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The Roman Limes in the Netherlands: how a delta landscape determined the location of the military structures

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Abstract

From the 40s A.D. onwards a dense military system was established in the Lower Rhine delta in the Netherlands. Long since, it is questioned why this system was established in a wetland area and even turned into the northwest frontier of the Roman Empire, the *Limes*. A new detailed palaeogeographical map, based on a digital elevation model (LIDAR), soil maps and excavation results, was constructed. This reconstruction provides insight and understanding of the interactions between the natural environment in this part of the delta on the one hand and the establishment of this part of the *Limes* along the Old Rhine between Utrecht and Katwijk on the other. This study shows that the distinctive landscape of the western Rhine-Meuse delta, with an exceptionally large number of tributaries, determined the spatial pattern of the military structures. All forts (castella) were erected on the southern natural levees of the river Rhine, directly alongside the river, regardless of height and composition of the subsoil and alongside or opposite routes that provided natural access to the river. We conclude that their aim was to guard all waterways that gave access to the river Rhine from the Germanic residential areas further north and from/to the Meuse tributary further south in the delta. In addition, a system of small military structures, mostly watchtowers, was erected between the forts to watch over the river Rhine and its river traffic. Furthermore, at least two canals were established to create shorter and safely navigable transport routes to the river Meuse. At first, this integrated system of castella and watchtowers probably aimed to protect against Germanic invasions and to create a safe corridor for transport and built up of army supplies for the British invasion in 43 A.D. Only later on, probably by the end of the first century, this corridor turned into a frontier zone.

Keywords: fluvial geomorphology, geoarchaeology, Old Rhine, Rhine-Meuse delta, Roman castella

Introduction

During the first centuries A.D., the Roman army established a linear frontier system in the Rhine-Meuse delta in the Netherlands (Van Es, 1981; Willems, 1981; Bechert & Willems, 1995). By the middle of the 1st century A.D. a series of small auxiliary forts was built in the western part of this delta from the present-day city of Utrecht down to the North Sea over a distance of about 60 kilometres (Bosman & De Weerd, 2004; Polak et al., 2004; Polak, 2009). The fortifications were constructed on the left bank of the Lower Rhine and built exceptionally close together compared to the upstream part of the delta (Fig. 1).

During the Holocene the Rhine-Meuse delta consists of a varying landscape formed by the interaction of fluvial and marine processes. The downstream part of the delta was relatively starved of both fluvial and tidal sediments (Erkens et al., 2006), the distance to other Rhine distributaries was large, while the distal parts of the flood basins were isolated from influence of active river channels. This situation favoured peat formation (Gouw, 2007). This caused extensive peat formation in this part of the delta during the Roman period which resulted in a landscape that has been considered previously as a hardly accessible and marginal landscape (Van Es, 1981; Bloemers, 1983; Whittacker, 1994). Hence, the question arises why such a closely spaced linear defence system was established here at all and in the course of time even turned into the northwest frontier of the Roman Empire, the *Limes*.

While providing constricted conditions for settlement in Roman age, the preservation conditions of artefacts, especially

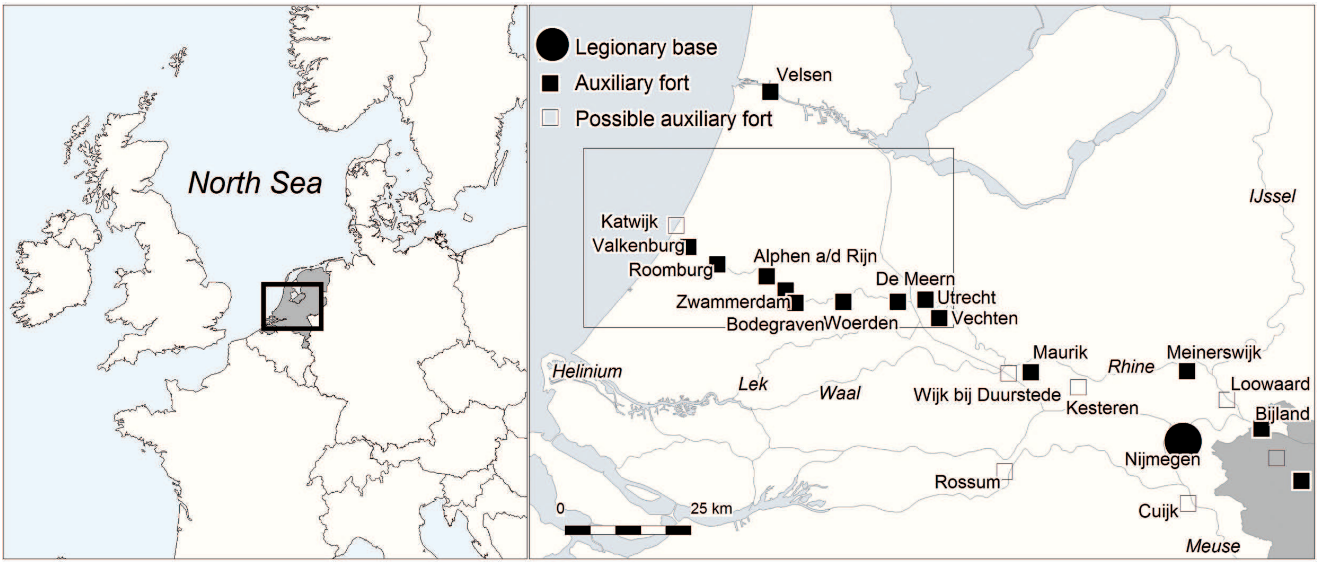


Fig. 1. Roman fortifications in the Rhine-Meuse delta, the Netherlands, in the first two centuries A.D., projected on modern topography (after Polak, 2009). Box indicates the research area.

ecological material, have been exceptionally high due to the high water levels in this wetland area. Furthermore, the Roman military structures along the Lower Rhine are well preserved in subsurface, because hardly any post-Roman river erosion occurred in contrast to the central and eastern part of the delta (Bechert & Willems, 1995). Hence, it is an ideal study area for both archaeological and geological research onto this reach of the Roman *Limes*.

Archaeological research into the military history of the Roman frontier zone was traditionally almost exclusively focused on the size and lay-out of the individual forts and their building history (e.g. Van Giffen & Glasbergen, 1947; Van Giffen, 1948, 1955; Van der Klei, 1970; Glasbergen, 1972; Haalebos, 1977; Bogaers & Haalebos, 1983; Kalee & Isings, 1984; Ozinga et al., 1989; Polak & Wynia, 1991; Van der Gauw & Van Londen, 1992). Usually, little attention was given to the reconstruction of the surrounding landscape. Only during extensive archaeological excavations near Valkenburg (Fig. 1) thorough geological research was carried out (Van Dierendonck et al., 1993). This research showed that the human occupation here occurred in a very dynamic environment. Since then, geological and environmental investigations became an essential part of the many archaeological excavations in the former *Limes*-zone. These investigations provided considerable information about the landscape and its development during the first centuries A.D. and showed that the Romans had to adapt to the specific problems and restrictions nature imposed (e.g. Berendsen & Wynia, 1993; Vos & Lanzing, 2000; Vos & Blom, 2003; Polak et al., 2004; Van der Kamp, 2009).

However, the results of these studies have not been integrated into a larger framework. Therefore, a detailed insight and understanding of the interactions between the natural environment in the Rhine river delta on the one hand and the establishment and maintenance of this section of the *Limes* on the other hand is lacking. The objective of the study reported here is to assess the influence of the landscape on the location and size of the military structures erected in the western *Limes*-section in the first two centuries A.D. based on available geoarchaeological data (Fig. 1). This paper first presents a new and detailed reconstruction of the palaeo-landscape in this part of the *Limes*-zone in the Roman period. The processes active in this landscape at different scales and the resulting development of the environment are described. In addition, the location of all military structures in this landscape is outlined. Finally, the influence of the landscape on the position and lay-out of the various military elements in the research area is revealed. In this way, this paper contributes to a better understanding of the reasons why the Roman army settled along a river branch in an unembanked delta plain.

The study area

Geological setting

During the Roman time period, wide-spread peat formation occurred in the Netherlands. Therefore, extensive areas were almost inaccessible and habitation was limited. The apex of the delta was located near the German border (Gouw & Erkens, 2007). The delta was bordered by topographically higher Pleistocene deposits in the north and south and the coastal dunes in the west. The current research area is situated in the north-western part of the Rhine-Meuse delta (Fig. 2).

Alluvial ridges and flood basins formed the major geomorphological features with only slight height differences of less than one to two metres. The alluvial ridges consist of natural levees, completely or partly silted up swales and residual

Fig. 2. Palaeogeographic map of the Netherlands in 1st century A.D. Box indicates the research area. The map is based on several studies (Westerhoff et al., 2003; De Bont, 2008; Van Beek, 2009; Cohen et al., 2009; Vos et al., 2011).

channels, and point bars (Cohen et al., 2009). The elevated levees were gradually formed during annual floods, when the rivers deposited overbank sediment along their channel. In the low-lying flood basins farther away from the river clay was deposited during overbank flooding. Furthermore, small channels could erode through the natural levees during peak discharges, resulting in the deposition of coarser sediment in the flood basin, referred to as crevasse splay deposits (Smith, 1983; Berendsen, 2004).

During the Roman period, a network of coexisting Rhine and Meuse tributaries was active within the delta. The distribution of active channel belts in the first centuries A.D. is shown in Fig. 3. The river branch along which the chain of Roman auxiliary forts was built formed the second largest river mouth of the Rhine-Meuse delta and is nowadays referred to as Old Rhine (Berendsen & Stouthamer, 2001) or '*R(h)enus*' by the Romans (Tacitus, Ann. II, 6). In Utrecht, the Vecht, bifurcated from the Rhine. This branch, referred to as '*Flevum*' by Plinius, discharged into the North Sea near Castricum, but was most likely also connected to Lake Flevo (Plinius, Nat. Hist. IV, 101; Fig. 2). By the middle of the 1st century A.D., the estuary near Castricum had silted up (Bosman, 1997; Vos, 2008). Thereafter, all Vecht water discharge was diverted to lake Flevo and in turn to tidal flats in the North (Fig. 2; Plinius, Nat. Hist. XVI, 2-3). The southernmost river mouth of the combined Waal and Meuse rivers was the largest outlet to the North Sea and called '*Helinium*' or '*Os Immensum*' by the Romans (Plinius, Nat. Hist. IV, 101; Tacitus, Ann. II, 6; Fig. 2). Yet, the channel system in the delta was a continuously changing network. The actual position of the river channels altered in time through lateral migration, meander cut-offs and avulsions (Berendsen & Stouthamer, 2001).

The water discharge of the Old Rhine gradually decreased during the Roman period. This was caused by a steadily redirection of the water flux in the Nederrijn towards the more southerly Hollandsche IJssel distributary and later on to the Lek (Fig. 3; Berendsen 1982). Because of this development, the fluvial activity of the river Vecht also reduced, ultimately resulting in the onset of peat growth on the lower parts of the natural levees from the end of the 3rd or early 4th century A.D. onwards (Weerts et al., 2002).

Despite the reduction of the water discharge in the Old Rhine, the flood frequency and magnitude of the floods probably increased along the Old Rhine during the Roman period,

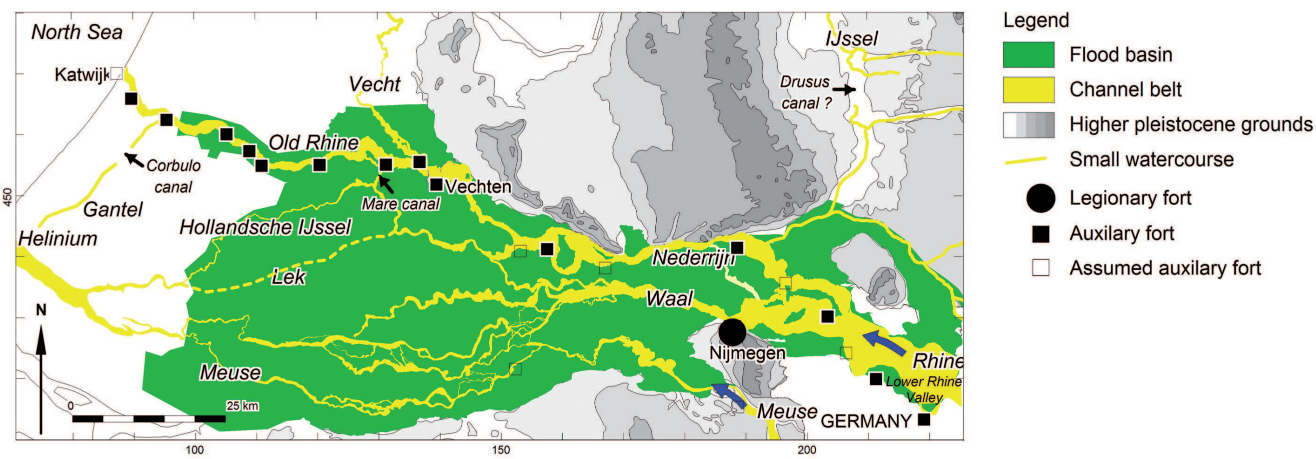


Fig. 3. Active channels belt in the Rhine-Meuse delta in the first two centuries A.D. (modified after Erkens & Cohen, 2009).

concurrent with the general trend in the Rhine-Meuse delta during this time period (e.g. Kwadijk, 1993; Berendsen & Stouthamer, 2001; De Moor, 2007; Gouw & Erkens, 2007). This increase is attributed to increased human impact in the upstream catchments of Rhine and Meuse through intensified forest clearing and agricultural land-use. This also resulted in considerable increases in sediment supply and overbank sedimentation (Erkens et al., 2011). Because of large-scale clastic sedimentation peat formation in the flood basins ceased in the eastern part of the Rhine-Meuse delta (Stouthamer, 2001; Gouw & Erkens, 2007). Furthermore, it triggered vertical channel aggradation instead of incision in the Lower Rhine Valley in Germany just upstream of the Rhine delta (Erkens et al., 2011).

Roman occupation

Roman occupation of the Rhine-Meuse delta started during the Augustian military campaigns with the building of a large legionary base in Nijmegen between 19-16 B.C. (Driessen, 2007). Soon, in 12 B.C., this camp was abandoned (Kemmers, 2006). Only in the early part of the 1st century A.D., a sequence of smaller military bases were erected further to the west along the Rhine: a fort at Vechten, at Meinerswijk and at Velsen (Willems, 1984; Morel, 1988; Polak & Wynia, 1991; Bosman, 1997; Bosman & De Weerd, 2004; Polak, 2006). From 40 A.D. onward a number of new auxiliary forts was established on the left bank of the Old Rhine downstream of Vechten. Together they formed a chain of ten forts built exceptionally close together (Fig. 1).

Until recently, it was generally thought that Valkenburg was built in A.D. 39/40 by Caligulan troops, while the others were only erected in or shortly after A.D. 47, the year that general Corbulo was ordered to withdraw his troops to the left bank of the river Rhine by emperor Claudius (Polak, 2009; Tacitus, Ann. XI,19). However, recent excavations have radically changed this theory as founding dates around 40 A.D. are established for Valkenburg, Alphen aan de Rijn, De Meern and supposedly also for Woerden (Kemmers, 2008). This implies that the birth of the Lower Rhine *Limes* took place during the reign of Caligula instead of Claudius' (Polak, 2009). Occupation of most forts along the Old Rhine and their associated settlements, the vici, is generally assumed to end in the third century A.D. (Van Es, 1981; Kemmers, 2008).

All fortifications in the research area were initially constructed out of timber and earth, had a rectangular plan form and covered roughly one to two ha. Thereby, the forts are relatively small compared to fortifications upstream along the river Rhine. Furthermore, they differ in lay-out with only two strips with buildings in stead of three. The small size of the forts is generally attributed to limited width of the natural levees (Hessing, 1995).

Methods and materials

Palaeogeography

Although a general overview exists of the landscape of the Rhine-Meuse delta in the Netherlands (Fig. 2) understanding of the position of the fortifications requires a much more detailed reconstruction of the environmental settings of the military structures. To reconstruct the landscape of the first centuries A.D., a detailed palaeogeographical map of the study area was created using a Geographical Information System (GIS; Fig. 4 and Appendix 1, available online). Soil maps, geological and geomorphological maps, scale 1:50,000, formed the starting-point for this reconstruction (Appendix 2, available online). These maps show the composition of the subsoil, the origin of the landforms and the age of formation, and together provide a good overview of the palaeogeography of the study area. All maps were geo-referred in the Netherlands Coordinate System – Netherlands National System. Following this, these maps were adapted and improved by using a high-resolution digital elevation model (DEM) of the present land surface based on laser altimetry (LIDAR; Rijkswaterstaat-AGI, 2005). This dataset allowed to add more spatial detail to the maps and to provide a greater accuracy, as well as to map patterns and features that were invisible in the field and/or missed in earlier mapping campaigns (Berendsen & Volleberg, 2007; De Boer et al., 2008).

The DEM was created from the original laser data points by means of inverse squared distance weighting, resulting in a 5 × 5 m elevation grid used in this study. The general downstream gradient of the terrain surface was determined by plotting the highest altitudes of the river levees versus the horizontal-coordinate (Berendsen, 1982). The original elevation models were corrected for this general terrain gradient by subtracting this gradient surface from the original model. In this way, an elevation model was obtained indicating the local terrain elevation relative to the general terrain slope, at 10 cm height intervals to allow detection of the small elevation differences (Berendsen, 2007). By overlaying this relative DEM over the existing maps, it was possible to correct and refine the mapping in the present-day agricultural areas (Berendsen & Volleberg, 2007). In urban areas, borehole data, archived in the DINO-database of TNO – Geological Survey of the Netherlands were used to retrieve information on composition of the subsoil and thereby the palaeogeographical situation in former times.

Because micro topographical differences determined local flooding frequency and ground water level, and accordingly the suitability of the area for human activities, the legend units 'natural levees' and 'flood plains' were subdivided into sub-classes according to their height, using elevation steps of about three dm (Appendix 1). In most areas, the modern surface topography of the natural levees and flood basins does not reflect the palaeo surface topography due to later erosion and disturbance of the deposits. Firstly, post-Roman fluvial erosion and sedimentation occurred, but – fortunately – lateral river migration of the river Rhine in the research area occurred only to a small extent (Bult et al., 1990; Nokkert et al., 2009). From the medieval period onwards large-scale excavation of clay or sand occurred by humans as raw material for e.g. bricks, roads and dikes to a depth of one to two metres in the natural levees of the Rhine, resulting in low-lying excavated plots, often with steep edges.

Furthermore, the micro topographical differences in the past were presumably smaller due to subsidence by peat compaction caused by artificial lowering of groundwater tables during the last centuries (Van Asselen et al., 2009). This subsidence not only occurred in the peat area and flood basins, but also along the margins of the alluvial ridges where the natural levee deposits lie on top of older flood basin and peat deposits. Field studies have shown that subsidence of several mm/yr occurred in the central part of former fen peat areas, leading to surface subsidence of at least one metre since land reclamation in the eleventh century (Schothorst, 1977; Beuving & Van den Akker, 1996; Jansen et al., 2007). The induced subsidence accordingly resulted in relief amplification of channel belts.

Crevasse splays were included in the unit 'natural levees', because the splay deposits formed relatively high areas extending from the distal parts of the levees and provided similar conditions for human land-use (Van Dinter & Van Zijverden, 2010). Several excavations provided evidence that crevasse splays formed during the first centuries A.D. (Vos & Lanzing, 2000; Vos & Blom, 2003; Vos & Blom, 2004; Ploegaert, 2006; Den Hartog, 2009; Langeveld & Luksen-IJtsma, 2010). Unfortunately, we have no absolute age evidence on the formation of the majority of the splays complexes. In addition, the splays gradually lost their relatively high position in the landscape due to subsidence and ongoing sedimentation in the flood basins. Yet, archaeological finds dated to the Roman period are recorded on top of many splays revealing human land-use in Roman times (Appendix 1). Therefore, all splays that are visible in the DEM due to differential compaction were mapped in this study.

The reconstruction of the position of the river within its channel belt during the Roman period is based on a number of excavations that revealed the location and depth of the Roman river channel (Appendix 2). Furthermore, the DEM shows elongated depressions in the alluvial ridge of the Old Rhine suggesting the presence of swales and residual channels. Unfortunately, no ^{14}C dates from these channels were available to give age control. The reconstruction of the river mouth, the estuary, is based on a detailed soil map of this area (Van der Meer, 1952). The spatial distribution of the salt marshes in the estuary is, however, not based on detailed field data, and has therefore been indicated in a more schematic way to give an impression of the former landscape.

Although different botanical types of peat must have been present in the wetlands of the river delta in former times, palaeogeographic maps usually do not distinguish between them (Van Es, 1981; Henderikx, 1983; Westerhoff et al., 2003; Vos, 2006; Bos et al., 2009; Vos et al., 2011). The peat types in the palaeogeographical reconstruction are mainly based on the Soil maps of the Netherlands, scale 1:50,000, that distinguish the type of peat present in the subsoil (Appendix 2). Due to large-scale peat digging for fuel from Medieval times onwards, nowadays only small remains of the former peat domes have been preserved in the Netherlands. Nevertheless, excavations in some of these remains confirmed the presence of *Sphagnum* and *Eriophorum* peat in the presumed peat domes in the research area (Roller, 2003; Bakels & Kuijper, 2007; De Kort & Raczynski-Henk, 2008). The spatial distribution of the oligotrophic peat domes and surrounding mesotrophic reed and sedge fields is roughly based on the contours of the modern polders, because they supposedly mark the boundaries of these types of peat that were the most useful to excavate for fuel purposes (Van Wallenburg, 1966; Pons, 1992).

The reconstructed lakes in the former peat domes are situated in areas that have the toponym '-lake' on historical topographic maps (in Dutch: '-meer'), indicating the presence of former lakes (Appendix 2). Lakes are common phenomena in present-day peat domes. Unfortunately, we have no time control on the establishment of the lakes. Presumably, the lakes gradually expanded eastward in time, because of prevailing westerly winds (De Bont, 2008). Some of the 'lake'-areas, such as Braassemermeer, Haarlemmermeer and Zijdelmeer, formed the starting point of curved ditch patterns, indicating the presence of a former drainage network.

The distribution of the dunes is based on the geological map of the Netherlands, scale 1:50,000 (Van der Valk, 1995) and slightly modified on the basis of micro topography shown on the DEM. Yet, detailed coring campaigns and archaeological excavations have shown that their distribution is even more complex than appears from the map (Veenenbos & Van der Knaap, 1954; Rieffe, 2007; Rieffe, 2009).

After Roman times, sea level rose by ca two metres and the coastline in the study area experienced progressive coastal erosion (Beets & Van der Spek, 2000; Vink et al., 2007). As a result, the Roman coastal landscape has partly disappeared. The reconstruction of the Roman shoreline was therefore based on existing reconstructions (Beets et al., 1992; Beets & Van der Spek, 2000; Van Heteren & Van der Spek, 2008).

Archaeology

The position and lay out of the Roman forts were based on Chorus (forthcoming), and the location of watchtowers and canals were obtained from archaeological excavations (Appendix 2). Only field campaigns carried out before 2009 are included in this study. Locations where additional military complexes are postulated are indicated in grey. The course of the Roman road, *via militaris*, is mainly based on Luksen-IJtsma (2010). Furthermore, all Roman finds spots reported to the Dutch Cultural Heritage Agency and administered in the ARCHIS-database until January 2009 are shown (Appendix 1). The depicted rural settlements are only partially based on actual excavations (Appendix 2). The majority is inferred from the ARCHIS-reports with the method described by Vos (2009; Van Dinter et al., submitted).

Results

Palaeolandscape

The palaeogeographical situation in the study area in the first centuries A.D. is shown in Fig. 4. A more detailed map, scale 1 : 50,000, is presented in Appendix 1.

Natural levees

The alluvial ridge of the Old Rhine formed a relatively narrow corridor of accessible terrain within a vast wetland. The natural levees consisted of sand and sandy clay and reached a maximum of one and a half metres above the surrounding flood basin. The alluvial ridge reached a maximum width of about two kilometres around Utrecht and a minimum of ca 800 metres between Bodegraven and Alphen aan de Rijn. Under natural conditions, natural levees in the Dutch fluvial area carried an alluvial hardwood forest characterised by a high species diversity with beech (*Fagus sylvatica*), hazel (*Corylus avellana*), lime (*Tilia cordata*), field maple (*Acer campestre*), oak (*Quercus robur*), elm (*Ulmus* sp.), ash (*Fraxinus excelsior*) and hornbeam (*Carpinus betulus*) (Fig. 5a; De Klerk et al., 1997; Wolf et al., 2001). Wood remains of the Roman fort in Alphen aan den Rijn reveal that the timber used between A.D. 40-70 was retrieved from such forests, probably located in the vicinity of the fort (Van Rijn, 2004; Van Rijn, forthcoming). Around A.D. 70 these forests had almost completely vanished (Kooistra et al., in press; Van Rijn, forthcoming). The natural levees in the eastern and the western part of the research area were already largely deforested in the early Roman period due to exploitation of the natural woodlands in the preceding Late Iron Age (Vos, 2009).

The width of the river channel of the Rhine in the Roman period varied within the research area. In the eastern part of the research area, between Vechten and Utrecht, the river channel was around 100 metres wide and 7 metres deep (Aarts, 2012; Jansen et al., in press). In this area, Pleistocene aeolian sand deposits are present only a few metres below the surface. This sand was easily erodible, causing rapid river migration and the formation of shoals. Downstream of Utrecht and the bifurcation of the river Vecht, the river channel seems to have been around 40 to 80 metres wide, around 4-6 metres deep and

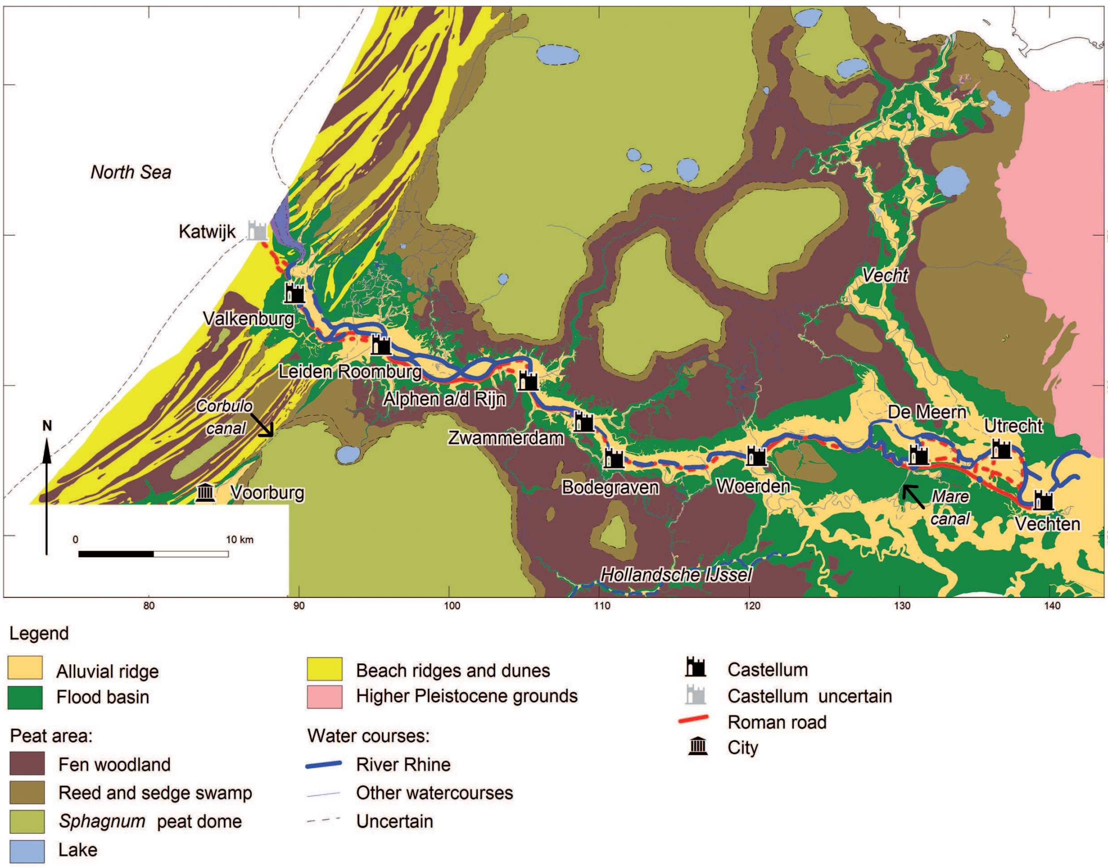


Fig. 4. Palaeogeographical map of the study area.

probably contained fewer sandbanks (Aarts, 2012). Between Alphen aan de Rijn and Leiden, the river probably had two channels that successively divided and merged over a length of around 15 kilometres. In between these channels, stable islands around one kilometre wide and two to three kilometres in length were present. Approximately two kilometres west of Valkenburg, the river graded into a funnel-shaped estuary with a mouth just over two and a half kilometres wide. As in all estuaries, tidal channels separated by sandbanks were present in the centre and flanked by muddy flats and salt marshes dominated by halophytic herbaceous plants. (Fig. 5b; Reading & Collins, 2006).

Fig. 5. a. Natural levee covered with alluvial forest (Doesburg, the Netherlands); b. Estuary with sand banks and flanked by salt marshes (river Nith, Scotland, UK; photo: Scottish Environment Protection Agency); c. Productive grasslands in flood basin (Tulcea, Romania; photo H. Weerts); d. Fen woodland (Barneveld, the Netherlands); e. Peat bog (Kemeru National Park, Letvia; photo H. Weerts); and f. Dune valley in between dune ridges (Burg Haamstede, the Netherlands; photo H. Weerts).

Flood basins

On either side of the alluvial ridge of the Rhine, low-lying flood basins spread out. The subsoil of these flood basins consisted of clay. In a natural situation, this area was covered with grasslands and open water (Fig. 5c; De Klerk et al., 1997 a, 1997b). The width of these flood basins in the research area varied considerably. In the eastern part of the research area the basin reached width of around two kilometres, whereas it was only a few hundred metres wide in the central part between Woerden and Alphen aan den Rijn. Near Leiden, it widens again to over 4 kilometres with complex drainage networks.

Peat lands

Further away from the alluvial ridge, behind the distal parts of the flood basin vast peat lands stretched out (Fig. 4). In most parts of the research area, extensive fen woodlands occurred behind the flood basins (Fig. 5d). Studies on wood remains from this peat area show that an Alno-Padion woodland with alder (*Alnus*) and small percentages of oak and ash were present here in Roman times (Kooistra et al., 2006; Fokma, 1998; Jansma, 1995; Visser, 2009; Bouma et al., 2011). Mean annual groundwater levels usually varied between 10 cm above and below the surface (Stortelder et al., 1998).

The nutrient concentration in the groundwater in the forested fens gradually decreased away from the rivers. Consequently, the nutrient rich fens changed gradually into poor ones, subsequently into transitional mires consisting of mesotrophic reed and sedge swamps, and ultimately into nutrient poor *Sphagnum* peat bogs (Fig. 5e). These vast peat domes often measured over several kilometres in diameter, probably raised ca 4-5 metres above the surrounding area, and thereby released a fair amount of drainage water (Pons, 1992; Westerhoff et al., 2003; De Bont, 2008). A complex network of small watercourses received this drainage water and transported it to the rivers Rhine and Vecht. The existence of these brooks, so-called peat rivers, was already known, but hitherto it was assumed that these rivers developed individually in the peat area and were not connected to each other (Fig. 2). However, the curved ditch patterns visible on historical topographical maps extend much further into the former wetland area, indicating that the former peat rivers not only were much longer, but even formed an interconnected network in the vast fen woodlands both north and south of the river Rhine (Fig. 4; Appendix 1).

Delta borders

In the north-east, the delta was bordered by higher Pleistocene ice-pushed ridges and aeolian cover sands raising up to 30 metres height above sea level. On the western side, the delta was bordered by a coastal zone consisting of series of beach ridges with low dunes and barrier plains with peat formation (Jelgersma et al., 1970; Van Staalduinen et al., 1979; Westerhoff et al., 1987). The gently undulating dunes raised only a few metres above the surrounding plains. The natural vegetation consisted of dune shrub of Sea Buckthorn (*Hippophaë rhamnoïdes*), Common Juniper (*Juniperus communis*), Hazel (*Corylus avellana*) and Oak (*Quercus*), while in the low-lying plains between the dunes fen woodland and reed-sedge swamps were present (Fig. 5f; (Jelgersma et al., 1970; De Jong & Zagwijn, 1983; Bakels, 2008; Kooistra, 2009). Only in the centre of the broadest plains, nutrient poor conditions prevailed, so here small peat bogs could develop (Stichting voor Bodemkartering, 1982). It is assumed that the shoreline near the Rhine estuary in Roman times was located some 400 metres offshore of the current fore-dunes (Bloemers & De Weerd, 1984; De Weerd, 1986).

Landscape dynamics

River floods

Floods were annual phenomena in the delta. Peak discharges of the Rhine mainly occur in winter to spring resulting from precipitation excess and snow melt (Middelkoop & Van Haselen, 1999; Middelkoop et al., 2001). During average peak discharges, the lower parts of the natural levees and the flood basin were inundated. The highest parts of the levees were only flooded during extreme floods. Hence, these areas were used for settlement and cultivation of cereals (Groot & Kooistra, 2009; Groot et al., 2009).

The natural levees bordering the river channel regularly breached during periods of high flow, resulting in the formation of crevasse splays. The palaeogeographical map shows these splays by their irregular dendritic shape, protruding from the alluvial ridge into the flood basin (Berendsen & Volleberg, 2007). During flood periods, river water also penetrated into the lower reaches of the peat brooks draining into the Rhine and Vecht rivers. Accordingly, sediment was deposited as miniature levees alongside these channels decreasing in size and thickness in 'upstream' direction towards the centre of the peat area.

The shape of the flood basins and the dimension of the floods determined how far nutrient-rich water could penetrate into these basins. This is reflected by the distribution of the fen woodlands (Fig. 4). This distribution shows that during the first centuries A.D. eutrophic river water was generally dispersed up to several kilometres behind the flood basin, while the dispersal perpendicular to the peat brooks was restricted to several hundreds metres only.

Tidal influence

In the estuary, a mixing zone between fresh and salt water occurred, with variations in water level and salt intrusion along with the tides, storms and varying river discharge. Palaeoecological studies in the western part of the research area have revealed that salt water could occasionally reach by about 15 kilometres upstream. In this freshwater tidal district, the environment only sporadically received an influx of salt water (Glasbergen, 1972; Jansma, 1988; Bult & Hallewas, 1990; Kuijper, 1990; Bakels & Stronkhorst, 2004; Kooistra, 2005; Van Zijverden, 2007; De Wolf, 2007; Van der Linden et al., 2009; Van Amen & Brinkkemper, 2009). The temporal influx of salt water probably prevented the formation of an alder forest in the tidal district. Consequently, sedge swamps are present behind the flood basin in this area instead of fen woodlands (Fig. 4). The multiple river channel pattern that occurred in this area was presumably inherited from an earlier period in which the estuary reached further east and ebb and flood tide channels were present in this area (Westerhoff et al., 2003, 225).

During each tide river discharge was blocked, causing the water level in the lower reach of the river to rise, enhancing the formation of so-called 'perimarine' crevasse splays (Berendsen, 1982). The distinct decrease in the abundance of small crevasse splays between Bodegraven and Woerden suggests that the tidal backwater effect reached up to here (Fig. 6). Geological and palaeoecological research in the area strengthen this assumption. An excavation three kilometres east of Alphen aan de Rijn revealed the presence of numerous channels formed by repeated levee breaching in a fresh water environment (Vos & Blom, 2004). These channels are filled with laminated sediments characteristic for the blocking effect in the lower reach of the delta plain (Berendsen, 1982). Such laminated sediments were not deposited near the castellum in Woerden in the first centuries A.D. (Blom & Vos, 2008). We thus conclude that in the first centuries A.D. the water level in the river regularly rose as a result of blocked river discharge up to a maximum of around 30 kilometres upstream measured from the apex of the estuary.

Channel migration

Lateral channel migration in the research area was relatively small during the Roman period. Straight river stretches showed hardly any lateral channel migration (Polak et al., 2004). Only in river bends lateral channel migration up to several tens of metres occurred (Ozinga et. al., 1989; Van Dinter, 2008). Nevertheless, directly downstream of De Meern a series of meander bends developed in the re-activated Heldam channel belt during the first two centuries A.D. In each bend, the channel gradually shifted over ca 100 metres in a period of two centuries (Van Dinter & Graafstal, 2007).

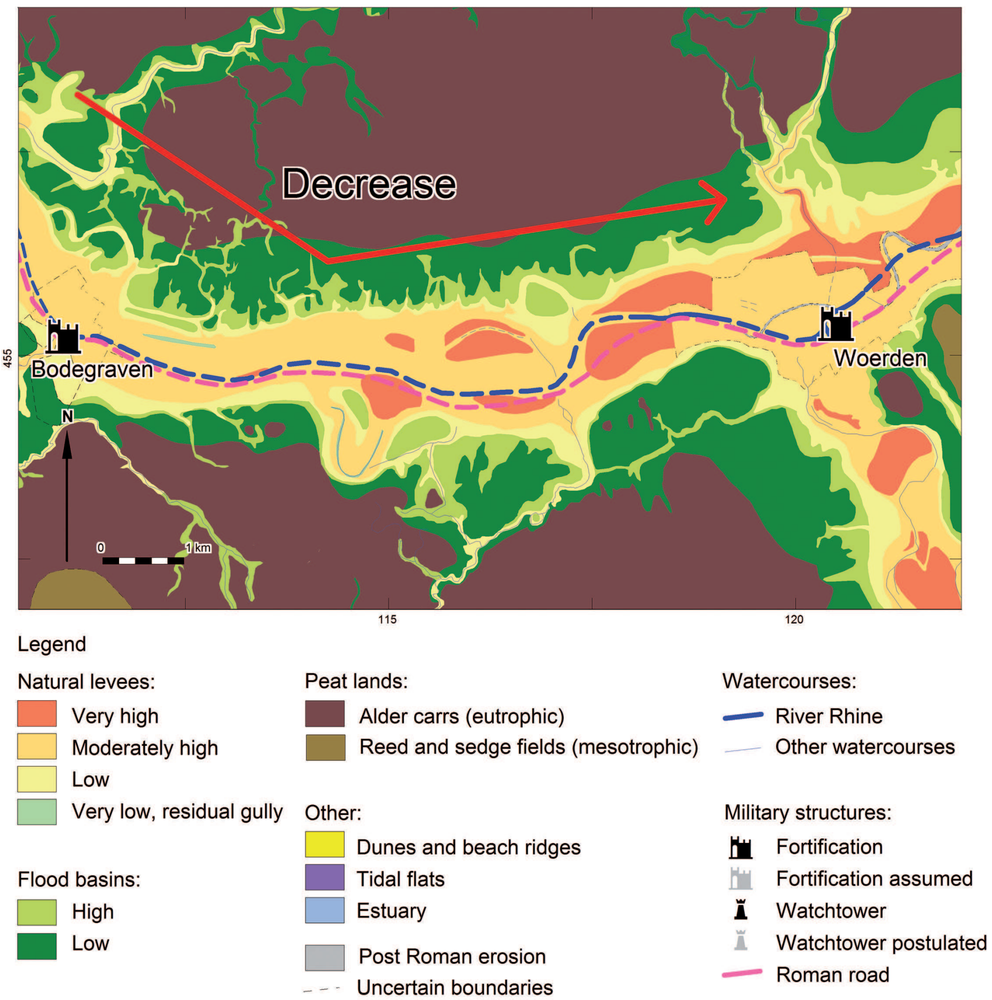


Fig. 6. Decrease of number of crevasse splays in easterly direction. Legend also for Figs 7-9.

Groundwater flow and aeolian processes

The ice-pushed ridges in the northeast supplied a constant flow of seepage water to the low-lying river valley (Van Loonen et al., 2009). The exfiltration of alkaline groundwater resulted in the formation a vast, low productive fen at the foot of these hills in the Roman Period and prevented the succession to fen woodlands and peat bogs (Van Loonen, 2010).

In the dune area significant aeolian activity occurred. Several Roman settlements and their arable fields became covered with a layer of drift sand (Waasdorp, 1998; Van der Velde, 2008). This can only occur if at least parts of the dunes were not vegetated, probably due to agricultural use (Weerts et al., 2011). Deforestation of the beach barriers in this period is indeed reflected in pollen diagrams from the dune area (Kooistra, 2009).

Military structures

Forts

All Roman forts were built on the southern natural levee of the river Rhine, with the long fronts of the castella facing the river. In many cases, clusters of timber pole remains were found at a distance of only 10-15 metres from the castellum wall. These are interpreted as the remains of water front installations such as revetments, simple quays or mooring stages (Haalebos, 1977, 1998; Hazenberg, 2000; Polak et al., 2004; Van der Kooij et al., 2005; Lesparre - de Waal & De Kort, 2006). This implies that the forts were positioned almost directly adjacent to the river channel (Fig. 7). The majority of the castella was erected directly alongside or directly opposite the mouth of peat brooks: the Woerden fort was built opposite the Grecht, the Bodegraven fort alongside the Oude Bodegraven, the Zwammerdam fort opposite the Meije, the Alphen aan de Rijn fort opposite the Aar, and the Leiden Roomburg fort alongside the Vliet (Fig. 7d-h). The fort in Utrecht was positioned at or close to the river bifurcation of the rivers Rhine and Vecht (Fig. 7b).

The three remaining forts of De Meern, Valkenburg and Katwijk were, likewise, erected at specific positions in the landscape as well. The fort in De Meern was built at the junction of two alluvial ridges: the Old Rhine and the Heldam ridge (Fig. 7c). The river in the Heldam branch was active during the Roman Period. However, it is uncertain whether the northerly Old Rhine was active at this time. If so, the river bifurcation of the Old Rhine and Heldam river was situated approximately 1 kilometre north of the De Meern fort (Aarts, 2012). The fort in Valkenburg (*Praetorium Agripinne*) seems to have been built near the apex of the estuary, on the first location where the natural levees of the Rhine were broad enough and not prone to daily flooding (Fig. 7i). Finally, the fort near Katwijk, presumably Brittenburg or *Lugdunum*, was lost due to retrograding of the coastline in post-Roman times, but was most likely built in the dune area at the south-western border of the estuary (Fig. 7j).

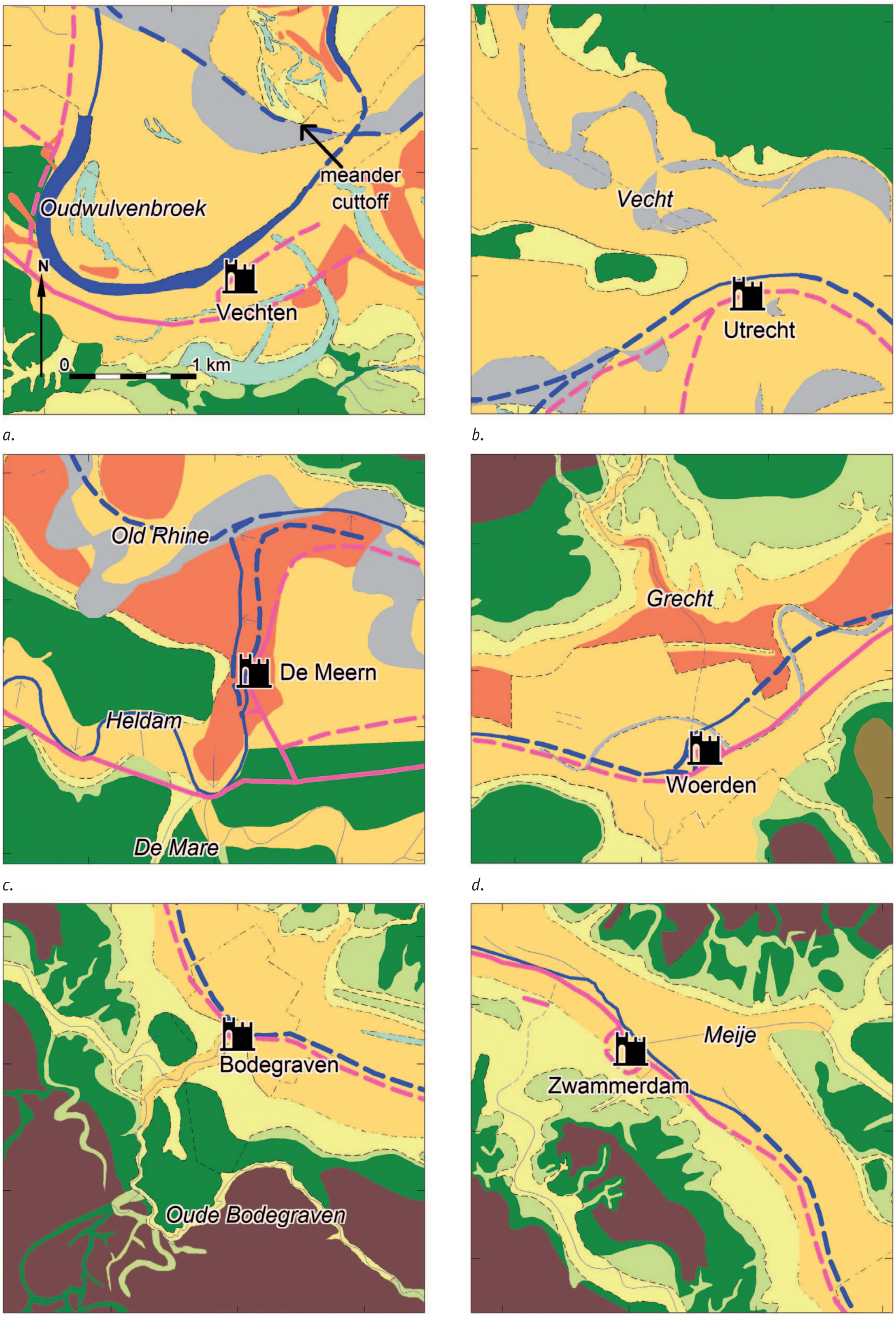
Remarkably, most forts were not built at the highest sites that were less prone to flooding, as was hitherto presumed (Bechert & Willems, 1995). The castellum in Alphen aan den Rijn was even built in a low-lying residual channel (Kok, 2000; Polak et al., 2004). Plant remains unearthed in the soldiers barracks demonstrate that damp conditions prevailed in the fort during its usage. Some forts were positioned less than a few hundred metres away from higher levee plateaus (Haalebos & Franzen, 2000; Blom & Vos, 2008; Duurland, forthcoming).

The erection of forts directly along the waterside inevitably made them vulnerable to flooding. Evidence of flooding and devastation has been demonstrated in several forts and their surroundings (Glasbergen, 1972; Bult & Hallewas, 1990; Ozinga et al., 1989; Polak & Wynia, 1991; Hessing et al., 1997; Polak et al., 2004; Blom & Vos, 2008). Sand lenses regularly found in the forts and their surrounding ditches reflect the occurrence of flood events. Sometimes, even washed-away objects and construction parts, such as writing tablets, wattle, tent pegs, and wooden doors, were found in these layer (Polak et al., 2004). Unfortunately, most layers could not be dated very accurately. Nevertheless, there are indications of a severe flood in the early 40s A.D. (Bogaers & Haalebos, 1987; Hessing et al., 1995; Polak, 2006; Blom & Vos, 2008). Synchronicity of other severe floods that must have occurred along the Rhine and affected the forts could not be determined.

The fort at Vechten was built on a natural levee along the concave bank of the Oudwulverbroek meander in the Rhine (Fig. 7a). The Oudwulverbroek river channel started to silt up during the Roman occupation phase, probably as early as the second half of 1st century A.D. (Polak & Wynia, 1991; Van Tent & Vogelenzang, 1996; Polak, 2006). Based on toponymic arguments it is commonly believed that the fortification in Vechten was built near the bifurcation node of Rhine and Vecht (Polak & Wynia, 1991; Bechert & Willems, 1995; Hessing et al., 1997). However, the residual channel of the Oudwulverbroek downstream of fort Vechten is situated along the edge of the meander belt, thereby ruling out the possibility that a river bifurcation was located within ca 3 kilometres distance downstream of the fort (Fig. 7a). A bifurcation node just upstream of the castellum is unlikely as well, as the entrance of the Vecht channel would have been almost perpendicular to the Rhine, thereby inhibiting the inflow of water. Furthermore, both rivers would then have nearly converged downstream of the Oudwulvenbroek meander bend. Hence, it is more likely that the bifurcation of Rhine and Vecht was located in the city of Utrecht during the early 1st century A.D., presumably at the fort at Utrecht (Fig. 7b).

The abandonment of the Oudwulverbroek residual channel probably coincided with the silting up of the upstream Zeist meander (Berendsen & Wynia, 1993; Berendsen & Stouthamer, 2001). In this way, the silting up of both channels can easily be explained by a river avulsion that occurred ca one and a half kilometres upstream of the castellum around the middle of the

1st century A.D. (Fig. 7a). The clayey and peaty fill of the proximal part of the abandoned channel indicates that the water supply through the Oudwulverbroek channel was suddenly interrupted (Toonen et al., 2012; Jansen et al., in press). Yet, the location of fort Vechten did not change after relocation of the channel. Driessen (2007) proposed that some military and civilian settlement locations remained in use at an initial setting because the effort required to give up a selected and organised



a. b. c. d. e. f.

Fig. 7. Palaeogeographical situation in the surroundings of the Roman castella along the western Lower Rhine in first centuries A.D. (for legend see Fig. 6).

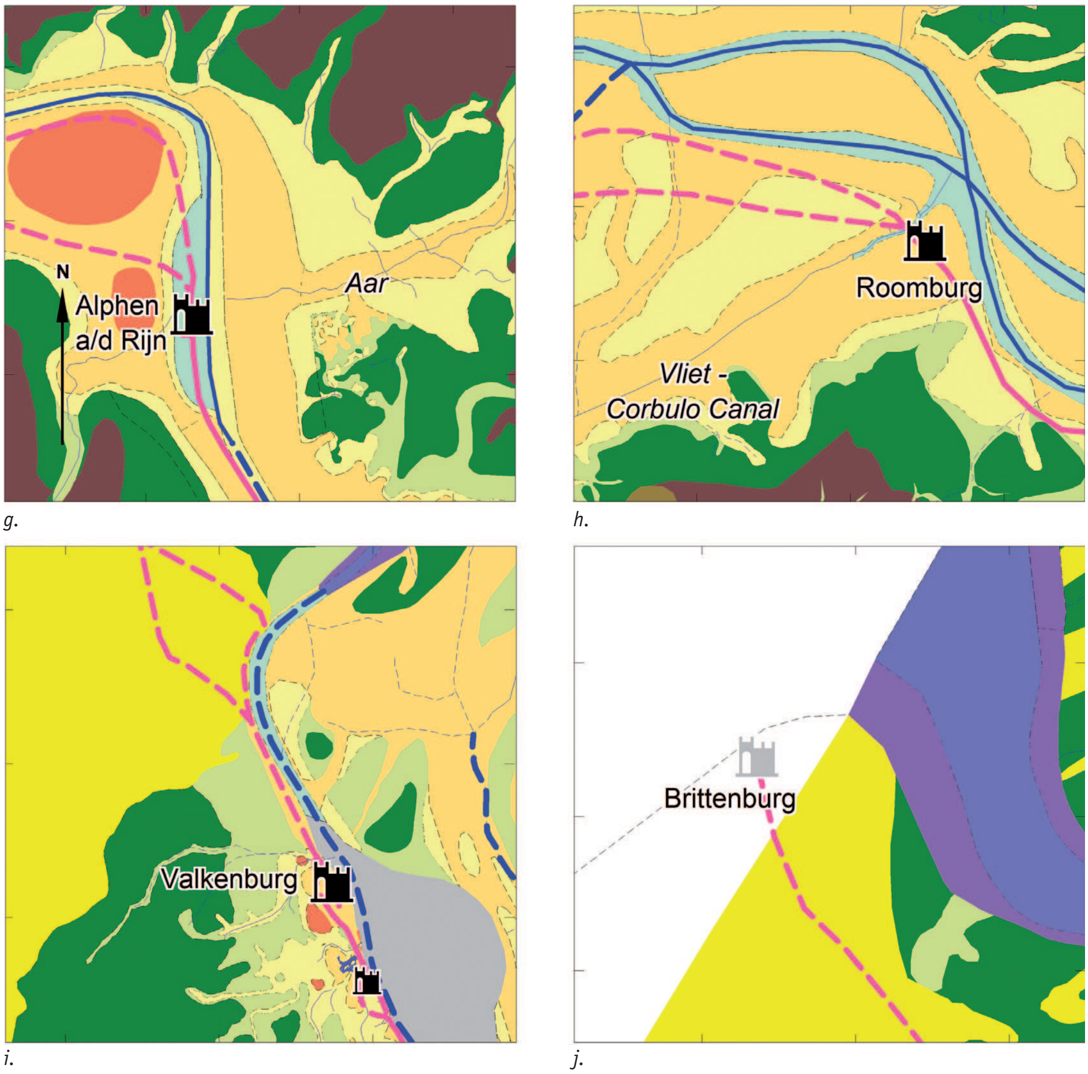


Fig. 7 continued.

foothold and setup a new one was too high. This so-called 'path dependency' might also apply to fortifications in Vechten. Nevertheless, a new, smaller military post might have been built at the cut-off point to watch over the newly formed channel (Fig. 7a).

The path-dependency mechanism might also be applicable to the consecutive fortifications in Woerden. Although only a small part of the fortifications has been excavated, its first establishment is dated early-Claudian (A.D. 41-47) or even earlier, under the reign of Caligula (Blom & Vos, 2008). As no sign of any buildings have been unearthed (yet), it is postulated that it only achieved the state of an enforced encampment with tents. Shortly after its erection, the camp was flooded and covered under a layer of sediment (Van Dinter, 2008). Subsequently, a new fortification was built during the later 40s. This new castellum was erected several tens of metres to the east of its precursor, while the plan form was rotated 10 degrees in clockwise direction (Blom & Vos, 2008). This reorientation suggests that a slight change in the position of the river channel or the mouth of the Grecht had occurred. The discovery of a sunken Roman vessel and a sequence of bank enforcements north of the castellum revealed that the river bend continued to shift in north-western direction during the 1st and 2nd century A.D. By the end of the 2nd century A.D., the channel had moved just over 50 m (Haalebos, 1998; Van Dinter, 2008). Yet, the successive castellum phases were erected at the same location as the second phase, which again might be explained by path dependency.

Watchtowers

Watchtowers were considered rare phenomena along this part of the *Limes*-zone (Van Dierendonck, 2004). Until recently, only one defended watch or signal tower adjacent to a small fortlet was revealed to be located ca 1 kilometre upstream of fort Valkenburg (Fig. 8). The tower and fortlet presumably functioned both during the last quarter of the 1st century A.D., but most likely not simultaneously (Van Dierendonck, 2004).

Recently, three watchtower complexes were discovered near fort De Meern (Fig. 9a). One tower was built ca 1 kilometre north

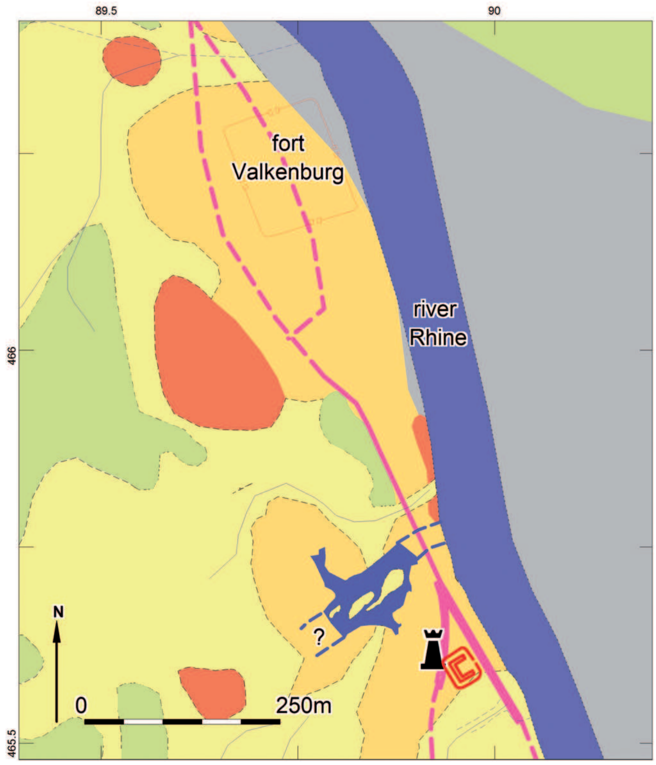
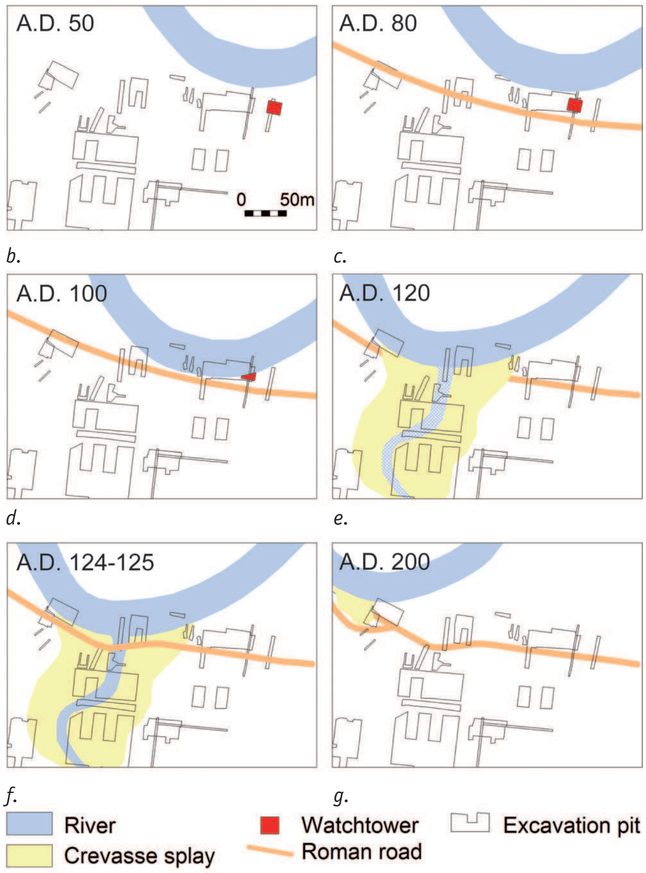


Fig. 8. Location of fortlet (in red) and watchtower south of fort Valkenburg (for legend see Fig. 6).

of the castellum and at least two watchtowers were erected along the strongly meandering river downstream of the fort at ca two kilometres intervals in the middle of the 1st century A.D. (Van der Kamp, 2007; Langeveld & Luksen-IJtsma, 2010; Wynia, 2004). The towers were constructed out of timber and earth, they had a square plan form with ca 3.5 metres long sides and were surrounded by a wooden palisade and a ditch with pointed stakes. The towers were rebuilt several times and functioned at least until the seventies of the 1st century A.D. (Van der Kamp, 2007; Langeveld & Luksen-IJtsma, 2010). Based on the size, depth and distance between the corner posts, the towers were presumably two-storey buildings. The younger tower built on top of the earlier one at the westernmost site was probably a three-storey building (Van der Kamp, 2007).

The towers were not erected on the highest parts of the natural levee, but close to the river, overlooking a large stretch of river. The tower north of the fort De Meern was built ahead of a sharp river bend, while the two towers downstream of the fort were located on the southern levee and at the lower end of subsequent meander bends (Fig. 9a). Evidence for the presence



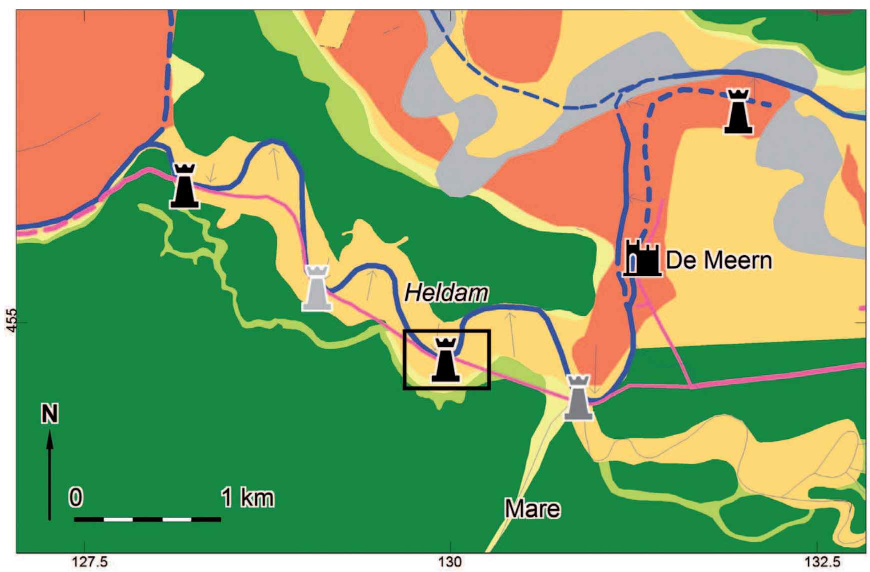


Fig. 9. a. Distribution of military complexes near fort De Meern (for legend see Fig. 6); b-g. River migration along the eastern most watchtower complex along the Heldam river through time (box in Fig. 9a indicates location).

a.

of a raised platform was lacking (Langeveld & Luksen-IJtsma, 2010). Furthermore, the youngest phase of the easternmost site along the Heldam river was erected ca 30 metres to the west of its precursor (Fig. 9b-c; Langeveld & Luksen-IJtsma, 2010). In the mean time, the river bend had shifted its position over a comparable distance and in a similar direction. By the end of the 1st century A.D. this complex was partly destroyed due to ongoing river migration and no trace of a new tower complex was discovered (Fig. 9c).

Roman road

The *Tabula Peuteringia*, a medieval copy of a Roman itinerary originating from the reign of Diocletianus (A.D. 284-305), shows the presence of a road along the river Rhine, *fl(evius) R(h)enus* (Fig. 10). The map also reveals the mutual distances between fortifications in the Dutch river delta. The distances between the castella in the Lower Rhine delta are irregular and relatively short; usually less than half a day's march, sometimes even only one hour walk (Table 1).

The earliest archaeologically recognisable traces of proper land infrastructure date to the eighties of the 1st century A.D (Luksen-IJtsma, 2010). The road ran south of the river, mostly on the natural levees of the river Rhine, but some parts were constructed in the flood basin (Luksen-IJtsma, 2010). The road was kept as straight as circumstances permitted, cutting short river bends (Fig. 4). The castella could be reached by branch roads. Sometimes, floodings and river bend migration damaged parts of the road. Subsequently, bypasses were built to overcome the damage (Fig. 9d-g; Hallewas & Van Dierendonck, 1993; Vos & Lanzing, 2000; Hissel, 2008; Van der Kamp, 2009; Langeveld, 2011; Weterings & Meijer, 2011). When the distances on the Tabula are compared to the length of the reconstructed road sections, it becomes obvious that the distances are approximately similar, implying that the present identification of the forts along the lower Rhine is trustworthy (Table 1).

The Roman road usually was 4-6 metres wide, on a low, dyke of sand, clay and sods, bordered by one or two ditches and paved with gravel, fragmented roof tiles and/or shells (Luksen-IJtsma, 2010). As gravel is not naturally present in this part of the delta, the material must have been shipped in from elsewhere, most likely from upstream pits (Aalbersberg, 2004; Dijkmans, 2004). The shells that occasionally were used for paving were collected near the sea shore and must have been transported upstream (Kuijper, 1990; Ploegaert, 2006). The road in the research area seems to have functioned until the early 3rd century A.D. (Luksen-IJtsma, 2010).

Table 1. Comparison of distances between castella on Tabula Peuteringia and palaeogeographic map.

	Tabula Peuteringia		**Palaeo-geographic map**	
	legua*	**km**	**km**	**∑**
Vechten (*Fletione*) – De Meern			8.7	
(Utrecht – De Meern)	12	24.4	(6.8)	22.3
De Meern – Woerden (*Laurium*)			13.6	
Woerden – Bodegraven	5	11.2	10.2	12.8
Bodegraven – Zwammerdam (*Nigropullo*)			2.6	
Zwammerdam (*Nigropullo*) – Alphen aan den Rijn (*Albaniana*)	2	4.4	5.1	
Alphen aan den Rijn (*Albaniana*) – Leiden Roomburg (*Matilone*)	5	11.2	~12	
Leiden Roomburg (*Matilone*) – Valkenburg (*Praetorium Agrippine*)	3	6.6	7.8	
Valkenburg (*Praetorium Agrippine*) – *Katwijk (Lugduno)*	2	4.4	~5	

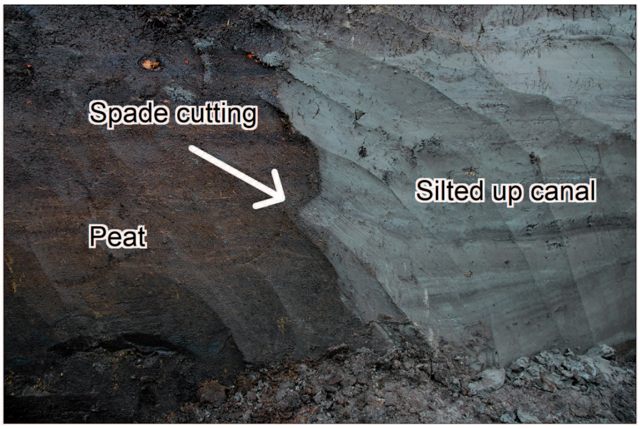
* 1 *legua* = around 2.2 kilometres

Canals

At least two canals were dug during the first centuries A.D.: the Corbulo canal and the Mare canal (Fig. 4; Van Dockum, 1997; Hessing et al., 1991; Vos, 2007; De Kort & Raczynski-Henk, 2008). By digging a relatively short canal through the watersheds the canals linked existing gullies. In this way, the Corbulo canal connected the Rhine to the Gantel/Meuse and the Mare canal connected the Rhine to the Hollandsche IJssel. Due to the subsequent water flow and resulting erosion it is hard to prove that the canals were initially dug by man (Cohen et al., 2009). Nevertheless, relicts of spade cuttings were discovered in the

Fig. 10. Part of Tabula Peuteringia *segment 1, depicting rivers, roads and fortifications with mutual distances in legua in the western part Lower Rhine delta (Weber, 1976).*

a.



b.

Fig. 11. Corbulo canal in Leidschendam-Voorburg (photos by E. Graafstal). a. Silted up canal; b. Spade cuttings in peat.

Corbulo canal (Fig. 11; De Kort & Raczynski-Henk, 2008). Near the mouth of the Mare canal in the Rhine, ca one kilometre south of fort De Meern, a small military complex was discovered (Jansen, 2006). Yet, the exact outlay and dating of this feature is still unknown (Fig. 9a).

Discussion

Forts

This study demonstrates that the castella built in the western Lower Rhine delta from the early 40s A.D. onwards were erected at strategic positions in the landscape. Not only the major river bifurcation of the river Rhine with the river Vecht and the estuary were guarded, but also seemingly minor nodal points in the river system, i.e. the junctions with small peat brooks. In contrast to earlier assumptions, these small rivers were not used as harbours (Bechert & Willems, 1995), but they formed an interconnected network of waterways, thereby creating uninterrupted natural transport routes from the Rhine to the river Vecht in the north as well as the Hollandsche IJssel and further to the river Meuse in the south. In contrast, the entries of crevasse channels that ended in the flood basins were not guarded and sometimes used as harbour (Hallewas & Van Dierendonck, 1993; Vos & Blom, 2003). Apparently, only entry points through which military trade and expeditions to the north could be performed were watched over. These waterways could not only be used by the Roman army to reach Germanic residential areas further north, but also formed the easiest passageways through which potential enemies could enter this part of the Rhine-delta as well. As the vast wetlands behind the natural levees of the Rhine were almost uninhabited and thus provided no threat, these enemies must have come by boat from far distances, like Frisia for example (Fig. 2). It appears that penetration and raiding of the delta was prohibited by guarding all bifurcations of continuous navigable transits to the river Rhine.

The castella were erected directly alongside of the river irrespective of terrain height. Apparently, the accessibility of the forts by boats and the view over the river were more important than the increased risk of floodings and the presence of a firm soil. The moorings and landings stage in front of the forts facilitated the unloading of soldiers and provisioning from the boats. Thousands of shiploads a year were necessary to provide the Roman Rhine army with food and building materials in the 1st century A.D. (Konen, 2008). The river was suitable for large-scale transportation of material as well as people, being cheap and fast, at least in a downstream direction (Sommer, 2009). Until recently, it was generally assumed that the wooden barges used for transport only served as 'packaging' for the cargo before its wood was re-used in the delta (Bazelmans et al., 2007). However, recent research has shown that Rhine transport was not an exclusive downstream traffic (Moeyes, 2007). Some of the recently unearthed Roman vessels had a surprisingly long lifespan, sometimes even several decades (Jansma & Morel, 2007; Blom et al., 2008). They were not only fitted with sails, but it is currently proven that they could easily be punted, hauled and rowed upstream (Moeyes, 2007). Besides, some vessels possessed oar arrangements and they might have been built in the Dutch delta (Jansma, 2007; Vos et al., 2011). The fact that a proper military road along the Rhine was only established at the end of the 1st century A.D., once more confirms the hypothesis that the river was the main transport corridor in Roman times (Polak, 2009; Sommer, 2009; Graafstal, in press).

Small military complexes

Free-standing watchtowers and fortlets in between the castella seem to have complemented the defensive system in the Rhine delta during the first decade of the 1st century A.D. In contrast to other frontier zones of the Roman Empire, the functioning of the 1st century A.D. watchtowers markedly preceded the construction of the Roman road, consequently excluding a connection between the watchtowers and Roman road in the Rhine delta in the 1st century A.D. (contra Wooliscroft, 2001). Yet, the locations of the watchtower complexes near De Meern and the small military complex at the mouth of the Mare were chosen in such a way that the river bends in between the forts could be over-seen. The reallocation of a tower complex following river migration at de Meern strengthens the assumption that their main aim was to over-see, monitor, and control the river. Thus, it seems that watchtowers formed an original and integral part of the concept and lay-out of the early defence system along the Lower Rhine (contra Van Dierendonck, 2004).

Assistance of troops could be called for through signalling warnings or messages with flags, lights or smoke to the larger military garrisons (Wooliscroft, 2001). Signalling in Roman times is commonly assumed to be based on intervisibility with the naked eye (Baatz, 1976; Woolliscroft, 2001). Experimental archaeology has shown that the maximum determination range of light signals with the unaided eye under perfect weather conditions is two to three miles, but this range reduces dramatically with fog or rain (Woolliscroft, 2001). Therefore, it seems likely that the maximum distances at which military installations were erected securing effective signalling at all times was roughly 2-2.5 kilometres. Based on this hypothesis, together with the assumption of a complete overview over the river Rhine, other watchtower locations or small military complexes are postulated along the Lower Rhine (Appendix 2). If indeed present, a varying number of watchtowers was situated in between the castella, up to a maximum of five. Several of these proposed towers would have been erected at a distance of more than 3 kilometres of a castellum and therefore could not have had direct intervisibility with a fort, similar to various watchtowers in the Wetterau *Limes* in Germany (Wooliscroft, 2001).

Canals

By digging at least two canals between the tributaries of the major rivers, i.e. Rhine and Meuse/Hollandsche IJssel, not only 'the uncertain perils of the ocean' were avoided (Tacitus, Ann. XI, 20), but it also shortened transport routes in the delta and made them less prone to piracy raiding.

Lower Rhine Limes

It seems that the military alignment along the western Lower Rhine was primarily a river based system, at first functioning as a fortified transport corridor. The location of the forts was chosen deliberately. Strategic and logistic motives determined the location of all military complexes. All bifurcations and mouths of tributary streams that exposed the Rhine to raiding were guarded by forts, while smaller military structures in-between the forts secured a complete overview over the river. The watchtowers in between the castella could not only detect problems (on the river), but also transfer messages between the forts.

The remarkable small size of the castella, permitting the housing of one garrison of ca 500 soldiers, also seems intentional. The natural levees of the Old Rhine were wide enough to accommodate larger forts (Fig. 6; contra Hessing, 1995). Apparently, their size was sufficient to fit the military purpose. If necessary, troops could quickly be transferred to neighbouring forts or other military installations.

The erection of the series of forts from the early 40s A.D. onwards suggests that their construction might be correlated with the conquest of Britain in A.D. 43 (Polak, 2009; Graafstal, in press). This invasion involved a large-scale transport of troops and supplies and was most likely largely realised over the river Rhine. Therefore, it is likely that the Romans aimed to guard and secure this supply line. Only in the late 1st century A.D. the river became the real frontier zone of the Roman Empire (Polak, 2009).

The earlier Imperial fortifications upstream along the Lower Rhine as well as those along the Danube in south-eastern Europe were also erected at strategic locations (Bechter & Willems, 1985; Driessen, 2007; Sommer, 2009). However, in contrast to the Rhine delta, the forts in the river valleys were erected at elevated river terraces, protecting the forts against floodings. Driessen (2007) likewise regarded the control of the bifurcations of the Rhine between Nijmegen and Cologne, referred to as logistic nodes, important for transporting troops and material from or to hostile terrain and protection against German attacks. Sommer (2009) similarly concludes that the main purpose of forts and fortresses along the Danube in earlier Imperial Period was primarily to control the river. It seems that the fluvial landscape in general determined the distribution of military structures (contra Gechter, 2002, who considers the presence of major roads as decisive for the construction of military structures).

Conclusions

Analysis and reviewing of published (geo)archaeological data, combined with LIDAR information and coring databases allows detailed palaeogeographical mapping of the Lower Rhine *Limes* in the first two centuries A.D. and gives a detailed insight and understanding of the influence of the landscape on the establishment of this part of the *Limes* as a whole. Hitherto, it was uncommon to integrate results of the natural sciences of geology and biology, and the cultural science of archaeology. This study shows that interdisciplinary research can bridge the gap between these disciplines. Furthermore, it provides a framework for future research as the method used is generally applicable and therefore potentially beneficial for the future mapping of other areas and other time periods.

This study reveal the following characteristics:

1. The Roman forts erected in the western part of the Lower Rhine from the 40s A.D. onwards were built remarkably close together, at irregular distances only a few kilometres

apart. The distinctive landscape of the Rhine-Meuse delta, with an exceptionally large number of tributaries, determined this spatial pattern. The castella down from Vechten were built on the southern natural levees of the river Rhine to guard all routes that provided natural access to the river. Not only the estuary (Katwijk, Valkenburg) and bifurcation of the river Vecht (Utrecht), but also the mouths of the numerous minor tributaries were watched over (Woerden, Bodegraven, Zwammerdam, Alphen aan den Rijn). These channels drained the peat area and formed transport routes to the river Vecht and the river Meuse. The Vecht river provided easy access to Germanic residential areas further north, while the Meuse formed the major tributary in the delta further south. In addition, at least two canals, c.q. Corbulo and Mare, were established to create shorter and safely navigable transport routes to the Meuse. The effort to construct these waterways was minimised by digging short passages through the watersheds, thereby connecting already existing channels. The mouths of these passageways in the Rhine were also guarded by military installations (Leiden-Roomburg, De Meern).

2. All forts were erected directly alongside the river, regardless of height and composition of the subsoil, with quays and landing stages directly in front of the forts demonstrating that provisioning of troops and supplies had priority over other aspects, like the living conditions of the soldiers. The width of the natural levees did not restrict the size of the forts, implying that the remarkable small size was chosen intentionally. Between the forts, a system of small military structures, mostly watchtowers, was initially erected aimed at observation of river traffic.
3. It is likely that initially an integrated system of castella and watchtowers ensured that the river Rhine in the Lower Rhine delta was completely watched over, just like the upper Rhine and Danube. In this way, a safe corridor was created to supply the Roman army invading Britain. Only later on, presumably after the establishment of the province Germania Inferior in the 80s of the 1st century A.D., this corridor turned into a frontier zone. From then on, the chain of forts along the Rhine together with a coastal and Meuse estuary defensive system, had to protect the delta and Roman Empire from Germanic invasions.

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Appendices

Appendix 1 to Van Dinter, M. (2013)

Palaeogeographic map of the Limes-zone along the western Lower Rhine, the Netherlands. Scale 1:50,000. **A0 format fold out, only downloadable on NJG website**

The Roman Limes in the Netherlands: how a delta landscape determined the location of the military structures.

Map layers digitally available at DANS (KNAW): *www.persistent- identifier.nl/?identifier=urn:nbn:nl:ui:13-08qf-sf*.

It is possible to add modern day topography as an additional layer to these map layers.

Appendix 2 to Van Dinter, M. (2013)

All sources used for the construction of the palaeogeographical map and the archaeological sites of Appendix 1. **Only downloadable on NJG website**