringen, aan de Koggeweg te Hem, gemeente Drechterland (N.-H.)*. Groningen: ARC bv.
5	Drechterland	2009	Postma-Saan, F.B. and Jelsma, J. (2009) *Westwoud, Dr. Nuijensstraat, Gemeente Drechterland (N-H.). Een Inventariserend Archeologisch Veldonderzoek*. Zuidhorn: De Steekproef.
6	Drechterland	2009	Boekema, Y. (2009) *Archeologisch onderzoek Westfrisiaweg Inventariserend Veldonderzoek*. Assen: Grontmij.
7	Drechterland	2010	Boekema, Y (2010) *Archeologisch onderzoek Westfrisiaweg Inventariserend Veldonderzoek: aanvullend verkennend booronder-zoek*. Assen: Grontmij.
8	Drechterland	2010	Hebinck, K.A. (2011) *Een archeologisch bureau-onderzoek en inventariserend veldonderzoek door middel van boringen aan de Zuiderdijk 51 te Schellinkhout*, gemeente Drechterland (NH). Groningen: ARC bv.
9	Drechterland	2014	Gerritsen, S. (2014) *Kringen op de bodem van de berging. Resultaten van het archeologisch onderzoek binnen de plange-bieden Blokdijk, Burg. J. Zijpweg (gem. Drechterland) en Kooiland (gem. Medemblik) in West-Friesland*. Hoorn: Archeologie West-Friesland.
10	Stede Broec	2006	Soetens, L. (2006) *Archeologisch onderzoek Waterberging Stede Broec*. Assen: Grontmij.
11	Stede Broec	2006	Warning, S. (2006) *Plangebied Hoofdweg 245 Bovenkarspel, gemeente Stede Broec*. Amsterdam: RAAP.
12	Stede Broec	2006	Fijma, P. (2006) *Archeologisch onderzoek waterberging Stede Broec*. Assen: Grontmij.
13	Stede Broec	2007	Soetens, L. (2007) *Archeologisch onderzoek Zesstedenweg te Grootebroek*. Assen: Grontmij.
14	Stede Broec	2008	Brokke, A.J. (2008) *Archeologisch Bureauonderzoek Landtongen Stede Broec*. Hoofddorp: Arcadis.
15	Stede Broec	2009	Leuvering, J.H.F. (2009) *Bureauonderzoek en karterend veldonderzoek d.m.v. boringen Hoofdstraat 97 te Bovenkarspel*. Doetinchem: Synthegra.
16	Stede Broec	2009	Hebinck, K.A. (2009) *Een archeologisch bureau-onderzoek en inventariserend veldonderzoek door middel van boringen aan de Hoofdstraat 17-19 te Bovenkarspel, gemeente Stede Broec (NH).* Groningen: ARC bv.
17	Stede Broec	2011	Exaltus, R. (2011) *Bovenkarspel, Geerling 4. Gem. Stede Broec (NH.) Een Karterend Archeologisch Booronderzoek*. Zuidhorn: De Steekproef.
18	Stede Broec	2011	Boekema, Y., Hekman, J.J., Osinga, M. and Thanos, C.S.I. (2011) *Archeologisch onderzoek Westfrisiaweg Inventariserend veldonderzoek (bureauonderzoek en waarderend onderzoek d.m.v. boringen)*. Assen: Grontmij.
19	Stede Broec	2012	Leuvering, J.H.F. (2012) *Inventariserend veldonderzoek, karterend booronderzoek Geerling 4b te Bovenkarspel gemeente Stede Broec*. Doetinchem: Synthegra.
20	Stede Broec	2012	Hakvoort, A. and Jansen, H. (2012) *Archeologisch proefsleuven onderzoek Westfrisiaweg Eindrapport Fase 1 en 2*. Assen: Grontmij.
21	Opmeer	2007	Van Putten, M.J. (2007) *Gemeenten Opmeer en Medemblik, Drie deelgebieden in de polder Vier Noorder Koggen Inventariserend Archeologisch veldonderzoek (verkennende fase)*. Deventer: BAAC.
22	Opmeer	2009	Leuvering, J.H.F. (2009) *Inventariserend veldonderzoek, verkennend en karterend booronderzoek De Veken en Middelweg 23 te Opmeer gemeente Opmeer*. Doetinchem: Synthegra.
23	Opmeer	2009	Leijnse, K. (2009) *Plangebieden Heerenweide en De Veken, gemeente Opmeer; een inventariserend veldonderzoek (zoeksleuven)*. Amsterdam: RAAP.
24	Opmeer	2009	Raczynski-Henk, Y., Leijnse, K., De Boer, G.H. and Leijnse, K. (2009) *De Vier Noorderkoggen – locaties Langereis, Liederik en Kooiland, gemeenten Opmeer en Wervershoof.* Amsterdam: RAAP.
25	Opmeer	2010	Soonius, C.M. and Sprangers, J. (2010) *Verbetering Weelkade en waterberging Waterpolder, gemeente Opmeer; archeologisch vooronderzoek: een bureau- en inventariserend veldonderzoek*. Amsterdam: RAAP.
26	Opmeer	2010	Verboom-Jansen, M. and Wullink, A.J. (2011) *Een archeologisch bureau-onderzoek aan de Spanbroekerweg te Spanbroek, gemeente Opmeer (NH)*. Groningen: ARC bv.

No	Municipality	Year	Publication
27	Opmeer	2010	De Roller, G.J. (2011) *Archeologisch bureauonderzoek voor de locatie Koningspade 12-13 te Hoogwoud, gemeente Opmeer (NH)*. Leek: MUG Ingenieursbureau bv.
28	Opmeer	2011	Ras, J. (2011) *Archeologisch Bureauonderzoek Reconstructie N241, te Opmeer en Spanbroek, Gemeente Opmeer*. Heinenoord: SOB-Research.
29	Opmeer	2011	Verboom-Jansen, M. (2011) *Een karterend inventariserend veldonderzoek door middel van boringen aan de Spanbroekerweg te Spanbroek (NH)*. Groningen: ARC bv.
30	Opmeer	2011	Van den Berg, G.T.C. and Médard, A. (2011) *Archeologisch booronderzoek en bouwhistorische opname Koningspade 12-13 te Hoogwoud, gemeente Opmeer*. Zaandam: ARGO.
31	Opmeer	2014	Nijdam, L.C. (2014) *Hoogwoud, Herenweg 64, hoek Oosterboekelweg (gemeente Opmeer)*. Lippenhuizen: ArGeoBoor.
32	Hoorn	2008	Walstra, J. and Van der Zee, R.M. (2008) *Molen te Benningbroek/ Oostwoud (gem. Medemblik)*. ADC-Amersfoort: ArcheoProjecten.
33	Hoorn	2013	Burnier, C.Y. (2013) *Dorpsstraat tussen nrs. 106 en 112, Zwaag, gemeente Hoorn. Een Bureauonderzoek en Inventariserend Veldonderzoek in de vorm van een verkennend booronderzoek*. Amersfoort: ArcheoProjecten.
34	Enkhuizen	2006	Van Zijverden, W.K. (2006) *Enkhuizen Kadijken IVO 2 een Inventariserend Veldonderzoek in de vorm van boringen*. Amersfoort: ADC-ArcheoProjecten.
35	Enkhuizen	2006	Lohof, E. (2006) *Bureauonderzoek "Kadijken" te Enkhuizen*. Amersfoort: ADC-ArcheoProjecten.
36	Enkhuizen	2006	De Roller, G.J. and Mulder S.A. (2006) *Een bureau-onderzoek en een archeologisch inventariserend veldonderzoek (IVO) door middel van boringen aan de Haling 1E te Enkhuizen, gemeente Enkhuizen (N.-H.)*. Groningen: ARC bv.
37	Enkhuizen	2006	Vaars, J.P.L. (2006) *Archeologisch Bureauonderzoek Gommerwijk West, gemeente Enkhuizen*. Zaandijk: Hollandia.
38	Enkhuizen	2007	Roessingh, W. and Van Zijverden, W.K. (2007) *Enkhuizen-Kadijken, een archeologische begeleiding en inventariserend veldonderzoek in de vorm van proefsleuven in het plangebied Kadijken, gemeente Enkhuizen*. Amersfoort: ADC-ArcheoProjecten.
39	Enkhuizen	2008	Fijma, P. (2008) *Archeologisch onderzoek Streekbos te Stede Broec. Quickscan met aanvullende boringen*. Assen: Grontmij.
40	Enkhuizen	2009	Vanoverbeke, R.W. and Verduin, J.T. (2009) Archeologisch bureauonderzoek Gezondheidscentrum Molenweg, Enkhuizen. Zaandijk: Hollandia.
41	Enkhuizen	2010	Roessingh, W. (2010) *Enkhuizen-Haling 13, een aanvullend proefsleuvenonderzoek*. Amersfoort: ADC-ArcheoProjecten.
42	Enkhuizen	2013	Van Der Zee. R.M. (2013) *Westeinde 62, Enkhuizen (gemeente Enkhuizen) Een Bureauonderzoek en Inventariserend Veldonderzoek in de vorm van een verkennend booronderzoek*. Amersfoort: ADC-ArcheoProjecten.
43	Enkhuizen	2014	Roessingh, W. (2014) *Enkhuizen Haling 20E Proefsleuvenonderzoek*. Amersfoort: ADC-ArcheoProjecten.
44	Medemblik	2006	Tulp, C. (2006) *Een Inventariserend Archeologisch Veldonderzoek in Plangebied 'Bedrijventerrein' te Medemblik (NH.)*. Zuidhorn: De Steekproef.
45	Medemblik	2006	Buitenhuis, H. and Mulder, S.A. (2006*) Een archeologisch bureau-onderzoek en een inventariserend veldonderzoek (IVO) bij de stadsuitbreiding Schepenwijk II te Medemblik, gemeente Medemblik (N.-H.)*. Groningen: ARC bv.
46	Medemblik	2006	Huizing-Schreur, A. (2006) *Archeologisch onderzoek Kielkade Medemblik*. Assen: Grontmij.
47	Medemblik	2007	Van Benthem, A. (2007) *Medemblik Schepenwijk ll (gemeente Medemblik): een inventariserend veldonderzoek in de vorm van proefsleuven*. Amersfoort: ADC-ArcheoProjecten.
48	Medemblik	2007	Jongste, P.F.B. and Knippenberg, S. (2007) *Inventariserend Veldonderzoek (IVO) Opperdoes-Kluiten-Zuid*. Leiden: ArchOL.
49	Medemblik	2008	De Kramer, J. (2008) *Nieuwe Veld, Abbekerk, Gemeente Medemblik Bureauonderzoek en Inventariserend veldonderzoek, verkennende fase*. Katwijk: Becker & Van de Graaf.
50	Medemblik	2009	Soonius, C.M. and Sprangers, J. (2009) *Plangebied fietspad Twisk, gemeente Medemblik; archeologisch vooronderzoek: een aanvullend bureau- en inventariserend veldonderzoek*. Amsterdam: RAAP.
51	Medemblik	2010	Van der Linden, B.A. Leuvering, J. and Wemerman, P. (2010) *Vekenweg 19 te Abbekerk, gemeente Medemblik*. Doetinchem: Synthegra bv.
52	Medemblik	2010	Soetens, L. (2010) *Archeologisch onderzoek Opperdoes Noord Inventariserend Veldonderzoek d.m.v. veldkartering.* Assen: Grontmij.
53	Medemblik	2012	Van Putten, M.J. (2012) *Gemeente Medemblik. Plangebied IJsbaan te Wognum Archeologisch bureauonderzoek*. Deventer: BAAC.
54	Medemblik	2015	Roessingh, W. (2015) *Middeleeuwse sporen in het 'Nieuwe Veld' in Abbekerk, gemeente Medemblik*. Amersfoort: ADC-ArcheoProjecten.

Table A.6: Publications used for the analysis of predictive modelling in West-Frisia.

Acknowledgements

My parents stimulated my interest in history and the natural environment from an early age onwards. After graduating high school I began to study physical geography at Utrecht University. Since my graduation in 1993 I have been working as a physical geographer in the field of archaeology. Reconstructing landscapes of the past and advising on sampling and sampling techniques has been my job ever since. In addition to my first Master's degree in physical geography I studied archaeology at Leiden University and graduated in 1997. In 2002 Walter Laan and I obtained a grant from SENTER for exploring the possibilities of LIDAR-databases in archaeological research (Laan and Van Zijverden 2005; De Boer *et al.* 2008; Waldus and Van der Velde 2006). This project was a stimulating experience in scientific research leading to renewed contact with the Faculty of Archaeology at Leiden University.

In the period 2003-2006 Harry Fokkens gave me the opportunity to work within the project "*Living in a dynamic (cultural) landscape, the Bronze Age in the Dutch river area*", a project funded by the Dutch Organisation for Scientific Research (NWO) (Fokkens 2003). In this project I had the opportunity to synthesize my previous work in the Dutch river area carried out in the service of ADC-ArcheoProjecten. During this project I worked together with the archaeologists Stijn Arnoldussen, Peter Jongste and the biologist Liesbeth van Beurden. It was my task to provide palaeogeographical reconstructions for the PhD-thesis of Stijn (Arnoldussen 2008). The unconventional approach to landscape reconstructions by Liesbeth (Van Beurden 2008), the constant pursuit of greater detail by Stijn and the more general approach by Peter confronted me with the issue of scale and resolution. Furthermore it clarified the often experienced mismatch between the questions asked by the archaeologist and the answers provided by the earth scientist. Discussions between archaeologists and earth scientists tend to follow a pattern of misunderstanding which is comparable to the discussions of RMA and SGS as presented in Flannery's "*The Early Mesoamerican Village*" (Flannery 1976).

Shortly after this project I got involved in two large scale excavation projects in the coastal area, *Enkhuizen-Kadijken* with Wouter Roessingh (ADC-ArcheoProjecten) and *Serooskerke* (N57) with Frieda Zuidhoff and Juke Dijkstra (both ADC-ArcheoProjecten) (Roessingh and Lohof 2011; Dijkstra and Zuidhoff 2011). The palaeogeography of both areas has been studied in great detail in the past. In advance of the projects I thought they would be short-lived and boring. I couldn't have been more wrong. Both projects showed spectacular results in archaeology and palaeogeography, offering new research questions on the exploitation of wetlands and the reaction of man to natural events in the past. The new results from *Enkhuizen-Kadijken* and the lack of proper excavation reports of the excavations of *Bovenkarspel-Het Valkje*, *Hoogkarspel* and *Andijk* triggered Harry to write a proposal for the research project "*Farmers of the coast, coastal farming communities on the southern North Sea coast, 2000-800 BC*" (Fokkens 2011).

In 2007 I started as a part-time lecturer at Saxion University for Applied Sciences. In 2009 I quitted my job at ADC-ArcheoProjecten where I had worked for 14 years with great pleasure and freedom in a very stimulating team of geographers, biologists, archaeobotanists, soil scientists and GIS specialists (Jan Bresser†, Marieke van Dinter, Walter Laan, Frieda Zuidhoff, Marjolein Bouman, Jop Brijker, Arjan de Boer, Jos de Moor, Cornelie Moolhuizen, Hanneke Bos and Kirsten van Kappel). I started to work part-time for a startup, EARTH Integrated Archaeology, a company founded in 2008 by my old colleague Eva Kars. By EARTH I was re-united with my old colleagues Jos de Moor and Myrthe van Brevoort. I have no regrets over this decision, never a dull moment with these three pioneers in Dutch archaeology. The combination of research (EARTH Integrated Archaeology) and education (Saxion University for Applied Sciences) is satisfactory.

In 2011 Harry Fokkens invited me for a PhD-position at Leiden University within the project "*Farmers of the Coast*" funded by the Dutch Organisation for Scientific Research (NWO). The main challenge for me in this project, would be to develop a new palaeogeographical model for West-Frisia. At this stage I want to thank Harry for this opportunity, his guidance during this project and the unforgettable trips to the Danube delta, Dartmoor and Must Farm. The research group consisted of four PhD-students, Patrick Valentijn (archaeologist), Wouter Roessingh (archaeologist), Yvonne van Amerongen (biologist), myself and Renate de Boer (archaeologist) as research assistant. The research group was supervised by Harry Fokkens and Corrie Bakels. Wim Hoek (University Utrecht) and later on Henk Weerts (Cultural Heritage Agency of the Netherlands) became successively involved in the project as co-promotor. Wim Hoek had to resign after a year due to a too great workload. In 2015 Henk Weerts had to resign due to health issues. During the last year Corrie Bakels has fulfilled his role. I have enjoyed her critical and constructive guidance during the process of writing this dissertation. Within the framework of this research I maintained a pleasant conversation with John van den Hof (Saxion University for Applied Sciences) on a yearly basis. For five years I worked with great pleasure in our research group. I am very grateful for this opportunity which was only possible due to the generosity of my employers, Saxion University for Applied Sciences and EARTH Integrated Archaeology.

Writing a dissertation is a lonely task in contrast with doing actual research for a PhD. During my research I met many inspiring people who stimulated me or helped me with retrieving data, digitizing data, data analyses and so on. I want to thank the following persons:

The interns from Saxion University for Applied Sciences: Bastiaan Steffens, Rob van Haarlem, Sidney Bakker, Bert van der Zwaluw and Daniel Smit. Special thanks to Esther Eilering who was invaluable during the inventory of the data of *Westwoud*. Also special thanks to Nandi Mink for a brilliant BA-thesis on the use of molluscs in archaeology and, of course, the diagrams of *Emmeloord J97* and the evaluation of all the mollusc samples of *Bovenkarspel-Het Valkje*. I want to thank two other interns for their contribution to this study, Rens Cronau (Radboud University) for his environmental reconstruction based on an analysis of game and Madelon Pronk (VU University Amsterdam) for her analysis of thin sections of various sites in West-Frisia.

The colleagues of Regio West-Friesland: Carla Soonius for discussion, documents and sharing her broad knowledge on the landscape of West-Frisia. Furthermore I am very grateful for the opportunity she gave me to perform a geoarchaeological assessment at the site *Noorderboekert*. Michiel Bartels for valuable lessons in public outreach in advance of (and during) "*De dag van de archeologie*". Sander Gerritsen for discussion and an overview of excavations, reports and observations of Bronze Age sites in West-Frisia. And last but not least the volunteers Kees Kiestra and Nico Bregman who helped me to formulate my ideas in plain Dutch and inspired me to write the article "*Wouden, wadden en water*" (Van Zijverden 2014).

The colleagues of ArchOL BV: Sebastiaan Knippenberg and the excavation teams of *Noorderboekert* and *Rijweg* (Pepijn van de Geer, Michiel Goddijn, Minja Hemminga, Judith van der Leije and Marleen van Zon) for their hospitality, discussions and old fashioned soil sections. Walter Laan for discussions on GIS, Westfrisians and West-Frisia in general and of course a very pretty LIDAR-image. Alastair Allen for reading the text for errors in English grammar.

Colleagues from various archaeological institutes: Jean Roefstra (Provinciaal depot voor archeologie Noord-Holland) for the finds and documentation of

Westwoud and *Opperdoes-Markerwaardweg*. Jos Kleijne (University Kiel) for discussions, sharing data and comments on the palaeogeographical reconstructions of the Late Neolithic. Ronald Visser (Saxion University for Applied Sciences) for discussions on GIS, databases and a broad spectrum of other digital topics which resulted amongst others in a paper on digital teaching (Visser, Van Zijverden and Alders 2015). Willy Metz (former University of Amsterdam) for her hospitality, survey- and excavation documentation of *Westwoud* and *Broekerhaven* and of course over 4000 well-documented aerial photographs of West-Frisia. Chris Evans and Marie Louise Sørensen (Cambridge University) great companions during an unforgettable trip by boat in the delta of the Danube. Hans Huisman (Cultural Heritage Agency of the Netherlands) for the help on the production and interpretation of thin sections and coaching of Madelon Pronk. Wim Kuijper (Leiden University/ Naturalis) for the discussions, analyses of mollusc samples and coaching of Nandi Mink. Alexander Verpoorte and Bleda Düring (Leiden University) for their upfront comments on my progress in the annual review which was very helpful to finish this project successfully.

Non-archaeological colleagues: Bas van Geel (University of Amsterdam) for discussion and his valuable comments during presentations of our research group. Fokke Brouwer (Alterra) for treasuring and lending approximately 5000 analogue descriptions of soil sections dated from 1972 onwards. Marjolein Bouman (Utrecht University) for the help on finding unpublished pollendiagrams. Peter Vos (Deltares) for discussions, data on the Oer-IJ estuary and the publications of national palaeogeographical maps. Marieke van Dinter (ADC-ArcheoProjecten) for discussions, valuable comments and over 25 years of friendship.

At last special thanks to three colleagues: Eva Kars (EARTH Integrated Archaeology) the most unconventional employer I have ever met. Thank you for your trust and the opportunities you have given me. Pim Alders (Saxion University for Applied Sciences) thanks for your trust, positivity, inspiration and the help in developing and achieving the weird posting construction for my appointment in this project. Jos de Moor (EARTH Integrated Archaeology) for discussions and valuable comments on this manuscript and of course the editing and writing of "*Het Groot Profielenboek*" during weekends, evenings and holidays (Van Zijverden and De Moor 2014).

Last but not least I want to thank my family. First of all my parents who always stimulated me to choose a challenging and satisfying path. Secondly my brother Jan and sister Nelleke who are, just like me, struggling to find a balance between work, study, family, social life and relationships. Judith, Jonathan and Ronja thank you for your patience with a partner/father who was often physically at home during the last five years, but didn't give the attention you all deserved. Looking back over the last five years I became a little older and hopefully wiser. We as a family cultivated our new allotment and built a cottage, our own paradise on earth. I learned that puberty arrives by thunder strike but departs gradually. I learned that it takes an effort to maintain a relationship and you never should take it for granted even after 25 years. I learned that live can be shorter than previously expected and one should enjoy every moment. Seize the day.

Curriculum vitae

Wilko van Zijverden was born on August the 6th 1969 in Rozendaal (the Netherlands). In 1987 he graduated from high school and he began to study physical geography at Utrecht University. In August 1993 he received his Master's degree in Quaternary geology. The subject of the Master's thesis was a reconstruction of the Late Weichselian landscape of the Bommelerwaard in the central river area of the Netherlands. In 1991 he started studying archaeology at Leiden University. In august 1997 he received his Master's degree in ecological archaeology. The subject of the Master's thesis was the methods used during the archaeological field evaluation in advance of the construction of the Betuwe freight railway.

After receiving his Master's degree in Quaternary geology he started to work as a physical geographer in the field of archaeology. After three successive years of temporary work in the Netherlands and Germany he started in 1996 as a physical geographer with the State Archaeological Service (ROB). He continued his work with ADC-ArcheoProjecten after the split-up of ROB and ADC-ArcheoProjecten in 1998. In 2007 he started, in addition to his job at ADC-ArcheoProjecten, as a part-time lecturer at Saxion University for Applied Sciences in Deventer. In 2009 he left ADC-ArcheoProjecten to join the newly founded company EARTH Integrated Archaeology where he is working to the present day.

In august 2011 he was part-time posted to Leiden University for a period of five years in the project "*Farmers of the Coast*". This project was funded by the Dutch Organization for Scientific Research (NWO). The project "*Farmers of the Coast*" revolves around the thesis that Bronze Age coastal communities were thriving farming communities with their own cultural identity and with a central position in communication networks. Within the framework of this project this PhD-thesis has been written. It focusses on the development of the landscape of West-Frisia between 2000 and 800 cal BC.

AFTER THE DELUGE

After World War II huge land consolidation projects measuring thousands of hectares were carried out in West-Frisia. Large scale excavations of Bronze Age settlement sites were carried out resulting in a convincing model for the Bronze Age habitation of West-Frisia. This model envisaged settlement sites situated on creek ridges in an open almost treeless landscape. After a sudden change in climate c. 800 cal BC parts of the landscape were inundated, peat bogs developed and West-Frisia was abandoned by man. It was widely believed that this densely inhabited Bronze Age landscape was almost completely destroyed during the land consolidation projects. At the start of this century, however, it turned out that well preserved Bronze Age settlement sites still exist in West-Frisia. These sites were not only well-preserved but also situated at unexpected locations. The excavation results also gave reason to think of the presence of woodlands and forests during the Bronze Age.

This thesis tries to unite the excavation results from the period of land consolidation and those of the later development led projects. In this thesis the palaeogegraphy is described at three scale levels. West-Frisia, the land consolidation project of Westwoud and several settlement sites. Based on an analysis of excavation results and environmental proxy data, a new model for the development of the landscape and habitation of West-Frisia during the Bronze Age emerges. For the construction of the palaeogeographical maps of Westwoud, a new approach is used, based on, amongst others, macro botanical remains. The thesis concludes with an alternative strategy for the prospection of Bronze Age sites in West-Frisia. This thesis is of interest for anyone who is professionally interested in the habitation history of West-Frisia and people who are professionally engaged with palaeogeographical and vegetation reconstructions.

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