After the deluge, a palaeogeographical reconstruction of bronze age West-Frisia (2000-800 BC)

Zijverden, W.K. van

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

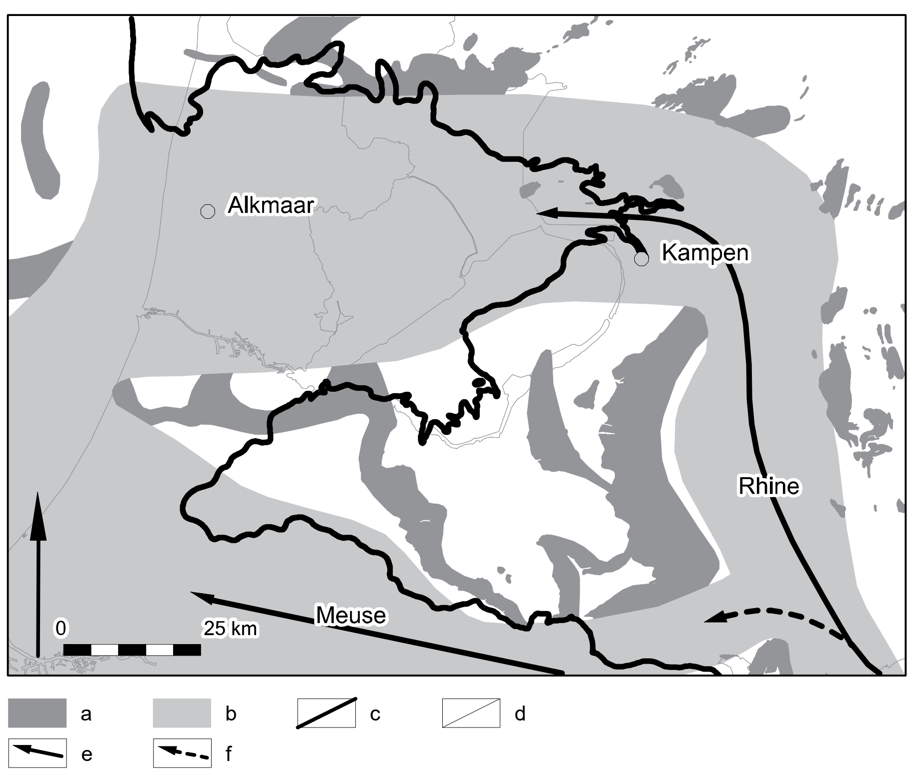


Figure 3.1: The location of the Middle-Pleniglacial river valley of the rivers Rhine and Meuse and Saalien glacial-tectonic landforms in relation to the development of the Bergen tidal basin. Legend: a Saalien glacio-tectonic ridges, b channel belts Middle-Pleniglacial, c boundary: marine and fluvial 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

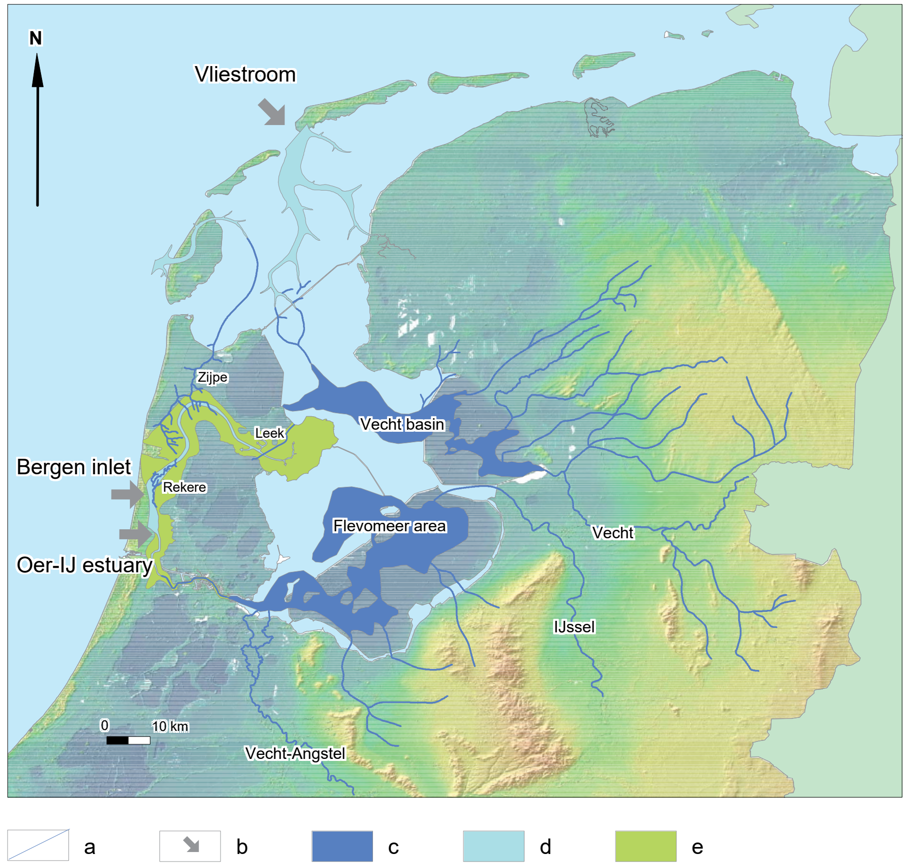


Figure 3.2: Study area with toponyms used in the text and the main palaeogeographical elements ± 1500 cal BC, with the exception of the Vecht-Angstel riversystem, Vliestroom, Rekere, Zijpe and Leek (After: De Mulder & Bosch 1982; Kok 2008; Vos 2015) plotted on a LIDAR-image of The Netherlands. Legend: 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.

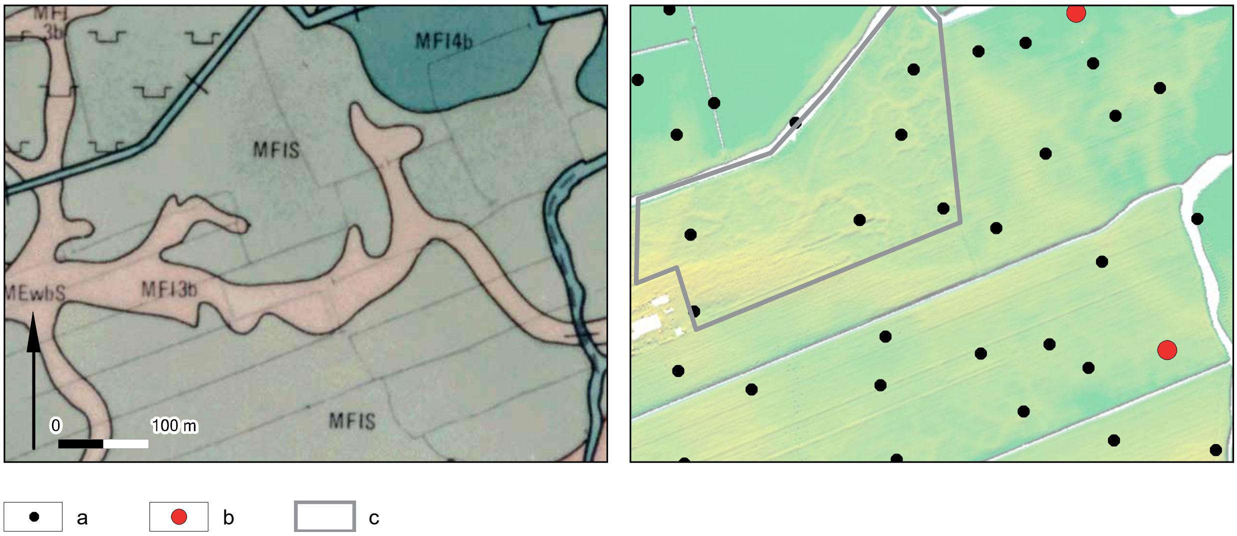


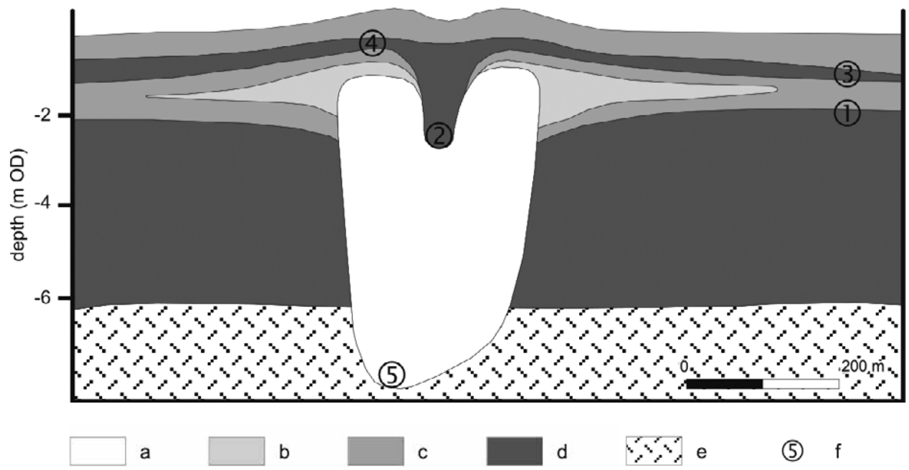
Figure 3.3: Detail of a soil map (Du Burck and Dekker 1975) and a LIDAR-image. Legend: a corings for land consolidation project, b corings from DINO-database, c unlevelled parcel.

(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

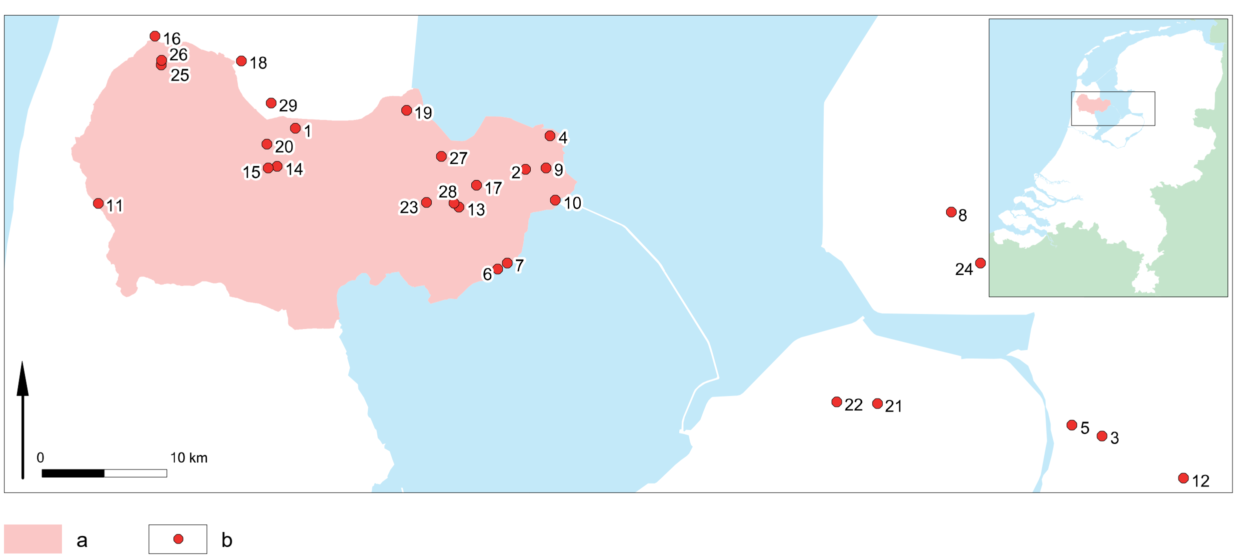


Figure 3.5: Topography and sites mentioned in text. Legend: a West-Frisia, b sites: 1 Aartswoud, 2 Bovenkarspel-Het Valkje, 3 De Enk-Zuid, 4 De Rikkert, 5 De Slaper, 6 De Spuiter, 7 Elbaweg, 8 Emmeloord J97, 9 Enkhuizen-Kadijken, 10 Enkhuizen-Omringdijk, 11 Geestmerambacht-De Druppels, 12 Hattemerbroek, 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.

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.

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

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).

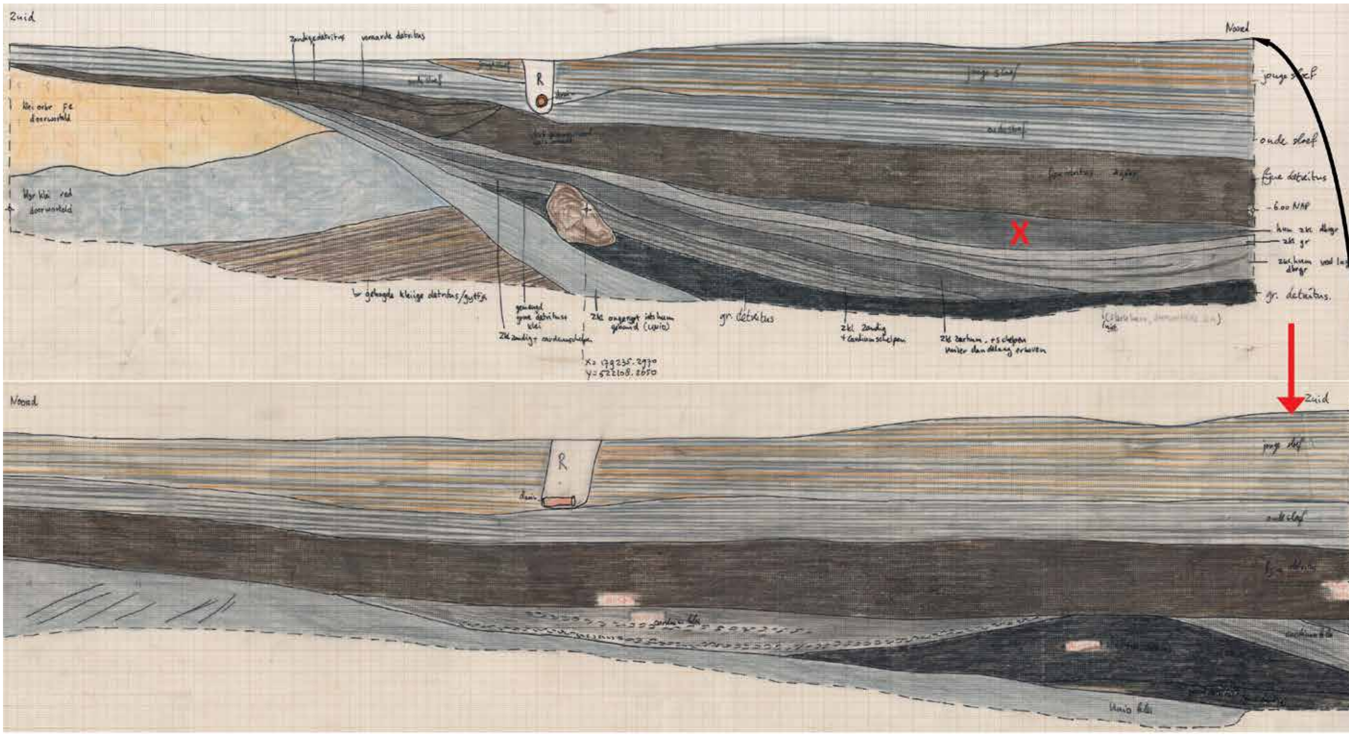


Figure 3.6: Original drawings of the section through the residual gully (Source: ADC-ArcheoProjecten). The drawing at the bottom is the continuation of the section in the diagonally opposite pit (black arrow). The section has been sampled at the location of the red arrow. The layer marked with a red 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.

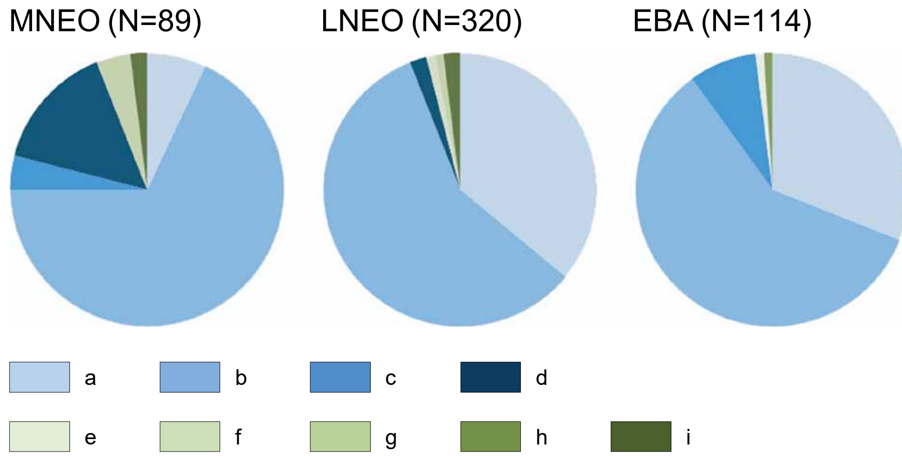


Figure 3.7: Wood types of poles present in fish weirs at Emmeloord J97. Legend: a birch, b alder, c poplar or willow, d willow, e ash, f hazel or ash, g elm, h elm or oak, i oak (After: Bulten et al. 2002, 73, figure 8.11).

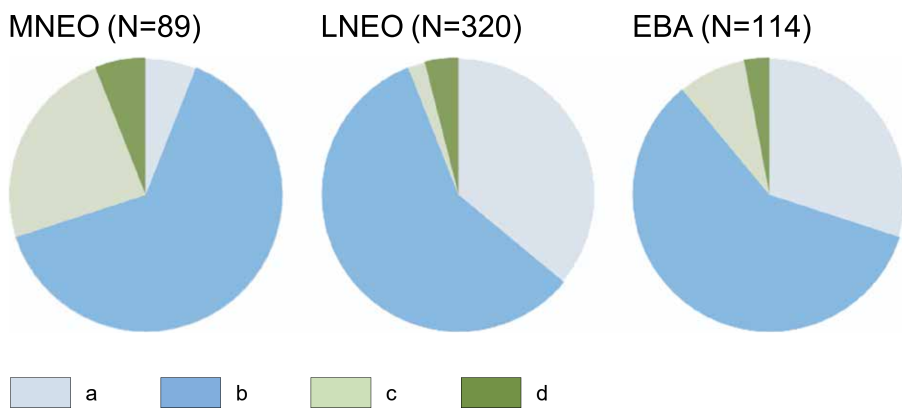
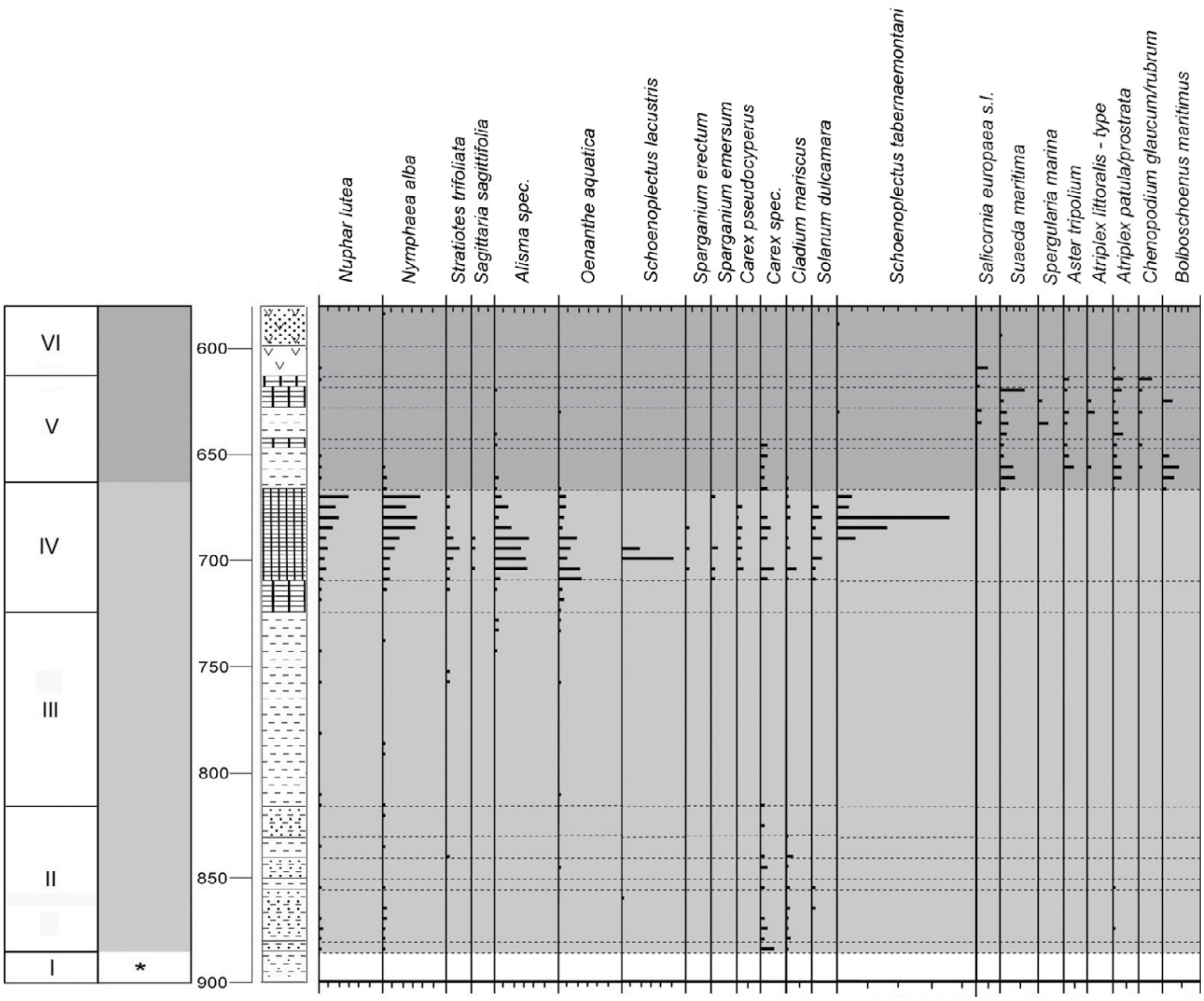


Figure 3.8: Woodland types present in fish weirs at Emmeloord J97. Legend: a birch carr, b alder carr, c riparian forest (softwood), d riparian forest (hardwood) (After: Bulten et al. 2002, 74, figure 8.12).

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



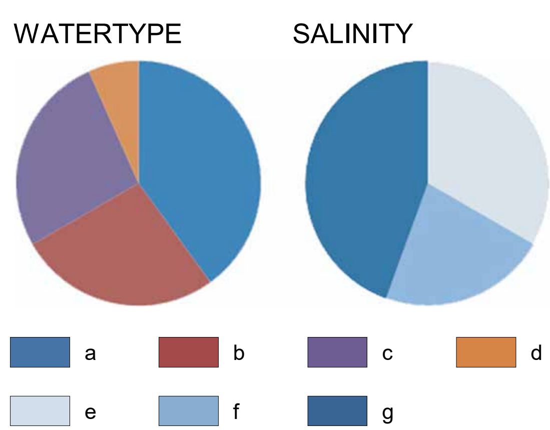


Figure 3.9: Part of the diagram of macrobotanical remains (After: Mink 2016, 69, figure 6.3).

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 *Poacea*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

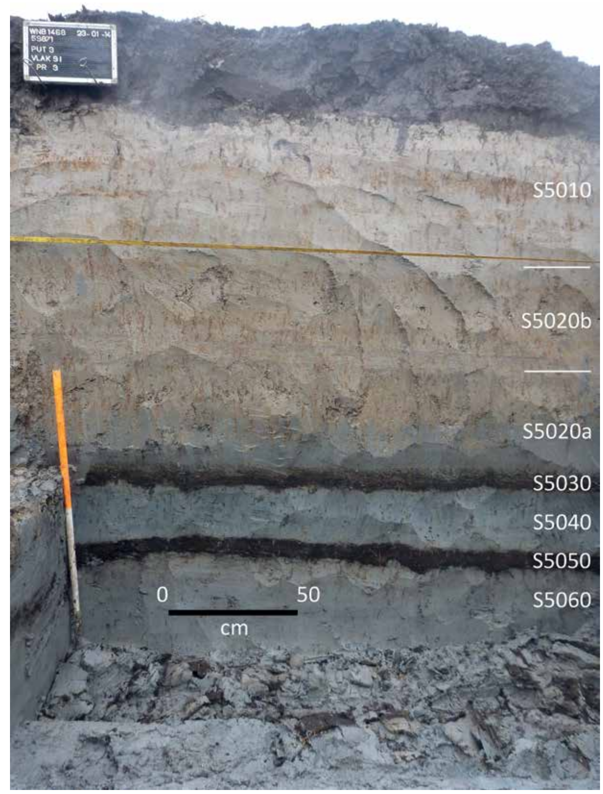


Figure 3.11: Soil section and lithological units from the site Noorderboekert. (Photo: ArchOL BV).

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

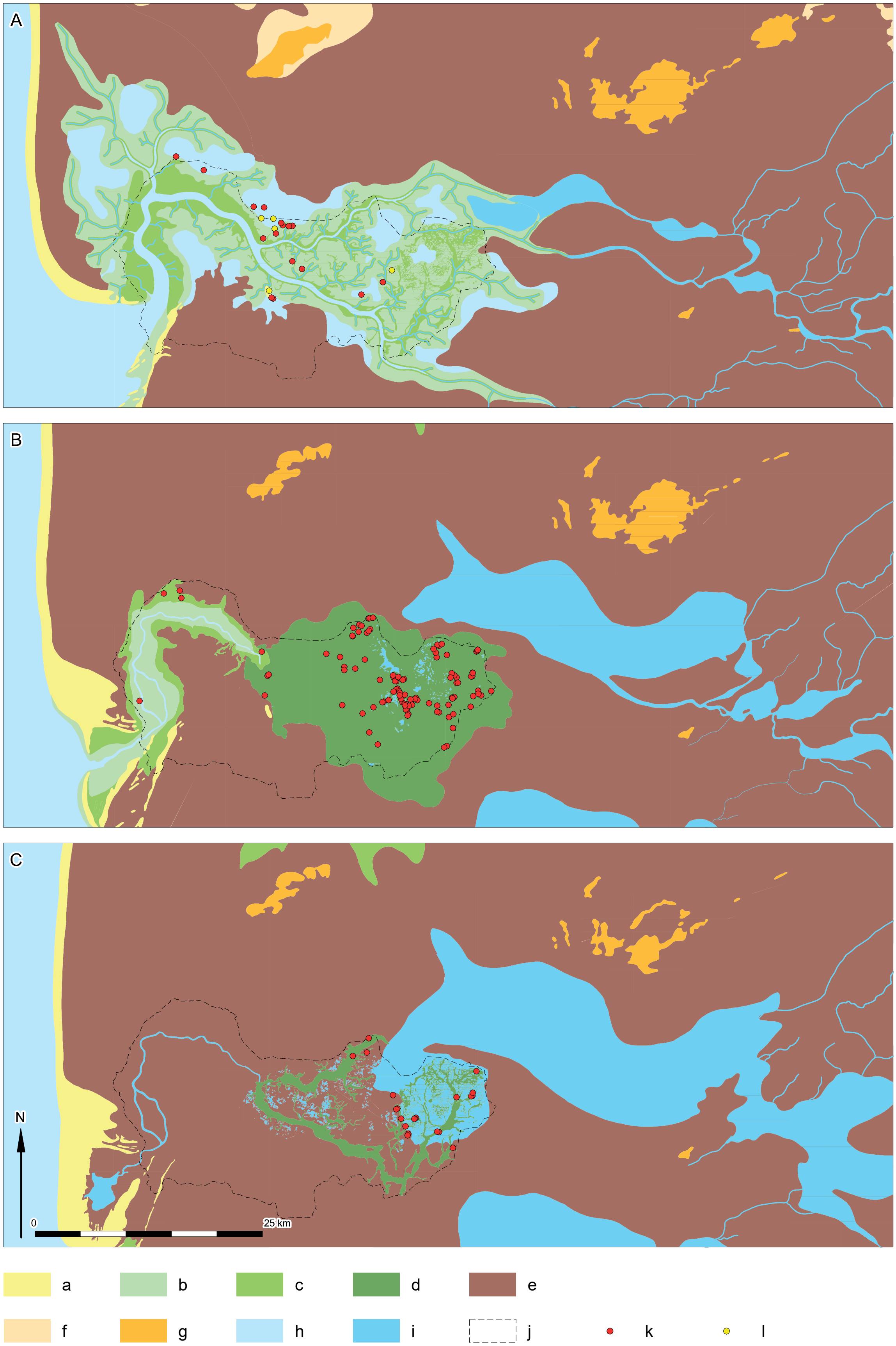
Based on the previous analyses, in figure 3.12 new palaeogeographical maps are presented for the time slices 2850 BC, 1500 BC and 900 BC. The new palaeogeographical maps are primarily based on the available soil maps, the palaeogeographical reconstructions for The Netherlands, an evaluation of the available 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


A
B
C
N
0
25 km
a
b
c
d
e
f
g
h
i
j
k
l

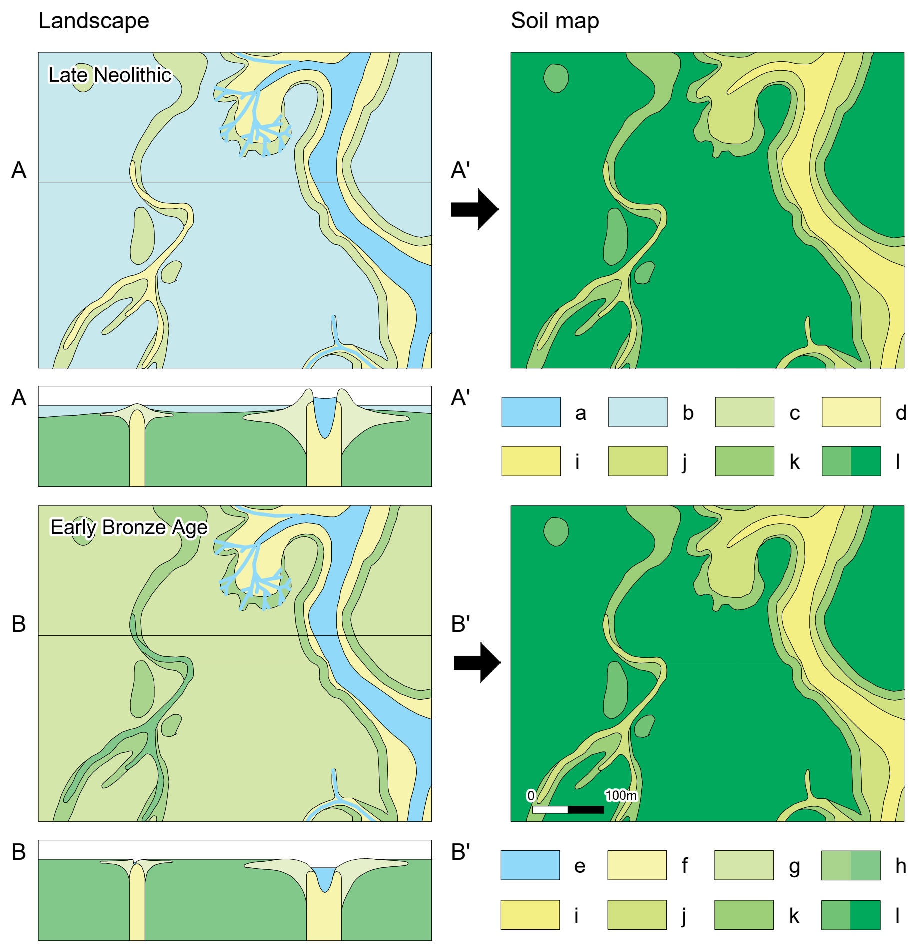


Figure 3.13: The relation between the former landscape and the present day soil map of eastern West-Frisia. Legend: a salt to brackish water, b brackish to freshwater and or reed swamps, c irregularly flooded levees and creekridges, d regularly flooded flats, splays and residual gullies, e salt to brackish 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.