ANALECTA PRAEHISTORICA LEIDENSIA

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Contents

The stable isotopes ^{13}C and ^{15}N in faunal bone of the Middle Pleistocene site Schöningen (Germany): statistical modeling

Juliette Funck, Thijs van Kolfschoten and Hans van der Plicht

The stable isotopes of carbon and nitrogen ^{13}C and ^{15}N extracted from bone collagen provide a unique perspective on the diet of Palaeolithic animals as individuals. Fauna from the Reinsdorf interglacial at Schöningen, a Middle Palaeolithic archeological site complex in Lower Saxony (Germany), has been successfully analyzed using this methodology. The approximate age of 300 to 400 ka makes the collagen samples among the oldest ever analyzed. In order to compare the results from Schöningen to other sites, databases of stable isotope values were assembled from published sources. These were used to compare parameters including trophic level, population dynamics, habitat, community dynamics and climate change.

Our study is primarily limited to Bos primigenius/Bison priscus, Cervus elaphus *and* Equus mosbachensis*; however,* Canis lupus, Ursus spelaeus, Sus scrofa *and* Vulpes vulpes *were also examined for the parameters on trophic level and community structure. These factors were evaluated using statistical tests.*

The $\delta^{15}N$ values for the trophic levels from Schöningen fauna showed enrichment equivalent to that in a reference database demonstrating the ecological quality of the data. The grouping of populations based on their dynamics failed to show significant differences in range or standard deviation; in particular, the Schöningen horses fall within the variation of almost all population dynamic types. The climate groupings showed significant differences in $\delta^{13}C$ values, with the Schöningen samples resembling most individuals from temperate ecosystems with some cold-temperate elements. The habitat grouping also showed significant differences in ^{13}C values, with the Schöningen samples resembling individuals from mosaic environments most frequently, with some individuals from strictly closed and some from open systems. Based on their $\delta^{13}C$ and $\delta^{15}N$ values, the herbivores appear to be consuming food from consistently different niches. The carnivores and omnivores results correspond with their known habitat and diet. The interpretation of the climate change parameter is not clear. It could demonstrate a trend towards increased openness, but this depends on how the data is grouped.

Overall the results of our statistical investigation demonstrate consistencies between the stable isotope values of Schöningen and other ecosystems.

1 Introduction

The sediments of a Middle Palaeolithic lake in Lower Saxony (Germany) known as Schöningen (fig. 1), preserve a vision into the ecological life of *Homo heidelbergensis*, with an abundance of faunal and floral remains providing context for the archeological artifacts (Thieme 1999). The analysis of the stable isotopes ^{13}C and ^{15}N from bone collagen are one way that these fossils can be used to interpret the ecological conditions present during the formation of the site and have already proven successful in the analysis of many Late Palaeolithic sites. The Schöningen 13-II sediments belong to the Reinsdorf interglacial dating 300-400 ka (Richter 2007; Richter and Thieme 2012; van Kolfschoten 2012; Behre 2012). This makes the collagen extracted from this site amongst the oldest ever found (Kuitems *et al.* in press). Therefore they need special consideration and care in how we interpret the results. This study will provide a statistical comparison of the stable isotope values of Schöningen to those of other archaeological

Figure 1 The location of Schöningen in Saxony, Germany

sites and modern habitats, in order to give context to the results and evaluate them. Despite the time depth, the results will be highly relevant to other measures of ecological conditions, such as fauna and flora species identification as well as geophysical features of the deposits.

Schöningen is a locality that includes a number of different sites formed by a series of glaciation events that covered lower Saxony with a thick layer of ice during intermittent periods of the Pleistocene, which eroded channels. Whenever the ice withdrew during interglacial periods these channels would be filled with spring water from Elm Ridge (fig. 1) creating a lake. The delta like bank of this lake encased many organic materials which were preserved by anaerobic conditions. These deposits were first discovered during a commercial mining operation conducted by the EON company, who lowered the water table in order to access the lignite below the soil. This exposed hundreds of thousands of years of accumulated sediment currently being excavated both commercially and scientifically.

Of particular interest to archeology are the deposits from the so-called Channel II, filled during the Reinsdorf Interglacial (MIS 9; Urban 2007, 431). This zone of the site contains the largest abundance of faunal remains and archaeological artifacts. The deposit is comprised of 5 sub-cycles of stadials and interstadials, Schö 13 II 1-5 (Mania 1995; Thieme 1999; Urban 2007). Level 1 represents approximately the highest temperatures of the Reinsdorf Interglacial; this level is characterized by open mixed forests. The climate then deteriorated into the last phase of deposition which is marked by the opening of forest and increasing numbers of grasses and herbs. In the final layer of this climatic cycle frost structures typical of periglacial environments provide further evidence of cooling (Urban 2007). It is noteworthy that the diversity of large mammals through these layers shows some turnover from forest dwelling species to steppe animals, but overall it appears relatively constant despite the climatic shifts suggested by the flora and by other vertebrates. Stable isotope values potentially give us a unique opportunity to understand how these animals adapted to a changing climate, possibly by changing diets or by finding suitable niches to continue their present life style. In this study we will narrow the scope of the investigations to three large herbivore species: *Bos primigenius/Bison priscus* (steppe bison/aurochs), *Cervus elaphus* (red deer) and *Equus mosbachensis* (horse) to characterize their ecological specialization. Additionally the carnivores and omnivores *Canis lupus* (grey wolf), *Ursus spelaeus* (cave bear), *Sus scrofa* (wild boar), and *Vulpes vulpes* (red fox) are used to investigate trophic structure and dietary specialization.

There are archaeological materials throughout most of Channel II, including the famous Schöningen spears. Layer Schö 13 II-4, known as the Spear Horizon, includes at least eight wooden javelins, flint artifacts and an estimated minimum of 20 butchered horses (*Equus mosbachensis*) (Thieme 2007). The horse bones show signs of human activities, almost certain from *Homo heidelbergensis*, because this is the only known species in the region at the time. Questions regarding the formation of this assemblage have led to a debate on the nature of interaction between hominins and horses; specifically whether all the horses were killed in a single hunting event or if this was an accumulation of many events. The different possibilities are currently being explored with a variety of methodologies. The bone stable isotope values for example were used to suggest the likely population dynamics of the horses based on their variability (Kuitems *et al.* in press). It was concluded that these horses could not be a single population. However, there is so far no consensus on how much variation is expected within a single cohesive population in nature. The variability of stable isotope values within a population will be one of the questions adressed here. Ultimately, the mystery of the horses could potentially unravel some of the hunting strategies of middle Palaeolithic hominins. The answer would be informative on their intelligence and foresight; whether they opportunistically scavenged large animals or were planning large hunting events.

This study follows Kuitems *et al.* (in press) who succeeded in producing high quality collagen from the fossilized bones of Schöningen. These results are remarkable given the age of the site, and fortunate because of the large quantity of individuals and species identified so far, allowing robust interpretation. Kuitems *et al.* (in press) found evidence that some animals in the older levels were possible full time forest dwellers; samples from later layers (including Schö 13 II 4) do not show traces of forest. Overall, the animals changed little over time suggesting a high level of resilience and persistence in their diet. The picture that emerges is that of a mosaic landscape through which the animals maintained their niche throughout climatic changes (Kuitems *et al.* in press). In order to further investigate these conclusions more animals were sampled and a database of stable isotope values from other studies was compiled for comparison based on statistical analysis.

2 Stable Isotopes

The stable isotopes of the elements Carbon and Nitrogen can be used as tracers for dietary and climatic cycles. Mass dependent factors affect chemical, physical and biological processes. Therefore, isotopes become distributed unequally; this is called fractionation. The isotopes are incorporated in the body tissues of plants and animals. In general, the heavier isotopes are more resistant to chemical reactions and to physical and biological processes. The ratio of heavy to light (or rare to abundant) isotopes trace these processes. The isotope ratios are measured relative to those of a reference material, and are expressed in delta values defined as follows:

$$\partial^{13}C = \frac{(^{13}C/^{12}C)_{sample}}{(^{13}C/^{12}C)_{reference}} - 1(\times 1000‰)$$

and

$$\partial^{15}N = \frac{(^{15}N/^{14}N)_{sample}}{(^{15}N/^{14}N)_{reference}} - 1(\times 1000‰)$$

The absolute isotope concentrations of the reference materials are precisely measured (*e.g*. Mook 2006).
Collagen is usually selected as sample material for dietary isotope studies. Generally, this compound remains chemically stable over large periods of time (Stanley 1990). It is the sample material selected for ^{14}C dating (Mook and Streurman 1983; Olsson 2009). This compound is also used for stable isotopes studies of palaeoecology and palaeodiet (*e.g*. Kohn 1999; Bocherens 2003).
From herbivores to carnivores, there is an increase of ca. 1‰ in $\delta^{13}C$, and ca. 3‰ in $\delta^{15}N$ (Fry 2006). Omnivores show values somewhere in between these numbers. Apart from that, both C and N stable isotope ratios can be used to identify or trace food sources from marine and riverine origins (Lanting and van der Plicht 1998). In addition, $\delta^{13}C$ provides information on the photosynthesis pathway, in particular C3 vs. C4 plants (Vogel 1978). All of this enables food web studies.

The C3 plants can differ from one another in a variety of ways, mostly depending on external spatio-temporal variables. One of the best studied and most useful of these differences is known as 'the canopy effect' which describes the depletion of ^{13}C in dense forest compared to open environments such as grasslands (Drucker *et al*. 2008; Noe-Nygaard *et al.* 2005).

Vogel (1980) and van der Merwe and Medina (1991) proposed that the decrease in $\delta^{13}C$ values in understory plants is caused by the recycling of the ^{13}C depleted carbon dioxide that is released from the detritus on the forest floor which becomes concentrated due to limited ventilation. Ehleringer *et al.* (1986) argued that ventilation can only be a significant factor in areas where little wind could penetrate the canopy.

The source of nitrogen in plants is also a factor to consider. Nitrogen cycling depends on healthy soil life: in glacial conditions much of the decomposition and processing of inorganic nitrogen is interrupted by permafrost and aridity, and plants consume mostly inorganic nitrogen. Species show lower $\delta^{15}N$ values at the onset of interglacial, likely as a response to increased soil cycling and isotope selective nitrogen digestion by micro-organisms (Stevens and Hedges 2004; Richards and Hedges 2003).

The stable isotope values $\delta^{13}C$ and $\delta^{15}N$ from Schöningen will potentially shed light on factors such as trophic level, aridity, temperature and the canopy effect.

3 Methods

3.1 Sampling

Samples of Schöningen fossils were sorted and identified at the Zooarcheology Laboratory (Leiden University) and processed in the Center for Isotope Research (Groningen University). The samples were selected in order to maximize the number of specimens per layers and to avoid duplication. All samples were prepared and processed using an improved version of the Longin method for collagen extraction (Longin 1971) detailed by Bocherens *et al.* (1997) and Kuitems *et al.* (in press).

3.2 Database

In order to understand the $\delta^{13}C$ and $\delta^{15}N$ values from the Schöningen fauna in ecological terms, it was necessary to compile a dataset suitable for comparison. For this purpose, relevant data published during the last two decades has been retrieved (Bocherens *et al.* 1999; Bocherens and Fogel 1995; Bocherens and Drucker 2003; Britton *et al.* 2012; Drucker 2001; Drucker *et al.* 2008; Feranec 2007; Fizet *et al*. 1995; Kuitems *et al.* (in press); Sponheimer *et al.* 2003; Urton and Hobson 2005; Weber *et al.* 2002). The data was annotated based on the information provided in the literature to compare the independent factors that may influence the $\delta^{13}C$ and $\delta^{14}N$ values obtained; in particular trophic level, population type, climate and habitat. In addition, two sites from Schöningen believed to have the same stratigraphy from the same sequence were grouped.

3.3 Normalization

DeNiro and Epstein (1978; 1981) first showed that tissues fractionate carbon and nitrogen differently depending on their diet. Sponheimer *et al.* (2003) quantified these differences which were used in Drucker *et al.* (2008) to normalize different tissues. Following this method one can convert tissue values to estimate of what the $\delta^{13}C$ of the diet must have been. Hair is on average 3.12 ± 0.34‰ more positive in $\delta^{13}C$ than the diet; collagen is on average 5.06 ± 0.38‰ more positive in $\delta^{13}C$ than the diet; and feces is 0.82 ± .32‰ more negative in $\delta^{13}C$ than the diet (Drucker *et al.* 2008). Furthermore, modern samples were corrected for atmospheric change in ^{13}C concentration caused by fossil fuel combustion. This normalization was performed using the correction formula in Long *et al.* (2005).

3.4 Population dynamics

"Populations Types" were used to describe population dynamics of a particular sample group, describing the either homologous or heterogeneous nature of the environment and time range. The groupings were done accordingly:
0 = domesticated populations feeding on a specific diet;
1 = a natural single population; 2 = a population from a single ecological setting spread over the span of several decades; 3 = an archeological population from a good stratigraphic context; 4 = an archeological population from a poorly defined stratigraphy; 5 = an archeological population from multiple stratigraphic layers. The populations of a single species had a minimum size of N=3, and included a total of 40 populations of the herbivores *Bos*, *Cervus* and *Equus*. Our analysis is limited by the lack of comparable data. Ideally it should be repeated using a larger and more uniform database, when it becomes available.

3.5 Climate and Habitat

The climate at the model sites was identified and grouped into three categories in order to determine if either the $\delta^{13}C$ or $\delta^{15}N$ value were predictive for these differences. The three climate categories are cold-temperate, temperate, and warm-temperate. They were based on environmental data collected in context of the fauna bones, independent of the stable isotope values or by direct observation of the ecosystem. The habitat denotes the type of vegetation and biological environment that the animals lived in, in particular to determine if we can expect a canopy effect or not. This is not always easy to determine in archeological records and even in modern populations because habitats are generally a mosaic of different ecosystems with both open and closed components. The categories were used to define the prevalence of habitats that are either open, mixed or closed.

3.6 Schöningen layers

Schöningen is a complex site with multiple excavations. Some of these excavations have uncovered stratigraphy believed to be deposited at the same time. In order to evaluate the Schöningen ecosystem it is imperative to use as many individuals as available. Therefore we use the scheme of Kuitems *et al*. (in press), shown in table 1.

Grouped layer	Archaeological layers
1	Schö 13 II-1, Schö 12 B, Schö 12 II-1
2	Schö 13 II-2, Schö 12 A
3	Schö 12 II-3
4	Schö 13 II-4, Schö 13 II A

Table 1. Grouped stratigraphy of correlated archaeological layers

3.7 Statistics

The statistics used in this study are meant primarily to establish differences in $\delta^{13}C$ or $\delta^{15}N$ values between groups of independent variables in the two model databases. Significant differences between groups was identified using a one-way ANOVA (analysis of variance), and subsequently with a post-hoc analysis to consider possible effect of differences in group size. All statistical evaluations were conducted using SPSS 20.

4 Results and discussion

Our first objective was to determine which interpretive methods can be applied to the stable isotope values from the Reinsdorf Interglacial at Schöningen. Secondly, we seek to interpret the data based on the statistical context of a larger database of comparable sites. The categories we investigate include trophic level, inter-population diversity, habitat, population dynamics, and climate change.

4.1 Trophic levels

The biochemical preservation of the Schöningen bone material was demonstrated by Kuitems *et al.* (in press). Additional samples were accepted based only on the high standards outlined this paper. Figure 2 shows the mean value and confidence intervals for the $\delta^{15}N$ values of animal bones. It compares the 3 trophic levels (herbivore, omnivore and carnivore) of the database with Schöningen. All Schöningen individuals appear to be within the range of the database.

4.2 Inter-population diversity

The standard deviation (SD) and range (R) of the $\delta^{13}C$ values were compared with the population types (annotated 0-5 as defined above) as a possible indicator of population diversity. The groupings did not show significant differences for either standard deviation or for range. The diversity of populations did show some patterns, as shown in figure 3. There are similarities between population type 1, samples collected from a single year in a modern population, and population type 3, those from a good stratigraphic layer. There are also similarities between type 2, samples collected over multiple decades from a modern population, and type 4, those from a poor stratigraphic context. However, the presently available data are not sufficient to draw firm conclusions about the population dynamics of the horses or other large assemblages of butchered animals from layer Schö 13 II-4. The standard deviation (SD=0.58) and range (R=2.10) for the Schö 13 II-4 horses fall within or near the range of every population type (see dashed line in figure 3). Except for the artificial population (0), none of the wild population types can be rejected (fig. 3). The possible predictive power for population dynamics or homogeneity of diet needs more detailed investigation.

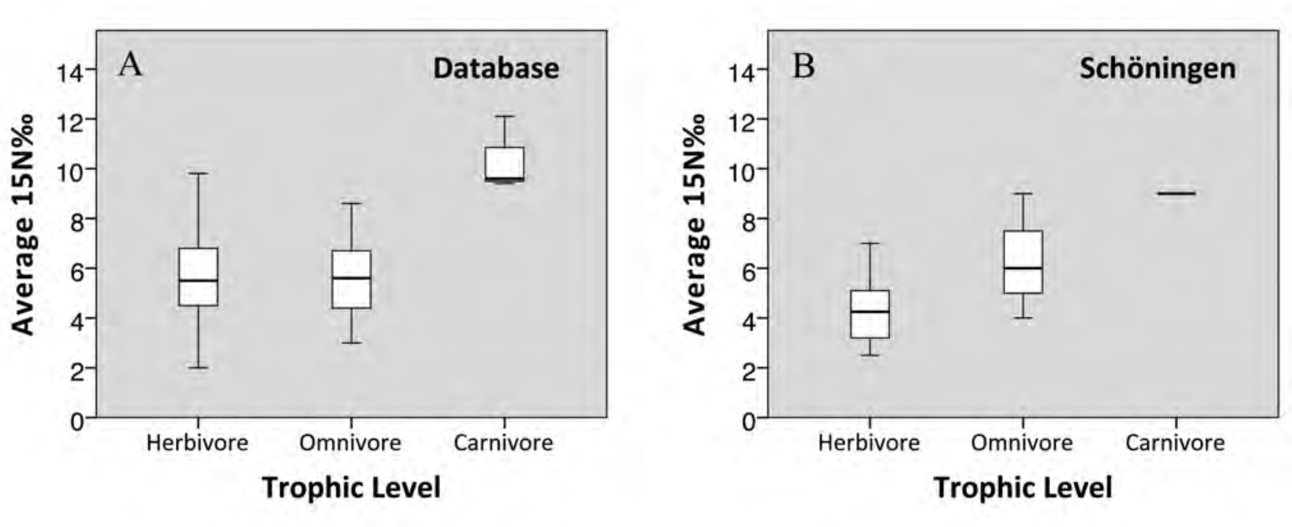

Figure 2 Mean values and confidence intervals of animal $\delta^{15}N$ values from three trophic levels: values from the literature (N=292, fig.2A) compared with those of Schöningen (N=44, fig. 2B)

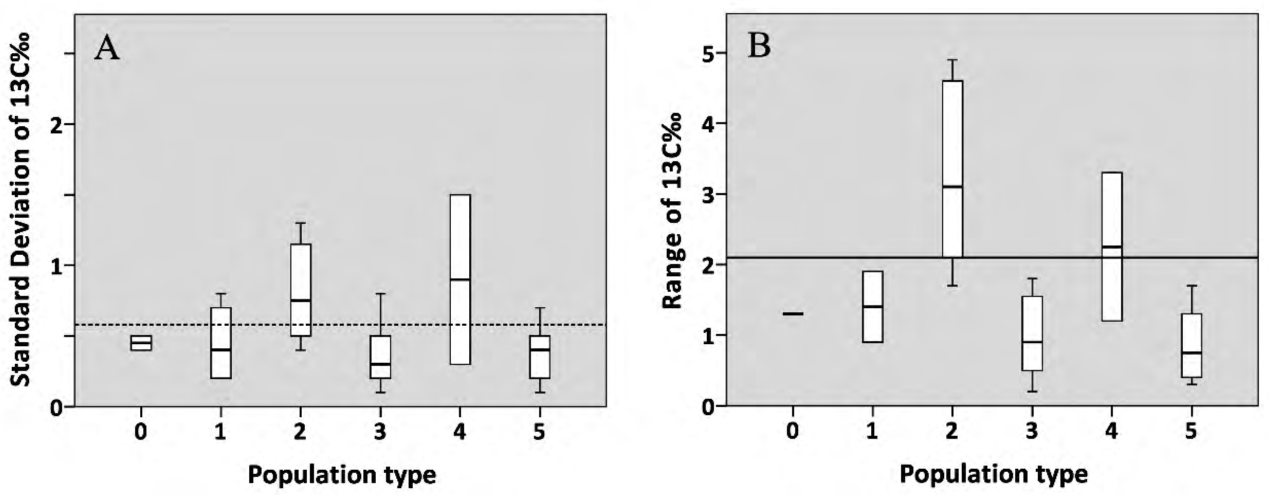

Figure 3 A: Average standard deviation of $\delta^{13}C$‰ within populations grouped by population dynamic type (N=46). The dashed line indicates the average standard deviation of the Schö 13 II-4 *Equus* population (N=10) at 0.58; B: Range of $\delta^{13}C$‰ within populations grouped by population dynamic type (N=46). The line indicates the average standard deviation of the Schö 13 II-4 *Equus* population (N=10) at 2.1

4.3 Habitat

Climate groups from the database show significant differences in $\delta^{13}C$ values for the cold-temperate, temperate, and warm-temperate groups (fig. 4). When the post-hoc test was applied the results showed that the difference between the database and Schöningen for cold-temperate groups was larger than the temperate and warm-temperate ones. The temperate and warm temperate groups were not statistically different from each other. The cold-temperate group shows the highest $\delta^{13}C$ values (-26.2‰), while those of the warm-temperate group has $\delta^{13}C$ = -27.0‰, slightly higher than the temperate group which has $\delta^{13}C$ = -26.9‰. This trend may be caused by the dependence of the canopy on temperature.

The results on habitat, shown in figure 5, also shows significant differences of $\delta^{13}C$ values for the groups closed, mosaic, and open. The post-hoc test shows that both the difference between the closed and mosaic group and the

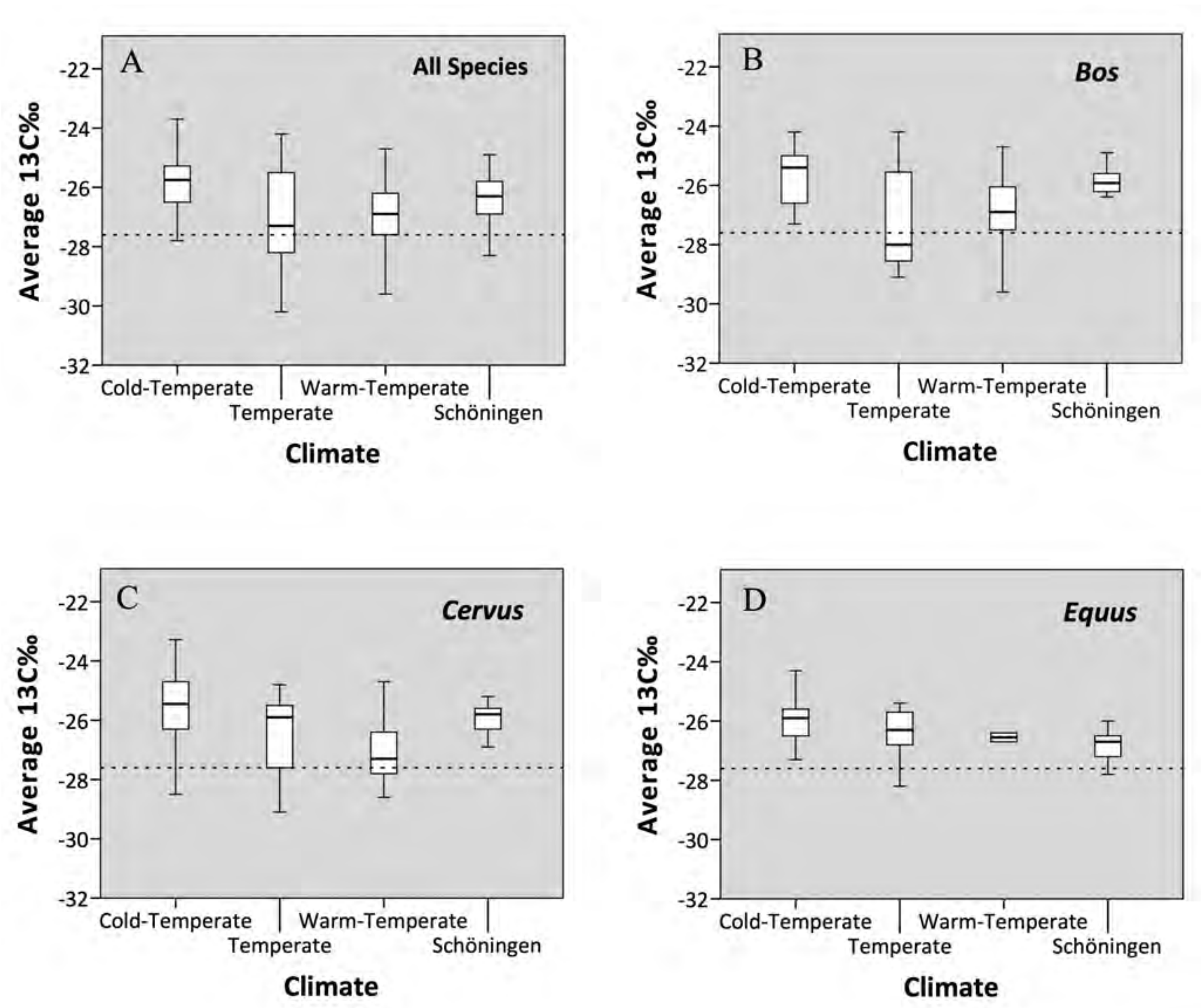

Figure 4 The $\delta^{13}C$ values of individuals from the reference database grouped by Cold-Temperate, Temperate, Warm Temperate and Schöningen. A: All Species (N=238), B: Bos (N=98), C: Cervus (N=71), D: Equus (N=46). The dashed line indicates the expected start of a canopy effect at $\delta^{13}C$ = -27.6, following Drucker *et al.* (2003)

closed and open group are significant. The differences between mosaic and open shows a trend, albeit not statistically significant. In addition the *Cervus* (fig. 5c) has significantly different values, but no trend in the data is seen. For all groups except *Cervus* the closed ecosystems has lower $\delta^{13}C$ values (-27.4‰), the mosaic one has an intermediate value (-26.4‰), and the open environments have the highest values (-26.0‰). This is indicative for the canopy effect as discussed in the literature (Drucker *et al.* 2003a; 2003b; Drucker *et al.* 2008; Van der Merwe and Medina 1991; Noe-Nygaard *et al.* 2005; Vogel 1978).

The majority of the cases in the closed ecosystem shows $\delta^{13}C$ values higher than -27.6‰, which is the cut-off value for the canopy effect as proposed by Drucker *et al.* (2003a, 2003b). This shows that this criterium may only apply to animals feeding exclusively under the canopy. The significant differences in $\delta^{13}C$ between groups is surprising given the diversity of samples and second hand nature of the information on which the annotations are based in the modeling database. These findings suggest that the interpretative power of $\delta^{13}C$ are valid for the Schöningen samples. Thus, it is possible to examine the paleoecology of

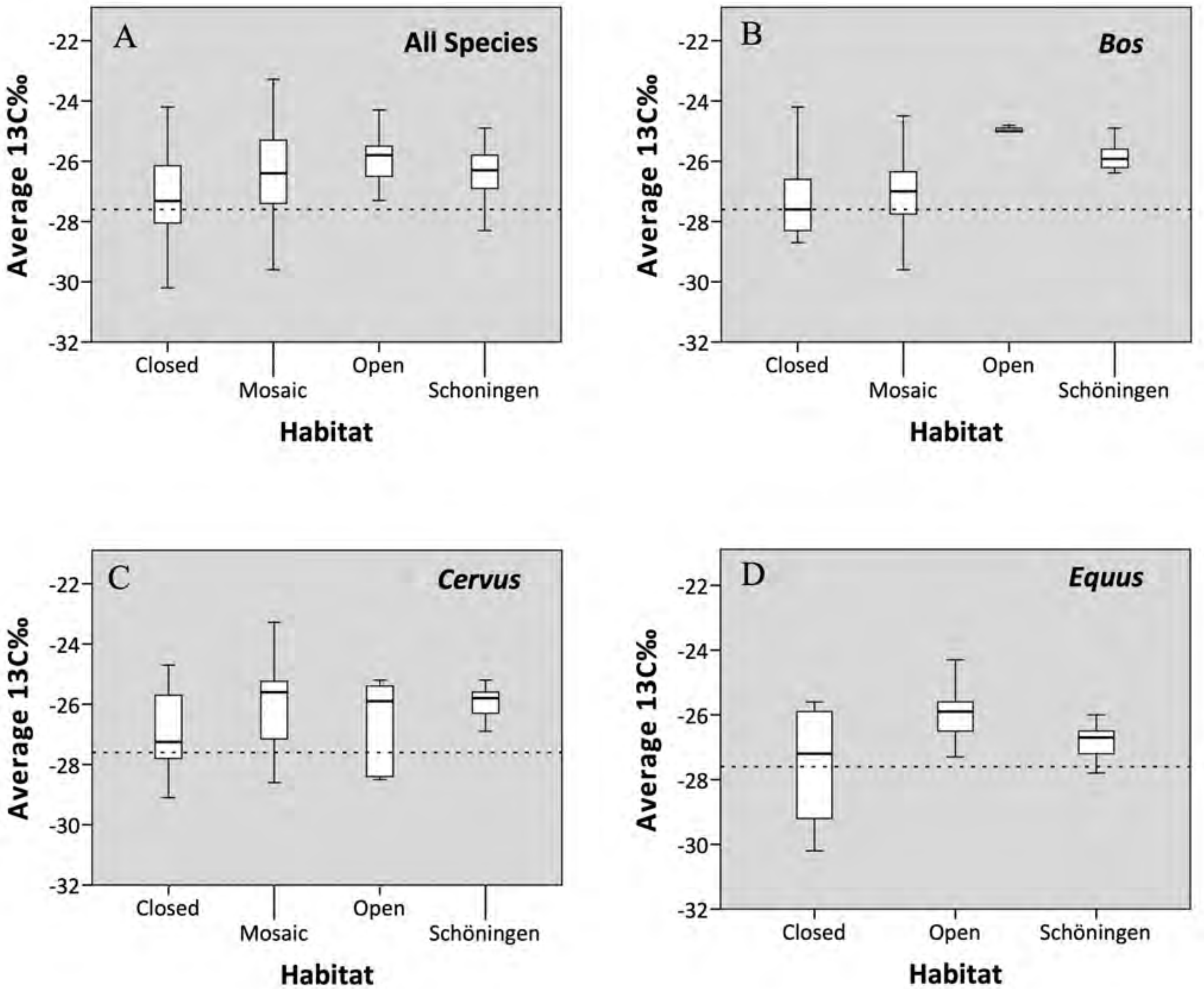

Figure 5 δ^{13}C values of individuals from Database 1 and Schöningen grouped by Closed, Mosaic, Open, Schöningen environments. A: All Species (N=210), B: Bos (N=77), C: Cervus (N=70), D: Equus (N=39). The dashed line indicates the expected start of a canopy effect at δ^{13}C = -27.6, following Drucker *et al.* (2003)

Schöningen. The values for δ^{15}N do not have significant differences between the groupings of climate or habitat. Apparently, δ^{15}N is not effected by the canopy effect.

The stable isotope data from Schö 12 II and Schö 13 II are in good agreement with other paleoecological investigations such as archeobotany, archeozoology and dental morphology.

For three genuses the values from Schöningen (confidence interval CI = 95%) for δ^{13}C ranging from -26.7 to -26.1‰) correspond most closely with the individuals from the temperate environment (95% CI from -27.2 to -26.4 ‰). The *Cervus* (95% CI from -26.9 to -25.4 ‰) and *Equus* (95% CI from -26.2 to -26.3 ‰) from Schöningen resemble carbon values of individuals from temperature environments from the model database (95% CI range for *Cervus* and *Equus* in temperate environments range -26.9 to -25.9‰ and -30.9 to -24.2‰, respectively). Unfortunately, no information is available for *Equus* from warm-temperate environments. The *Bos* (95% CI range -26.6 to -25.5‰) appear to have experienced some colder elements when compared to the modeling database (95% CI range -26.3 to -25.1‰).

When considering habitat grouping, the individuals from Schöningen (for all herbivores the 95% CI range is -26.7 to

-26.0‰) resemble most individuals from mosaic environments in the modeling database (95% CI range -26.7 to -26.1‰). The *Bos* (95% CI range -26.6 to -25.5‰) from Schöningen are on the open side of the spectrum when compared to the database (95% CI range -25.2 to -24.8‰). *Cervus* from Schöningen (95% CI range -26.9 to -25.5‰) fit best in the *Cervus* from mosaic ecosystems (95% CI range -26.3 to -25.5‰), while *Equus* (95% CI range -27.2 to -26.3‰) appear to be more like forest dwelling species from the database (95% CI range -30.8 to -24.2‰). However this is based on limited data for *Equus*. The observation may also be biased by the low δ^{13}C values from *Equus* from layers Schö 12 A and Schö 12 B, which are substantially lower than those from Schö 13 II 1-4.

4.4 Community dynamics

Competition and niche differentiations at Schöningen were also studied by examining the average difference between species following the methodology used by Britton *et al.* (2012), as shown in figure 6. The range between the mean stable isotope values is quite high for *Bos* and *Equus*, comparable to Neumark-Nord 2 (Britton *et al.* 2012). The *Bos* and *Cervus* appeared more similar and also more variable, while *Equus* is consistently different. How this compares with the investigation of climate where *Bos* rather than *Equus* were the outlier group is unclear. According to Britton *et al.* (2012) the results may be related to the extent to which animals feed from different food sources. This is expected to increase in times of greater ecological stress and competition following the principle of niche differentiation. The interpretation of these differences should become more clear as more studies investigate dietary stable isotopes and their relation to community structure. It is important to note that the stable isotope values from collagen are an average, the elements of diet that make up this average may vary considerably.

The general features of the relationship between the three species is shown in figure 7. The general trend is that *Bos* shows the highest δ^{15}N values and also the highest (less negative) δ^{13}C values; *Equus* shows the lowest δ^{15}N and δ^{13}C values. The values for *Cervus* are in between. The δ^{15}N values are consistent for all layers in which multiple species were found, except for layer 13 II-2. The relationship appears fairly consistent even if overall values change, possibly due to *Equus* eating at least partly under the canopy where CO_2 is recycled and the origin of Nitrogen is organic. *Bos* lived most likely in a more in open environment where Nitrogen was mostly of inorganic origin. Apparently, *Cervus* was feeding in both areas.

The results for the other species are shown in figure 8. The cave bear (*Ursus spelaeus)* (δ^{13}C = -27.5‰) and the two wild boars (*Sus scrofa)* (δ^{13}C = -27.9‰) from layer Schö 12 have δ^{13}C‰ values near or below -26.7‰, suggesting a closed canopy habitat. This is consistent with current knowledge of the preference of these species (Bocherens and Fogel 1995; Bocherens *et al.* 1999). The fox *Vulpes vulpes* (δ^{15}N = 9.0 ‰) and grey wolf (*Canis lupus*) (δ^{15}N = 9.0‰) from layer Schö 13 II-4 both have high δ^{15}N‰ values, typical for a carnivorous diet. The fox (δ^{13}C = -28.00‰) however has the most negative δ^{13}C value of our dataset, perhaps it was either hunting under a dense canopy for small mammals. The grey wolf shows more positive values (δ^{13}C = -25.4‰), suggesting that it hunted predominantly in an open environment. It is promising to find such strong correlation between the paleoecological conditions and the stable isotopes values found in other similar environments.

4.5 Climate Change

Climate change at Schöningen is difficult to assess from the stable carbon and nitrogen isotope ratios of faunal bones. Palynological data show that the climate was cooling and the habitat was opening in layers Schö 13 I to Schö 13 IV, becoming increasingly dominated by scrubs and grasses. However, the δ^{13}C values tell another story (fig. 9). If the archaeological layers are grouped together as stratigraphic layers believed to be formed at the same time (fig. 9a), it appears that the trend seems to be towards slightly more open values. However, when separated in archeological layers we see that the layers Schö 12B and Schö 12A are considerably lower than Schö 12 I and II. This distorts the data when grouped, and raises questions on the relationship between Schö 12 and Schö 13. Without the Schö 12 data, layers I-IV are fairly consistent and show a mild increase in the final stage. This would suggest that animals continued to find similar food resources as the climate deteriorated.

One possibility is that the archeological layers were formed at the same time and represent two co-existing micro-ecosystems and populations. For example *Bos* from layer Schö 12 could be a forest dwelling aurochs, whereas in Schö 13 it could be a grassland bison. Individuals within the horse and red deer populations could similarly be utilizing different resources. As the climate cooled, the forest resources dwindled and forest species either went extinct or began relying more on open ecosystems. An alternative scenario is that the layers from Schö 12B and Schö A are from an entirely different period than Schö 13, which was formed when thick forest cover dominated the landscape. More data on the relationship between these two areas should clarify how animals responded to climate change.

5 Conclusion

The objective of our paleoecological investigation is to gain information about the life of Middle Pleistocene animals, and also about *Homo heidelbergensis* – in particular how they

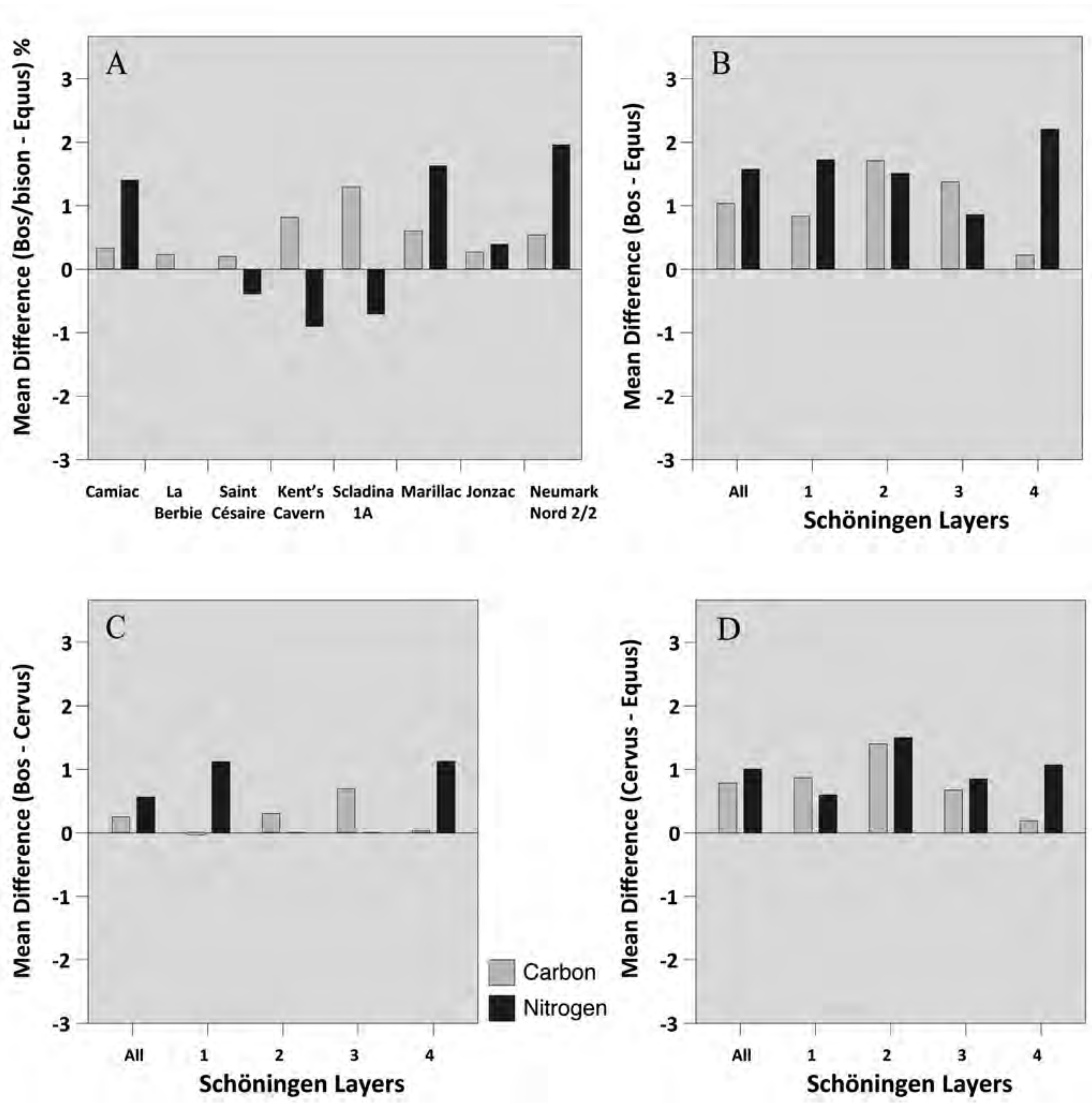

Figure 6 A: difference between Bos and Equus the $\delta^{13}C$ and $\delta^{15}N$ values from 8 Paleolithic sites. Figure taken from Britton et al. (2012);B, C and D: difference between the average $\delta^{13}C$ and $\delta^{15}N$ values of resp. Bos (N=11) and Equus (N=17), Bos (N=11) and Cervus (N=9), and Cervus (N=9) and Equus (N=17) at Schöningen

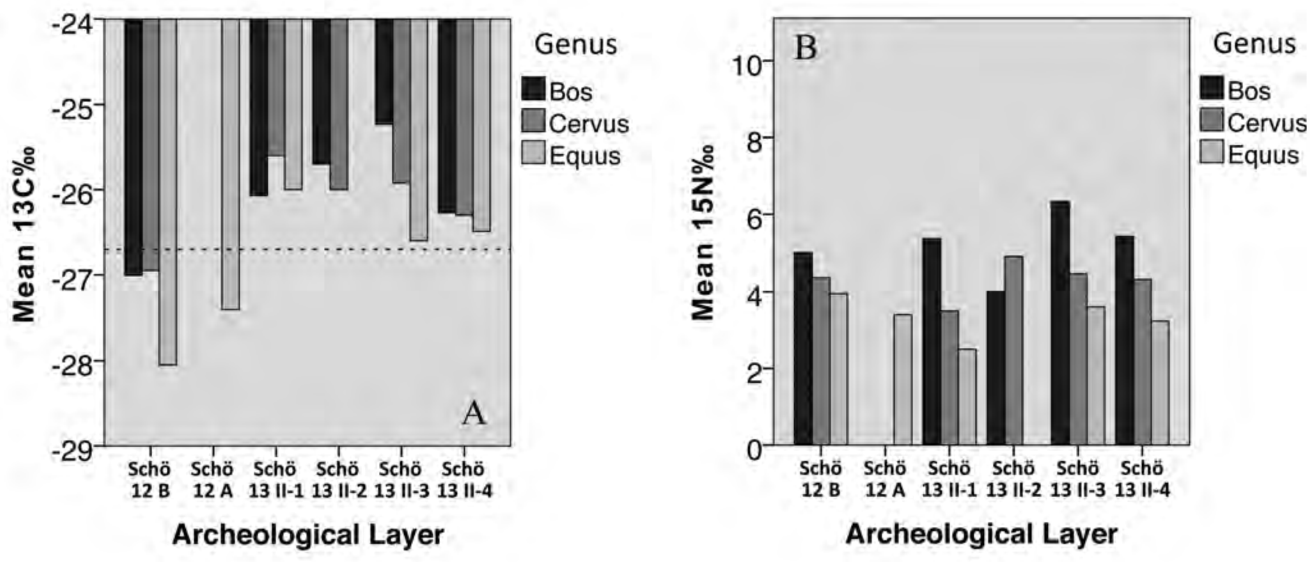

Figure 7 A: the average $\delta^{13}C$ value of the herbivores from Schö 13 II and Schö 12 for the genus Bos (N=11), Cervus (N=9), and Equus (N=17). The dashed line indicates the expected start of a canopy effect at $\delta^{13}C$ = -27.6, following Drucker et al. (2003). B: The average $\delta^{15}N$ value for archeological layers from Schö 13 II and Schö 12 for the genus Bos (N=11), Cervus (N=9), and Equus (N=17)

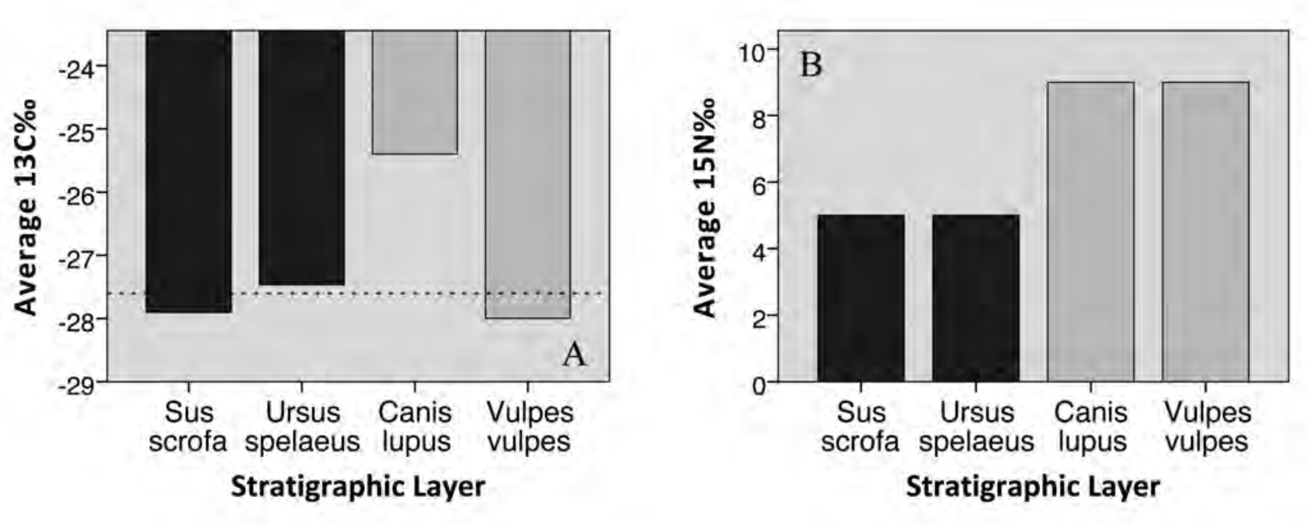

Figure 8 A: the $\delta^{13}C$ values for carnivores the Canis and Vulpes samples from Schö 13 II-4, and for the omnivores Sus scrofa and the Ursus spelaeus samples from Schö 12 B (N=5). The dashed line indicates the expected start of a canopy effect at $\delta^{13}C$ = -27.6, following Drucker et al. (2003). B: the $\delta^{15}N$ values for the carnivores Canis and Vulpes from Schö 13 II-4,and the omnivores Sus scrofa and the Ursus spelaeus from Schö 12 (N=5)

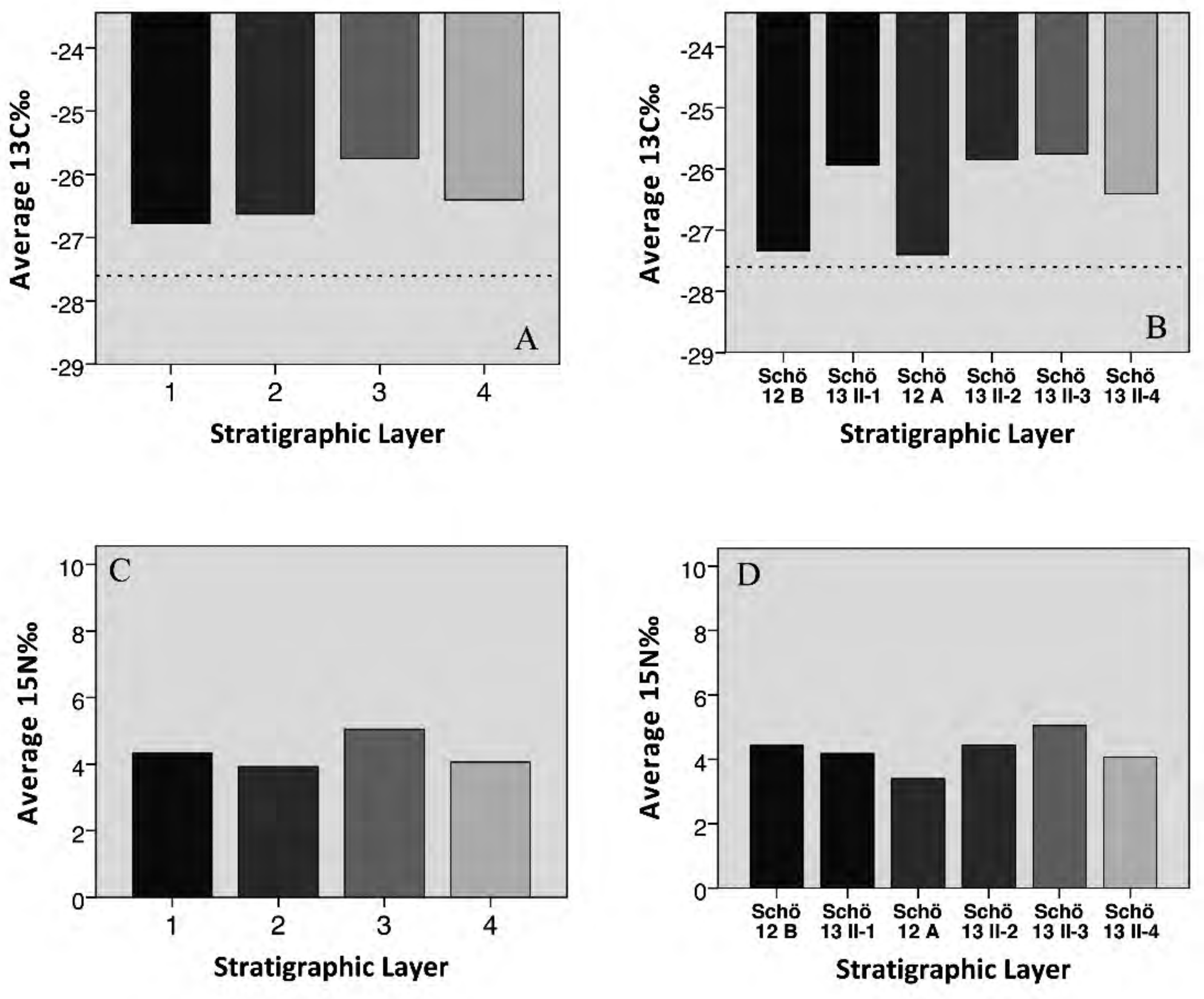

Figure 9 A and B: the average $\delta^{13}C$ and $\delta^{15}N$ values from herbivores in the archeological layers from Schö 13 II and Schö 12, grouped according to the stratigraphic interpretation shown in Table 1 (N=37). C and D: the average $\delta^{13}C$ and $\delta^{15}N$ values from herbivores in the archeological layers from Schö 13 II and Schö 12 separately (N=37). The dashed line indicates the expected start of a canopy effect at $\delta^{13}C$ = -27.6, following Drucker *et al.* (2003)

made their subsistence 300-400.000 years ago in Schöningen. In the layer Schö 12 the presence of forest dwelling species as well as the depletion of ^{13}C in their bones suggest that *Homo heidelbergensis* could live and hunt animals in a closed canopy environment. The fauna from layer Schö 13 was likely hunted in an open forest environment that became even more open in Schö 13 II-3, with *Bos*, *Cervus* and *Equus* slightly adjusting their diet. This is of significance for the ecological tolerance of the hominin species living in the area. Investigating paleoecology in context of a well preserved kill site with ample botanical and zoological remains is ideal, but often we are interested in faunal bones that are found in other contexts, such as a camps or cave dwellings because they are associated with more cultural and technical objects. The stable isotopes ^{13}C and ^{15}N from bone collagen are consistent with several earlier observations about the ecological context of Schöningen. In other cases where stable isotopes do not reflect such expectation, one can ask how a particular species may respond to aspects such as climate change. Future research and analysis will make it possible to interprete the ecological environment of early hominins wherever well preserved bones are found.

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'Trapping the past'? Hunting for remote capture techniques and planned coastal exploitation during MIS 5 at Blombos Cave and Klasies River, South Africa

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We review indications for the behavioural complexity of foraging strategies during Marine Isotope Stage 5 (~130 – 74 ka) at Blombos Cave and Klasies River, South Africa. Although the sites were occupied by anatomically modern humans, it is debated whether they were also behaviourally modern. The exploitation of terrestrial small nocturnal browsers may be an indication for the use of complex foraging strategies such as trapping or net-hunting. Hence we analyse the terrestrial fauna of the sites in terms of represented size classes, dietary preference and activity patterns. Seasonally planned coastal visits are also considered 'modern' and may be recognised by the presence of large numbers of adult male seals and by shellfish only accessible at low tide. We therefore analyse the representation of marine mammals and the represented molluscs in terms of their habitat preference. Our study suggests that trapping and net-hunting were practised in Marine Isotope Stage 5. In addition, coastal visits were probably planned.

1 Introduction

The Middle Stone Age (MSA; ~300 – 40 ka) archaeological record of South Africa has provided important insights into the way of life of early anatomically modern humans (*e.g.* Deacon 1989; McBrearty and Brooks 2000; Henshilwood and Marean 2003; Brown *et al.* 2009; Henshilwood *et al.* 2009; Wadley *et al.* 2009; Lombard and Phillipson 2010; Texier *et al.* 2010; Henshilwood *et al.* 2011; Wadley *et al.* 2011; Brown *et al.* 2012). The focus of most research is on Marine Isotope Stage (MIS) 4 Still Bay (~75 – 68 ka) and Howiesons Poort (~65 – 60 ka) occupations. During these periods many behaviourally 'modern' behaviours first emerge (Jacobs *et al.* 2008; Henshilwood 2012). Here we focus on the preceding MIS 5 (~130 – 74 ka). Although indications for 'modern' behaviours are less abundant during MIS 5 than during MIS 4, some engravings, often considered a hallmark of modern behaviour, have been reported (Henshilwood *et al.* 2009; d'Errico *et al.* 2012). Moreover, both Blombos Cave and Klasies River yielded MIS 5 anatomically modern human fossils (see Dusseldorp *et al.* 2013). As the capacity to develop modern behaviour is not restricted to MIS 4, we set out to study the organisation of resource exploitation during MIS 5 Blombos Cave and Klasies River.

The behavioural complexity of MSA subsistence strategies is debated. Based on prey skeletal element representation at Klasies River, Binford (1984) suggested that the MSA bone assemblages were mainly accumulated by scavenging. Microscopic analysis of cut- and carnivore marks on the bones subsequently showed that humans were the primary accumulator of the assemblages (Milo 1998). Klein (*e.g.* 1976; Klein and Cruz-Uribe 2000) suggested that MSA foragers hunted docile prey and avoided large and dangerous animals. However, in recent years, a consensus view has emerged that there is no good evidence to suggest hunting strategies during the MSA were less sophisticated than Holocene Later Stone Age (LSA) subsistence strategies (*e.g.* Marean and Assefa 1999; Faith 2008; Dusseldorp 2010; Clark 2011; Dusseldorp 2012a).

More recently, MSA hunting equipment has become the focus of debate. Increased reliance on large mammal exploitation is thought to have led to more technological investment in hunting technology during MIS 4 (Villa *et al.* 2009; McCall and Thomas 2012). This period may have seen the earliest use of weapon systems such as bow and arrow and spearthrower (Shea 2009; Lombard and Phillipson 2010). The predominance and taxonomic diversity of small prey in some MIS 4 MSA assemblages, especially the abundance of small carnivores, which are not often intensively exploited by hunter-gatherers, have prompted the suggestion that snares and traps were used (Clark and Plug 2008; Wadley 2010; but see Dusseldorp 2012b). Such equipment precludes the selection of individual prey items, leading to more diverse faunal assemblages. Similarly, the presence of nocturnal species has been suggested to support the use of snares and traps (Van Pletzen 2000). The use of net-hunting has also been considered (Wadley 2010; Collins submitted). The use of such devices would indicate a high level of planning depth (Wadley 2010).

With regard to coastal foraging, the wide age-range of represented seals at MSA sites have led to the hypothesis that the coast was visited year-round, while LSA foragers scheduled visits to the coast seasonally. Seasonal mobility during the MSA is suggested to be absent because of technological limitations (Klein and Cruz-Uribe 2000).

Here, we explore the representation of both marine and terrestrial fauna during MIS 5 at Blombos Cave and Klasies

River. We focus on the representation of small terrestrial fauna and on the activity patterns of the represented prey to evaluate whether trapping or net-hunting was used to exploit terrestrial animals. We also examine the taxonomic composition of the shellfish species and use the representation of different seal age classes to review whether coastal visits were planned during this period.

2 Materials and methods

2.1 Materials

2.1.1 Blombos Cave

Blombos Cave is located on the Indian Ocean, ~100 km east of Cape Agulhas (Henshilwood *et al.* 2001) (fig. 1). The site's MIS 4 Still Bay occupation levels (M1 and Upper M2) yielded a large number of shell beads and a piece of deliberately engraved ochre (*e.g.* Henshilwood *et al.* 2002; d'Errico and Henshilwood 2007). These levels (dated to ~78-72 ka) overlie a deep MIS 5 sequence with occupation layers from ~78 ka to > 100 ka (M2 Lower and M3) (Henshilwood *et al.* 2011) (fig. 2). The M2 lower occupation levels are ephemeral, but occupation intensity was high during the M3 (Thompson and Henshilwood 2011). The M3 levels contain pieces of engraved ochre and have yielded ochre processing toolkits (Henshilwood *et al.* 2009; Henshilwood *et al.* 2011). The stone artefact assemblages from the M2 lower and the M3 have not been described in detail. The M3 assemblage appears to be flake-based and poor in retouched tools. Levallois production was practised and the dominant raw material was locally collected silcrete (Soressi 2005). The M3 level yielded a number of isolated teeth of modern morphology (Dusseldorp *et al.* 2013).

The site is currently located in the fynbos biome and experiences predominantly winter rainfall (Mucina and Rutherford 2006; Chase and Meadows 2007). The micromammal assemblage from the M3 suggests relatively dry and open conditions with scrub vegetation prevailed during MIS 5c. During the M2 lower deposited during MIS 5b/a, the scrub vegetation was replaced by more bushy vegetation. This suggests that conditions were warmer and more humid (Nel 2013). To study sea surface temperatures, we have looked at very small species of shellfish (≤3 cm), the so-called incidentals. These are species that were not exploited as food by the site's occupants but were brought in with other materials, for example stuck in the *byssus* (beard) of larger shellfish like mussels, or in the stomachs of fish or birds (Buchanan 1988). Incidentally transported shellfish assemblages suggest that sea surface temperatures during the

Figure 1 Map showing the location of Klasies River and Blombos Cave

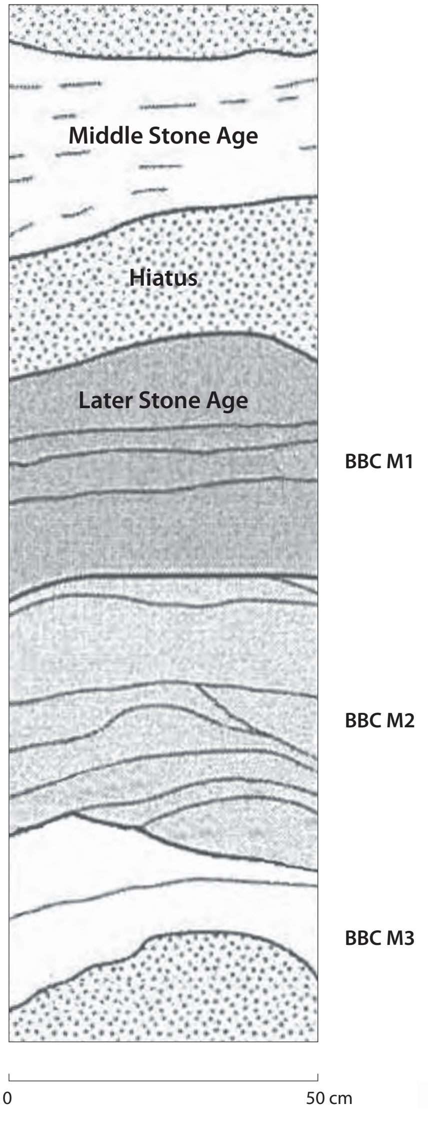

Figure 2 Blombos cave and its levels, after Henshilwood 2008

upper M3 were lower than nowadays; while during the Still Bay occupations they were similar to the modern situation. Unfortunately, the sample from the M2 lower is too small for meaningful interpretation (Langejans *et al.* 2014).

The taxonomic composition of the bone assemblages from the 1992-1999 excavations were only published for the M2 phase as a whole (Henshilwood *et al.* 2001). Since the upper part of the M2 was accumulated during MIS 4, we only consider the M3 materials here. The fauna of animals >4.5 kg from the 2000-2004 excavations was only studied taphonomically (Thompson and Henshilwood 2011) and published in terms of number of identified specimens (NISP) by general taxonomic class and body size category. The taphonomic analysis demonstrates that humans were the main accumulators of the fauna at the site, with minor contributions by carnivores (Thompson and Henshilwood 2011). The taxonomic composition of the M3 assemblage is reproduced in table 1 (after Henshilwood *et al.* 2001). The importance of (small) bovids may be underestimated in this sample as the assemblage is highly fragmented and most ungulate long-bone fragments are identifiable only to body size category (Thompson and Henshilwood 2011; see also Reynard *et al.* 2014). The M3 bone assemblage is dominated by small animals, mainly rock hyrax (*Procavia capensis*). Taphonomic analysis of the rock hyrax remains demonstrates that the majority of the animals were brought to the site by humans, while raptor accumulation accounts for a small proportion. The age of hyrax remains from the site suggests both summer and winter visits to the site during the M3 (Badenhorst 2014).

Non-mammal vertebrates such as fish and birds are rare with one exception: angulate tortoise (*Chersina angulata*) (Henshilwood *et al.* 2001; Thompson and Henshilwood 2014a; 2014b). Only a subsample of the tortoise bones was studied taphonomically; it appears they were brought in by humans in both the Still Bay and the M3 layers (Thompson and Henshilwood 2014a). For the M3, 33% of the volume of the deposit excavated between 2000 and 2004 was analysed for tortoise remains, yielding a total NISP of 1029. The three-fold volume of deposit for which large mammal remains were taphonomically analysed yielded a mammal NISP of 1256 (Thompson and Henshilwood 2014a). This shows that angulate tortoise is the most common species of vertebrate represented in the level.

Marine resources are represented mainly by molluscs and bones of Cape fur seal (*Arctocephalus pusillus*). The importance of seals is likely overestimated in the taxonomically analysed sample as otariid bones have a distinctive bone structure, making them easily identifiable. However, the proportion of marine mammals, although lower, is still considerable in the taphonomically studied sample (4.8% of the total studied assemblage) (Thompson and Henshilwood 2011). The M3 phase yielded a high density of shellfish, 68.4 kg/m^3 of excavated sediment, while the quantities recovered from the M2 lower are small (Henshilwood *et al.* 2001; Langejans *et al.* 2012; Langejans *et al.* 2014).

2.1.2 Klasies River

Klasies River was first excavated in the 1960s, and again from the 1980s onwards (Singer and Wymer 1982; Deacon and Geleijnse 1988) (fig. 1). The site consists of a number of caves overlooking the Indian Ocean and is located ~100 km west of Port Elizabeth. The combined stratigraphic sequence at the site is over 15 metres deep and contains remains of occupations from MIS 5e to MIS 3 (Wurz 2002). The MIS 5 occupations yielded a number of anatomically modern human fossils, which may have been cannibalised (Rightmire and Deacon 1991; Dusseldorp *et al.* 2013).

The oldest occupation phase at the site was recovered from the LBS member (fig. 3). It was originally termed MSA I and is referred to technologically as the Klasies River phase. This has been dated to ~115 ka, falling in MIS 5e. Following a hiatus, the SAS member contains the Mossel Bay (previously MSA II) technocomplex, dated to ~100 - <80 ka, spanning MIS 5c-a (see references in Wurz 2002). The Klasies River phase is characterised by the production of blades on cores of local raw materials, while the Mossel Bay phase is characterised by the production of pointed blanks using the Levallois method (Wurz 2002). One piece of engraved ochre and two pieces of notched bone have been recovered from the Mossel Bay phase (d'Errico and Henshilwood 2007; d'Errico *et al.* 2012).

The area around the site receives year-round rainfall and experiences higher temperatures than the area around

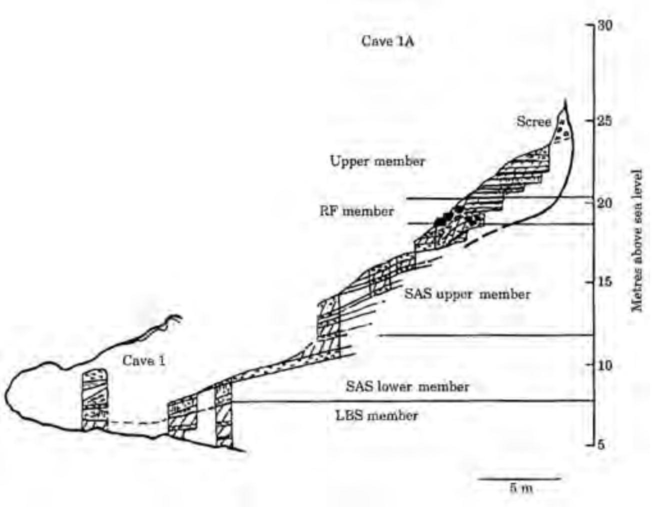

Figure 3 The stratigraphic sequence of Klasies River, after Wurz 2002

Species		Activity pattern	Dietary preference	Klasies River				Blombos Cave
				LBS (MIS 5e)	SAS (MIS 5c-a)			M3 (MIS 5d-b)
					bottom	middle	top	
Hedgehog	*Erinaceus frontalis*	N	-	-	-	-	-	4
Cape hare	*Lepus capensis*	N	-	-	3	1	-	6
Scrub hare	*Lepus saxatilis*	N	-	-	-	-	-	11
Cape dune molerat	*Bathyergus suillus*	NA	-	-	5	1	-	168
Porcupine	*Hystrix africaeaustralis*	N	-	-	26	10	1	1
	Homo sapiens	NA	-	2	8	1	-	1
Chacma baboon	*Papio ursinus*	D	-	-	2	1	-	-
Black-backed jackal	*Canis mesomelas*	N	-	-	-	-	-	1
Striped polecat	*Ictonyx striatus*	N	-	-	-	-	-	2
Clawless otter	*Aonyx capensis*	N	-	-	2	-	-	1
Genet	*Genetta* sp.	N	-	-	-	-	-	2
Small grey mongoose	*Herpestes pulverulentus*	D	-	-	-	-	-	10
Hyenidae	(*brunnea* at Klasies, likely also at Blombos)	N	-	-	7	-	-	1
Wild cat	*Felis lybica*	N	-	-	-	-	-	2
Cape fur seal	*Arctocephalus pusillus*	NA	-	26	79	89	29	60
Indet. Carnivore		NA	-	4	12	19	3	-
Aardvark	*Orycteropus afer*	N	-	-	1	-	-	-
Rock hyrax	*Procavia capensis*	D	-	51	322	71	26	408
Black rhinoceros	*Diceros bicornis*	N	B	-	-	-	-	1
	Rinocerotidae	NA	NA	-	-	-	-	3
Cape zebra	*Equus capensis*	NA	G	-	-	-	-	4
Zebra	*Equus* sp.	D	G	3	4	2	-	-
Pig	Indet. suid	NA	NA	1	1	2	-	-
Hippopotamus	*Hippopotamus amphibius*	N	G	5	8	2	-	-
Eland	*Taurotragus oryx*	C	M	5	57	14	6	15
Kudu	*Tragelaphus strepsiceros*	C	M	1	18	-	1	-
Bushbuck	*Tragelaphus scriptus*	N	B	-	21	2	-	-
	Tragelaphus sp.	NA	NA	-	2	-	-	-
Blue antelope	*Hippotragus leucophaeus*	NA	G	6	14	1	-	-
	Hippotragus sp.	NA	G	-	4	2	-	-
Southern reedbuck	*Redunca arundinum*	C	G	-	-	4	2	6
	Redunca sp.	C	G	1	5	-	-	-
Wildebeest/Hartebeest	*Connochaetes gnou/ Alcelaphus buselaphus*	NA	G	3	11	7	-	1
Springbok	*Antidorcas* sp.	C	M	-	1	-	-	1
Bontebok/Blesbok	*Damaliscus dorcas*	D	G	-	-	1	-	-
Blue duiker	*Cephalophus monticola*	N	B	-	-	1	-	-

Species		Activity pattern	Dietary preference	Klasies River				Blombos Cave
				LBS (MIS 5e)	SAS (MIS 5c-a)			M3 (MIS 5d-b)
					bottom	middle	top	
Grey duiker	*Sylvicapra grimmia*	D	B	2	5	2	-	-
Steenbok	*Raphicerus campestris*	C	M	-	-	-	-	4
Grysbok	*Raphicerus melanotis*	N	M	3	61	26	1	3
Steenbok/Grysbok	*Raphicerus* sp.	NA	M	-	-	-	-	56
Vaalribbok	*Pelea capreolus*	D	B	4	3	4	-	1
Cape buffalo	*Syncerus caffer*	N	G	3	24	5	3	
Giant buffalo	*Pelorovis antiquus*	NA	G	5	5	-	-	1
	Indet. bovid	-	-	14	148	48	4	-
	Bovid class IV+V	-	-	65	233	45	43	72
	Bovid class III	-	-	127	312	91	18	62
	Bovid class II	-	-	66	268	122	17	61
	Bovid class I	-	-	35	413	358	55	242
Whale	Indet. Cetacea	-	-	1	1	-	-	2
	Indet. mammal	-	-	42	412	207	22	-

Additional identified species in the Klein (1976) sample at Klasies River		MSA I (roughly equivalent to LBS member)	MSA II (roughly equivalent to SAS member)
Black-backed jackal	*Canis mesomelas*	-	+
Honey badger	*Mellivora capensis*	-	+
Genet	*Genetta* sp.	-	+
Egyptian mongoose	*Herpestes ichneumon*	-	+
Cape grey mongoose	*Herpestes pulverulentus*	-	+
Water mongoose	*Atilax paludinosus*	+	+
Wild cat	*Felis libyca*	-	+
Caracal	*Felis* cf. *caracal*	-	+
Leopard	*Panthera pardus*	+	+
Elephant seal	*Mirounga leonina*	-	+
African elephant	*Loxodonta africana*	-	+
Black rhinoceros	*Diceros bicornis*	+	+
Bushpig	*Potamochoerus porcus*	+	+
Warthog	*Phacochoerus aethiopicus*	+	+
Oribi	*Ourebia ourebi*	-	+
Mountain reedbuck	*Redunca fulvorufula*	+	+
Wildebeest	*Connochaetes gnou*	+	+
Hartebeest	*Alcelaphus buselaphus*	+	+

Table 1 Taxonomic composition of the Klasies River MIS 5 assemblages (after Van Pletzen 2000) and the Blombos Cave M3 assemblage (after Henshilwood *et al*. 2001). Species identified by Klein (1976) in the sample from the 1960s sample but not identified in the more recent sample are also listed. Activity patterns: D = diurnal; C = cathemeral; N = Nocturnal (following Bennie *et al.* 2014; Skinner and Chimimba 2005). Dietary preference: G = grazer; M = mixed feeder; B = Browser (following Gagnon and Chew 2000; Skinner and Chimimba 2005)

Blombos Cave. The site is located near the transition of the fynbos and the Albany thicket biomes (Mucina and Rutherford 2006); vegetation around the site consists of a mosaic of forest, grassland and fynbos (Klein 1976). The environment of the site during the MIS 5 occupations was relatively stable. However, micromammal analysis suggests that the importance of grassland decreased from the LBS member throughout the SAS member, with more closed vegetation becoming dominant (Nel 2013, 387). The representation of foraged shellfish suggests warm sea surface temperatures, comparable to the current range, throughout the Klasies River and Mossel Bay phases; the small sample of non-foraged species consists of catholic species only (Langejans *et al*. submitted).

The large mammal fauna of the earliest excavation campaign was subject to a collection bias, with specimens deemed to be unidentifiable discarded in the field (Klein 1976). This has led to an underrepresentation of smaller taxa in the assemblages (Van Pletzen 2000; Faith 2008). The assemblages of these excavation campaigns were published in terms of the minimum number of individuals (MNI) (Klein 1976). Taphonomic analysis of part of this sample shows that the assemblage was accumulated by humans, with an ephemeral role for carnivores (Milo 1998). The mammal assemblages from the excavations conducted from the 1980s onwards were analysed in terms of NISP. The fauna assemblage was subdivided per member: LBS, SAS; the latter was further subdivided in, SAS top, middle and bottom (Van Pletzen 2000). Tortoises are rare in the excavated deposits at Klasies River (Klein 1998). This is probably because they occurred in very low population densities in the area around the site (Thompson and Henshilwood 2014b).

The importance of seal is high in both the sample from the early and that from the later excavation campaigns (Klein 1976; Van Pletzen 2000). Based on the total NISP, seal bones account for just over 6% of the bone assemblage in both the LBS and SAS members (Dusseldorp and Langejans 2013). The density of shellfish recovered from the LBS and SAS members is high, 46.4 and 35.5 kg/m^3 of excavated sediment respectively (Thackeray 1988; Langejans *et al.* 2012).

2.2 Methods

We base our analysis of foraging for terrestrial fauna in the Blombos M3 phase on the taxonomically studied sample (Henshilwood *et al.* 2001). For Klasies River, we base our analysis on the sample from the second excavation campaign (Van Pletzen 2000) as it does not suffer from a collection bias. We supplement the data with the results of the earlier excavation campaign where appropriate (Klein 1976). Since the data from Klasies River is only available in terms of NISP, we also focus on the NISP data from Blombos Cave (table 1).

We divided the terrestrial fauna assemblages into the represented animal size classes (class I: < 23 kg; II: 23 – 84 kg; III: 84 – 296 kg; IV: 296 – 400 kg; V: > 400 kg) (cf. Brain 1981; Thompson and Henshilwood 2011). We also characterised the represented ungulates at Blombos by their dietary preferences (following Gagnon and Chew 2000; Van Pletzen 2000; Skinner and Chimimba 2005; Clark and Kandel 2013) and compare their representation with that at Klasies River (following Van Pletzen 2000). Finally, we characterised the assemblage in terms of their activity patterns in diurnal, nocturnal and cathemeral species (following Skinner and Chimimba 2005; Bennie *et al.* 2014). We excluded *Homo* from this review, as humans were likely not exploited as prey.

The marine mammal remains from the taphonomically studied sample at Blombos Cave were classified into animal size classes (Thompson and Henshilwood 2011). We have used this to approximate age-profiles of the represented individuals in the different levels (Dusseldorp and Langejans 2013). Size classes I - III marine mammals are represented at Blombos Cave. Adult female Cape fur seals grow to around 54 kg, or size class II. This means that the largest animals are adult males, while class I animals are assumed to be pups and subadults (Dusseldorp and Langejans 2013). Their representation allows an evaluation of whether it is likely that seals were scavenged throughout the year during seasonally diffuse visits to the coast (Klein and Cruz-Uribe 1996).

The different sea surface temperatures on the South African eastern and western coasts result in different shellfish communities. To untangle the environmental data, we used the current geographical occurrence of species to characterise them as West Coast, Cape, or East Coast typicals (Langejans *et al.* 2014; Langejans *et al.* submitted). In addition, we recorded what type of shore each species favours: Rocky shore, rocky shore and estuaries, rocky shore with sand, rocky shore with silt, sand beaches and mud flats, estuaries, or lagoons (Langejans *et al.* submitted). We also recorded in which coastal zone the species occur (Langejans *et al.* 2012); species that occur higher up the shore are more readily collected, whereas species occurring in lower zones can only be collected at set times twice a day, or sometimes only during spring low tides. The shellfish were recorded in MNI by Thackeray (1988; pers. comm. 2009).

3 RESULTS

3.1 Terrestrial resources

The bone assemblage of the M3 occupations at Blombos Cave is dominated by small animals, while at Klasies River other size classes are better represented (fig. 4A). At both sites rock hyrax is the most common determined species. This species is easily killed (Bousman 2005) and may represent a foraged resource, as may Cape dune molerat

(*Bathyergus suillus*). Removing these species from the analysed sample shows that in most phases the importance of small animals at Klasies River remains smaller than in the M3 occupations at Blombos (fig. 4B).

The importance of low-ranked small game at Blombos suggests that large-bodied prey was uncommon around the site (Dusseldorp 2009; 2012a). Generally, 'encounter hunting' is assumed to be the basic manner of acquisition of animal prey. Human foragers are assumed to search the environment until prey, or its spoor, is encountered and then pursue and kill it. This generally leads to high return rates for hunting large mammals, even though up to 97% of expeditions may be unsuccessful (Hawkes *et al.* 1991). The inclusion of smaller prey can lower the risk of failure, yet is generally characterised by a much lower return rate. The use of snares is unlikely to substantially increase the return rate (Hawkes *et al.* 1991; Ugan 2005).

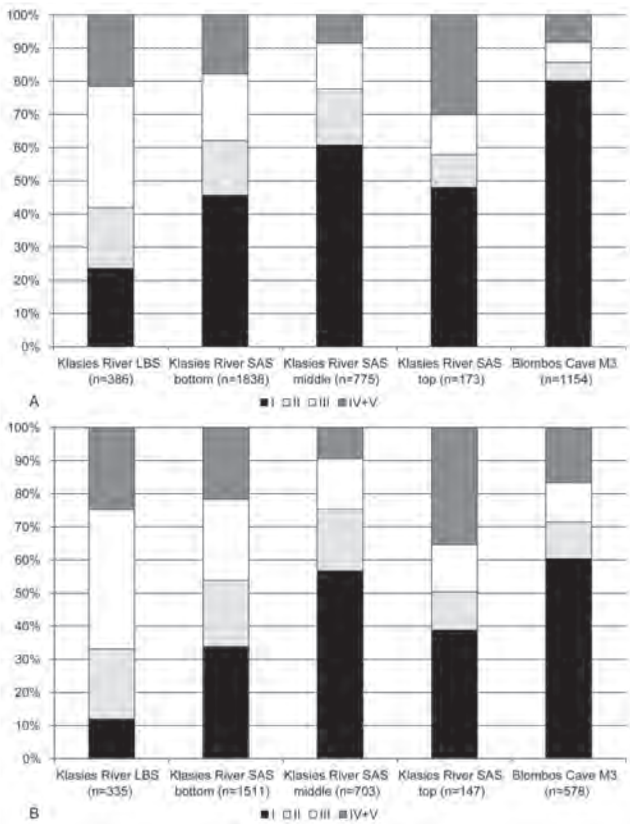

Figure 4 A: Representation of animal size classes identified in the MIS 5 bone assemblages at Klasies River and Blombos Cave based on Van Pletzen (2000) and Henshilwood *et al.* (2001).
B: Representation of animal size classes excluding rock hyrax and Cape dune molerat in the samples studied by Van Pletzen (2000) and Henshilwood *et al.* (2001)

To evaluate whether the different representation of large-bodied prey at Blombos Cave and Klasies River is explained by differences in the available prey, we reviewed the dietary preferences of the represented ungulates. Generally, browsing ungulates are more likely to be small and live dispersed or in small groups, while grazers are more likely to be large-bodied and gregarious (Estes 1974). Our analysis shows that the importance of grazers in the Blombos M3 assemblage is smaller than in the Klasies River assemblages (fig. 5), with the majority of ungulates being mixed feeders. This suggests large-bodied animals were less common in the vicinity of Blombos Cave.

To gauge if exploitation strategies like trapping and net-hunting are implicated by the composition of the faunal assemblages, we divided the identified taxa in the assemblages according to their temporal activity patterns (fig. 6A) (following Bennie *et al.* 2014, table S2). This shows that the majority of identified specimens are from diurnal species. However, this analysis is hampered by the inclusion of rock hyrax, which is classified as diurnal, but may not have been targeted in the same manner as ungulates. When this species is omitted, the importance of diurnal and cathemeral species decreases (fig. 6B). A majority of specimens in the SAS bottom and middle assemblages belongs to nocturnal species, and at Blombos Cave, almost 50% of specimens belong to nocturnal species. With regard to the Klasies River assemblages, all *Raphicerus* specimens are categorised as grysbok (*Raphicerus melanotis*), which is nocturnal. However, it is likely that some of these specimens represent steenbok (*Raphicerus campestris*), which is cathemeral. The distributions of these species overlap; they are difficult to distinguish from each other. Hence the importance of nocturnal animals in the Klasies River SAS bottom and SAS middle assemblages may be somewhat exaggerated.

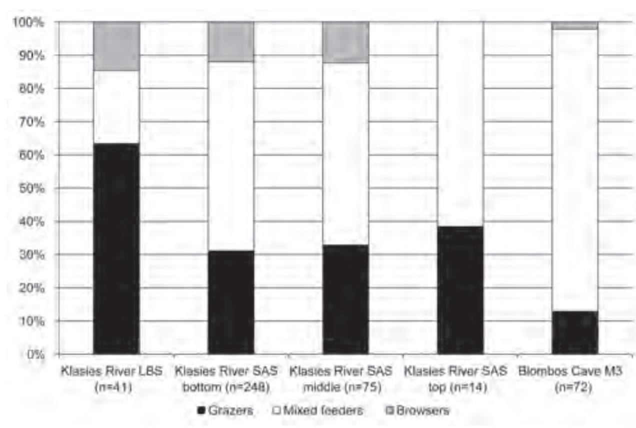

Figure 5 Representation of grazers, mixed feeders and browsers among the ungulates identified by Van Pletzen (2000) and Henshilwood *et al.* (2001)

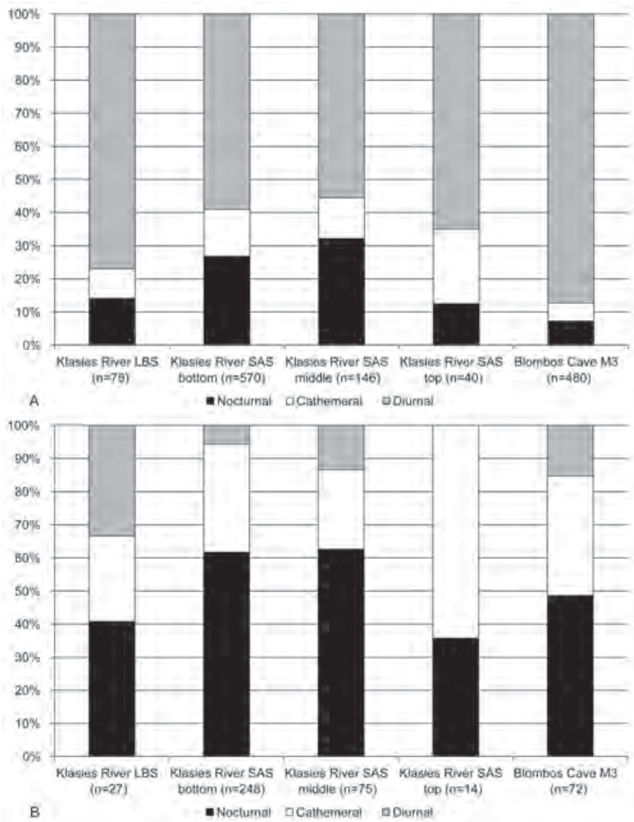

Figure 6 A: Representation of diurnal, cathemeral and nocturnal species in the samples of Van Pletzen (2000) and Henshilwood *et al*. (2001), following Bennie *et al.* (2014). B: Representation of diurnal cathemeral and nocturnal species excluding rock hyrax

3.2 Marine resources

Both Klasies River and Blombos Cave are currently located on the coast, an attractive resource patch with abundant, reliable resources. During much of MIS 5 sea levels were lower than currently. During the Blombos Cave M3 occupations, the coast was likely located 2.3 km from the site, and during the SAS occupations the coast was likely located 2.2 km from Klasies River (Langejans *et al.* 2014; Langejans *et al.* submitted). At both sites the main represented marine resources are shellfish and seals.

The representation of seal size classes shows that size class III seals, fully adult males, are rare in the M3 phase (Thompson and Henshilwood 2011). Size class I specimens, juvenile individuals, account for 30% of the assemblage and 60% of specimens are from size class II animals, adult females and subadult and young adult males (Thompson and Henshilwood 2011; Dusseldorp and Langejans 2013). At Klasies River, the sample of seals recovered in the 1960s excavations consisted mostly of adults (Klein and Cruz-Uribe 1996). However, due to the recovery methods of this campaign, juvenile seal remains are likely underrepresented (Van Pletzen 2000). Unfortunately, the excavations conducted during the 1980s yielded too small a sample of seal remains to construct a reliable age profile. However, juveniles are well-represented in the sample (Van Pletzen 2000). This suggests that a similar age profile is present at Blombos Cave and Klasies River. Unfortunately, no information on the presence of very large adult males at the latter site is available.

Shellfish are a reliable resource that can be gathered throughout the year, making coastal foraging a worthwhile year-round endeavour. However, shellfish collection was probably especially important during winter and spring when plant foods were scarce (Parkington 1976; Dusseldorp and Langejans 2013). The Blombos Cave M3 shellfish assemblage is dominated by large species suggesting selective exploitation of high-yield species such as *Turbo sarmaticus* and *Haliotis midae*. The later Still Bay assemblages are dominated by brown mussel (*Perna perna*), a smaller species that can be easily mass-collected (Langejans *et al.* 2012). The assemblage composition from MIS 4 is influenced by lower sea levels meaning the shells had to be transported to the site over a larger distance (Dusseldorp and Langejans 2013). The Klasies River MIS 5 shellfish assemblages are dominated by the mass-collectable brown mussel. High-yield species are not as well represented as at Blombos Cave (Langejans *et al.* 2012).

4 Modelling MIS 5 resource exploitation

The representation of terrestrial mammals suggests that the exploitation of small animals was important at both sites, but most important at Blombos Cave. The greater representation of large-bodied animals at Klasies River, especially in the LBS can be explained by environmental factors, as grazers were abundant during this phase. The decreased importance of grazers in the SAS occupations dated to MIS 5c-a compared to the LBS phase dated to MIS 5e, is likely a reflection of the changing vegetation patterns also apparent in the micromammal assemblages reflecting increasingly bushy vegetation (Nel 2013). However, in the sample of unidentified bovid bones from Klasies River, large bovids remain well represented during the SAS bottom and middle phases, suggesting grazers continued to be available (table 1, figure 4).

Nocturnal species account for a large proportion of the assemblages, notably at Blombos Cave and in the SAS bottom and middle assemblages at Klasies River. This suggests that prey exploitation during the SAS phase at Klasies River increasingly resembled that at Blombos Cave, which is dated to roughly the same period. The importance of nocturnal species in the assemblages does not automatically imply that trapping was practised. Nocturnal animals can be found in their hiding places during the day and hunted using normal hunting weaponry. However, ethnographic studies show that encounters with nocturnal species are rare during diurnal hunts unless hunting dogs are employed (Koster 2008; 2009). Nocturnal species can also be caught in communal net hunts, where prey is flushed out of hiding and driven into nets to be killed (*e.g*. Noss 1998; Collins submitted). The return rate of such hunting methods is generally also low (Ugan 2005). At Klasies River, the importance of larger bovids suggests encounter hunting was an important strategy. However, the representation of smaller, browsing and nocturnal animals in the SAS members and at Blombos Cave suggests that trapping or net-hunting may also have been practised.

The importance of marine mammals at both sites is unsurprising. For most of the year seal meat has higher levels of fat than terrestrial mammals (Marean 1986). Currently, seals' presence on the mainland shore is unpredictable. Most colonies are located on offshore islands. However, during July-September, when pups are weaned, many starving individuals wash up on the mainland shore. During the LSA, foragers profited from this predictable winter peak in seal availability; the wider age-representation of seals during the MSA has been interpreted to suggest that MSA foragers opportunistically scavenged seals throughout the year (Klein and Cruz-Uribe 1996; 2000). However, Pleistocene seal populations were much larger than current populations, which are still recovering from intensive commercial exploitation from the 17th century onwards (David and Van Sittert 2008). Thus, colonies and haul-outs were likely present on the mainland, enabling the focussed exploitation of older seals as well as juveniles.

In the M3 at Blombos, size class III marine mammals make up around 10% of the assemblage, while size class I accounts for around 30%. This means that around 60% of the assemblage consists of adult females and subadult and young adult males. The dominance of size II animals, an uncommon age class in living populations, is surprising. If the assemblage was accumulated by scavenging, this means the most common carcasses, those of size I individuals, pups and subadults, were often ignored. The fact that seals are a relatively important component of the bone assemblage also makes scavenging unlikely. If seals were scavenged, their proportion of the entire mammal bone assemblage would suggest that the remains of other mammals were accumulated very slowly. However, many indicators suggest that the site was intensively occupied for much of the stratigraphic sequence (*e.g*. Thompson and Henshilwood 2011; 2014b). We think that the representation of seal age classes indicates that onshore colonies or haul-outs were targeted, resulting in a high representation of adult females (cf. Dusseldorp and Langejans 2013). The rarity of adult males suggests that this happened largely in autumn and winter, when males are absent from colonies. After summer, males disperse for the remainder of the year, and only adult females and young animals can be exploited regularly. Due to the absence of data on the age representation per level at Klasies River, it is unclear if the pattern is repeated there. Interestingly, during the subsequent MIS 4 occupations at Blombos, fully adult males are well represented. This is the rarest class of animals in natural populations, making it even more unlikely that these assemblages were accumulated by scavenging. It also suggests that the seasonality of the site's occupation changed through time (Dusseldorp and Langejans 2013).

It is striking that at Blombos Cave individually collected large mollusc species only accessible during low tides are dominant during the M3, while at Klasies River brown mussel that can be mass-collected higher up on the shore dominates (Langejans *et al.* 2012). During the subsequent Still Bay occupations at Blombos brown mussel becomes dominant, while at Klasies River, the proportion of *Perna perna* diminishes during subsequent phases in favour of individually collected mostly high-yield species.

The difference in the representation of foraged shellfish species between the sites is difficult to interpret. Since the large species in the Blombos assemblage are only accessible at (very) low tides, coastal foraging was likely planned to coincide with these moments (Langejans *et al.* 2012). Brown mussel is easily accessible and is mass-collectible. Its increasing exploitation at Blombos Cave may represent a shift to more frequent coastal foraging leading to the addition of this smaller more accessible species to the diet. However, this species is easily transported, and since more processing is required than with other species such as limpets, may be more likely to end up at archaeological sites as sea levels dropped (cf. Dusseldorp and Langejans 2013). The dominance of brown mussel during MIS 5 at Klasies River and its diminishing representation later on suggests routine coastal foraging during the MIS 5 occupations. One possible explanation is that the increase in sand mussel (*Donax serra*) and lagoon-loving species signify the increased importance of sandy shores in the vicinity of the site (Langejans *et al.* submitted). Sandy shores are unproductive with regard to foraging for shellfish (Thackeray 1988; Jerardino and Marean 2010; Langejans *et al.* 2012). Rocky shore species remain common in later phases, maybe signalling that planned foraging trips to pockets of rocky shore became more productive than routine foraging in the sandier coastal areas.

5 Synthesis

When modelling the subsistence strategies practised during MIS 5 along the southern Cape coast, one needs to take into account that the importance of gathering is largely archaeologically invisible. However, a number of resources do shed light on gathering activities. Shellfish show the importance of gathering along the coast. The representation of tortoise may be seen as a reflection of terrestrial gathering activities. Similarly, Cape dune molerats, living in underground tunnel systems without access to the surface may have been collected similarly to geophytes, the main vegetable resource of the fynbos (Deacon 1989; Deacon 1993; Marean 2010). Finally, rock hyrax is easily caught, and may have been exploited during gathering activities as well. The importance of the archaeologically visible gathered resources is larger at Blombos Cave than at Klasies River. The absence of tortoise at Klasies River is probably due to their low population densities around the site (Thompson and Henshilwood 2014b). Mole-rats were present around Klasies River (Avery 1987), so their poor representation is not due to environmental factors alone. Similarly, the environments around Klasies River and Blombos do not appear differently suitable to rock hyrax. This suggests either a larger reliance on archaeologically invisible vegetable resources at Klasies River, or a larger importance of hunted foods in the diet.

The predominance of small bovids at Blombos Cave in the M3 occupations suggests that return rates of hunting terrestrial game were low. Since trapping and net-hunting require many man-hours to be invested in game drives and the checking of traps and handling cost of small mammals remains high, ethnographically known return rates for the exploitation of small mammals using such techniques are uniformly low (Ugan 2005, 82-83). An increased importance of gathered resources might be expected in this situation. This may explain the importance of tortoise, rock hyrax and Cape dune molerat in the assemblage. It should be noted that the caloric contribution of gathered animal resources during this phase was probably lower than that of hunted large mammals and gathered plant foods (Thompson and Henshilwood 2014b). However, if we assume that rock hyrax, tortoise and molerat exploitation was embedded in foraging for plant foods, their representation at Blombos Cave suggest an overall higher emphasis on gathered resources. In addition, the amount of shellfish transported to the site appears larger than at Klasies River.

At Klasies River, where large ungulates were more common, the importance of gathering is expected to be smaller and this may indeed be supported by the represented resources at the site. However, in later phases, when the density of the vegetation increased, the importance of gathering strategies is expected to also increase, as may be the case during the SAS middle phase.

Finally, if we accept a high representation of small animals and nocturnal species as circumstantial evidence for the use of trapping, the importance of small and nocturnal prey at Blombos and in part of the SAS assemblages at Klasies River suggests that such hunting strategies, or net-hunting, requiring a large amount of planning depth were practised prior to MIS 4. With regard to marine resources, we suggest that the taxonomic representation of the shellfish assemblages suggests that some planning was involved in the timing of visits to the coast. Moreover, the importance of adult seals in the M3 faunal assemblage argues against random scavenging along the shore, but suggests the active targeting of colonies or haul-outs. Considering the presented evidence it appears likely that people at Blombos Cave and Klasies River employed modern subsistence strategies during MIS 5. They not only used traps/nets, but also planned the timing their coastal foraging trips.

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A Late Neolithic Single Grave Culture burial from Twello (central Netherlands): environmental setting, burial ritual and contextualisation

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During a recent, large-scale excavation near the village of Twello (central Netherlands) a relatively well-preserved Single Grave Culture burial was found. This offered the rare opportunity to study this monument by using modern techniques and to analyse it in its local and wider archaeological and environmental setting. At first sight, the burial does not appear to deviate much from 'the standard' for the Single Grave Culture in the Netherlands. However, when all excavation data and specialist analyses are combined some interesting patterns emerge. Whereas the Single Grave Culture is generally seen as a tradition that had strong links with the north and east, the stone axe head and flint blade that were deposited in the grave rather point to a southern origin. Chemical residue analyses and palynological research indicate that the protruding foot beaker that was found probably contained a primitive type of wheat beer or porridge and may have been sealed with animal fat. Furthermore it is demonstrated that the burial played an important role in later landscape organisation and was still perceived as an important location many centuries after it had been erected.

1 Introduction

During the recent excavation of a Late Bronze Age/Early Iron Age urnfield near the village of Twello (province of Gelderland) a relatively well-preserved Single Grave Culture burial dating to the Late Neolithic was found. The site is located within a 32 hectares large area east and south of the village of Twello (fig. 1). Over the last few years this area has seen several campaigns of rescue excavation in advance of housing development. Following surveys, the most important parts of this area were excavated (fig. 2), producing a high density of finds dating from the period between the Mesolithic and Middle Ages. The first excavations were undertaken in 2010-2011 by the archaeological company ARC (De Wit 2012). In 2013 Archol BV excavated several prehistoric and Roman-period settlement features as well as the urnfield, in the course of which the Single Grave Culture burial was found (Meurkens 2014). This find offered the rare opportunity to study a relatively well preserved burial from this period. Nowadays, most burial mounds in the Netherlands are protected monuments.

When it became clear that the burial pit contained a well-preserved body silhouette with accompanying grave goods, it was decided to lift the burial pit in its entirety. In the laboratory of Restaura in Haelen, the lifted block was first radiographically scanned, and then carefully excavated up to the level that the body silhouette was still preserved. This enabled additional specialist research in a controlled laboratory setting. For example, targeted samples from different contexts were taken for archaeobotanical research. Furthermore, this strategy offered the possibility to preserve the burial for exhibition purposes and future scientific study.

The aim of this paper is to present the excavation data and the environmental and archaeological context of the burial. The landscape and vegetation of the study area are reconstructed by means of physical geographic and palynological research. Mapping of contemporary archaeological finds in the vicinity gives some insight into the broader cultural context of the burial. The burial is compared to other burials in the Netherlands in order to assess its added value in the study of Single Grave Culture burial customs. Finally, a reconstruction is made of how it was perceived and interacted with in later phases.

2 Landscape and habitation

The site of Twello is situated at the easternmost part of the central Dutch Veluwe region. The IJssel valley lies about a kilometer east of the site. The Veluwe area is generally classified as a Pleistocene sandy region and is part of the so-called European Aeolian Sand Belt (Hilgers 2007; Koster 2009; Tolksdorf and Kaiser 2012). The landscape in the study area was mainly formed in the Saalian and Weichselian ice ages. In the Saalian period (238.000-128.000 BP) the IJssel valley was part of a 125 m deep glacial basin formed by glaciers that also led to the formation of the ice-pushed ridges of the Veluwe and Salland regions. This basin was filled in with meltwater deposits. These are covered with gravelly fluvial sediments that were deposited by the Rhine during the Weichselian period (116.000-11.700 BP). This Weichselian Rhine branch, that can be seen as an early predecessor of the IJssel, probably was abandoned between 60.000-40.000 BP (Busschers *et al*. 2007). In the surroundings of the study area its deposits consist of a

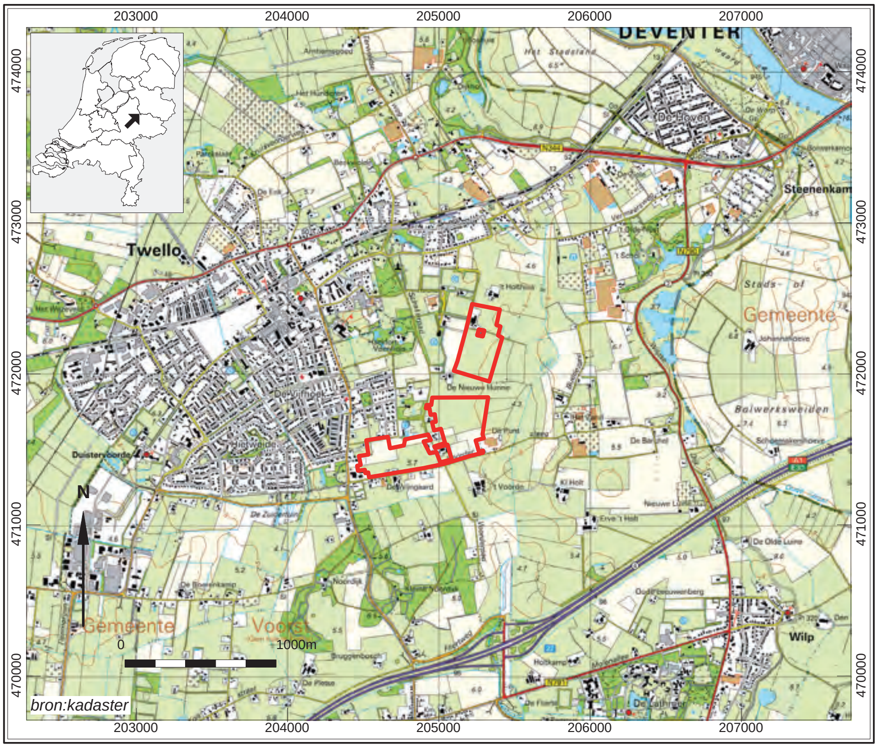

Figure 1 Site location of Twello. The excavated areas are outlined in red

system of generally north-south oriented terraces alternated with depressions. During the colder phases of the Weichselian, sand was deposited on top of this river terrace landscape, enhancing the original elevation differences as a result of deflation of low-lying areas and sedimentation at higher areas. These sand deposits are generally indicated as cover sands.

The excavation area is situated on a coversand plateau that was formed on river terrace deposits, and on its adjacent eastern slopes which pass into a wide, south-north oriented depression. The maximum elevation differences in this gently undulating region do not exceed 2,5 meters (fig. 3). In the Early and Middle Holocene clay was deposited in the lowest parts of the research area, on top of the older river terrace sediments. These sediments were deposited by small, local streams. The present-day IJssel only formed in the Late Roman period or start of the Early Middle Ages, after an avulsion of a cover sand barrier south of the nearby city of Deventer (Cohen *et al*. 2009). From *c*. 700 AD onwards a large river developed, which deposited clay in the lower eastern parts of the study area (Heunks 2014).

The excavation results (De Wit 2012; Meurkens 2014) suggest that especially the highest parts of the large coversand ridge were very suitable for habitation throughout prehistory and early history, although it should be noted that only small parts of the low-lying areas were excavated. These areas were investigated by trial trenching, which yielded only a limited amout of features.The main trends in habitation are similar to those documented during large-scale settlement research in neighbouring parts of the eastern Netherlands (Van Beek 2009, 2011). Various finds from the period between the Late Palaeolithic and Early Bronze Age probably indicate short-term habitation phases and specialised activities. Two Late Neolithic burial monuments, one of which is central to this paper, form the only evidence for more ‘fixed’ forms of landscape organisation (fig. 2, 3). The study area may have been settled continuously between the Middle Bronze Age and Early Middle Ages (*c*. 1500 BC – AD 700). Finds from the Middle Iron Age and part of the Late Iron Age (*c*. 500-150 BC) are lacking, but these may be situated outside the excavated area. Virtually all farmsteads, outbuildings and other structures are found on the higher parts and slopes of the coversand ridge. The lower parts of the landscape yielded prehistoric wells and water holes.

The Late Neolithic burial that is presented here is situated at the highest point of a sandy ridge at the southernmost part of the coversand plateau. The elevation differences with the areas immediately west, south and east of the ridge are up to 1,5 meters (fig. 4). Therefore a marked location was chosen to erect this monument.

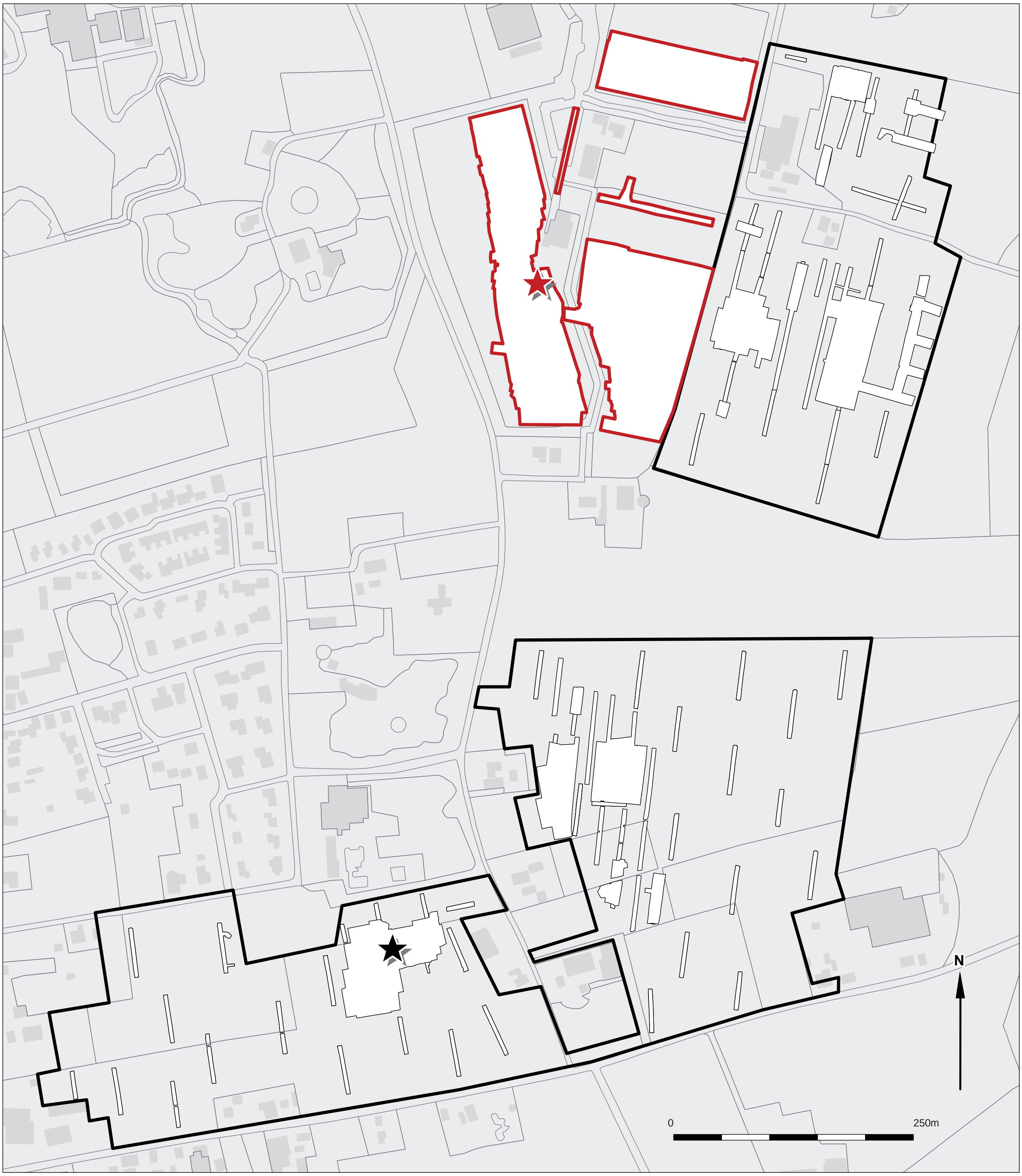

Figure 2 Research area with excavated surfaces (red: ARC 2010-2011; black: Archol 2013). The black star indicates the position of the burial central to this paper. The remains of another possible late neolithic burial have been found at the location of the red star

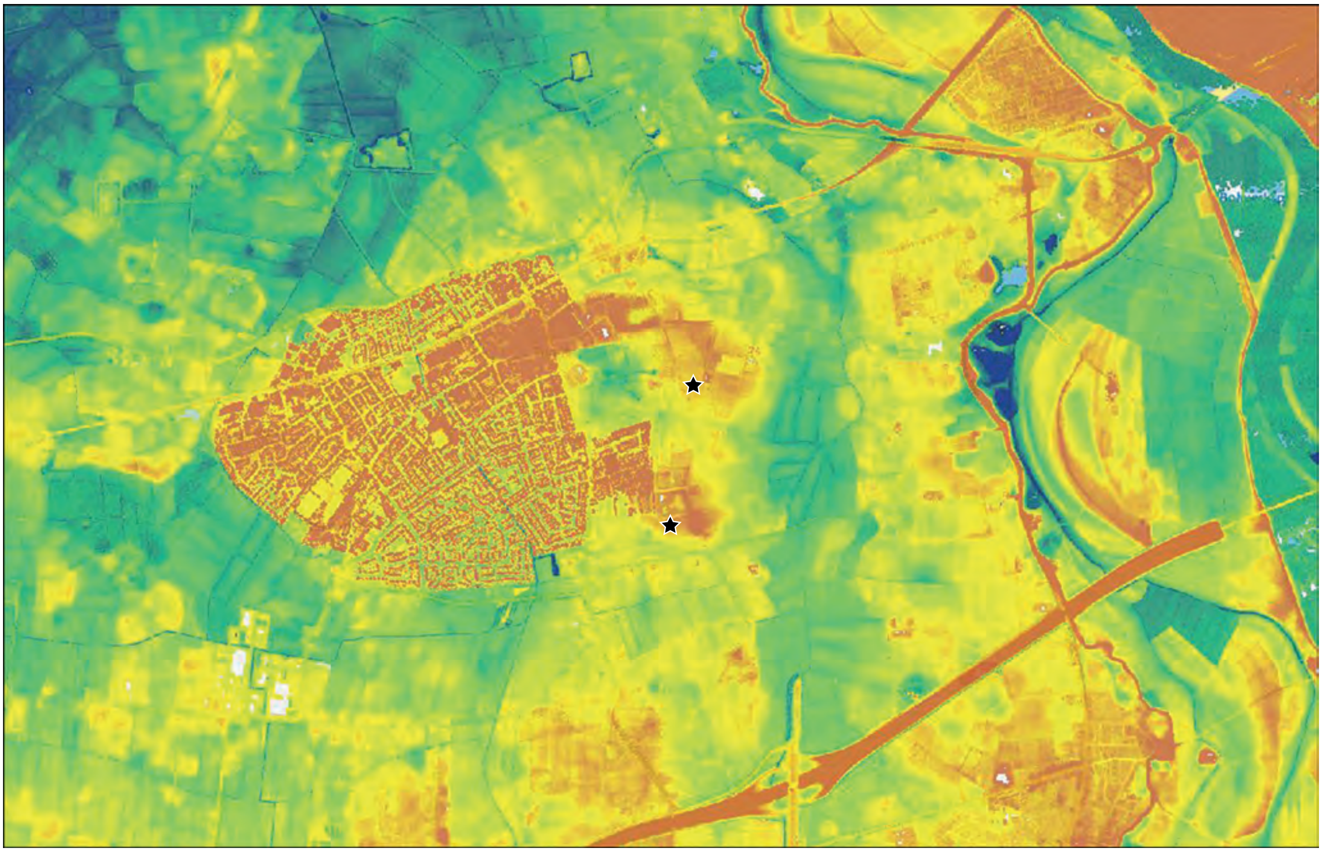

Figure 3 Elevation map of Twello in its wider setting (source: www.ahn.nl). The two late neolithic sites are indicated with black stars

3 The Single Grave Culture burial

3.1 *Excavation method*

The Single Grave Culture burial was located centrally within the younger urnfield. It consists of a more or less rectangular burial pit surrounded by a closed circular ditch (fig. 5). A barrow mound has not been preserved, but may originally have been present (see below). The burial pit was excavated in layers and segments in order to retrieve both horizontal and vertical information. Six levels were documented. All sediment from the pit was dry-sieved in order to collect any small artefacts that had possibly been missed during excavation. However, apart from a protruding foot beaker, stone axe and flint blade found near the body silhouette at the bottom of the pit (see below), no objects were found. All levels and fills of the burial pit were sampled for palynological and macrobotanical analysis. The ditch was documented by six cross-sections at regular intervals. Two sections were sampled for pollen analysis. After documentation and sampling the ditch was excavated in levels in order to collect finds and locate possible post settings.

3.2 *Circular ditch*

The ditch is almost perfectly circular and has a diameter of *c*. 9,9 m (fig. 6). It was 50-65 cm wide and 15-25 cm deep. About 30-40 cm of the original surface has disappeared due to ploughing and erosion, implying that the ditch originally would have been *c*. 70-85 cm wide and 45-65 cm deep. It has a bowl-shaped cross-section in which two distinct fills could be discerned. No evidence was found for the presence of a palisade within the ditch. The upper fill is dark brownish-gray in colour and has a heterogeneous structure, possibly partly due to animal burrowing. The lower fill is more homogeneous in texture with a light beige-brownish colour. The relatively 'clean' lower fill was mainly located on the inside of the ring ditch, suggesting that the ditch had filled up rather rapidly. The sediment possibly originates from the mound body, which in a 'fresh' state would have been vulnerable to erosion. The upper fill is likely to have formed relatively slowly after consolidation of the barrow.

The position of the circular ditch in relation to a possible barrow mound is difficult to assess. In the Late Neolithic,

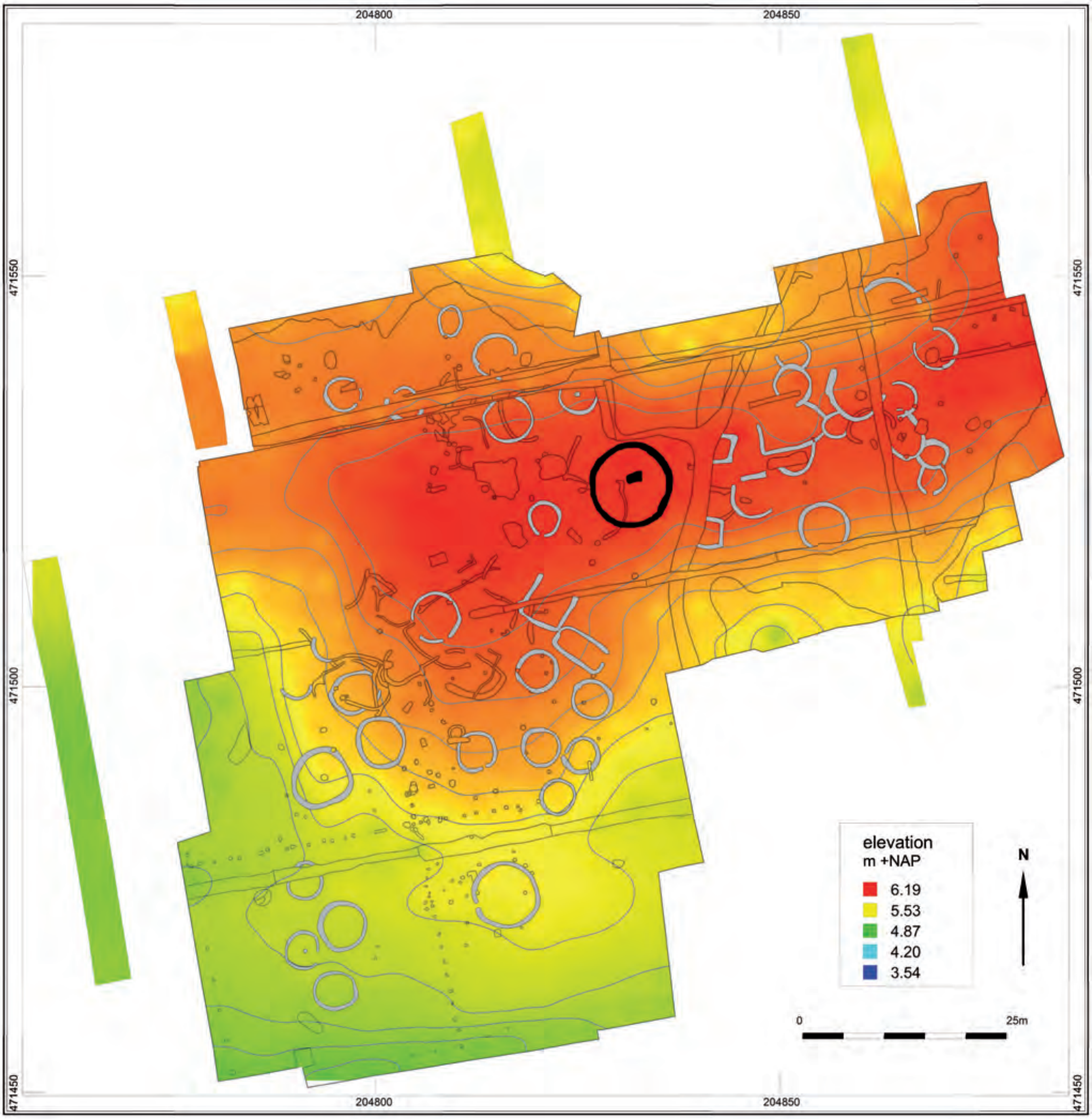

Figure 4 Site plan showing the location of the Single Grave Culture burial (black) and younger urnfield-period burials (grey)

Figure 5 Late neolithic circular ditch and burial pit during excavation

circular ditches can be found at different locations beneath a barrow mound: directly surrounding the burial pit, halfway between the burial pit and foot of the barrow (intermediary), or surrounding a barrow. According to Bourgeois (2013, 37) in the Neolithic the latter always are palisaded ditches, although that is often not easy to observe. At Twello we are probably dealing with a ditch around a barrow, though a palisade has not been observed. The diameter of the ditch is large enough to surround a burial mound, and it is well within the range of Late Neolithic barrow diameters (5-15 m). Moreover, the fact that it is respected by all urnfield burials *c*. 1500 years later, suggests that a mound was still present then. Even in the Middle Ages a barrow was probably still visible at this location, judging from the position of several field ditches (see section 4.4).

Establishing contemporaneity between the circular ditch and burial pit is not unproblematical. The ditch could not be dated directly since no suitable material for radiocarbon dating was found. Furthermore, it only contained some indeterminable pottery ‘crumbles’, two small pieces of flint and a fragment of a granite quern. It is clear that the fill of the circular ditch differs from some of the urnfield-period features, and that the pollen spectra deviate as well (see section 3.6.3 and 4.4). This indicates that the circular ditch certainly is older than the urnfield-period ditches. In combination with the observations on the fills of the ditch, for the present we assume contemporaneity of circular ditch and burial pit (for additional palynological evidence on the age of the ditch, see 3.6.3).

3.3 The burial pit

The burial pit was oriented more or less east-west and measured 1,7 x 1,15 m (fig. 7). At the uppermost level (level 2) the contours of the pit were rather vague and heavily disturbed by animal burrows. During excavation of the pit its size and shape hardly changed. From level 4 downwards different fills could be discerned. These are a pale light grey

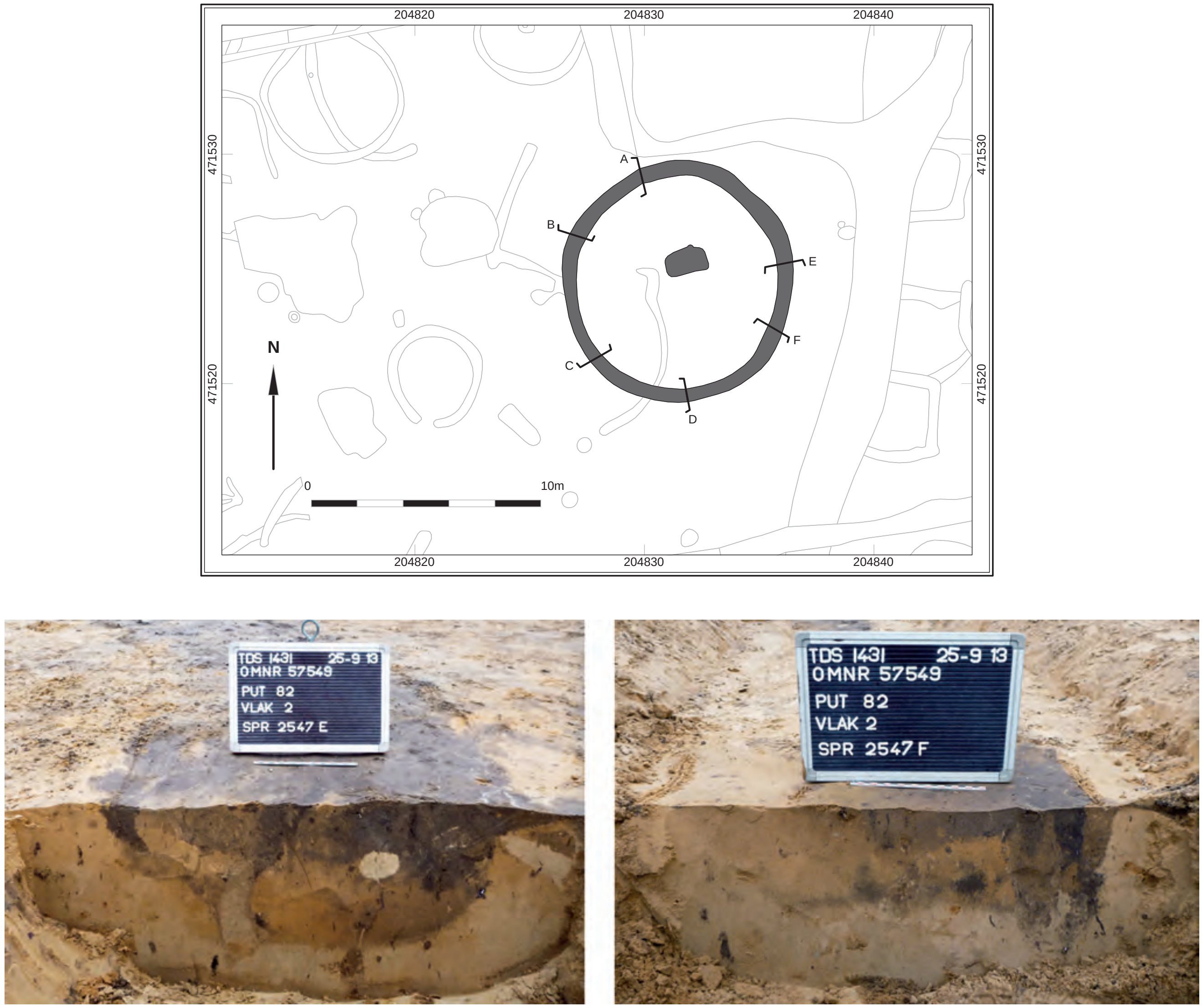

Figure 6 Excavation plan of the burial monument and photographs of two ditch sections

homogeneous fill (1) and a darker brownish fill (2). Parts of the latter were rich in charcoal (3).

The preserved part of the pit was 35-40 cm deep. If we compensate for 30-40 cm that have disappeared due to land use and erosion, it follows that it originally was 65-80 cm deep. Its sides were straight and its bottom flat. No signs of a wooden coffin or other sort of strengthening structure were observed. There is however a clear distinction, particularly in the lower levels of the pit, between the greyish fill 1 and the brownish fill 2. The former includes the body silhouette and grave goods (see below). A similar situation was found in a Bell Beaker culture burial excavated at Hattemerbroek, *c.* 30 km north of Twello (burial 1). This burial did contain a wooden coffin, but between the coffin planks and the body silhoutte a layer of clean sand was found. This suggests the body had been covered when it was placed in the grave, possibly by an animal skin or other organic material, which had left no archaeological trace (Drenth and Meurkens 2011, 199-201). Covering of the body has also been observed at the Late Neolithic burial site Schokland-P14, where the skeletal remains in burial 11 were covered with a large piece of bark (Ten Anscher 2012, 333-335).

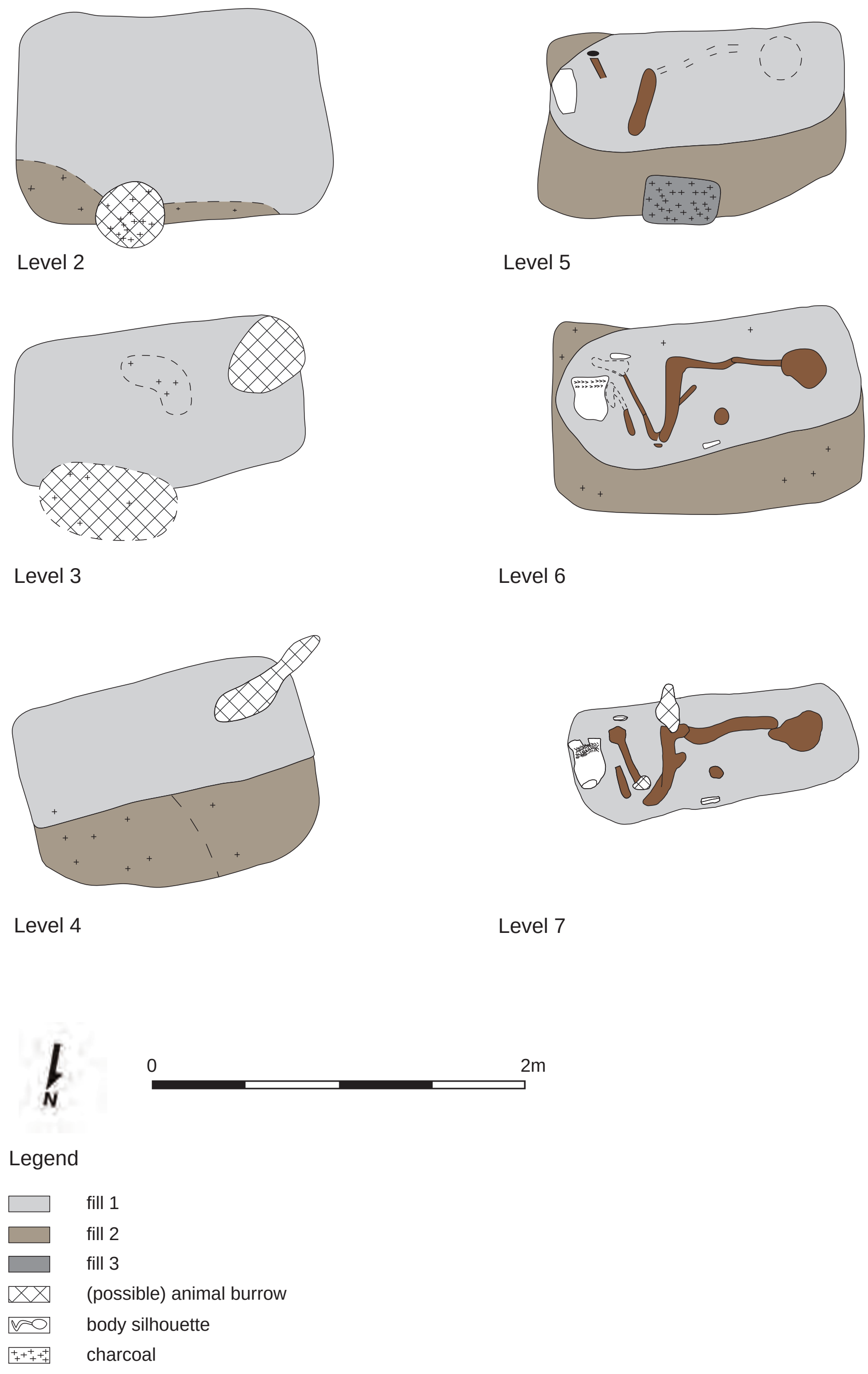

Figure 7 The burial pit at different excavation levels

3.4 Body silhouette

As the acidic nature of the Dutch sandy soils does not allow the preservation of organic material above groundwater level, no skeletal remains were preserved. However, the position of the body was clearly recognisable by a light brownish discoloration of the soil, a so-called ‘body silhouette’ (fig. 8). Both in the Netherlands and beyond these are relatively rare finds. The first traces of the silhouette were observed on excavation level 5, when the remains of what later turned out to be the right femur were documented. On level 6 most of the skeletal elements were recognisable, in particular the skull, spinal column and upper and lower legs. No traces of the arms were found. These might still be preserved in the remaining unexcavated lifted block of the burial pit. The deceased was buried in a characteristic crouched position, lying on his or her left side. The legs are located on top of each other, more or less in the same position. The body is oriented west-east (head to feet) and is looking in northern direction. During excavation detailed measurements were taken of the different skeletal parts. The silhouette as a whole was also measured and turned out to be 170 ± 5 cm long. The measurements indicate that the buried person was either an adolescent or an adult. Due to the fact that no bone was preserved neither sex nor exact age can be established.

3.5 Grave goods

On excavation levels 5 and 6 three grave gifts were found: a protruding foot beaker, a small stone axe and a retouched flint blade (figs. 9, 10). These three types of objects are (in this order) the most popular grave goods in the Single Grave Culture (Wentink in prep. and pers. comm.). The beaker was found lying against the lower legs (fig. 8). It had been crushed due to the pressure of the overlying soil, but was otherwise complete. It is a grog-tempered beaker with a partly smoothed outer surface and a relatively coarse inner surface. Based on its decoration of spatula impressions in a herringbone motive on the shoulder and neck, it can be classified as a type 1d beaker in the typology of Lanting and Van der Waals (1976).

The stone axe was found lying against the feet with its cutting edge pointing towards the head of the deceased (fig. 8). If the axe head was hafted when placed in the grave, the shaft would have been positioned on top of the legs. The axe head can be classified as a flat axe with rectangular cross-section and trapezium shape. It is only 7,3 cm long. This rather short dimension is probably due to repeated re-sharpening of the cutting edge. Axes are common in Single Grave Culture burials, although they are usually made of flint. The raw material used for the Twello axe has been determined microscopically as a probable fine-grained grano-diorite (microscopic determination by dr. H. Zwaan, Naturalis Biodiversity Center, Leiden). Fine-grained crystalline rocks occur in ice-pushed sediments in the Netherlands, but this particular variety is rather uncommon in such deposits. A possible origin is the Hautes Fagnes area the in eastern Belgian Wallonia region, where grano-diorites and very similar stones (tonalite, quartz and diorite) can be found, including fine-grained varieties (Knippenberg 2014).

The flint blade was found at some distance north of the body silhouette at the height of the pelvis (fig. 8). It measures 9,7 x 2,9 x 1,1 cm, but is incomplete. The distal, presumably pointed, tip is missing and must have broken off in prehistoric times. The long sides of the blade have been retouched. Retouched blades occur frequently in Single Grave Culture burials, and are usually referred to as ‘daggers’. However, it is far from clear whether these objects were actually used as stabbing weapons. Knife may be a better description. The Twello flint knife was probably made of Hesbaye flint, also known as Light Grey Belgian flint. This glassy opaque type of flint is grey to light grey in colour and found near Avennes, again in Belgian Wallonia (Knippenberg 2014).

Flint blades are frequently found as grave goods in all phases of the Single Grave Culture. In the Netherlands the beautifully crafted ‘daggers’ made of honey-coloured flint from Le Grand Pressigny or Romigny Léry in Central France (*e.g.* Beuker 2010; Van Gijn 2010) are included in this broad categorisation as well, although they only appear in association with All Over Ornamented beakers (from *c*. 2600 cal. BC onwards). This is emphasised here because in all other regions where they occur, the AOO phase marks the start of the Bell Beaker Culture rather than the end of the Single Grave Culture (cf. Fokkens 2012a). The AOO beaker-GP dagger association also marks the development of contacts with southern regions. Interestingly, the non-GP flint knives are exclusively produced of (probably imported) Scandinavian flint (Van Gijn 2010, 141-143). The Twello blade however deviates from this pattern because it was made of Belgian flint. It may therefore represent a shifting orientation of contacts and exchange networks from north (Scandinavia) to south (eastern Belgium/ France) at the transition period from the Single Grave to the Bell Beaker period.

3.6 Specialist research

3.6.1 Residue and use-wear analysis of the stone tools

The stone axe and flint blade were analysed for traces of residue and use-wear (Verbaas 2014). They were left uncleaned after removal from the burial in order to minimize chances of contamination. Both tools were first analysed for residue, i.e. microscopic traces of hafting or the material that was worked. Subsequently they were cleaned in water in an ultrasonic tank and checked for traces of use-wear. A stereo microscope (enlargement 7,5-60) and metal microscope (enlargement 50-300) were used for both types of analysis.

Figure 8 The body silhouette at excavation level 6 showing the location of the grave goods

The residue analysis yielded no results. Some black residue was observed on one side of the blade. This was initially thought to be tar, but Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray spectroscopy (EDX) analysis demonstrated a mineral composition (usually aluminiumsilicate) and therefore a natural origin (probably clay).

Use-wear analysis did produce interesting outcomes. The axe head has probably been used for cutting wood, based on the specific type of use-wear found all along the cutting edge. Some chipping of the cutting edge was observed, which is also typical for woodworking. Additionally, the surface and back end of the axe head demonstrate clear traces of hafting. The use-wear traces on the Twello axe head are similar to those observed on analysed axes from other Single Grave Culture burials, most of which bore traces of woodworking and hafting. An interesting difference is that the Twello find has not been re-sharpened directly before deposition in the burial, whereas according to Van Gijn (2010, 143-144) and Wentink (in prep.) that practice was rather common.

The Twello blade shows traces of prolonged use. Across the entire length of the artefact longitudinal traces are

Figure 9 The protruding foot beaker *in situ* (above) and restored (below; scale 1 : 2)

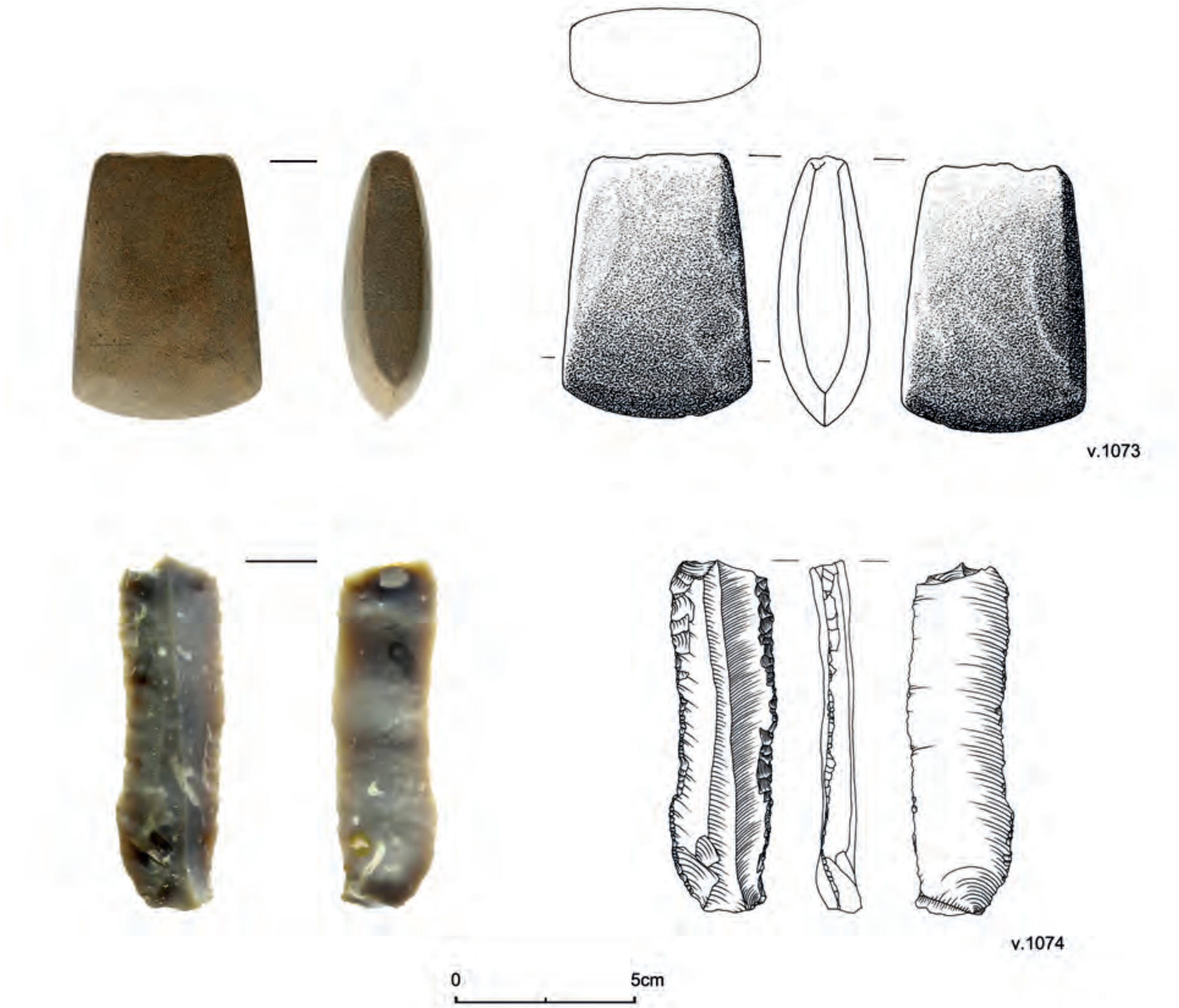

Figure 10 Stone axe head and flint blade found near the body silhouette (scale 1 : 2)

present. These can be linked to the working of plant material, probably bark. No traces of hafting are observed. The evidence of rather intensive use of this blade are remarkable. Many flint blades from Single Grave Culture burials hardly show use-wear at all (Van Gijn 2010, 189-191). This especially applies to 'daggers' made of Scandinavian flint (clear use-wear traces on only 4 out of 23 analysed artefacts). Roughly similar traces have only been observed on a find from Borger. 'Daggers' made of GP flint show use-wear traces frequently. However, these generally do not result from use as a knife but from the constant retrieving of the blade from a sheath made of bark. This results in well-developed traces on the blade surface and only slightly developed traces on its lateral sides. Contrary, the Twello blade has well-developed use-wear on the lateral sides and only light traces on the ribs and ventral side. These clearly indicate its use as a knife in cutting plant material, probably bark. Traces on one of the proximal sides suggest that the blade was used for scraping bark as well. No traces of hafting are observed, which usually are present on GP daggers.

3.6.2 Residue and pollen analysis of the beaker

In order to determine the content of the protruding foot beaker at the time of deposition, a small sherd from its base was submitted for organic residue analysis (Debono Spiteri and Meirsman 2014). 0.6 grams of the interior and exterior surfaces were drilled of the surface of the pottery. 1.4 grams of the associated soil deposit was also sampled. The external surface and associated soil were used to test for exogenous contamination. Absorbed lipids were solvent extracted, and subsequently analysed by Gas Chromatography (GC), which separates out and quantifies the lipid constituents present in the extracted residue, and GC-Mass Spectrometry (GC-MS), which provides structural information on the detected lipids, allowing a preliminary identification of the original fatty source based on biomarker identification.

Analysis of the residue extracted shows that significant yields (>5 µg g^{-1}) were obtained for all three samples (Evershed 2008). The results (table 1) however show some perplexity, since the residue yield obtained from the external surface (127.4 µg g^{-1}) is much higher than that obtained from the internal surface (11.8 µg g^{-1}), and the residue yield in the associated soil sample (21.7 µg g^{-1}) was also considerable. The lipid profile obtained for the exterior surface (sample N1112E) is indicative of a ruminant animal fat. The sample comprises a suite of undiagnostic fatty acids, dominated by $C_{16:0}$ and $C_{18:0}$ fatty acids. A ruminant origin is suggested by the presence of branched and odd-chained fatty acids, which are formed by microorganism in the rumen. The mono- and diacylglycerols identified in the exterior surface (N1112E) indicate decay, and result from the hydrolysis of triacylglycerols. The lipid composition of the interior surface (N1112I) and the associated soil sample (N1112S) are similar to the lipid profile obtained for the external surface, albeit in lower quantities. The profile is again comprised mainly of undiagnostic fatty acids, and branched and odd-chained fatty acids were also present. A cholesterol product was identified in the sample taken from the internal surface, and cholesterol was identified in the soil sample. The latter also contained phytosterols (campesterol, stigmasterol, β-sitosterol), which are indicative of plant oils since these sterols are unique to plants, and confirm their origin from plant material present in the soil.

Additional information on the content of the beaker is gained from palynological analysis (Doorenbosch 2014). When the vessel was lifted for conservation, a small amount of sediment was found in its interior. This was clumped and had a reddish colour, differing from the soil outside the beaker. This soil was sampled and analysed for pollen (fig. 11). The spectrum is dominated by grain pollen (Cerealia) and grasses (Poaceae). These have percentages of *c*. 230% and *c*. 145% compared to the pollen sum (arboreal pollen minus *Betula*). A significant number of pollen (*c*. 185%) could only be determined as either grain or wild grasses, so the total percentage of grain pollen could be higher still. Apart from grain the pollen spectrum from the beaker is very comparable to the spectra from the circular ditch (see below). Although the number of pollen was not very high, the considerable percentage of Cerealia indicates that the beaker was filled with food or beverage containing cereals when it was deposited in the grave.

The residu analysis indicated higher quantities of organic residu on the exterior surface of the beaker than on the interior and adhering soil. Ruminant animal fat was here possibly used as a sealant to waterproof the beaker.
Both vegetable and animal fats, including beeswax and milk, can be used to seal pottery (Heron and Evershed 1993; Charters and Evershed 1995). If the vessel indeed was made waterproof, this would imply that it indeed contained a fluid. This fits well with the palynological data. Chemical residue analysis and palynological research of samples from Scandinavian and Spanish beaker burials demonstrate that some beakers contained a primitive sort of wheat beer when

Lab Code	Sample Type	Relative quantification µg^{-1})	MS identification
N1112I	Interior	11.8	**FATTY ACIDS:** C14:0, C16:1, C16:0, C17:0, C18:1, C18:0; **ALCOHOLS:** C14(?), C16, C26(?); **STEROLS:** Cholesterol product; **Phthalate**
N1112E	Exterior	127.4	**FATTY ACIDS:** C9:0, C10:0, C12:0, C13:0, C14:0, C15:0br, C16:1, C16:0, C17:0br, C18:1, C18:0, C19:0, C20:0, C21:0; **MONOACYLGLYCEROLS:** 1-Monopalmitin, 2-Monostearin, 1-Monostearin; **DIACYLGLYCEROLS**, 1,2-DAG Unidentified, 1,3-DAG Unidentified; 1,2 -D30, 1,3-D30, 1,2-Dipalmitin, 1,3-Dipalmitin, 1,2-D34, 1,3-D34; **Phthalate**
N1112S	Soil	21.7	**FATTY ACIDS:** 9:0, C12:0, C14:0, C15:0br, C16:1, C16:0, C17:0br, C18:1, C18:0; **ALCOHOLS:** C:14, C18, C20, C26; **STEROLS**: Cholesterol, **PHYTOSTEROLS**: Campesterol, β-Sitosterol; **Phthalate**

Table 1 The lipid compounds identified using GC-MS in each sample. [**Br:** Branched; Cx:y: Denotes the carbon chain length (x) and the degree of unsaturation (y); **DAG:** Diacylglycerol; **Phtalate:** contamination from contact with plastic]

deposited in the grave (Klassen 2008; Lagerås 2000; Rojo-Guerra *et al*. 2006). Other options are bread, porridge or soup (Lagerås 2000), which for example is shown by the remains of porridge in a bell beaker from a burial in Barnack, Cambridgeshire (UK) (Guerra Doce 2006, 251).

3.6.3 Palynology and charcoal analysis

Samples from the Late Neolithic burial were analysed for pollen: three from the circular ditch, two from the burial pit and one from sediment found within the beaker (Doorenbosch 2014). The results of the latter have already been discussed above.

Palynological analysis of the three ditch samples (fig. 12) served to obtain a relative date of this feature compared to the urnfield ditches, and to reconstruct the vegetation at the time of construction of the barrow. The samples show comparable pollen spectra. The main tree species that are represented are oak (*Quercus*) and hazel (*Corylus*). Pollen from lime (*Tilia*) and alder (*Alnus*) are found as well. The latter usually appears at wet locations. The percentage of non-arboreal pollen is about 50 %. Dryland herbs mainly consist of heather (*Calluna vulgaris*) and grasses (*Poaceae*), with percentages of *c*. 75 % and 50 % compared to the pollen sum. There are also some indications for human activity and grazing, such as narrowleaf plantain (*Plantago lanceolata*) and sorrel (*Rumex acetosa*-type). Among the wetland herbs marsh arrowgrass (*Triglochin palustris*) is present. This plant is mainly found in wet grasslands and watersides.

The pollen spectra indicate that the circular ditch, despite the morphological similarities, is older than the urnfield-period ditches. The main indications for this are the absence of hornbeam (*Carpinus*) and the absence or smaller quantities of beech (*Fagus*) in samples from the older feature. Hornbeam only appears in the Iron Age. In this period the percentage of beech increases at the expense of lime (Janssen 1974; Van Geel 1978; Fanta 1995). Whether the ditch around the Late Neolithic burial pit was contemporary with it, cannot be determined with certainty. As mentioned above (section 3.2) primary dating evidence is lacking, and the ditch does not have the palisade that appears to be typical for Late Neolithic barrow burials (Bourgeois 2013, 23-38). Therefore the possibility that it is a secondary feature, perhaps dating to the Early or Middle Bronze Age, cannot be fully excluded. Nevertheless, based on a combination of stratigraphic and palynological evidence, for the present we assume that the ditch indeed was dug in the Late Neolithic. If that is correct, the barrow was erected in a clearance in the woods which was mainly covered with heather and grasses. An arboreal percentage of *c*. 50 % indicates the forest edge was located on average 100 meters from the barrow (Doorenbosch 2013, 83). The forest at the sand ridge mainly consisted of oak with some lime, and hazel on the forest

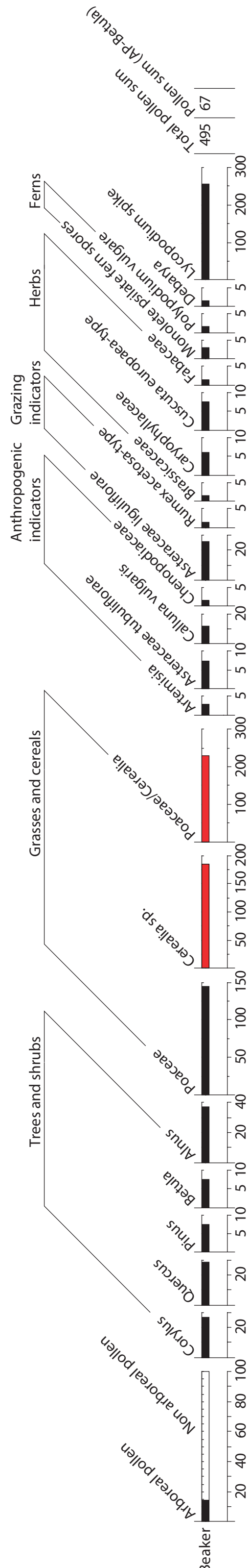

Figure 11 Pollen spectrum obtained from the protruding Foot Beaker

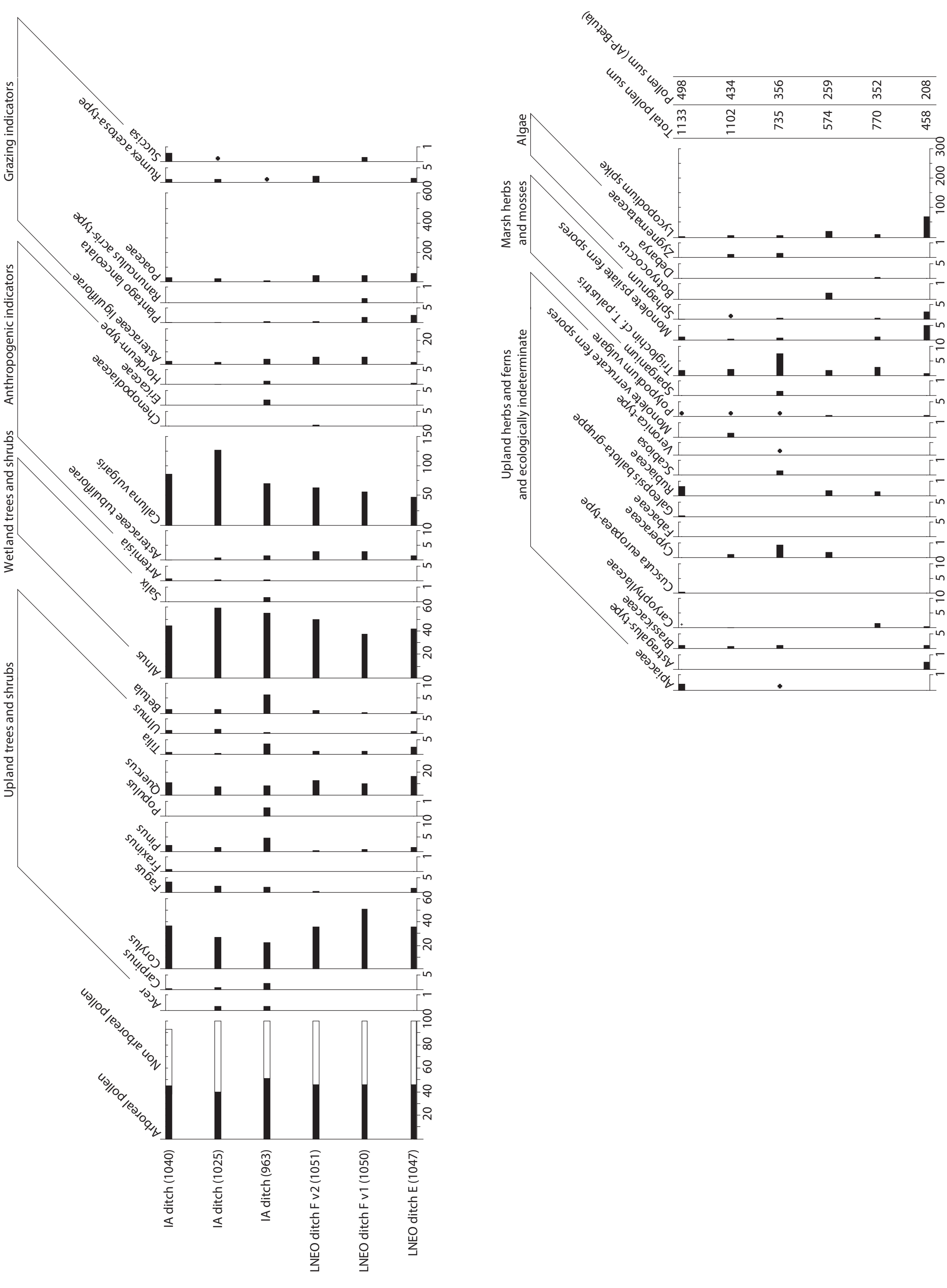

Figure 12 Pollen spectra obtained from urnfield-period ringditches (upper three samples) and the late Neolithic circular ditch (lower three samples)

edges. The wetter parts of the environment, presumably the low-lying areas to the south and southeast of the site, harboured an alder carr vegetation. There are no indications in the pollen spectra for nearby settlements or fields, but the area may have been grazed by cattle or sheep.

The two samples from the burial pit were analysed for pollen to check for intentional deposits of flowers or plants. This practice has been demonstrated at several Late Neolithic burials at the site of Hattemerbroek, *c*. 30 km north of Twello (Van Haaster 2011). Unfortunately hardly any pollen were preserved in both samples, and therefore this research question cannot be answered.

On levels 4 and 5 the burial pit showed a charcoal rich fill. Two soil samples from level 5 were analysed for charcoal and macrobotanical remains (Van Hees 2014). Both were found to contain only charred wood. The amount of charcoal is small (10,78 grams). The fragments of charcoal are small as well, measuring between 2 and 5 mm. Two wood species could be identified with certainty, *i.e.* alder (*Alnus sp.*) and ash (*Fraxinus excelsior*). These trees could be found locally, as is shown by the pollen spectra from the circular ditch. Due to the small quantity and fragmentation of the material nothing can be said of wood collecting strategies.

3.7 Dating

The Single Grave Culture is generally dated between *c*. 2800 and 2400 cal BC (cf. Lanting and Van der Plicht 1999/2000). There are some indications that the Twello burial dates in the younger part of this period. Unlike earlier attempts to date specific beaker types, Beckerman has shown that dating of specific protruding foot beaker types is problematic. There is no actual correlation between specific types and phases, at least based on ^{14}C dates. Beckerman lists 8 ^{14}C dates of Single Grave Culture burials containing type 1d beakers, only 2 of which are without problems. Both fall in the younger phase of the Single Grave Culture (Beckerman 2012, 63). The Twello burial was ^{14}C-dated through a sample taken from a charcoal concentration on level 5 of the burial pit was, producing a date of 4000 ± 40 BP (Poz-63268). Calibration with IntCal 13 gives dates between 2569-2474 cal BC (1 sigma: 68,2% probability). The 2 sigma probability gives different possible dating ranges between the period 2831-2356 cal BC. A date range between 2631 – 2454 cal BC has the highest probability (94 %). This date agrees well with the other known (unproblematic) ^{14}C-dates of 1d type beakers.

4 Interpretation and contextualisation

4.1 Burial and burial ritual

In the Late Neolithic, both flat graves and barrow burials occur. Even though no remains of a mound body have been found, there are various reasons to assume that the Twello burial originally was covered with a mound (see also section 3.2). First, late neolithic ringditches typically are found at barrow burials (Drenth and Lohof 2005, 440). Second, the lower fill of the ditch suggests that the feature was filled up rather rapidly with sediment originating from its interior. Third, the position of younger features clearly indicates the presence of a barrow (section 4.4).

Some observations and hypotheses can be made on the burial ritual that was performed between the death of the buried person and the erection of the barrow. After the burial pit was dug, the deceased was buried in a crouched position, lying on his or her left side and facing north. A protruding foot beaker, stone axe and flint blade were selected as grave goods. The beaker was probably filled with a primitive type of wheat beer or porridge, and may have been sealed with animal fat. After the deceased and the grave goods were placed in the burial pit, they probably were covered with an organic material such as bark or a leather or textile cloth. Then the pit was filled in with sand, part of which contained charcoal. This probably originated from the vicinity of the burial pit and may indicate that a fire was associated with the burial ceremony. That fire may have played a part in late neolitic burial practices has also been suggested by Ten Anscher for the burials at Schokland-P14. He suggests that fires may have been lit to consecrate or 'cleanse' the burial location (2012, 371).

It is unclear whether the circular ditch was dug before, during or after the burial. The rather clean lower fill of the ditch seems to indicate that it was filled up rather rapidly after the erection of the mound body. If the size of the circular ditch is indicative of the size of the mound body, the barrow would have measured around 10 meters in diameter. This is an average size for Late Neolithic barrows which vary between 5 and 16 meters in diameter (Bourgeois 2013).

4.2 Site location and landscape organisation

The Late Neolithic barrow of Twello was erected at the highest part of a sand ridge at the southernmost part of a relatively large coversand plateau. This marked elevation slopes down to low-lying areas immediately to its east, south and west. During the excavations in 2010-2011 a large number of shards from an All Over Ornamented Beaker was found at a location 500 meters north of the site of the Single Grave burial (fig. 2, 3; De Wit 2012). They were found in a small concentration in the topsoil, and originally must have formed a complete pot (fig. 13). This find is interpreted as a probable grave gift in a destroyed Late Neolithic burial (Hermsen 2012, 86-87). All Over Ornamented Beakers and 1d Beakers share more or less the same dating range, probably between *c*. 2600-2400 cal BC (Beckerman 2015, 157 ff.). This would imply that within a relatively short time span two burial monuments were erected at the large

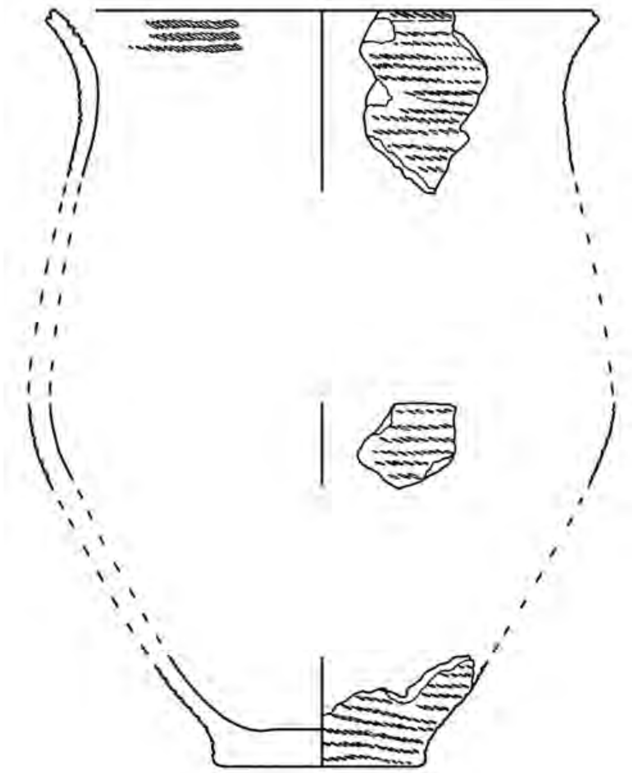

Figure 13 Reconstruction of an All Over Ornamented Beaker found during the 2010-2011 excavation, possibly indicating the presence of a second late neolithic burial. After Hermsen 2012, fig. 4.3 (scale c. 1 : 2)

coversand plateau of Twello, with an intermediate distance of 500 meters.

Palynological evidence (see section 3.6.3) demonstrates that the Single Grave Culture burial was erected in a clearance in the woods which was mainly covered with heather and grasses, and that the forest edge was located *c*. 100 meters away from the barrow. There are no clear indications for nearby settlements or fields, but the area may have been grazed by cattle or sheep. An alder carr vegetation occurred at nearby low-lying parts of the landscape. These data indicate that human impact on the landscape in the Twello area around 2500 cal BC was relatively limited. Nevertheless, several Late Neolithic finds have been recovered during both excavations (De Wit 2012; Meurkens 2014), which do point to human activity. These finds generally consist of small scatters of beaker pottery, in a few cases associated with flint and stone artefacts. At one location a small number of flint and stone objects was found in the topsoil, including a heavily weathered quartzite axe with oval cross-section. This axe type is generally dated to the Middle and Late Neolithic (Schut 1991). Additionally, at another location a Late Neolithic hearth pit was found.

The archaeological evidence indicates that the coversand area was visited repeatedly during late neolithic times. These finds probably represent relatively short-lived habitation phases, or possibly specialised activities. Indications for prolonged habitation, or even for the presence of farmsteads, are completely lacking. The Protruding Foot Beaker Culture barrow and its possible counterpart further north formed the first 'fixed' man-made structures in a still quite densely forested microregion that was inhabited and exploited on a relatively small scale. Very similar patterns have been documented during large-scale excavations in neighbouring parts of the eastern Netherlands (Van Beek 2009, 2011). Only in West-Frisia Single Grave settlements are known (cf. Kleijne *et al.* 2013). The explanation for this lack of clear settlement data outside West-Frisia, at this moment still evades us. It may well be that we search in the wrong places, because we assume that Late Neolithic farmers were the first ful-time dedicated farmers. But the settlements sites that we so-far have located in the Netherlands, all make the exploitation of wetlands, and fishing, fowling and hunting possible as well. Settlement sites therefore may have been located in other ecological zones than we have been looking for them.

4.3 *The Twello burial in a wider context*

Late Neolithic, Single Grave Culture barrows occur in some numbers in the central Netherlands, in particular in the Veluwe region (fig. 14). This large area has a tradition of barrow research going back to the 19th century. Most of these barrows are found at or in close proximity of the generally north-south oriented ice-pushed ridge complexes (*e.g.* Bourgeois 2013). Significantly fewer barrows are known from the coversand areas in the region. This certainly applies to the elongated zone bordering the IJssel river, where Twello is situated. Most evidence from these coversand areas derives from chance finds of single objects, often retrieved during reclamations, some of which can possibly be interpreted as grave goods. The recent large-scale excavations of previously unknown Late Neolithic burials at Hattemerbroek (Drenth and Meurkens 2011) and Twello indicate that these 'blind spots' at our distribution maps may not be as 'empty' as they seem. Actually, they can yield high-resolution data with an additional value to the data retrieved during (often far) earlier excavations at ice-pushed ridges. The differences in site density between ice-pushed ridges and other parts of the landscape, most notably coversand areas, are probably partly due to research history and post-depositional factors (cf. Bourgeois 2013, 39-50). Many barrows in settled areas have probably fallen prey to reclamations. Those situated at larger distances of early modern settlement nuclei and in later nature preserves (which often are parts of ice-pushed ridges), may have survived.

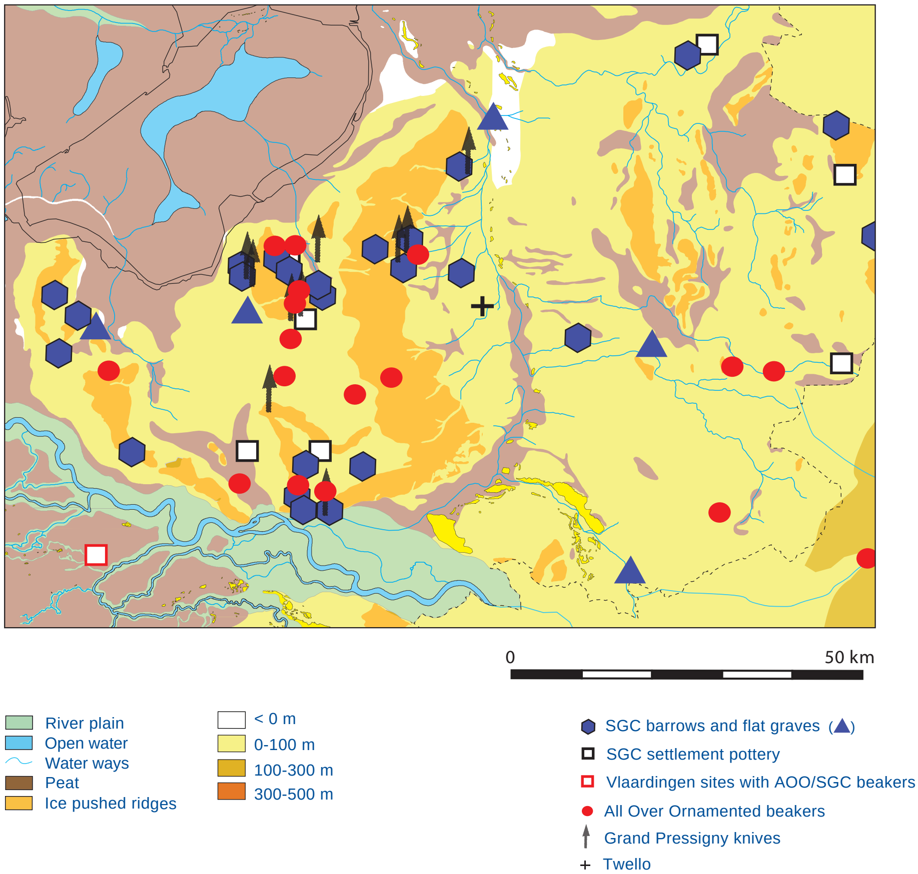

Figure 14 Distribution of Single Grave Culture and All Over Ornamented finds in the wider region around Twello (central and eastern Netherlands). Based on Vos *et al.* 2011, 51 (palaeogeography 2750 BC), Lanting 2007/2008, fig. 8a (AOO beaker pottery), Drenth *et al.* 2008, fig. 2 (Single Grave Culture barrows and settlement sites) en Wentink in prep. (GP flint knives)

The Twello burial demonstrates that it cannot simply be assumed that the position of the deceased and the character of the grave goods were gender-specific during the Single Grave Culture. Even though we have very little positive evidence because of the lack of skeletal data, Drenth and Lohof (2005, 435) state that body orientation probably was gender specific. In other parts of Europe, men are buried on their right side with their head towards the west, and women on their left side with their head towards east. Both men and women face south (Lanting 1969; Lanting and Van der Waals 1976, 44). Drenth and Lohof assume that grave goods at least to a certain extent were also gender-specific during the Single Grave Culture (2005, 443). Typically ‘male’ attributes are stone hammer axes, stone and flint axes, ‘daggers’ made of French flint and whetstones. However, the Twello burial indicates that practices and patterns probably were less fixed or rigid than suggested. The position of the deceased on the left side would imply that we are dealing with a woman. In that case, the position of the head and its orientation are atypical. Based on the grave goods, however, and especially the stone axe, a man would be more likely.

The grave goods of Twello are common for Single Grave Culture burials (Wentink in prep.), but specialist research has yielded interesting insights into their provenance, life history and condition at the time of deposition. The raw materials used for the stone axe head and flint blade appear to originate from the south (eastern Belgium), whereas the blade typo-chronologically shows more similarities with those from northern regions (Scandinavia). Whereas many axes in Single Grave Culture burials were re-sharpened before deposition (Van Gijn 2010, 143-144; Wentink in prep.), this does not apply to the Twello axe. And while Scandinavian-type flint blades from these burials generally hardly show any use-wear traces (Van Gijn 2010, 189-191), the Twello blade was used intensively and was missing its tip when deposited in the grave. Traces of relatively heavy use are observed more frequently on 'southern' Grand Pressigny 'daggers'. This interesting 'mixture' of elements appears to indicate that the Twello burial takes a sort of transitional position in both time (transition Single Grave-Bell Beaker Culture) and space (in between northern and southern influence spheres).

4.4 *Perception of the Single Grave Culture burial in later periods*

The Late Neolithic barrow was erected at a marked elevation in the landscape. In the central Netherlands, where megalithic burials are lacking, barrows were the first man-made structures that remained visible for prolonged periods of time. As such they prompted reactions of later communities, some of which left traces in the archaeological record. In the case of Twello it is possible to study the interactions of later communities with the Single Grave Culture barrow.

In the second half of the Late Bronze Age (*c*. 1000-800 BC) and the Early Iron Age (800-500 BC) an urnfield developed around the Late Neolithic barrow. This cemetery has been excavated integrally and has an elongated, northeast-southwest oriented form that is determined by the shape of the sand ridge. The cemetery consists of 38 ring ditches and four rectangular structures. Originally all monuments will have included at least one central cremation burial, but most of these have been lost due to ploughing and erosion. Based on observations on well-preserved Dutch urnfields it is probable that the burials – or at least those with ditches – were covered with low barrows, but none of these have been preserved. Only nine cremations have been found. Three are primary burials enclosed by ditches. Two are secondary burials in ringditches. The other four cannot be linked to ditched structures. The presence of burials without ditches, which are a common feature in Dutch urnfields (Hessing and Kooi 2005), indicates that the original number of burials in the cemetery must have been higher than the available data suggest. A total of *c*. 50-70 burials is likely. Judging from the typology of the burial monuments and material finds, combined with eight ^{14}C-dates, the cemetery was used for about 300-400 years. This indicates that it was used by only one nuclear family. This agrees with the data on the Late Bronze Age and Early Iron settlement that was excavated *c*. 200-300 meters northeast of the cemetery and which consisted of a single farmstead that shifted repeatedly. Most Dutch urnfields that produced demographic data were used by no more than 1-3 nuclear families (*e.g.* Verlinde 1987; Hessing and Kooi 2005; Van Beek and Louwen 2013).

The Late Neolithic barrow was situated at the centre of the urnfield (fig. 15). The monument, erected approximately 1500 years earlier, was recognised as such and was not cut by any of the urnfield features. It is highly likely that the age-old barrow was deliberately chosen as the focal point for the new cemetery. This is a well-known practice that is documented throughout northwest Europe (see section 5.2). Palynological analyses of samples from three ditches demonstrate an arboreal pollen percentage of *c*. 40%, which is a slight decrease compared to the pollen spectra obtained from the Late Neolithic ditch. The composition of the tree pollen has hardly changed, except for the almost complete disappearance of lime (*Tilia*) and the appearance of beech (*Fagus*) and hornbeam (*Carpinus*). The percentage of heather (*Calluna vulgaris*) has increased to *c*. 100%, whereas grass pollen (*Poaceae*) slow a slight decrease to *c*. 25%. The increase of heather indicates that the heath area that already was present in the Late Neolithic had expanded. The presence of a number of grazing indicators may evidence deliberate grazing to maintain the heath area at the urnfield site (cf. Hjelle 1999; Doorenbosch 2013, 237) in order to keep the cemetery visible and accessible.

Archaeological evidence for use of the cemetery in the younger phases of the Iron Age and the Roman period is lacking. A small number of pottery finds (so-called Hessens-Schortens pottery, *c*. AD 500-825) point to some short-lived activity during the Early Middle Ages. During the High (AD 1000-1300) and Late Middle Ages (AD 1300-1500) the area was reclaimed again. This is mainly demonstrated by the presence of ditches and palisades, which can be divided in two systems (fig. 14). The first consists of a south-north oriented ditch that splits directly north of the Late Neolithic barrow. One of the branches follows the curve of the monument without disturbing it. This clearly was a conscious decision, but whether it was made for practical or ideological reasons is difficult to establish (see also section 5.2). Some pits and postholes, mainly in the eastern part of the excavation area, contain High Medieval pottery. Both these features and the ditch may be part of the periphery of a nearby farmstead. The same might apply to two small rectangular buildings that were erected at the southwestern part of the area, which cannot be dated precisely. The second, younger ditch system at the cemetery site consists of a regular series of ditches and palisades, that divide the area in rectangular plots. These structures are still visible at 19th century cadastral maps, but probably are late medieval in origin.

5 Concluding remarks

The unexpected discovery of a Single Grave Culture burial in Twello was discussed here with regard to its environmental setting, cultural relations and impact on later habitation. At first sight, the burial did not appear to deviate much from 'the standard' for the Single Grave Period in the Netherlands. Of course the discovery of a body silhouette was special, but the grave goods were not out of the ordinary. However, when

Figure 15 Artist impression of the site during the Iron Age by Mikko Kriek (Vrije Universiteit Amsterdam/BCL Archaeological Support)

all excavation data and specialist analyses were combined an image emerged that does give food for thought. Also, the preservation of the burial for future scientific research and for public outreach purposes is a rare event. The municipality of Voorst has to be given credit for their insight to enable this.

5.1 The grave goods in context

An interesting point of discussion are the southern origins of the flint knife and the stone axe head, where we would expect northern imports. We think that this is significant, because thee Single Grave culture is generally seen as a tradition that has strong links with the north and the east, but much less with the south. In the Netherlands the distribution pattern of Single Grave burials and settlements is concentrated in the northern and central Netherlands. Only when one considers the complex of 1e, 1d and AOO beakers, a different distribution of sites occurs. These do occur in the south as well, as do the associated artefacts, most notably the GP-dagger (Wentink in prep., Fokkens 2012a). Even though the exact chronological position of these beaker types is still problematic (cf. Beckerman 2015), in general the AOO type marks the cross-over to the Bell Beaker type. This is substantiated by the fact that in other regions where the Bell Beaker tradition has developed, but Single Grave Culture remains are absent, the AOO beaker is present as well. This for instance is the case in the UK and in France (Salanova 2000; Lemercier 2012). This transition is positioned between 2600 and 2400 cal BC by most researchers (cf. Furholt 2003; Beckerman 2012).

If we now consider the Twello burial again, we see that the southern origin of the flint knife and the stone axe fits in the development of networks with the south. The people who buried the person at Twello probably had access to Grand Pressigny flint as well. However, they chose an object of different origin, but from equally far away. We can speculate

Figure 16 Excavation plan showing all medieval features (grey) and the Late Neolithic burial (black)

about the meaning of this observation. Drenth (1990) has suggested that knives of non-GP flint were (poorer) imitations of the original and their owners therefore of lesser status, but in our view there is too little evidence to support his case. Moreover, the theoretical basis for statements of that kind on the basis of burial data alone, is under discussion.

The flint knife or blade is interesting for another reasons as well. Micro-wear analysis shows that it was intensively used for cutting organic materials, probably bark (section 3.6.1). No signs of hafting were observed. This is in contrast with GP-knives, that generally show no use-wear other than from sliding the knives out and in a sheath of organic material and generally show traces of hafting (Van Gijn 2010, 143). Therefore, even though there are some formal similarity similarities between GP-knives and the Twello knife, they may belong to different functional categories of tools altogether.

The beaker and its contents offer food for thought as well. A typological or typochronological discussion is rather uninteresting given the fact that beaker types cannot be dated very precisely (cf. Beckerman 2012, 2015). Much more interesting are its contents and the conclusion drawn from it (section 3.6.2.). Residue analysis has shown the presence of animal fats on the outside of the beaker, whereas pollen analysis shows a residue containing grain pollen. The inside remains appear to contrast with the outside residue. Unless the residue is functional, and implies that the beaker was sealed with animal fat. That is an interesting suggestion that may need more research. Lipid analysis is still one of those scientific methods that may need more discussion as to what the meaning is of the residues found. The Twello Beaker is an interesting point in case.

5.2 The burial mound in context

The site location of urnfields near existing burial monuments is a common phenomenon in the Low Countries (*e.g.* Fontijn 1996; Theunissen 1999, 102-103; Gerritsen 2003, 140-145; Fokkens 2012b).

These studies demonstrate that reuse of barrow of urnfield sites was a common and diverse practice, and that both ‘positive’ and ‘negative’ forms of appraisal occur. The main trends have recently been discussed by Van Beek and De Mulder (2014). It is clear that people were aware of these burial mounds as monuments for past ancestors, even if these may have been very distant (Fokkens 2012b). At Twello, it appears that in the Early Iron Age a deliberate link was created with the Late Neolithic barrow, which – more than 1,500 years after the erection of the monument – must have been ‘mythical’ rather than based on actual knowledge on the persons who were buried there. The Late Neolithic barrow became the central, and probably most conspicuous, monument of the cemetery.

That fact that evidence for later use of the cemetery for funerary purposes is absent might be due to a habitation hiatus (part of the Middle/Late Iron Age). However, in the Roman Period a settlement was situated c. 700 meters north of the urnfield. Yet, no Roman Period burials or other features have been found in the urnfield, although numerous Dutch and Belgian sites have produced evidence for Roman-period reuse of barrows and urnfields (*e.g.* Roymans 1995; Hiddink 2003, 45-52; Van Beek and De Mulder 2014). These practices generally include the erection of new burial monuments near existing ones. Such features would certainly have been found during the excavation, especially because Roman-period burials in this region generally contain pottery and other grave goods. This means that the inhabitants of the Roman Period settlement did not use the Twello urnfield. If this was a conscious decision is hard to tell, but it seems unlike that the inhabitants were unaware of the presence of the old prehistoric cemetery nearby.

The Merovingian period is the last phase to produce irrefutable evidence for a positive appraisal of late prehistoric monuments in the Low Countries (Van Beek and De Mulder 2014). The small number of early medieval pottery finds at Twello demonstrate some activity at the burial site, the character of which cannot be determined. The Late Neolithic barrow was spared when a ditch system was dug in the High Middle Ages. Whether this happened for practical reasons or because the inhabitants perceived it as a meaningful place is unclear. The same ditch and some of the other features do cut various urnfield-period ditches. This demonstrates that these monuments, which probably were less monumental than their predecessor, either had disappeared at an earlier stage or were levelled deliberately.

The High and Late Middle Ages are a period of drastic reorganisation of the landscape. Various farmsteads were founded in the wider study area, which are generally situated at the lower slopes of sand ridges (Willemse *et al*. 2008). The higher parts of the landscape were reclaimed and used as arable land. The construction of the second ditch system, possibly around the 14^{th} or 15^{th} century, marks a complete restructuring of the area for the purpose of agricultural intensification. All prehistoric relics that had survived until then were probably levelled to this end.

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The Agro Pontino region, refuge after the Early Bronze Age Avellino eruption of Mount Vesuvius, Italy?

Corrie Bakels, Jan Sevink, Wim Kuijper and Hans Kamermans

In recent years it was discovered that the Middle to Late Holocene infill of the Agro Pontino graben (Central Italy) held a tephra layer originating from the Avellino eruption of the Vesuvius volcano. The eruption is dated to 1995 ± 10 calBC and took therefore place during the Early Bronze Age. This was a violent eruption, covering large parts of Campania, the region in which the volcano is situated, with its ashes. The local population had time to flee, but did not return for a period of hundreds of years. One of the possibilities is that people fled to the quiet Agro Pontino, at a distance of 120 km, to settle.

The fact that the low-lying parts of the graben hold wet, organic deposits of the appropriate age, containing the Avellino tephra layer, provided an opportunity to assess whether an influx of new inhabitants is discernable directly after the Avellino event, as a substantial number of newcomers might be detected by an intensification of anthropogenous stress on the environment. The question is tackled by means of pollen analysis, plant macro-remains, malacology and a small excavation.

The outcome of these investigations shows that some impact on the environment is visible, but that it is far from clear whether this effect is due to people from abroad or due to an increase of the local population.

1 Introduction

In recent years, the Agro Pontino graben (Southern Lazio, Central Italy) was shown to hold an important Middle to Late Holocene geo-archive, which offers major possibilities for retrieving detailed information on the history of the vegetation and human occupation over that period (*e.g.* Van Joolen 2003; Eisner and Kamermans 2004; Sevink *et al*. 2011; Feiken *et al*. 2012). Crucial for our present research was the discovery by Sevink *et al*. (2011) that sediments in the low-lying central part of the Pontine plain hold the Early Bronze Age Avellino pumice layer (AV layer) originating from an eruption of the Monte Somma/Vesuvius volcano and dated with great precision to 1995 ± 10 calBC (fig. 1). This eruption was much heavier than the well-known eruption that covered Pompeii with its ashes.

The AV layer is intercalated in a lacustrine sequence, deposited in a shallow lake (fig. 2). To the northwest this lake graded into a river delta and further upstream into a riverine plain with levees (Sevink *et al*. 2013; Feiken 2014). The lake came into full existence around 2000 calBC and its border zone is known to hold Bronze Age archaeological sites, such as Tratturo Caniò (Feiken *et al*. 2012) and Campo Inferiore (Sevink *et al*. 2011). Peaty deposits at its edges reveal traces of repeated burning of the local carr, interpreted as anthropogenous. Later on, during the Iron Age and subsequent Roman Period, the lake gradually shrank to a poorly drained, prevalently marshy area in the northeast of the graben, a situation that more or less persisted until the reclamation of the area in the 20th century (Feiken 2014).

The study presented here was triggered by publications on the impact of the Avellino eruption on Early and Middle Bronze Age human population in Campania (southern Italy), especially the 2013 publication by Di Lorenzo *et al*.. To cite them: "The Pomici di Avellino eruption had a very strong impact on a large area, striking both the Campanian Plain and the surrounding Apennine Mountains… A careful reappraisal of the reports regarding the Early and Middle Bronze Age sites, evidenced a protracted period of depopulation of the area affected by the by-products of the eruption… A complete reoccupation of the area occurred at the end of the Middle Bronze Age, about five centuries after the eruption."

The population is not reported to have perished. People must have fled to other areas, to resettle there and remain there for a long period. Where could they have fled to? Northwards, as far as the Agro Pontino, about 120 km away? The Agro Pontino is reported to have been not very densely populated at that time (Kamermans 1993; Van Joolen 2003; Alessandri 2009) and may have provided a refuge. If so, a substantial influx of newcomers, essentially farmers, should have had an impact on its vegetation.

The various Holocene deposits were studied in the past more than once, but recent research has led to the conclusion that their radiocarbon datings are not reliable (Sevink *et al*. 2013) and that earlier hypotheses on the vegetation and prehistoric land use of the Agro Pontino were fraught with errors due to the poor time frame (Van Joolen 2003; Eisner and Kamermans 2004). This prompted the palaeoecological study of new sections. Moreover, the well-dated AV-layer had not been noticed in earlier studies, and looking for it in

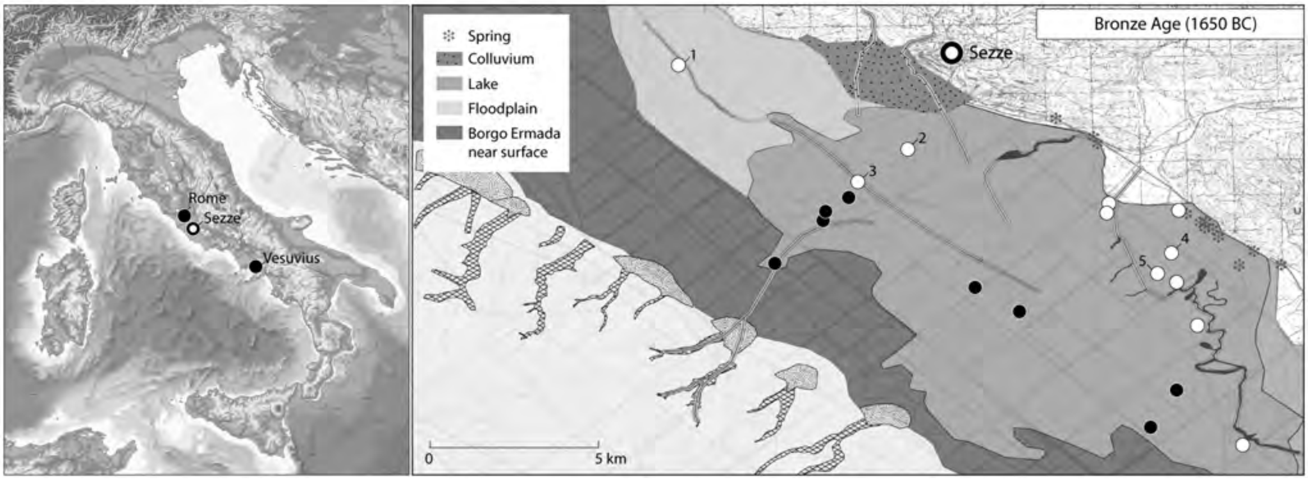

Figure 1a and b. The situation of the Agro Pontino and Mount Vesuvius (a); the lake (situation 1650 BC) with indication of the places mentioned in the text (b). Paleogeography after Feiken 2014. White dots: AV ash in lacustrine deposits, black dots: AV ash in black clays/marsh. Tratturo Caniò 1, Campo Inferiore 2, Ricci 3, Mezzaluna3 4, Mezzaluna cored by Eisner and Kamermans 5

Figure 2. The section Mezzaluna 3 with the layer of AV ash embedded in the whitish lake marl. Photo J. Sevink

suitable new sections was also an important aim of the recent work.

In this paper, results are reported for two new sites in the Agro Pontino graben holding the AV-layer: Ricci and Mezzaluna.

2 Material and methods

2.1 general

The distribution of the AV ash in the central and southern extension of the lake and the characteristics of the sedimentary sequences in which this layer occurs was checked by systematic coring, using as background the distribution of Holocene peats and of clays that form part of the Terracina complex (Holocene marine/lagoonal deposits) as indicated on the soil map by Sevink *et al*. (1984). Observations were made through coring by hand (to about 5 m depth) and by observations in all pits and trenches that were found during regular visits to the area over the past years. Relevant sections were described and sampled for palaeoecological study and identification of volcanic ash layers. Two main facies types can be distinguished: a) calcareous and more or less peaty lacustrine deposits formed under aerobic conditions in open water, and b) pyritic black clays formed under anaerobic marshy conditions. The latter type of deposits prevail in the south-western extension of the lake, where the Holocene deposits are generally thin (less than 1 m mostly) and rest on Pleistocene clays of the Borgo Ermada complex (see Sevink *et al*. 1984). The AV-layer is the only distinct ash layer encountered in the Holocene deposits. It is a nearly continuous layer about 1-2 cm thick, which invariably has a rather light yellow to grey colour and contains macroscopically identifiable millimetre-size dark biotite and sanidine crystals. A full description of its composition is given in Sevink *et al*. (2011).

This work led to the selection of two sections for a more detailed study: a section in a very large and deep temporary pit, dug for the construction of an irrigation water reservoir and called Ricci after the owner of the land, and a new section in the area where previously important palynological work had been carried out, *e.g.* Mezzaluna (Eisner and Kamermans 2004). This new section is called Mezzaluna 3. The identification of ash layers encountered as the AV-layer was based on the known tephrochronology of Central Italy and on the habitus and mineralogical composition of the tephra. The vegetation before and after ash deposition was studied by means of pollen analysis, botanical macro-remains analysis and malacology. AMS dating of material of terrestrial origin provided reliable dates in addition to the date provided by the ash. For the Ricci pit, an archaeological study was carried out, following the discovery of Bronze Age artefacts in this pit.

2.2 Ricci

At Ricci an 83 cm thick layer of peat was exposed beneath a 203 cm thick deposit of reddish-brown loams with a coarser textured core, representing a filled-in river bed and associated levees. These loams consist of eroded soil material that has largely retained the colour and (micro)structure of the mountain soils from which it originates, and are ascribed to man-induced soil erosion starting in the Late Bronze Age to Early Iron Age (Sevink *et al*. 1984; Van Joolen 2003; Feiken 2014). As regards the peat deposits below, these are in the transitional zone between the calcareous lacustrine deposits and pyritic black clays mentioned earlier and formed in the delta of a river that ran into the lake from the NW (NW of the pit) and adjacent truly lacustrine environment (SE of the pit). The AV ash was detected at a level 211 cm below the surface, that is just within the peat. The pit was sampled by cutting 1 cm thick samples directly from the SE section wall, neglecting the loam deposits on top and starting with the uppermost organic layer. An AMS date obtained from the depth of 248 cm below surface revealed an age of somewhere between 2471 and 2213 calBC, which is before the start of the Bronze Age (GrA-56801, 3885 ± 35 BP, *Schoenoplectus* seeds). Higher up, at 218 cm but still below the AV ash, an AMS date was obtained of 2131-1779 calBC (GrA-56630, 2600 ± 45 BP, *Alnus* seed and catkin). As the aim of the investigation was to study the Bronze Age, pollen analysis focused on the upper 50 cm of the peat.

Thirteen samples were selected for analysis. For the extraction of pollen the samples were treated with 10% KOH, HCl, Bromoform/Ethanol s.g. 2.0 and acetolysis. Before treatment, tablets with *Lycopodium* spores were added following the method Stockmarr (1971). The residue was mounted in glycerine-gelatine. After identification and counting, a pollen diagram was drawn using the TILIA and TILIAView programs (Grimm 2011). Identification was based on Beug (2004) for pollen and spores, and Van Geel (2001) and Van Geel *et al*. (2003) for non-pollen palynomorphs. Pollen identified as cereal pollen have diameters > 36 μm and an annulus as broad as the pore diameter with a sharp demarcation towards the pollen grain's surface (Grohne 1957).

The pollen sum is an upland (dryland) sum. All taxa that could have grown locally were excluded. As the peat was mainly alder carr peat it is obvious that *Alnus* and other trees growing in wetlands had to be excluded as well. The number of pollen and spores aimed at to include in the sum was 300, but in two cases this number was not reached. In addition to pollen etc., micro-charcoal was counted following the method for microscopic charcoal in pollen slides advised by Mooney and Tinner (2010/2011), which means counting only black, opaque, angular fragments of more than 10 μm length.

Detection of a gully in the top of the peat in the NW wall, filled with an organic deposit consisting of reworked peaty material, plant macro-remains, molluscs and other material led to sampling for this kind of material. The fill of the depression was sampled at four locations, total sample volume 11 litres, sieved with tap water on sieves with meshes up to 0.25 mm, and subsequently analysed.

During inspection of the large Ricci basin, not only palaeo-ecological samples were taken but also three ceramic fragments and one bone fragment were salvaged. One nearly complete vessel was found on the spoil heap resulting from the emptying of the gully mentioned earlier (fig. 3a). Two ceramic fragments and one bone were found in the section, directly below the AV layer, in the NW wall. The bone is a human bone. The finds led to a small excavation comprising two test pits, pits 1 and 2, 22 m^2 and 31 m^2 respectively next to the rim of the Ricci pit.

From test pit 1 no archaeological material was recovered. The AV layer was visible in the section and some tree branches were found, which did not look natural.

In test pit 2 a number of ceramic sherds were found (fig. 3b). Since the AV was not visible in this pit, the finds could not be related to this layer. Also in this pit was a layer with tree branches.

2.3 Mezzaluna

The sediment encountered at Mezzaluna is representative of the lacustrine deposits mentioned before. A freshly cleaned side of a small drainage channel provided an opportunity to take samples for pollen and mollusc analysis. Up to 67 cm below the surface samples could be taken directly from the section wall. Deeper samples were obtained by coring with a side-filling corer. At 111 cm below the surface coring was stopped by an impenetrable log. The upper 32 cm consisted of peat. Below this, a whitish lake marl stood out. The AV ash was visible as a 1 cm thick band at a depth of 63 cm below the surface (see fig. 2). The deposit of lake marl ended at 79 cm, to change into carr peat.

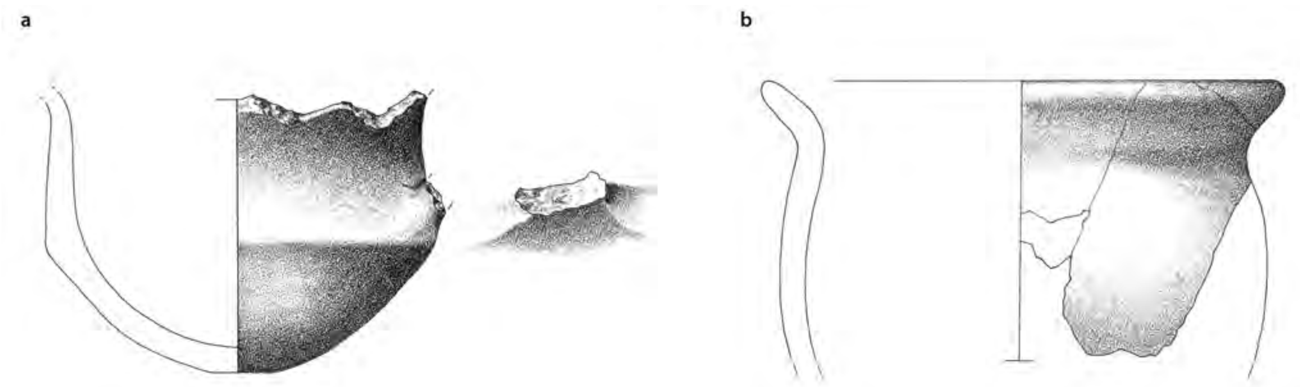

Figure 3. The ceramics found at Ricci. Max. diameter a 12 cm, b 14.5 cm; drawing C. Anastasia and R. Timmermans

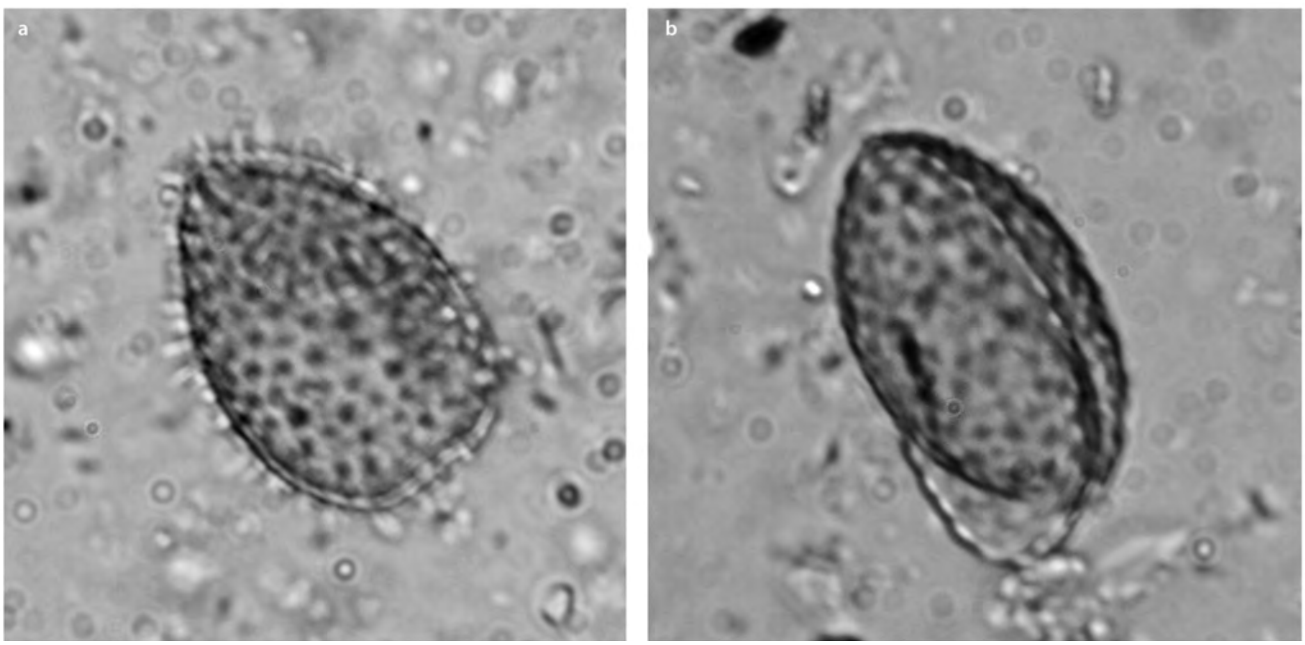

Figure 4. Non-pollen palynomorphs, left type a and right type b, photos C. Bakels

Section and core were cut up into slices of 1 cm thickness. Fourteen were selected for pollen analysis and treated in the way described before, though an adjustment was made to the content of the pollen sum: *Myrtus* was excluded because the pollen grains of this dryland shrub are so dominant in the lowest spectra that they distort the picture.

Two non-pollen palynomorphs, which turned up in rather important numbers, could not be ascribed to known NNP types (van Geel pers. comm.). Non-pollen palynomorph type a is brownish hyaline, oval, 35 by 25 μm and provided with 2 μm long spines. Type b is also brownish hyaline, oval, 25 by 20 μm but provided with scabrae (fig. 4).

To retrieve botanical macro-remains and molluscs samples were taken from the base of the upper peat layer (sample 1), the lake marl (samples 2-6) and the top of the underlying peat (sample 7). The sample volume amounted to two litres. After sieving with tap water on sieves with meshes up to 0.25 mm the residue was analysed with the use of a microscope.

3 Results

3.1 Ricci

Figure 5, table1 and table 2 present the results.
In figure 5 pollen, spores and non-pollen palynomorphs are depicted in percentages, charcoal in particles per cm^3. The diagram suggests three local pollen zones.

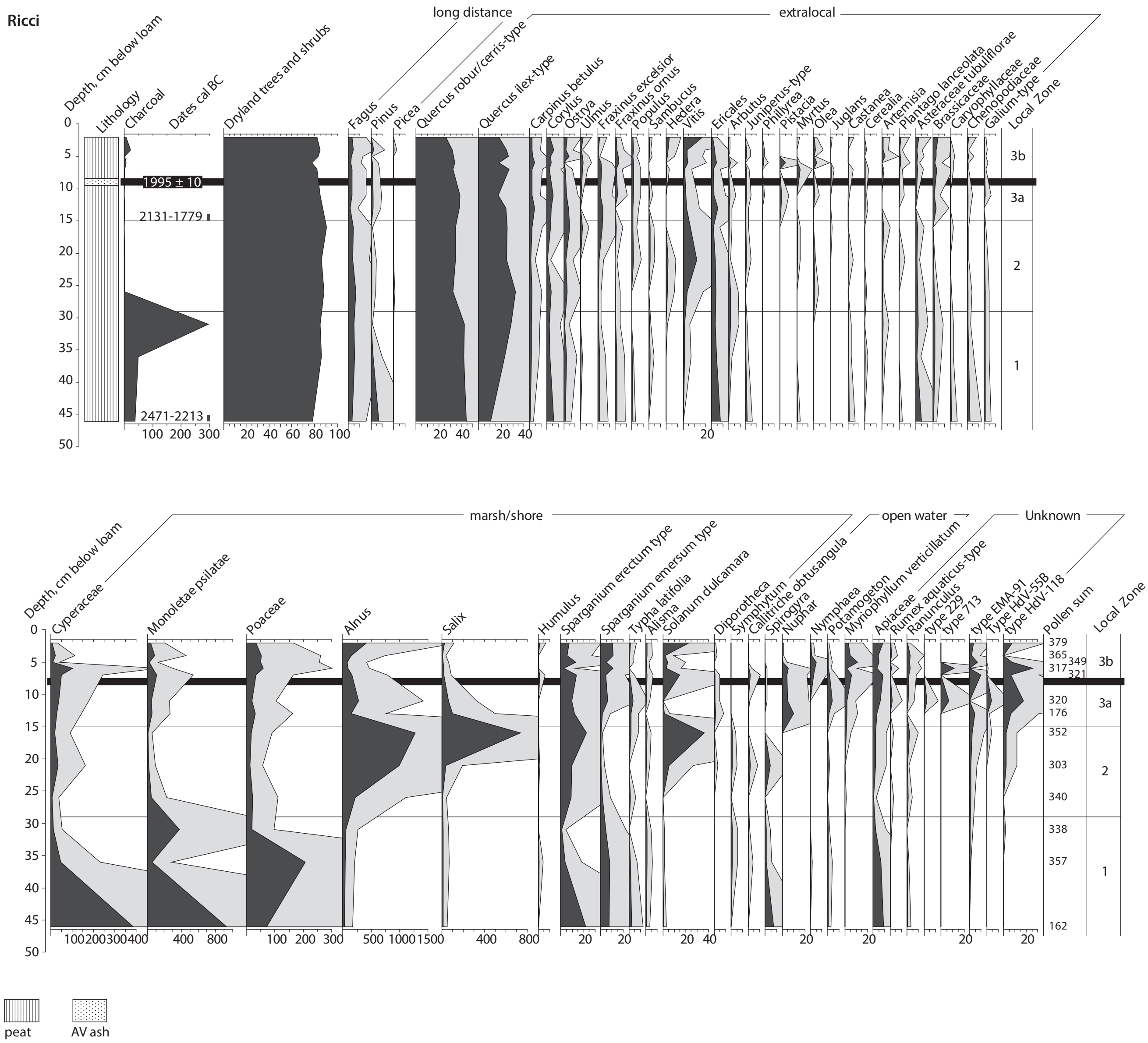

Figure 5. The Ricci pollen diagram, exaggeration of curves 5x in grey; the heavy horizontal line indicates the position of the AV ash

In *zone 1* dryland trees and shrubs are present with percentages between 75 and 80. Although it is difficult to estimate the cover of forest versus open land from this kind of data, the percentages allow the assumption that open spaces were present close to the lake (Sugita *et al*. 1999). Some trees are not supposed to have grown in the Agro Pontino area, because they belong to vegetation types in more elevated positions, *i.e.* mountains (*Fagus*, *Picea*), or in a coastal zone (*Pinus*) (Pignatti 1982). The vegetation in the area itself was dominated by oak species, deciduous and evergreen. Of the deciduous oaks both *Quercus robur*-type and *Quercus-cerris* type are present, but as part of the pollen could only be identified as *Quercus robur-cerris type*, these are taken together. The *Quercus cerris*-type also includes the evergreen cork oak *Quercus suber*. *Quercus ilex*-type stands for the evergreen oaks *Quercus ilex* and *Q. coccifera*. *Carpinus betulus*, two kinds of ash, *Fraxinus excelsior* and *Fraxinus ornus*, and *Corylus* are continuously present as well, as is chestnut, *Castanea*. Elements of secondary shrub vegetations show that the original landscape was already

Pollen and NPP not in diagram	Ricci	Mezzaluna 3
Trees		
Acer	21=0.3	35=1.0; 50=0.3; 90=0.3; 100=0.4
Betula	2=0.3; 4=0.3; 6=0.3; 7=0.3; 11=0.3; 13=0.6; 36=0.3	40=0.5; 55=0.4; 65=0.9; 85=0.4; 100=0.4
Buxus	11=0.3	
Celtis	4=0.3;13=0.6	50=0.3; 60=0.6;
Cornus sanguinea	7=0.3;11=2.2	
Malus-type	11=0.6	90=0.6; 100=0.4; 110=0.9
Platanus	11=0.6	
Sambucus	in diagram	40=0.3; 90=0.3
Sorbus-type	6=0.3	
Tilia		35=1.0
Shrubs		
Cistus salvifolius/monspelianus		65=0.3
Genista-type	2=0.3;31=0.3	
Hippophae		55=0.2
Rhamnus	2=0.5; 6=0.6 ;7=0.9; 11=0.6; 16=0.6; 21=3.6; 31=0.6	35=0.3; 45=0.3; 55=0.2; 85=0.8; 90=0.6; 110=1.7
Tamus	5=0.3; 7=0.6	
Viburnum	31=0.3	90=0.6
Upland herbs		
Asteraceae liguliflorae	2=0.8; 7=0.6; 13=0.6; 21=0.3; 36=0.8	in diagram
Asteraceae tubuliflorae	in diagram	40=1.6; 50=0.3; 60=0.6; 65=0.6; 90=0.3; 100=0.4
Gagea-type		74=0.3
Galeopsis/Ballota	4=0.6	
Galium-type	in diagram	45=0.3; 50=0.3; 90=0.6; 100=0.4
Hedysarum		60=0.3
Helianthemum nummularium		90=0.3
Hypericum perforatum	4=0.3; 11=0.3; 16=0.3	45=0.5; 50=0.3
Lamium-type	7=1.9; 16=0.9	
Lithospermum arvense	36=0.3	
Lygeum	21=0.3	
Plantago major/media-type	4=0.6; 7=0.6; 16=0.6;	40=0.3; 45=0.3; 80=0.3
Polycarpon	31=0.6	
Polycnemum	11=0.3	45=0.5
Polygonum aviculare	2=0.3; 11=0.3; 31=0,3; 36=0.6; 46=0.6	80=1.0; 90=0.6
Polypodium	21=0.7; 31=0.6; 36=0.6	
Prunella-type	2=0.3	
Rumex acetosa-type		45=0.3; 70=0.3
Salvia officinalis-type	5=0.3	
Scabiosa		74=0.7
Spergularia	2=1.3; 7=0.6	in diagram
Trifolium	5=0.3	40=0.3; 90=0.3; 100=0.7

Pollen and NPP not in diagram	Ricci	Mezzaluna 3
Vicia	5=0.3; 11=0.9	
Viola		55=0.2
Wetland herbs		
Butomus	4=0.6; 31=3.0; 36=0.3	
Caltha-type	7=0.6; 21=1.3; 31=0.3; 36=0.8	60=0.3
Cladium	2=0.3; 4=0.6; 5=0.6	
Filipendula	4=0.3; 6=0.6; 11=0.6; 46=0.6	35=0.3; 50=1.6; 70=0.5; 80=0.3
Lysimachia	2=0.3; 6=0.6; 7=0.9; 16=1.7; 21=1.3; 31=0.6; 36=0.3	40=0.5; 100=0.4
Valeriana officinalis	5=0.3	100=0.4
Aquatic herbs and algae		
Elatine	16=0.3	
Lemna	36=0.6	85=0.4
Myriophyllum spicatum	2=0.6; 5=0.3; 13=0.6; 16=0.3; 31=0.6	45=0.3; 50=0.5; 55=0.4; 60=0.3; 70=0.5
Nuphar		45=0.3; 80=0.6; 85=0.4
Nymphaea		35=0.4; 55=0.2; 60=0.6; 65=0.3; 90=0.3
Mougeotia	46=3.7	45=1.1; 50=0.5; 55=0.2; 80=0.3
Pediastrum		65=0.3; 74=1.0
Zygnema	6=1.0; 46=0.6	55=0.4
Unknown		
Cyperus		55=0.3; 90=0.6
Iris		85=0.4
Lotus	46=0.6	
Lythrum-Peplis	2=0.5; 5=0.3; 6=0.3; 7=1.3; 26=0.3	
Mentha-type	5=0.3; 6=0.3; 7=0.3; 13=0.6; 16=0.6	
Persicaria maculosa-type	21=0.3; 26=0.6	80=0.3
Scrophularia	31=0.6	
Stachys-type	11=0.3; 36=0.6	40=0.3
Urtica	2=0.3; 7=0.3; 11=0.3; 16=0.3	
Veronica	2=03; 7=0.3	40=0.3
Tetraedron		40=0.8; 45=0.5; 55=0.9; 65=0.3
HDV 55B	6=0.3; 11=4.1; 13=0.6; 16=0.9	
HDV 229	11=2.5	40=0.8; 45=0.3
HDV 501	21=2.3; 26=13.2; 36=0.3; 46=8.0	
HDV 713	6=11.7; 11=6.6	

Table 1. Pollen, spores and non-pollen palynomorphs not depicted in figures 5 and 6; depth=percentage

	Ricci				Mezzaluna 3				
					40 cm	55 cm	ash	65 cm	75 cm
sample size, litres	5	2	2	2	2	2	2	2	2
molluscs freshwater species									
running water									
Theodoxus fluviatilis	xxx	xx	xx	xx	-	-	-	-	-
Theodoxus fluviatilis - operculum	x	x	-	x	-	-	-	-	-
Viviparus contectus	x	x	1	1	-	-	-	-	-
Belgrandia latina	xxx	xx	xx	xxx	-	-	-	-	-
Pseudamnicola moussonii	xxxx	xxx	xxx	xx	-	-	-	-	-
Ancylus fluviatilis	x	-	-	x	-	-	-	-	-
Pisidium amnicum - valve	xx & x d	x &x d	x & x d	x	-	-	-	-	-
running and stagnant water									
Bithynia tentaculata	xxxx	xxx	xxx	xxxx	x	x	1	x	x
Bithynia tentaculata - operculum	xxxx	xxx	xxx	xxxx	x	x	x	x	x
Valvata piscinalis	xxx	xxx	xxx	xxxx	-	-	-	-	-
stagnant water (plant rich)									
Valvata cristata	x	x	x	xx	-	-	-	-	-
Bithynia leachiii	x	xx	xx	xx	xxx	xx	xx	xxx	xxx
Bithynia leachii - operculum	x	xx	xx	xx	xx	xx	xx	xx	xx
Acroloxus lacustris	xx	xx	xx	xx	2	-	-	1	2
Lymnaea stagnalis	x	x	x	x	-	-	-	-	-
Radix auricularia	x	x	2	x	-	-	-	-	-
Radix ovata	1	-	-	x	x	x	x	x	x
Stagnicola palustris s.l.	x	x	x	x	1	-	-	-	-
Gyraulus crista	xx	xx	1	xx	x	x	x	x	xx
Planorbis planorbis	x	x	x	x	-	-	-	-	-
Bathyomphalus contortus	-	-	3	-	-	-	-	-	-
Hippeutis complanatus	-	-	1	-	1	-	-	2	1
Unio sp. / Anodonta sp. - valve	xx	x & x d	1	2 d	-	-	-	-	-
Pisidium sp. - valve	xx & x d	xx & xx d	xx & xx d	xx	-	-	-	-	-
molluscs land species					-	-	-	-	-
Carychium minimum	-	1	-	-	-	-	-	-	-
Oxyloma sp.	x	x	1	x	-	-	-	-	-
Vertigo antivertigo	-	-	1	-	-	-	-	-	-
other animal remains									
bone fragment	x	x	-	x	-	-	-	-	-
Arvicola terrestris, jaw	-	-	1	-	-	-	-	-	-
fish remains	x	x	-	x	-	-	-	-	-
Ostracoda	x	xxx	x	x	-	-	-	-	1
insects	x	x	x	-	-	-	-	-	-

	Ricci				**Mezzaluna 3**				
					40 cm	**55 cm**	**ash**	**65 cm**	**75 cm**
plant remains									
charcoal fragments	x	x	x	x	-	-	-	-	-
wood remains, twigs, rootlets	x	x	x	x	-	-	-	-	-
cultivated									
Ficus carica	2	2	x	-	-	-	-	-	-
trees, shrubs, dryland herbs									
Alnus glutinosa - seed	x	1	x	x	-	-	-	-	-
Alnus glutinosa - catkin, bud	x	x	1	x	-	-	-	-	-
Vitis sylvestris	x	1	x	-	-	-	-	-	-
Cornus sanguinea	x	2	x	-	-	-	-	-	-
Rubus fruticosus	x	8	x	x	-	-	-	-	-
Solanum nigrum	-	-	-	-	-	-	1	-	-
herbs from marshes									
Carex sp.	1	5	x	1	-	-	-	-	-
Cladium mariscus	x	xxx	xxx	xxx	1	-	1	-	-
Sparganium erectum	x	20	x	x	-	-	-	-	-
Schoenoplectus tabernaemontani	x	3	2	1	-	-	-	-	-
Typha sp.	x	-	1	-	-	-	-	-	-
Lycopus europaeus	-	-	1	1	-	-	-	-	-
Mentha sp.	x	1	x	x	-	-	-	-	-
Solanum dulcamara	1	1	1	1	-	-	-	-	-
Stachys palustris	1	2	1	-	-	-	-	-	-
Eupatorium cannabinum	1	4	x	-	-	-	-	-	-
cf Sium latifolium	2	-	-	-	-	-	-	-	-
Berula erecta	1	-	-	-	-	-	-	-	-
Lamiacea	1	-	-	-	-	-	-	-	-
Apiaceae	-	-	x	-	-	-	-	-	-
cf Persicaria maculosa/minus	2	10	x	-	-	-	-	-	-
aquatic plants									
Ceratophyllum demersum	x	4	x	1	-	-	-	-	-
Chara sp.- oögonium	-	-	-	-	xx	xxx	xx	xxx	xxx
Chara sp. - stemfragment	-	-	-	-	xxx	xxxx	xxx	xxxx	xxxx
Myriophyllum sp.	-	1	-	-	-	-	-	-	-
Nuphar lutea	2	1	1	1	-	-	-	-	-
Nymphaea alba	x	2	x	2	-	-	-	-	-
Potamogeton cf coloratus	x	5	x	x	-	-	-	-	-

Table 2. The molluscs and botanical macro-remains found at Ricci and Mezzaluna 3; x = some, xx = tens, xxx = hundreds, xxxx = thousands, d = doublet

disturbed. Ericales (*Erica* sp.), *Arbutus*, *Juniperus*-type (including *Juniperus* and *Cupressus*) and *Myrtus* belong to this category. *Artemisia*, *Plantago lanceolata* and Cerealia attest to open space. The latter are supposed to represent cultivated cereals, though certain wild grasses release the same kind of pollen. Such grasses mainly grow in dune areas and such areas are present west of the Agro Pontino, but as other elements of coastal vegetation are not very obvious in the pollen record, an explanation of cereal-type pollen as shed by cereals is considered most likely. The local vegetation in the lake at the place of sampling is a marsh vegetation of first Cyperaceae (sedges), Monoletae psilatae (ferns), *Sparganium* species, *Typha latifolia* and *Alisma*, followed by Poaceae (grasses including reed) and *Symphytum*. Open water is hardly present. The alga *Spirogyra* can grow in very shallow water. Charcoal is continuously present.

Local *zone 2* shows a slight decline in the group of tall oaks (deciduous and cork oaks), an initial rise in *Quercus ilex*-type oaks followed by a decline, and an increase in the percentages of other taxa such as *Populus*, *Fraxinus* species and the lianas *Hedera* (ivy) and *Vitis* (vine). This is an indication that the dryland oak forests suffered a decline. More light offers lianas better chances of flowering. Pollen does not provide a clue whether the vine was wild or cultivated, but pips discovered amongst the macro-remains in the uppermost part of zone 3 are of the wild type (see below). The same question, cultivated or not, is raised by *Olea* (olive) and *Juglans* (walnut), which appear in this zone. These trees belong to the OJC group, *Olea*, *Juglans*, *Castanea* (chestnut), which at present are all considered indigenous in Italy, but are also known to include cultivated varieties (Mercuri *et al*. 2013). *Castanea* is already present during zone 1. It is questionable whether the low pollen percentages represent cultivation. But the curves of the OJC group tend to rise everywhere in Italy from the Bronze Age onwards and it is quite possible that part of the Ricci pollen has an origin in human cultures.

The vegetation in this part of the lake develops into an *Alnus* (alder) carr, which in its turn is followed by *Salix*. Usually *Alnus* carr is the last stage of the natural succession. Therefore, something must have happened here, either in a natural way or induced by human action, but as there are no indications of a natural cause in this phase of the history of the lake, such as a change in water level, an anthropogenous trigger is the most likely explanation. The alder carr disappeared to make way for a marsh with not only *Salix*, but also *Sparganium*, *Typha latifolia* and a locally abundant growth of *Solanum dulcamara*. Together with *Solanum dulcamara* the non-pollen palynomorph *Diporotheca* appears. It has been suggested that *Diporotheca* is a parasite on *Solanum dulcamara* (Hillbrand *et al*. 2012), a suggestion supported by the Ricci diagram.

Zone 3 shows even more disturbance in the upland part of the diagram. *Phillyrea* and *Pistacia* appear and *Myrtus* has an optimum. In the wet basin all tree and shrub vegetation has vanished. The *Alnus* pollen percentages are considered to have come from stands further away. The lake is now filled with open water in which *Nuphar*, *Nymphaea* and *Myriophyllum* flourished. This zone started somewhere after 2131 calBC, but before the deposition of the AV ash dated to 1995 ± 10 calBC. The AV ash appears halfway. The pollen record offers no reason to draw another zonation line at the depth of the ash, which implies that no large-scale changes are observed. The only substantial changes are shown by the curves of *Hedera*, *Vitis*, *Olea*, *Artemisia*, *Plantago lanceolata* and charcoal. Charcoal was almost absent during zone 2 and the pre-AV part of zone 3. An increase in human activity is indicated, either in the entire area around the lake, or only locally as a result of an intensification of activities near the Ricci pit. But there is no question of a striking difference due to a large-scale influx of new people after the eruption. The most important change in the landscape is the disappearance of the carr some time before the AV event.

The results of the macro-botanical analysis match those obtained by pollen analysis. Some taxa that were not indicated by their pollen are identified with more precision, such as the Apiaceae cf. *Sium latifolium* and *Berula erecta*. The *Vitis* pips mentioned earlier display the diagnostic features commonly associated with wild grapevine (Jacquat and Martinoli 1999) and may, therefore, be classified as wild, though there is an overlap between the identification criteria of wild and cultivated vine.

The samples from the gully in the top of the peat were remarkably rich in molluscs. It is clear that we are dealing with a freshwater fauna. Of the 21 species five are restricted to running water. Two species deserve special attention. *Pseudamnicola moussonii* is widespread throughout Italy, mainly in its western and southern regions, including Sicily and Sardinia. The mollusc prefers streams and rivers (www.iucnredlist.org). *Belgrandia latina* is endemic to Italy, and only found at some locations in the Apennines region of Lazio. This small spring-snail lives in deeper freshwater lakes and their tributary streams and outflows fed by spring water (www.iucnredlist.org). The mollusc is especially characteristic of situations of calcareous upwelling water.

Three other species are also characteristic of running water. Some other animals, such as *Bithynia tentaculata* and *Valvata piscinalis* (both with large numbers) occur both in flowing and standing water. The others indicate the presence of marshy shorelines. Regular fluctuations in the water level are not indicated.

Only three species of land snails were found. These animals live under wet conditions. In this case, they point to the presence of a marshy riparian zone along the water.

Together with the shells some pieces of bone, a molar of the watervole *Arvicola terrestris*, pieces of fish (tooth, vertebra, scale), insect fragments and, in larger numbers, ostracods valves were retrieved.

The dating of the archaeological finds was problematic. One of the main problems of Bronze Age studies in Central Italy is the absence of an absolute chronological framework (Van Rossenberg 2012, 9). There are many radiocarbon dates available for the Copper Age, the Middle Bronze Age (MBA) and later periods, but especially for the Early Bronze Age (EBA) absolute dates are scarce (Van Rossenberg 2012, 67). The dates that are available from EBA sites in Central Italy do not fit in the traditional EBA range (see Pacciarelli 2000, 68; Feiken *et al*. 2012, 115; van Rossenberg 2012, 9) and are considered anomalies but Van Rossenberg (2012, 67-72) is questioning this explanation.

So far the only absolute dates for the EBA we have in the Agro Pontino are for the ash layer from the Avellino eruption dating from 1995 ± 10 calBC established by ^{14}C dates from over and underlying organic materials (Sevink *et al*. 2011), and ^{14}C dates from Tratturo Caniò (Feiken *et al*. 2012) and Ricci.

The vessel from the gully could be dated on typological grounds as EBA II or MBA I (Pacciarelli 2000). The typological dating is problematic because both the rim and the handle of the vessel are missing. The vessel seems comparable to objects in Pacciarelli figure 9, C 7-10 (Pacciarelli 2000, 26), facies di Palma Campania and figure 11, C 4 (Pacciarelli 2000, 29), facies protoappenninico 1. The facies Palma Campania dates from 2100/2000 – *c*.1800 calBC and the facies protoappenninico from *c*. 1800 - 1550/1500 (Pacciarelli 2000, 68). The two other ceramic fragments from the water reservoir were dated typologically as EBA II.

Since the AV layer is dated to 1995 ± 10 calBC (Sevink *et al*. 2011) and the EBA II is dated by Pacciarelli (2000, 68) from 2100/2000 – *c*.1700 calBC, the two ceramic fragments must have a date between 2100/2000 and 1995 calBC.

Wood fragments from inside the vessel give a ^{14}C date of 1882 – 1681 calBC (GrA-51750). This date could be used as a terminus ante quem, and the vessel must thus be older than 1681 calBC. This would mean EBA II (2100/2000 – 1700) or MBA I (1700 – 1550/1500). We do not know the original position of the vessel compared to the AV layer.

The ceramic fragments from test pit 2 do not have any diagnostic features and could be roughly dated to the Bronze Age or the Middle Bronze Age.

The finds at Ricci prove that the site was used in the EBA II and/or MBA I. The human bone and the (almost) complete vessel suggest a burial or at least a funeral rite. However, this was not confirmed by finds from the test pits.

The not very precise date makes it impossible that these finds play a significant role in the discussion of the mass migration as a consequence of the Avellino eruption. All we can say for certain is that the site was in use before the eruption (the two ceramic fragments from the water reservoir come from below the AV layer), but the site could also have been used after the eruption (the vessel from the reservoir and the ceramic fragments from the test pits date on typological grounds to EBA II or MBA I). That could be shortly after the eruption or hundreds of years later.

3.2 Mezzaluna

The vegetation history told by the Mezzaluna section resembles that of the Ricci section (fig. 6, table 1 and table 2). Its lowest pollen zone corresponds with Ricci zone 2. Both deciduous and evergreen *Quercus* species are dominant in the area, whilst *Ulmus*, two kinds of *Fraxinus*, *Hedera* and *Vitis* are present as well. The OJC complex is present in low percentages. The end of this zone is expressed in the dryland by a rise in pollen percentages of *Ostrya* and a decline in *Ulmus* and *Vitis*, but more striking is the decline in wetland trees, *Alnus* followed by *Salix*. The end of zone 2 is also the end of carr peat formation. Striking too is the disappearance of *Solanum dulcamara* and *Diporotheca*.

Local *zone 3* represents a clear freshwater lake with, amongst others, *Callitriche obtusangula* and *Utricularia*. The deposit in this lake changed into an almost white lake marl, revealing also many needles of freshwater sponges and oögonia of *Chara*. The AV layer is situated halfway.

If an influx of new people had affected the environment on a large scale, it should be visible in the lake marl part of the diagram. However, dramatic changes are absent, except for a strong rise in the non-pollen palynomorphs type a and type b, and a rise in charcoal. *Alnus* pollen percentages decline, but these values were already declining in the pre-AV stage. In the dryland, tall *Quercus* declines and *Olea* and Cerealia are more important than before. The trend in the curve of tall oak is different from what is observed in the Ricci case where those trees show a decline that started already before the AV event. Only the curves of *Olea* and charcoal show trends matching those seen in Ricci.

The peaty samples did not present identifiable plant macro-remains. In the lake marl the most abundant taxon is *Chara* sp. found as oögonia (macrospores) and marl encrusted stems. Luxurious *Chara* growth is characteristic of clear fresh water rich in chalk and its appearance tallies with the presence of lake marl. The other plant remains identified are from *Cladium mariscus* and *Solanum nigrum*.

The peat revealed no molluscs and the fauna of the lake marl is remarkably low in species. Seven species were found, including three with only some individuals. The others (mainly *Bithynia leachii*) were found with higher numbers.

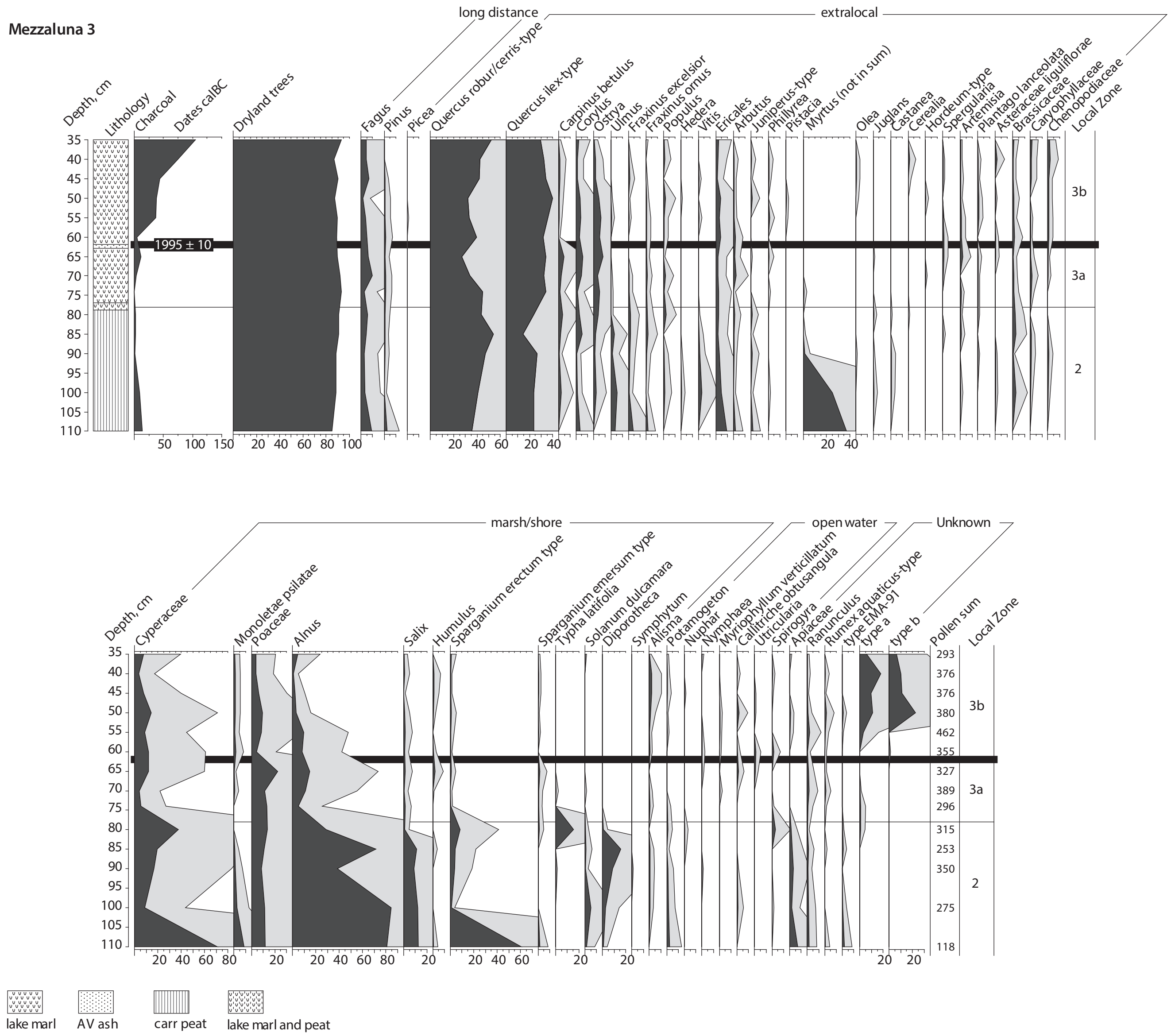

Figure 6. The Mezzaluna 3 pollen diagram, exaggeration of curves 5x in grey; the heavy horizontal line indicates the position of the AV ash

The species live in fresh water and are distributed all over Europe. The fauna indicates shallow, but not drying up, stagnant water. The water was clear and well provided with vegetation.

The absence of other aquatic animals in the lake marl is striking. Only in sample 6 a valve of an ostracod was observed. Both plant remains and molluscs do not give an indication concerning changes in the environment before and after the AV event.

Taking the results from the Mezzaluna site together, the conclusion must be that traces of human influence are not very strong, but after the AV event there seems to have been a slight enhancement in human interference.

4 Discussion and conclusion

Both the Ricci and Mezzaluna pollen diagrams show that the landscape surrounding the lake was already disturbed by human activities before the deposition of the AV-tephra. In the dryland part of the landscape the original forest, dominated by oak, had already to some extent been replaced by secondary shrub vegetations. In the wetland bordering the lake human interference was of a serious character. The disappearance of the alder carr is held to be of anthropogenic origin, as there are no clues that natural causes such as a change in hydrological conditions may have been responsible. Everywhere the peat in the basin, mainly alder carr peat, shows traces of repeated burning (Feiken *et al*. 2012). Burnt patches were also present in the Ricci pit and a piece of charcoal embedded in such a patch was dated 2135 - 1912 calBC (GrA 56678). Throughout the former lake somewhere below the AV-layer, generally only a few decimetres, remains of trees in the form of logs and thick branches abound, commonly embedded in the peat below the lake marls. Exposures are generally too limited in size to allow for detailed observations on the spatial distribution of logs and their mode of origin, but at Campo Inferiore a series of large trenches was dug, exposing many large wood remains. Virtually all logs and thick branches were free of bark and smaller branches, and many had been shaped into squared timber, showing clear traces of working. Some were sharpened at one end. Because of these characteristics, it was concluded (Anastasia, unpublished report for the Soprintendenza; Sevink *et al*. 2011) that during the Early Bronze Age trees, mainly alder and willow, had most likely been felled on purpose and subsequently been worked. But for some unknown reason timber had been left on this site, which was in the marsh. The burning and logging has to be attributed to the Early Bronze Age inhabitants of sites bordering the lake, of which unfortunately only Tratturo Caniò is truly known so far (Feiken *et al*. 2012).

The conclusion is that the land surrounding the lake was inhabited by an Early Bronze Age population which is not yet well known, but which already had a significant impact on the natural environment before the Avellino eruption. Whether the land immediately bordering the lake was inhabited everywhere by Bronze Age farmers cannot be established on the basis of the current palaeoecological data only. However, it is very likely that the marshy stagnant southwestern margin of the graben was probably far less attractive than the northeastern one, a hypothesis that might be checked by future systematic coring of this ‘hidden landscape’. There may have been relatively empty space but, if many people from Campania had fled to the Agro Pontino graben and had started a new life there, the impact of this event should be visible both in pollen diagrams and in the archaeological record. Up to date, the latter does not provide any information. The pollen diagrams Ricci and Mezzaluna 3 show a slight increase in the indications of human interference with the landscape, but these may also be attributed to a natural increase of the indigenous population. Of a mass immigration of people coming from elsewhere, there is no trace. Either investigations are still too limited in scale and number, or the population from Campania found asylum elsewhere. The first possibility is certainly true and the second needs to be explored.

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‘Set in Stone’? Technical, socio-economic and symbolic considerations in the construction of the Cyclopean-style walls of the Late Bronze Age Citadel at Tiryns, Greece.

Ann Brysbaert

Western views about both human and material resource usage dominate how we tend to believe that these were employed in the past too. In particular, non-western communities, just as certain past societies, often do not see minerals and, therefore, stones as exploitable commodities or passive materials to be manipulated for pure economic or utilitarian reasons, as we most often do. Stones may carry deeply interwoven symbolic meanings linked to their ritual powers as well as their economic, material, social, cosmological, mythical, spiritual aspects of life. This paper explores the nature of the stones employed in the various sections of the Tiryns citadel over time, and their multiple meanings as building materials and markers of social practices played out by the inhabitants of Tiryns in and with their socio-political landscape. Through the reassessment of geological and other literature on the topic of Tirynhian building stones, it is revealed how stones were very specifically chosen for various properties and reasons. These specific stone choices in terms of both their properties and their locations show conscious actions of creating and maintaining social memories of Tiryns’ Early Bronze Age ‘Rundbau‘ users, inhabitants, workers, builders and elite, thus linking themselves to a deep ancestral past through the long-term building efforts conducted during the Late Bronze Age. At the same time, it is argued that the stones chosen brought the local surrounding landscape together in one building complex in order to indicate, confirm and negotiate socio-political alliances between groups present in and near Tiryns, and that in a period during which Mycenae must have played an overall dominant political role in the region, a factor also played out in the stone use at Tiryns. I argue that both local and regional strategies embedded in the stones are not competing with each other but can be manipulated and played out at the same time for different but complementary reasons.

1 Introduction

‘Minerals remain irrevocably linked to power, wealth, and both local and global inequality’ (Boivin 2004, 1). In an important volume on mineral materials such as rocks, metals, certain pigments and clays, Boivin indicates how mineral-based technologies always fulfilled a central role in human trajectories over time as they were crucial in the creation of pyramids, palaces and monumental constructions. Non-western communities, just as certain past societies, often do not see minerals as exploitable commodities or passive materials to be manipulated, as we do (Boivin 2004, 4). In non-western contexts, minerals, and in extension stones and rocks, are often not separate from living or even divine matters. They may carry deeply interwoven symbolic meanings linked to their ritual powers and their economic, material, social, cosmological, mythical, spiritual aspects of life. In some contexts gender roles are embedded *in* the minerals, not only represented *by* it. For example, earth is often seen as female due to its fertile capacities, while stones as a mobile and hard matter are often understood as male. Bringing them together then in such activities as building may amplify the powers that each may already contain separately into one very powerful being of ancestral power (Taçon 1991, 204-5).

Various papers in the volume (Boivin and Owoc 2004) illustrate through world-wide case studies how a wide range of single or often combined properties of stones and minerals make up their values (see also Scarre 2009, 4-5). External to their intrinsic values is the value connected to the ritual journeys that these materials may have undergone. The very presence of these materials in specific locations was proof of people having undertaken these often long and dangerous routes to collect them and may have been part of rituals to initiate younger members of communities into adulthood or their entrance into specialized craft groups (see Adams 2009 on East Indonesia). Also the original location from where the materials were extracted, whether the quarry itself or the entire landscape, may have been imbued with value and power. The act of deciding to bring stone from afar, especially in stone-rich areas, indicates a specific intentionality which cannot be ignored, whether the materials are studied from an economic, utilitarian, aesthetic, or symbolic or combined perspective.

The aim of this paper, which is part of the larger ‘Set in Stone’ project, is to investigate one particular aspect of the architectural study of the overall project (see below), namely the nature of the stones employed over time in the various sections of the Tiryns citadel, and their multiple meanings as building materials and markers of social practices played out by the inhabitants of Tiryns in and with the socio-political landscape.

The overall aim of the 'Set in Stone' project, in which this paper is embedded, is to assess how monumental building activities in Late Bronze Age (LBA) Greece impacted on the political and socio-economic structures of the Mycenaean polities in the period between 1600 and 1100 BC, and how people responded to changes in these structures. Veritable building programmes took place in the Argive Plain from *c*. 1400 to 1200 BC, but especially in the 13th *c.* BC, and resulted in awe-evoking citadels, burial monuments, waterworks (*e.g*. Balcer 1974), roads and bridges (Jansen 2002). The density of these demanding building programmes must have mobilized substantial material resources (such as multi-tonne blocks) and labour forces over sustained periods of time (*e.g.* Wright 1987).

Since agriculture and animal husbandry were the predominant subsistence strategies for most people in the Greek LBA, such intensive and prolonged building efforts, requiring a consistent amount of human and material resources, may have affected local economies profoundly. Some scholars have expressed the detrimental nature of mobilising these workforces (resource exhaustion) to the sustainability of the socio-political structures toward *c.* 1200 BC (*e.g*. Galaty and Parkinson 2007). The human impact on dwindling resources and also climatic changes have been seen as contributors to the Mycenaean socio-political collapse (*e.g*. Fuchs 2007 with earlier references).

Despite such attempts to explain the Mycenaean LBA crisis or even collapse *c.* 1200 BC in these terms, the extremely complex nature of many impacting factors causing these societal upheavals is still poorly understood in the Aegean and beyond. Equally, the factors which caused the 'collapse' itself are hotly debated (Tainter 1988; Diamond 2005; McAnany and Yoffee 2010) since this phenomenon was much wider spread than in the Mycenaean world alone. The Mycenaean polities were part of the Mediterranean system in which multiple regional units interacted and co-depended on each other (recently: Cline 2014). The hypothesis that massive building programmes may have been detrimental to the LBA Mycenaean societies thus deserves to be revaluated even though it is likely that each region suffered case-specific internal features of this global prehistoric 'collapse' (*e.g*. Liverani 1987 for Syro-Palestine), and that many different configurations of combined factors affected each region differently (Cline 2014). Almost 20 years ago, Shelmerdine (1997, 566) stated that in order to understand the complexity of the Mycenaean system collapse, the effects of monumental building programmes from 1300 BC onwards need to be investigated, and the interdisciplinary 'Set in Stone' study investigates several combined factors through addressing the following key questions:

What were the minimum levels of human and material resources input in the prolonged building programmes (see *e.g*. DeLaine 1997; De Haan 2009)? Did these building programmes deplete the available human and environmental resources in the regions under study, and if so, to which degree?

What other subsistence activities did people undertake in the centuries leading up to the Mycenaean collapse *c.* 1200 BC and which resources did they have at their disposal?

If the 'misuse of these huge workforces' contributed to the Mycenaean collapse, how does this local Mycenaean phenomenon relate to societal 'collapse' in other regions of Greece and the East Mediterranean which also suffered major setbacks even though they did not undertake major building programmes?

Attempting to contribute to all these questions falls well beyond the scope of this paper. Apart from one short geological study (see below) and the use of different types of limestone and conglomerate at Tiryns (*e.g*. Küpper 1996, 5-6), hardly any consideration has been given to the 'DNA' of the Mycenaean citadel, its building blocks (but see Maran 2006b on the meaning of conglomerate, see also Müller 1930). This paper thus aims to contribute to this specific issue by reconsidering the different stones used, their location of origin, their location of placement and what the biographies of these stones may have meant in people's daily social interactions there over time. It is, therefore, important to be aware of the technological processes of acquiring, transporting, and constructing monumental cultural commodities, and trace the builders' communicative and logistical strategies. Since many technical aspects of building on such a prolonged and monumental scale benefits from a bottom-up approach and cannot, therefore, be divorced from their socio-political implications involving the labour, craft specialists, elites and food providers alike, a brief overview of earlier work on technical aspects of monumental building and their interpretations in the context of Mycenaean citadels in the Argolid and beyond follows below. This then sets the scene for the rest of the paper by highlighting the importance of taking the stones themselves into account since these actively impacted on the day-to-day activities of building and the social-political interactions of people at different time-levels.

2 Overview of earlier work

Monumental architecture as an expression of power by the ruling class over their subjects has been well argued for the prehistoric Mediterranean (Kilian 1988a; Maran 2006a; 2006b; Thaler 2006; Fischer 2009), and equally for other cultural settings (*e.g.* Inka imperial architecture: Alconini 2008, esp. 64, 66-67). Furthermore, cross-cultural studies have compared and assessed similarities and differences in early states employing monumental architecture as one of several criteria (*e.g.* Englehardt and Nagle 2011, 367-8 with refs, 376-77). At Tiryns, Joseph Maran (2006a; 2006b; 2012) has focused on the performative space of Mycenaean Bronze Age palatial structures, thereby choosing a holistic approach to the phenomenon of the constructed environment that emphasises the dialectical relation between social practices and architectural spaces. Similar conclusions were reached by T. Mühlenbruch for the usage and meaning of the LH IIIC dated Building T at Tiryns (Mühlenbruch 2007; see also Maran 2009).

The social role of power and symbolism in relation to built mortuary contexts in the Argolid, specifically at Mycenae but also beyond have also been studied (Mylonas 1966; Mee and Cavanagh 1984, 1990; Darque 1987; Wright 1987; 2006; Voutsaki 1999, 2010; Wright 2006; Mason 2007; Fitzsimons 2011). With the highest concentration of tholos tombs and the most spectacular ones in terms of size anywhere in the Mycenaean context, Jim Wright (1987) emphasized the importance of looking into the energy expended and the time needed to construct tholos tombs since such undertakings must have required some very specific labour force organisation. This latter fact was also pointed out by Dörpfeld (1886) and Müller (1930) when they investigated Tiryns architectural wonders more generally, and specifically the citadel structures. An early interest, including the technical know-how and building techniques, into socio-economic discussions of the extant power institutions existed but was not pursued as a strand of research until much later (see *e.g.* Wright 1978 and Küpper 1996). Kurt Müller (1930) discussed early observations on building techniques and the relations between the wall constructions of the different areas. He usefully remarked on the style of construction in relation to the way the stones were worked, which types of stones were employed, and how these were/were not coursed in the different areas of the citadel (*e.g.* the Main Gate area, the Tower: Müller 1930, 55). Whereas his three-phase understanding of the citadel building has been corrected since (Wright 1978: 207; Kilian 1988b), the detailed observations he made are of very high quality and, as such, crucial to the content of this paper, see below.

Wright's earlier suggestions (1987) on investigating labour input figures for Mycenaean tholoi was taken further by Fitzsimons (2011) who calculated, in terms of labour input, the amount of fill that had to be excavated in preparation for the construction of each of different tomb type in and near Mycenae. His study, based on published data, showed that, over time, an increasing amount of labour input was required and he linked these results to the changing socio-political structures of the Mycenaean mainland in the Argolid. His abbreviated version of employing architectural energetics, however, dealt mainly with the labour input of soil digging while the tholoi and certainly the massive stone-based Mycenaean citadel complexes involved quite a bit more work and joint, organized efforts than soil removal alone.

Such systematic fieldwork was carried out for the first time on Tiryns citadel as part of the 'Set in Stone' project, now in its third year (Brysbaert 2013, 2015; Brysbaert *et al.* in preparation). In these studies were the stones themselves and their quarry sources were taken into account from a transport costing perspective. These same stones, seen also beyond their transport issue, now form the focus of this paper.

3 Tiryns in context

Recent overviews of Tiryns's archaeological research provide useful detail (Papadimitriou 2001; Maran 2010). Occupied since the Neolithic period, Tiryns was a crucial settlement in the EH II-III period and later evolved into one of the largest Mycenaean palatial centres on the Greek mainland, with a major harbour, a still working dam (13th *c.* BC: Balcer 1974), and two tholoi (Müller 1975: 15th *c.* BC; one is unpublished). A multi-phase palace with two *megara* occupied the Upper Citadel and the last phase of the cyclopean fortifications around the entire hill was constructed around the middle of the 13th century BC (Grossmann 1967, 1980). An extensive palatial and post-palatial settlement existed (Kilian 1978) and investigating its multi-period boundaries is ongoing under the direction of Professor J. Maran. These data play a crucial role in understanding the Tiryns's socio-political system within the wider Argive Plain in these periods. Early contributions to Tiryns's architectural research (Dörpfeld 1886; Müller 1930) are still pivotal but neither construction techniques nor building materials are covered in the necessary detail for the current project, so Tiryns still awaits full-scale architectural investigations.

In order to contribute towards a full-scale investigation of its many architectural features, especially the overall economics, I initiated the 'Set in Stone' project at Tiryns in the course of 2011 and this has received funding in 2012 through the Senior Marie Curie – Gerda Henkel Research Fellowship held at Leiden University (2013-2015) and through a collaborative training field school (directed by Dr. J. Pakkanen, Finnish Archaeological Institute) set up during the summer of 2014.

Homer eternalised Tiryns describing it as 'walled Tiryns' (Papadimitriou 2001, 6), while Pausanias (II: 25, 7-9) made a colourful exaggeration in that not even a pair of mules could have moved the smallest of the blocks employed there. However, it does bring the point home that for the masses of larger stones, some serious labour input would have been required and likely over sustained periods of time. At least during the palatial period, skilled and unskilled labour, specialised knowledge, advance planning, and mobilisation of work forces, probably co-ordinated by local palatial staff of architects/engineers, and the many supportive human and other resources that worked alongside the construction activities, were likely the driving *collaborative* powers in the Argive Plain that achieved these exceptional constructions (see Brysbaert 2013, 2015; Brysbaert *et al.* in preparation).

However, especially the *complexity* of the practical human *and* material involvements in *monumental* and megalithic Mycenaean architecture remain unstudied with notable exceptions in the very useful study on labour input on the construction of the Atreus tomb in a paper by Cavanagh and Mee (1999). They also consider the architectural phenomena as more active ‘participants’ in socially interactive groups. Equally, the paper by Santillo Frizell (1997-1998) on the effect such monumental building may have had on the people involved directly and indirectly stand in contrast to those in which architecture is seen as mere ‘theatrical backdrops’ against which the scenes developed. However, since these papers focus solely on Mycenae, it is, perhaps, less perplexing that we know so little of what made Tiryns, a World Heritage Site, so famous: (1) the building processes *and* their people: builders, architects and engineers alike (most recently Brysbaert 2013), (2) and the logistics and infrastructure required to make these admirably solid vestiges, (3) the stones themselves and how they got there.

Finally, geological research (Varti-Matarangas *et al.* 2002) conducted in Tiryns and surroundings demonstrated that the building stones employed on the Tirynthian acropolis belong to 12 lithofacies. While this study is a welcome addition to our knowledge of the building materials employed at Tiryns, it is not without its problems (see below) and as a study it stands very much on its own. This paper assesses and brings together the information from geological papers and other sources on the stones used at Tiryns.

4 Interdisciplinary approach

Both the *chaîne opératoire* and cross-craft interaction approaches allow detailed studies of people’s technical processes and social practices within architectural contexts. They may show how people’s movement along pathways *changed while* they worked together, and how these pathways became hubs of technical and social interaction. “Buildings, like other environmental structures, are never complete but continually under construction, and have life-histories of involvement with both their human and non-human habitants” (Ingold 2000). In this way, the focus of this paper falls on the many processes involved in building itself as a series of *activities*, on both the human and material resources, and the forces involved in the decision-making and the creation of the citadel complex. In investigating the stones themselves, the paper addresses issues of the interwoven nature of human and environmental resources active in and around Tiryns, the pathways of communication, along which orders from elites to workers and knowledge-transfer between builders took place. Finally, it addresses how the resources and lines of contact impacted on each other within the builders’ task-scape (Ingold 2000) and within the local and regional political economies (on prehistoric economy: *e.g.* Halstead 2001; Sjöberg 2004; Voutsaki 2010; Pullen 2013).

Practically, documenting stone-by-stone of each construction via extensive 3D reflectorless total station surveys results in fully compatible data sets for statistical purposes (Pakkanen 2009). These fieldwork data are next analysed in a CAD programme to derive the dimensions from which masses and volumes of the building materials are calculated. These results are then used to calculate cost-estimates per construction task per material and combined with labour time-units invested, i.e. expenditure of human energy: man-days. This method of extracting econometric data is very well-suited together with the *chaîne opératoire* and cross-craft interaction approaches since it forces us to think of each possible process involved in the building procedures. The cost-estimates (human and animal labour) form the minimum expenditure required from the population to realise these constructions, while also continuing other aspects of life (*e.g.* agriculture). After having carried out test runs in November and December 2013, we conducted two successful field campaigns in 2014. During the 2014 field school (three weeks of six working days), students were paired up with experienced fieldworkers in using architectural survey equipment at the Tiryns citadel. Additionally, a first large-scale and detailed photographic campaign was undertaken on site of all sections of the walls, both inside and outside. These are now being studied in detail and similar work is planned for the summer of 2015 and future years. Especially the newly taken photographs are compared with many much older sets taken before too much extensive conservation work was carried out (Dörpfeld 1886; Müller 1930). Several sets also serve for photogrammetric studies and are being processed at the moment of writing. The combination of the photographic study, combined with earlier captured econometric data and the geological information collected, form the basic data for this paper.

5 Tiryns’s building blocks reconsidered (Table 1)

At Tiryns 12 lithofacies were employed: 7 different limestones and 1 type of dolomite, mostly used for construction; 2 types of conglomerate and 2 types of sandstone were employed as decorative stones (Varti-Matarangas *et al.* 2002). Below, the most important

Lithofacies	Category of stone	Employment at Tiryns	Quarry information
A	Biomicrite-Biopelmicrite with orbitolina (limestone)	Constructive: cycl walls, internal bldgs Acropolis	Acropolis basement
B	Biosparite (limestone)	Constructive: cycl walls, internal bldgs Acropolis	-
C	Turbiditic limestone	Constructive: bathroom floor, palace staircase	-
D	Biomicrite with mixed biota/fauna	Constructive: bldgs of lower Acropolis	Profitis Ilias
E	Red/brown biomicrite	Constructive: walls Decorative: in palace	Aria, hill adjacent to Profitis Ilias
F	Beige biomicrite with calcispheres	Constructive: walls	Aria, hill adjacent to Profitis Ilias
G	Dolomicrite (mudstone)	Constructive: acropolis walls but rare	Not possible to determine
H	Conglomerate	Decorative: entrances, also Mycenae	Moudanies, N of Mycenae, near Nemea
I	Polymictic conglomerate	Decorative: see H	See H, of different stratigraphic horizon
J	Very coarse litharenite with nummulites (sandstone)	Decorative: sparse use	-
K	Lithic arkose-litharenite (sandstone)	Decorative	-
L	Oocalcarenite ('porolithos', limestone)	Decorative	-

Table 1 Overview of the lithofacies recognised at Tiryns (based on Varti-Matarangas *et al.* 2002 only)

lithofacies descriptions are reviewed and assessed towards a better understanding of their location, both that of their origin and where they were used in the citadel, and their use(s) and meaning within the citadel itself. Several lacunae in the literature are revealed and, where possible, additional information is provided to reconstruct a more comprehensive picture of the blocks employed. It is, for instance, not clear wherefrom precisely the samples were taken that form the basis of the geological sourcing of the stones employed at Tiryns, and no analytical data are provided in the paper itself. They studied 70 thin sections but it is unclear how many of these were geological versus archaeological (Varti-Matarangas *et al.* 2002, 478). Equally, matching the individual lithofacies recognised and analysed at Tiryns to the specific locations of their uses is not described in sufficient detail for archaeological purposes when looking at the stones' value beyond being building blocks. XRD analyses were carried out on the insoluble residues from the dissolved samples (sample size unknown) that underwent treatment in a 10% acetic acid solution in order to be able to separate soluble from insoluble matter from which the qualitative mineralogical composition could be determined. The dissolution allowed the percentage calculation of this insoluble residue but it is unclear how many and which geological and archaeological samples were treated this way since no analytical data was provided in the paper. Finally, a number of typos in the geological names of stones and formation processes are corrected which allows an easier geological follow-up study of the literature for archaeologists with such interests.

5.1 Lithofacies A (limestone): biomicrite – biopelmicrite with orbitolina (Wackestone-Packstone)

Varti-Matarangas *et al.* (2002, 479) stated that this lithofacies was used in the "Cyclopean" walls and the internal buildings of the Acropolis. It should be recognisable as a beige colour on recently revealed surfaces and a light colour on older exposed surfaces. Porosity is almost non-existent and the degree of weathering is very low to negligible. Likely based on the thin-sections showing specific benthic (i.e. from the sea bottom) foraminifera (Varti-Matarangas *et al.* 2002, fig. 4 where they are called 'benthonic', but see any geological dictionary), the geologists could source stones of the locations mentioned to the lithological formation of the Tiryns outcrop, the low hill on which the citadel is constructed. This hill sits at its highest point about 20-25 m above current sea level. No colour descriptions they provide, however, are munselled, no details are given about what they consider to be 'recent surfaces' and it is difficult to capture when the study was being carried out (possibly in 1991 or

1997 as figs 6 and 10 seem to suggest). I assume they refer to freshly excavated sections, possibly under K. Kilian in the Lower Citadel. More importantly, a much more detailed description of which sections of the Cyclopean walls and which internal buildings of the Acropolis were constructed with this stone would have been helpful. Müller's account (1930, 177) on the materials used referred in the first place to a dark grey limestone. He does not suggest any extraction location in relation to this stone but it seems, to him, the most used stone from the earliest construction phase of the citadel onwards.

What we can be entirely sure of is that the Tiryns outcrop formed a quarry to extract blocks from for various areas and throughout the construction time of the citadel, especially on the west side of the Acropolis where, as has been observed a long time ago already (Dörpfeld 1886; Müller 1930), various quarry zones can be recognised in the diagonal rock partitions (fig. 1). It would be logical and cost-effective for the builders at Tiryns to pry as many of these stones away from their parent rock beds as possible since it reduces substantially any transport operational efforts (Brysbaert 2013 on transport costs at Tiryns). However, stones of several tonnes as many are (esp. Brysbaert 2013), still need to be moved from where they are extracted to the actual wall or feature in which they are placed (Brysbaert: 2015; Brysbaert *et al*: in preparation). Of interest too is that the Western Staircase and its massive 7 m thick curved outer wall, one of the last features constructed in the 13th century BC (Maran 2010, 726), was partially if not entirely built inside the Tiryns outcrop quarry zone, thus inside the zone of lithofacies A. At least several of its steps are cut out in the bedrock while others were assembled as steps of the same and/or other stone types (see also under 'lithofacies C' below). As such, an (exhausted) quarry became a building locale.

5.2 Lithofacies B (limestone): biosparite (Greystone-Packstone)

This lithofacies is described as light beige to beige and grey with a low porosity but higher than lithofacies A, and its

Figure 1 Tiryns west side of the citadel: diagonally bedded limestone outcrops used as quarry for lithofacies A

weathering is as low as for lithofacies A. It was used in the walls and the palaces (Varti-Matarangas *et al.* 2002, 480). Also this lithofacies consists of several types of foraminifera (including orbitolinidae, as in lithofacies A). Without thin sections, thus based on the colour description and the location of where these stones were used, it is, in fact, impossible to distinguish between lithofacies A and B. Importantly, A matches the local outcrop while B has not been sourced at all. One can thus easily, based on visual inspection alone, mistake B for A and ascribe more stones to the outcrop than necessary. Müller may have referred to lithofacies B in describing a dark grey, very hard limestone as the main building stone since his grey colour description matches at least in part that of the geologists for lithofacies B. The easily confused lithofacies A and B suggest that it would have been very useful if the geologists had carried out a thorough fieldwork campaign in order to be able to suggest rough percentages of each stone type 'visible' in the built elements of the citadel (see also lithofacies F, below). Such work has now been undertaken in the 'Set in Stone' project and the detailed photographic survey will aid in a first step to get a better understanding of the ratio between lithofacies A and B. In the future, we hope to complement our observations with systematic sampling from several areas of the citadel in order to obtain a comprehensive image of the locations and patterns of usage between lithofacies A and B, also chronologically. Likely, the west quarry side of the outcrop must have been considered exhausted or in need for abandonment *as a quarry* when the western staircase and its curved outer wall were constructed and could, therefore, not have been the source for that entire part of the complex once building started (see below). Logically, stones could have been extracted from nearby parts of the outcrop for this staircase (some of its steps are) and curved wall, but it is still worth testing whether all courses were in fact built up from the actual outcrop or not.

5.3 Lithofacies C (limestone): dark grey turbiditic limestone with breccia texture

This stone type is dark grey with a brecciated texture and cross-cut by white veinlets (fig. 2) (Varti-Matarangas *et al.* 2002, 480), some being quite long and running across large sections of the stone. The stone was used for the bathroom floor and the palace staircase according to the geologists but there is no further indication which staircase is meant. There are several candidates: (1) the monumental Western Staircase; (2) on the same side but further north is the small staircase through thickness of the fortification wall located between the Middle and Lower Citadel; (3) a shallow stepped staircase leading from the Middle Citadel to the suite of rooms east of the Great Megaron towards the bathroom; (4) the stairs leading from the outer court (nbr 56,

Figure 2 Tiryns upper citadel: white veinlets on lithofacies C of the bathroom floor

Papadimitriou 2001, fig. 19) to the entrance of the East Galleries; and (6) another one within the complex of the South Galleries. The most likely candidate meant is the Western Staircase but several of its steps are carved out of the actual outcrop (thus lithofacies A, see above) and others have been restored. A more precise description would be very helpful to identify the usage of lithofacies C which has also not been sourced yet. The bathroom floor, recently discussed in great detail (Shaw 2012, but see Dörpfeld 1886, 231; Müller 1930) was a *c.* 23 tonne monolith and cannot have been easily brought into the citadel.

5.4 Lithofacies D: biomicrite with mixed fauna

This stone is described as beige to reddish containing plenty of micro to macrofossils and was used in the buildings of the lower Acropolis, but where exactly is not clear. The degree of weathering is medium and the stone has been sourced to the hill of Profitis Ilias (Varta-Matarangas *et al.* 2002, 480-1), *c.* 1 km distance east from the citadel (based on Zangger 1993, fig. 43). This stone may be easier to recognise macroscopically due to the large amount of fossil inclusions, rather than by its colour descriptions.

5.5 Lithofacies E: red-brown biomicrite (Wackestone - Packstone)

Varti-Matarangas *et al.* (2002, 481) sourced this red-brown limestone to the hill adjacent to Profitis Ilias (i.e. *c.* 2 km away from the Tiryns citadel) and was, according to them, used in the Cyclopean walls, the Acropolis monuments, and as decorative stone in various parts of the palace, with no further details mentioned. The nodular look, clearly noticeable at Tiryns by macroscopic observations, is formed by veinlets that run perpendicular to or across the stylolites, further emphasised by chert inclusions (Varti-Matarangas *et al.* 2002, 481), again macroscopically visible (fig. 3). Benedicto and Schultz (2010, 1250-51) describe clearly how stylolites nucleate around local heterogenous inclusions in a very similar Italian limestone rock (in the Tiryns case the named chert inclusions), and how stylolites in limestone relate to the contractual strain in the stone versus the stone surface's capillary forces. While they do not form structural fractures, stylolites may thus indicate, by their (growing) length, the (growing) level of contractual strain on the stone, and that this increasing contractual strain in the host rock increases the length of the stylolites (Benedicto and Schultz 2010, 1255). This, in turn, may indirectly suggest potential stone weakening, *already* within the geological outcrops of the stone, since it is also accompanied by mass-loss alongside the actual stylolites, until a certain point is reached. Bell (1990, 1871) and Benedicto and Schultz (2010) describe the mechanisms by which limestones of less dense porosity allow greater movement of water in its cells which, in turn, encourage both mass-loss of specific constituents which are diffused by means of such water-assisted movement, and stress of water in the rock when under pressure. Also Varti-Matarangas *et al.* (2002, 481) suggest endogenous decay as the result of a high percentage of insoluble residue, mineralogical composition of the stone and especially the presence of veinlets, chert inclusions, stylolites and swelling clay minerals, the latter which are most likely to be shifted by the fluid-drive action (see above). The stylolite phenomenon is especially well documented in figs. 1a, 2a, 2c (Benedicto and Schultz 2010, 1251-52) showing the stone disintegration patterns that are very similar to what I observed on several stones of this lithofacies in Tiryns. Of interest here is the fact that these stylolites and their accompanying stone weakening may occur *within* the geological outcrop (also details in Labaume *et al.* 2004) as well as in stone blocks used in the context of building (fig. 4).

Müller (1930, 55-56) mentioned the overall use of a solid grey limestone *while red blocks were occasionally used too*

Figure 3 Lithofacies E block showing inclusions of chert and a nodular look caused by veinlet running perpendicular to the stylolites, giving the stone its less robust character

Figure 4 Tiryns east side of citadel, main entrance with Great Ramp showing badly flaked lithofacies E blocks

and were always carefully chosen (my emphasis). His keen and detailed observations of the use of different stone types, especially the role of the red stone, and construction differences in several sections of the walls, were linked by him to different chronological phases (but see Wright 1978; Kilian 1988b). However, he equally mentioned the possible impact of the different master builders in choosing specific stones, especially for his 'second' phase (Müller 1930, 57). In his 'third' building phase, which seems to correspond in large parts to the second half of the 13th century BC additions to the citadel complex, he emphasizes not only the frequent usage of the red stone at the outer south wall of the south galleries, but also his amazement over the pure massive character of the wall constructions; a point I come back to later.

Wace (1949, 137) saw the reason for using the red stones in Tiryns as aesthetic because he considered that the stone could take a good polish. Such usage of this lithofacies was noted, for instance, on the Acropolis as the upper of the two steps between the Central Court and the Great Megaron Complex where the red seems to be used to contrast with the duller sandstone (fig. 5), a fact already noted by Müller (1930, 195) and Dörpfeld (1886, 238). Also Maran (2006b, 82-83) mentions this fact and questions whether any symbolically charged meaning may be behind this variegated stone usage. He also refers to the red stone used for all the column bases in the Great Megaron, although Küpper (1996, 113-114), in Maran's view, has convincingly argued that these were plastered over. I come back to this below.

5.6 Lithofacies F: beige biomicrite with calcispheres (Wackestone)

This stone is beige with subconchoidal fracture patterning and its particles are biogene containing mainly fossils (see also previous lithofacies) and fragments of thin shells and calcite crystals are present. Porosity is absent and almost no weathering was noted. The stone employed in the walls and possibly also other parts of the Acropolis monuments can be sourced to the hill adjacent to Profitis Ilias, where ancient quarrying is evident (Varti-Matarangas *et al.* 2002, 481). As with lithofacies B it remains impossible to distinguish

Figure 5 Tiryns upper citadel: (1) lithofacies E (red limestone) and (2) lithofacies J or K (sandstone) low steps leading into the Great Megaron complex

lithofacies F from both lithofacies B and A based on the macroscopic descriptions while this stone was sourced and lithofacies B was not. This stone type, therefore, falls under the same discussion as made for lithofacies B in relation to A (see above).

5.7 Lithofacies H and I: Conglomerate and polymictic conglomerate respectively

Both lithofacies are treated together here since Varti-Matarangas *et al.* (2002, 482) consider both potentially of the same lithological formation but of a different stratigraphic horizon while the different lithofacies features may help in sourcing the latter. The weathering of conglomerate is considerable and the decay factors are inherent to the stones' mineralogical make-up. This is clearly visible, for example, at the almost 'layered peeling' of the right door jamb at Tiryns Great Gate (fig. 6).That conglomerate can vary in quality, both visual and strength-wise, corresponds with Cavanagh and Mee (1999, 95-96) who discuss two different qualities of conglomerate available in the Mycenae area: the stronger material is to be found 1.5 km away from the building site of the Treasury of Atreus and forms the main material used in the construction. As discussed before (Brysbaert 2013, 51), this opposes both Fitzsimons (2011) and Wright (1978, 229, n. 329) who refer to local conglomerate only, i.e. the weaker material in the middle of which beds the construction of the Treasury of Atreus took place. In fact, both stone types may have been used at the Treasury of Atreus (to my knowledge no geological work has been carried out there), and may have had their respective uses at Mycenae and possibly also at Tiryns. In describing lithofacies H, Varti-Matarangas *et al.* (2002, 482) determined its source at Moudanies, near the town of Nemea, north of Mycenae. This location could not be found on any map of the area, several archaeologists working in the region did not know about it either, and most archaeologists (e.g. Wace 1949, 136; Wright 1978, 229, 242-43) referred to the conglomerate outcrops at the construction site of the Treasury of Atreus, at the Panagia and Kalkani ridges, or a little beyond (Cavanagh and Mee 1999, 95-96). Müller (1930, 177-78) refers to the conglomerate from the Dervenaki valley and towards the Heraion east, and Dörpfeld (1886, 289) mentioned the vicinity of Mycenae near the village of Charvati as its place of origin.

Because of its distant source location, Müller suggested that conglomerate was much more valued at Tiryns than at Mycenae and thus only used for thresholds, column bases, or antae blocks and for the Great Gate. Varti-Matarangas *et al.* (2002, 482) mentioned that lithofacies H was used as decorative stone at the entrance of the Acropolis (the Great Gate is meant) and also lithofacies I was used as decorative stone (no location specified, possibly the antae and column bases were meant, see Maran 2006b, figs 12-13). The decorative value of lithofacies I would certainly be enhanced due to the fact that the conglomerate was polymictic, i.e. its clasts were of various different stone types, thus bringing out its multiple colouring as the result of several stone inclusion sizes and shapes that would become a beautiful mottled pattern after a good surface polish. It is very likely that the antae stones sitting at either end of the flat steps between the Central Court and the entrance to the Great Megaron Compex were of this type (fig.7).

Figure 6 Tiryns east side of the citadel, Great Gate: badly flaking conglomerate upright post

5.8 *Lithofacies J: very coarse litharenite with nummelites*

Varti-Matarangas *et al.* (2002, 482) consider this dark grey sandstone as rather rarely used at Tiryns. Both lithoclasts and crystalloclasts are densely packed and moderately sorted, containing especially nummelite fossils. Due to its heterogeneous structure, mineralogical composition and the presence of swelling clay minerals, its weathering is considerable. The authors (2002, 484) consider this stone used as decorative (see their conclusions) but no details are given about its whereabouts.

5.9 *Lithofacies K: coarse lithic arkose-litharenite*

This sandstone is light green-yellow and considered a building stone at the Acropolis monuments with no further specifications (but see conclusions: Varti-Matarangas *et al.* 2002, 482 vs 484). Also this stone weathers considerably and both this and lithofacies J are not sourced.

Müller (1930, 177-188, esp. 178-179) refers to the selected and limited use of sandstone which he and H. Lehmann source back to Mycenae as being located between the layers of conglomerate. Müller suggests (see also Dörpfeld 1886, 289) that the sandstone was used sparingly but mainly for some antae blocks, *e.g.* at the entrance to the Small Megaron (Dörpfeld 1886, 317), the building courses of Court 16 (in front of the Small Megaron [17-18] and the Megaron-plan building [20-22], Papadimitriou 2001, fig. 19), the lowest courses of the Great Megaron (also Dörpfeld 1886, 289), the small staircase from the palace to the Middle Citadel and its connecting 'Plattenweg', the stones of the round altar in the Main Court and the gutter stones of the drains (not further specified). Müller considered these features of a nature that needed a specific shape and were thus hard to create in other stone types. However, we know that several other walls were built in the available limestone types discussed above, that several antae were executed in conglomerate (Müller 1930, fig. 85; Maran 2006b) which is the most difficult stone type to work, or in limestone (Müller 1930, 183, figs 86-87; see also Dörpfeld 1886, 300), and that the run-off spout of the bathroom floor was done in limestone as part of the monolithic slab.

Overall, in comparing Müller's detailed observations with the much more recent geological report, though, it is clear that neither Müller's nor Dörpfeld's work were consulted. This is a pity because these could have been helpful in providing more detailed descriptions of the use of several lithofacies, in the sourcing of the sandstone and in verifying whether these may have originated from the Mycenae region as the conglomerate did, or whether other sources are present and accessed nearer to Tiryns.

6 Discussion

The simple fact that many different stone types were employed in the Tiryns citadel goes against the least cost – maximum benefit approach, since the closest quarry is the outcrop of Tiryns itself and this was not used for all the stone material as shown above. Instead, the intentional choices of materials were important for various, and often combined, reasons: economic, utilitarian, but also aesthetic and symbolic. Table 2 shows all discussed lithofacies against four categories of usage and several fit in multiple categories. Specific lithofacies may have been chosen for ease of access (*e.g.* lithofacies A, D, F) which may indicate an economic least-cost factor, while other choices reflect exactly the opposite (lithofacies C?, E, H-I, J-K?). Even when considering lithofacies A versus D and F, three types with very similar properties, their individual choice as material was likely not just dictated by ease of access because that would urge people to take *only* blocks from the outcrop itself.

Figure 7 Tiryns upper citadel: conglomerate sawn antae block, left from the low steps leading into the Great Megaron complex

Lithofacies	Economic	Aesthetic	Symbolic	Utilitarian
A	X			X
B				X
C		X	X	
D	X		X	X
E		X	X	X
F	X			X
H-I		X	X	
J	?	X?	X	X?
K	?	X?	X	X?

Table 2 The different lithofacies placed against different use values

Previous studies have pointed out that the conglomerate use in Tiryns, for instance, expresses its political alliance to Mycenae. Maran (2006b, 82) describes the route that people entering the citadel would take through the Main Gate on the east side passing via several liminal points expressed in architectural cues of doorways, corridors, light and dark passages and porticos which provided constant contrasting experiences. Certain of these liminal points were expressed in the specific local use of conglomerate (contra Küpper 1996, 113-118, esp. 114-115 and fig 220.2, who thought all were conglomerate). Conglomerate which sat both at the Main Gate and at the entrance of the Great Megaron was not there by accident. The fact that the stone came from Mycenae may have meant that the journeys and large efforts involved in getting these blocs to Tiryns may have had additional ritual connotations and may have formed a rite of passage for younger members of the builders communities (see comparatively: Adams 2009). An additional link to Mycenae is visible in the size and shape of the Great Gate at Tiryns which is almost an identical copy of the Lion's Gate at Mycenae (Dörpfeld 1886, 218; Müller 1930, 70-73; Maran 2006b, 81). Only the closing system of the gate is different which is logical: no two houses are supposed to have the same key and this may even indicate some independence from each other too. These observations indicate the following: it is likely that the same architects (Müller 1930, 70-73) and engineers were at work in both Mycenae and Tiryns (Maran 2006b). Possibly also similar groups of builders were working the conglomerate in both locales since they knew where to find the stone, extract it and work it effectively to be useful and aesthetic too, once polished properly. Wright (2006, 59) states that: … "the evidence of the deployment of the conglomerate masonry style abundantly illustrates how a local style of craftsmanship can be used to make powerful statements of control."

I argued previously (Brysbaert 2013; 2015) that if a distance of 10 km is hypothetically postulated for the yet unsourced bathroom floor block of *c.* 23 tonnes, its transport would have needed either 25 oxen yokes with ox guides and would have taken a minimum of two full days to get the block to Tiryns if loaded onto a wagon, possibly longer if placed on a sledge over rollers. If, on the other hand it was brought over on a sledge over rollers and pulled by pure manpower, this would have taken 200 men about 17-33 days, based on existing experiments. A lubricant and evened-out roads would have been a pre-requisite to make this feasible. As far as the conglomerate blocks used in various locations on the Upper Citadel and on the way there are concerned, Table 3 summarizes the information per block; their locations are indicated in figure 8 (several other smaller ones are not calculated here, but are indicated on plate 12, Maran 2006b). If well-organised, transport with multiple oxen yokes at a rate of 1.67-2km/hr, with a distance of *c.* 18 km between Mycenae and Tiryns would have taken 4 oxen 10.7-9 hours (a full working day) to bring over 3.5 tonnes of material, for example 2 blocks of *c.* 1.6-1.7 tonnes each. However, the trip may well carry over into a second day in order not to exhaust the animals. The two 12-yoke (24 oxen) transports of the Great Gate posts of *c.* 10 tonnes each would be done quite a bit slower and thus certainly be spread over two days. In total, a minimum estimation of 24 days, employing minimally 4 and up to 24 oxen per caravan (each oxen yoke with ox guide), would have brought the large conglomerate blocks to Tiryns. That large and performative efforts went into getting these blocks from their source to final location is undeniable through these examples alone, and for those reasons these stones were already imbued with non-economic values of power expressions and communal efforts (conglomerate: Maran 2006b; Wright 2006; bathroom floor: Brysbaert 2013; 2015), in addition to their aesthetic qualities.

Of great interest here is the reddish stone, lithofacies E, which is not the strongest of all. The significance of the distance between the quarry and the construction site plays a major factor in calculating the transport efforts of the stones to the site. Crucial in understanding the use of this reddish stone so typical for Tiryns alone, is that it identifies Tiryns *specifically.* Considering its geology (see above), however, it must have been known as a weaker stone, even at its source location *before it was extracted*. Yet, people still travelled 2 km to collect this weaker material, often in blocks of multiple tonnes!, while strong material was abundantly present on the outcrop itself (lithofacies A) and at 1 km distance (lithofacies D, F). Despite the likely ancient knowledge of this stone's weakness, it was still used at various *structural* points in all chronological phases of the Tiryns citadel *(e.g.* Müller 1930, 57). What is more, it continued to be in use after the large earthquake that struck Tiryns at the start of the 13th century BC (on earthquakes in 13th century Tiryns: Kilian 1996), in various parts of the galleries, the Lower Citadel wall, the Western Staircase and on the Upper citadel, for both decorative and structural purposes, the capstone of the Western Staircase entrance vault being a point in case of combined purposes. While the red stone used for the column bases in the Great Court were plastered over and thus invisible (Küpper 1996, 113-114; Maran 2006b, 82-83) that does not mean that the use of red stone there was not known and intentionally chosen for this specific purpose and location. Moreover, plastering may not have taken place immediately. Additionally, it may thus well be due to the internal stone faulting of lithofacies E that wall deformations and bulging came about later on at several places on the Tiryns Citadel, rather than being caused by earthquakes.

From a pure utilitarian and economic perspective, the choice of lithofacies E was a rather irrational one and thus needs to be explained differently. Wace's (1949) mentioning of the red stone being polished for aesthetic usage moves in one direction but only explains the stones used at the low steps between the Great Court and the Great Megaron porch. While Maran (2006b, 83) agrees with Kilian (1984, 46) that the entrance via the West Staircase was not staged as the east main entrance and therefore was a private entrance, I beg to differ for the following reasons. First, the curve of the wall alongside it is an extraordinary construction in its own right, marks a clear-cut division between outside and inside, and thus forms a liminal point, together with various other places (*e.g.* ritual character of the bathroom), along that route up/down and in/out. Second, an *intentional* creative colour play is visible on the Western Staircase starting at the actual

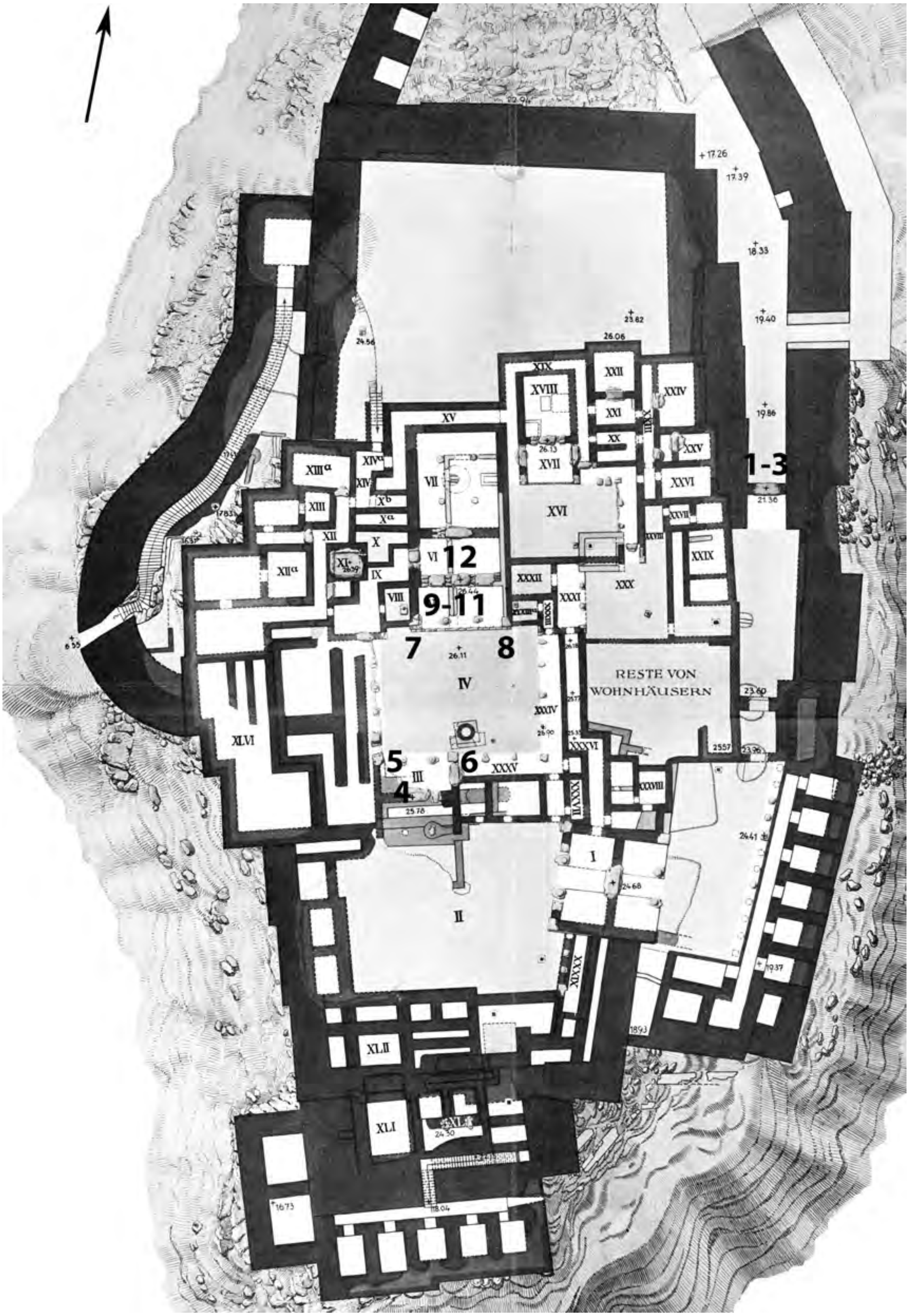

Figure 8 Tiryns upper citadel indicating the most important conglomerate blocks (after Müller 1930: plate 1), together with Table 3

Block nbr	Height (m)	Width (m)	Length (m)	Volume (m^3)	Mass (tonnes)	Oxen yoke(s)
1-2	3.20	1.40	0.95	4260	9.60	12 x 2
3	0.36	1.45	5.00	2610	5.87	6
4	0.20?	1.40	3.50	980	2.20	3
5-8	0.60	1.40	1.40	1180	2.65	3 x 4
9-11	0.20?	1.55	2.30	715	1.60	2 x 3
12	0.20?	1.25	3.00	750	1.70	2

Table 3 Summary of the major conglomerate blocks employed at Tiryns and their transport considerations

doorway, where the red stone plays both a constructive role as capstone of the vaulted entrance *but also* a decorative role. This is visible in the alternative placing of both red and grey stones, symmetrically on both sides of the doorway as it forms a closed vault with the red capstone at the top (fig. 9). Darvill (2013, 238-239) uses historical semantics and historical phonology of the Proto-Indo European languages to explain the juxtaposition of red with dark colours as expressing the passage of life and death. Whether similar explanations would be tenable for why certain colours were employed in Tiryns remains to be seen and will be investigated in the near future.

Play with colour in building materials is also known from the green stone use for the semi-columns of the Atreus Treasury at Mycenae (Higgins and Higgins 1996, 57; Wright 2006), and sometime later in intentionally decorative patterned use of differently coloured mudbricks in the geometric building at Lefkandi (Coulton 1993, 38, 55, 57, with references to the same situation at Kalapodi). At Tiryns, as one ascends through the entrance, stone steps from the outcrop are mixed with other ones (now possibly impossible to reconstruct due to subsequent restorations), possibly even containing lithofacies C stones (see section lithofacies C). As one arrived at the top of the stairs, the 'Plattenweg' and low steps running from the Middle to the Upper Citadel were in sandstone (Müller 1930; lithofacies J-K) which, eventually, allowed access via a narrow corridor, into the bathroom complex with a unique lithofacies C floor slab. In my view, none of the stone choices along this west entrance route are coincidental either. Especially the red stone can be seen both as aesthetically pleasing but equally as an identity marker for Tiryns. It is even conceivable that its 2 km away quarry may have formed a boundary marker for its territory in that direction and may have also represented the people who lived in that area for generations, possibly even the landowner of where the quarry was located if that was not the palace administration itself (for similar arguments: Bukach 2003, 30; Scarre 2009).

The use of the sandstone, independent from its source location, indicates a strong level of axiality and interconnectedness at the most important part of the entire citadel: the area of the Great Megaron and its immediate surroundings. Müller (1930, 178-79) mentions its use (we do not know whether lithofacies J and/or K are implied) in the altar of the Great Court, stone courses of the Great Megaron and the Small Megaron area, antae in the court before the Small Megaron and adjacent room complex, and the low steps and 'Plattenweg' between the Middle and Upper Citadel. Again, independent from its source of origin, this stone use may *physically* link the important *symbolic* link between the Great and the Small Megaron, already pointed out by Müller (1930) and Maran (2006b) as expressing the alliance between Tiryns and Mycenae, with Mycenae being the dominant faction. If then the sandstone may also *originate* from the region of Mycenae, as Müller and Lehmann suggested, the dominance of Mycenae may be symbolically expressed at the actual architectural heart of the residing powers atop the Upper Citadel, by forming the physical foundations of its two Megara. Moreover, a ritual importance is clear from the axial link to the altar too. At the Great Megaron and Great Court area we can see the sandstone use connecting up to the route in/out to the west of the citadel along the bathroom, the flat flight of stairs to the Middle Citadel and its 'Plattenweg',

Figure 9 Tiryns Western Staircase indicating intentionally alternating employment of lithofacies E with at least one grey limestone; B=grey, R=red

and up/down the Western Staircase (as mentioned above). It is possible that this route was equally ritualised as the eastern entrance route and thus formed ways of including and excluding. In following M. Douglas's seminal work (1966) thresholds, entrances and physical boundaries may mark a duality between sacral and secular places and could have been unstable and dangerous places once ritualised and initiated. In order then to protect both people and places from pollution, such places could only be entered through specific ritualised ways, maintaining that duality, which can in itself be employed as a tool of power by the initiated. The Western Staircase entrance route into the palace until the Great Megaron is reached manifests several such liminal places.

Each and every type of stone thus transported one or more specific meanings embedded in their incorporation of the citadel. Their individual properties such as their colour and texture may have been important active players in structuring socio-technical activities at the extraction and building sites. Several, s.a. lithofacies A blocks, may have linked the extraction source of the LBA stones to the social memory of ancestral presences, powers, mythical beginnings, there in the deep past. The EH II 'Rundbau' was, in the end, constructed on the hilltop and was to be found partially underneath both the Great Megaron (under but *between* the red column bases and *under* the throne: Papadimitriou 2001, fig. 8), and the Small Megaron. Maran (2006b, 84) argues against the socio-political power institutions in Tiryns built upon ancestral presence, as is done at Mycenae as rulers of the region because he sees Tiryns as secondary to Mycenae, which it likely was. However, this only considers the relation between both locales in the 14th-13th century BC. In the same paper Maran (2006b, 79) does mention certain associations between the EH II 'Rundbau' and the Great Megaron because both are located at the highest point on the outcrop and can thus be seen as landmarks from the sea, especially from the south. That landmark and thus strategic point obviously remained important through time, possibly referring to very early mythical descent, and likely independent of the changing relations between Tiryns and Mycenae over time. The people at Tiryns were very likely aware of the presence of the 'Rundbau' when they remodelled the Upper Citadel; what is not visible anymore is not necessarily forgotten. While all the *outer* signs – through stone use and other symbols – showed the alliance to Mycenae, one could understand that *inside*, the people and rulers of Tiryns may have felt strong enough about their *own* identity and past, expressed through specific other stone uses and its location: the 'hidden' 'Rundbau', the 'hidden' red stone for the Great Megaron column bases, the bathroom floor slab unique to Tiryns, the various locally quarried blocks. The accessed quarry locations in and near Tiryns may have linked significant inter-local alliances by extracting from all of these and joining their resulting blocks through joint efforts, thus materialising these efforts in one citadel complex. Any alliance to Mycenae does not need to exclude local alliances nor their self-awareness and identity and their deep-rooted link (literary!) to each other and their ancestral important places. In the end, the Tiryns ruler still had his own territory to look after as well. As Mason (2007, 49) argued for Mycenae's Treasury of Atreus, the power of the owner of the tomb did not just express status as ruler over Mycenae through the architectural grandeur of the tomb *alone* but also *through its very position in that landscape*, which was full of meaning, too (my emphasis; also Wright 2006). Therefore, the continuity of building on this *same* outcrop in EH II, LH IIIA-B and also LH IIIC (Building T) may show the presence of powerful lineages that were manipulated to get the work done on the *most central part* of the complex in *each* period, representing, most likely, the centre of power in each period (fig. 10). This may have been emphasized by the use of the red column bases even though they were not visible at all times. It has been noted in other cultural contexts that specifically coloured stones formed the means of communication between worlds (Darvill 2013 with references), as a sort of portal. The red stone in Tiryns may have been doing exactly that, especially atop in the Great Megaron and at the Western Staircase and Eastern entrance systems. Lefebvre (1991, 221) wrote: "[B]y building in monumental terms, people attempt to physically embody eternal and imperishable social orders, thus denying change and therefore transmuting 'the fear of passage of time and anxiety about death, into splendour".

7 Conclusions

A pure economic perspective of having to do the least effort and maximum output or a strategic perspective due to its high-point location overlooking the bay is not enough to explain large-scale building at Tiryns. Outcrop quarrying may well have carried more symbolically-laden values (see Scarre 2009, 9) as shown above. Several types of knowledge transfer, involving dexterity, memory and endurance in order to become a member of a group *(e.g.* like a guild), must have taken place over long periods of time. Knowledge about the sources of stones, their associated qualities, powers and meaning, the actual production processes involved in long-term monumental construction, and possibly long-standing sacred topography of the Tiryns outcrop which was perfect for ideological manipulation through claiming ancestral lineage to the place itself in the later phases, must have been well-understood and practiced at all social levels (*e.g.* Brysbaert and Vetters 2010).

Studies elsewhere (Huffman 2009; Huffmann 2013: pers. comm.) show how people's world views on sacred places and their inherent power shifted over time. The 13th century

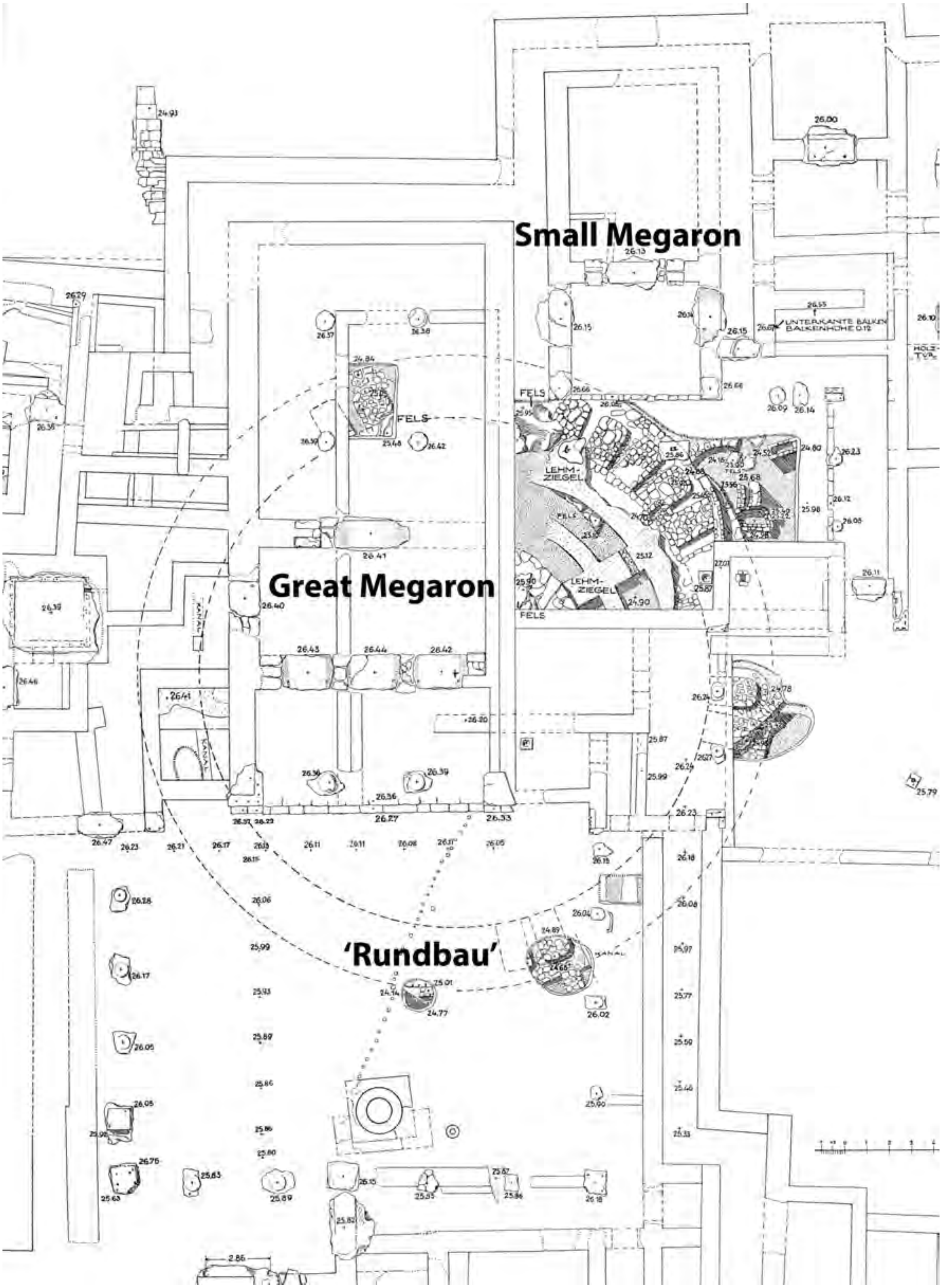

Figure 10 Map of the Great and Small Megaron area showing the 'Rundbau' traces underneath (after Müller 1930: plate 5)

AD king in the Mapungubwe region chose to build his palace exactly on top of the former ritual place, the mountain top, used in previous phases by the sacred leader in their community, the 'rain maker', who himself was a commoner. The king thus appropriated this sacred place in order to secure his opportunistically self-obtained power over the entire community. In a similar way, Great Zimbabwe was built on a rainmaking hill from which the king controlled a large territory through a hierarchically set up bureaucracy while he was both a political and sacred leader (see Maran 2001 for Mycenaean dual leadership). He established a new social order and his sacred power by talking to the gods through the medium of the ancestors of the hill. The hill, thus, as a material feature of sacral topography, brought the gods in contact with the king through the ancestors who dwelled on that hill top, which became even more accreted with importance over time and through its reuse as a chosen seat for power or sacrality (for similar arguments elsewhere: Scarre 2009, 9). In his dual capacity, the Great Zimbabwe king could be approached only by climbing zigzag up the hill, not directly. This is not unlike the complex entrance route described so well by J. Maran (2006a; 2006b) from the East entrance to the Great Megaron, or Western Staircase along the bathroom to the Great Megaron, in order to reach the ruler at Tiryns.

As such, I argue that long-term revisited locales are in fact active members in the process of rulers' power appropriation to specific places. Through activities of both quarrying and building and various combinations and mixtures of these, as the Western Staircase illustrates, leaders show that they can even remodel ancestral sacred locales (such as the Tiryns outcrop) to their new tastes and needs in the built shape of the citadel complex. Combining this with the fact that it must have taken organised labour forces of specific sizes to construct for prolonged periods of time and at such a large-scale (Brysbaert 2013; 2015; Brysbaert *et al.* in preparation) – we should not forget several other constructions undertaken during the second half of the 13th c BC in the same region – the intensity of the work is also visible in how the stones were placed. This was far from a random activity or a degradation of building techniques from the masoned building style (stated by Fitzsimons 2011). Instead, while cutting and preparing masoned stones takes time, they are much easier to construct with. Unworked rough boulders need careful fitting and balancing, and employing these types of building blocks will have taken considerably longer than employing masonry and much more know-how of the materials' capacities. The rough sight of often irregular rows of blocks, combined with their massive sizes, some of which were needed for static reasons, and a real mixture of grey and red stones, makes Müller suggest that: …"Vielmehr hat man sich ihrer gefreut und die ausserordentliche Arbeitsleistung, die Transport und Versetzen erforderten, nicht gescheut, ja man wird gerade besonders stolz auf die Mauern gewesen sein" (Müller 1930, 59). In constructing the magnificent vaults with gigantic irregular boulders, dating to the latter part of the 13th century BC, Müller (1930, 60-61) sees strong leadership, well-trained workers, careful stone selection and strong forward planning; I cannot agree more. When combining such building strategies with the variegated stone choices for their intrinsic meaning and value, and their colour play, it becomes obvious that not much was left to pure coincidence, at least for certain parts of the citadel.

These observations also have important implications for our overall understanding of monumental building of these citadels: picking out each stone for its place of origin, size, shape and its colour has human resource implications all the way back down the *chaîne opératoire* to where these were quarried, transported and subsequently built into the structure. It illustrates well-thought technical choices made by the builders and sponsors and it may even imply their active individual and/or group-made decisions in showing their creativity and know-how of their craft. In some way, one could see these as group/individual mason marks but at a larger scale, implemented by people who consciously left their, possibly competing, stamp on the building for millennia to come, if we care to notice them. If Grossmann, Dörpfeld and Müller are correct in observing that the 350 m long Lower Citadel wall was done in 'one go', several groups of builders must have been at work at the same time, possibly each under the direction of a master builder. Such situations must have created high levels of trust between the builders: they had to rely heavily on each other to make this work and to stay safe throughout all construction work. But certain levels of competitiveness may well have occurred regularly and may have been played out in their building activities (for similar arguments: Bukach 2003, 31). Whether all the builders had access to the same stones or whether specific local relationships or alliances allowed access to one or another stone is impossible to extract. Moreover, the suggestion that builders from Mycenae were involved in relation to the conglomerate stones is certainly tenable. To what extent, however, were Mycenaean builders involved in Tiryns, did they have the monopoly over handling the conglomerate, or were Tirynthians involved too, and were both also involved in working the other stones too? The evidence points strongly towards Mycenaean specialists at work in Tiryns the way the Main Gate is constructed, but the rest may have been in local hands, based on local know-how and the socio-political connections between them.

The relationship, then, between the original physical conception of these constructions, the intentional choices of stone and the location of their placement, their execution, and their ultimate physical, social and symbolic purposes became materialised in their individual configurations and shapes, such as the various parts of the citadel complex. These were, furthermore, determined by their natural topography, by their socio-political contexts, and by people's access to the necessary local and regional material and human resources (skill, know-how) to get them constructed as impressively as they are.

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‘Set in stone’? Constructed symbolism viewed through an architectural energetics’ lens at Bronze Age Tiryns, Greece

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Between c. 1400 and 1200 BC, concentrations of Mycenaean centres emerged in the Argive Plain, such as the site of Mycenae and the citadels of Tiryns, Midea and Argos. This region features a breath-taking amount and quality of large-scale architectural and engineering projects: huge ‘Cyclopean’ walls, corbelled vaults, amazingly modern drainage systems, and still working waterworks (Dam at Nea Tirynta). These features could not have been accomplished without a high level of special skills and knowledge, careful long-term forward planning, and the possibility of mobilizing large work forces. All these requirements had to be coordinated by a body of palatial staff comprising architects, engineers and supervisors.

Employing architectural energetics, I focus on the physical nature of this built environment, specifically on the ‘Cyclopean’ construction of the Lower Citadel wall at Tiryns, and how it linked in with the surrounding landscape while it was constructed during the final 50 years of the 13th century BC. A series of physical and social construction activities of several groups of people are analysed and quantified in order to improve our understanding of the efforts that went into constructing at such a scale and the implicated meanings of such massive fortification walls.

I explore the building experiences at Tiryns which incorporate builders’ choices in materials and techniques employed, and investigate how these building activities were embedded in the socio-political context of that period which allows multiple meanings associated with the Tiryns Lower Citadel fortification wall to be recognized.

1 Introduction

In the prehistoric East Mediterranean and Greek context, monumental architecture as an expression of power by the ruling class over their subjects has been well argued (Maran 2006a; Tiryns’ post-palatial phases: Maran 2012; for prehistoric Cyprus: Fischer 2009), and many insightful studies have shown several ways and contexts in which the power symbols were transferred from one social class to another, while such transfers were not always without difficulties (Maran 2006b). Social aspects of power and symbolism have also been studied in relation to mortuary contexts in the Argolid, more specifically at Mycenae. Simultaneously, few scholars have touched upon what large-scale structures may have meant for the ordinary people who saw and interacted with them on a regular basis (but see Adams 2007), and potentially even worked on them (Brysbaert 2013; 2015; in press). In discussing the social role of Bronze Age palatial structures beyond their defensive character, Maran has focused on their performative space, whereby he emphasizes the dialectical relation between social practices and architectural spaces (Maran 2006b, 76; 2012).

This paper explores the role of the Lower Citadel wall, how it was constructed and by whom, and how it achieved its defensive, socio-political and symbolic meanings. Both performative and military characteristics embedded in ‘Cyclopean’ architecture of this kind have been emphasized and discussed by Grossmann (1967; 1980) among others, who connected the niches and openings to the defensive role of the wall. Iakovidis (1983) saw store rooms in the niches, and Kilian (1988) discussed the cult room in one of them. However, the practical logistics involved in building such large-scale and complex constructions have, so far, been largely overlooked while these aspects stand directly in relation to how the structures were imbued with meaning, to whom was involved in producing such meanings and why.

This paper explores these questions in some detail by employing an architectural energetics approach. The method translates construction activities into labour time units, most often expressed in man-days (hereafter: md). Abrams and Bolland (1999) give a full description of the definition and method and refer to md as person-days but since construction work was/is often done by men, as DeLaine (1997) asserts, I employ the more standard term of man-day: md. Architectural energetics takes into account each step executed in the building process (from quarrying to constructing and decorating) and, as such, it is very compatible with a *chaîne opératoire* approach, as applied in other socio-technological contexts (Brysbaert 2008; 2011; in press), and also, for instance, employed in detail in the important work done by M. Devolder (2013 with further references to her work; 2015). The paper does not, however, address the question of site preparation for construction, such as clearing away standing buildings, levelling the terrain where needed, nor does it discuss the older LH IIIB1 stone rubble wall of the Lower Citadel (Kilian 1988, 139; Maran 2010) since this is beyond the scope of this paper. These aspects are, however, dealt with in a larger ongoing study of the site by the author. The energetics approach then estimates costs involved in the labour that was needed to complete each task, and the volume of materials needed to accomplish this. Over the last 80 years, several opinions on the labour involved in the constructions at Tiryns have been expressed. Müller (1930, 208) referred to several decades, Grossmann (1967) thinks that Müller's estimate is far too high but does not offer an alternative while Loader (1998, 65, 69) suggested 5–5.5 years for specific parts of Tiryns but she was not always systematic in her approach. Due to these largely disparate attempts and due to the lack of a systematic architectural study employing this combined systematic method I present here some preliminary results as a first attempt to address this issue.

The hill outcrop of Tiryns is about 300 m long, 100 m wide and lies about c. 22-26 m above sea level, sloping from south to north where the Lower Citadel and its circuit wall is located (fig. 1). This wall was constructed in the second half of the 13th century BC but several alterations to the original structure took place soon afterwards. A very detailed description on these changes is provided by Maran (2008). Moreover Maran (2010, 726–9) indicated that this massive wall was part of the first phase of the LH IIIB2 building programme and, as such, defensive in character, while in a second phase, but before the catastrophic end around 1200 BC, several alterations (*e.g.* insertion of the larger North Gate) suggested potential political stability and thus counteracted the defensive purpose of the wall structure at that point in time. The military purpose for which the Lower Citadel wall was constructed has been discussed at length by many others. Grossmann (1980, 480) described the shooting holes found in the niches and their changing use; these were apparently constructed to be smaller and narrower on the outside of the Lower Citadel wall than they were on the inside. These shooting holes were the clearest indication that the Lower Citadel wall was intentionally built with a strong defensive purpose in mind (Grossmann 1980, 489-491). These shooting holes became visible in Grossmann's last campaigns and some of the niches make the military aspect (and its failure or change of tactic, see how many niches had already been filled in LH IIIB Final) of the wall crystal-clear. Grossmann (1967, 96; 1980, 481–3) equally discussed the military aspect of the North Gate but recently Maran (2008, 88–9) reassessed the uses of the North Gate in LH IIIB Final, and Maran (2010) presented convincing arguments on the niches and their infill. His recent work in the area of the Lower Citadel has thus clarified many aspects of its circuit wall.

Based on architectural drawings of the Lower Citadel wall which were available through the Tiryns Archive and through several published plans (esp. Schnuchel 1983, figs 1–2; Grossmann 1980, fig. 2), I took a series of calibrated measurements that formed the basic data sets from which I was able to quantify several aspects of the construction activities as accurately as possible (table 1). These were complemented, combined and compared with existing literature on the natural resources that people at Tiryns had at their disposal, and with several sources on architectural energetics, employed both in the Old and New World. What follows are my investigations on aspects of quarrying, transporting materials from quarries to the construction site and the work carried out on the site itself.

2 Quarrying

Several types of limestone employed at the citadel of Tiryns have been observed by geologists: lithofacies A (the hill outcrop of Tiryns' citadel itself), B (unknown origin), E and F (hill adjacent to Profitis Ilias, Varti-Matarangas *et al*. 2002). These materials differ greatly from what is known from the palace of Pylos (Nelson 2001, 48–58, esp. 55–8). Unfortunately, Varti-Matarangas *et al.* 2002 were not specific about which lithofacies were employed where Wright (1978, 202, 204, 205–216), on the one hand, refers to different stones used in relation to the First, Second and Third Citadels but he actually opposes the three citadel phases (Wright 1978: 207-8; also Küpper 1996). Lithofacies A was likely to be the major extraction source for the first phase construction of Tiryns Upper Citadel's walls in LH IIIA1 (see also Loader 1998, 45).

During the entire remodelling of the citadel, the Lower Citadel wall, the Western staircase area, the East and South galleries and possibly the North wall of the Middle Citadel which were all done in LH IIIB, were executed in 'Cyclopean-style' stonework. The fact that the staircase was built possibly a little later than the Lower Citadel wall as indirectly suggested by Grossmann (1980, 41) goes against any large-scale usage of lithofacies A for the Lower Citadel wall since there would be no good practical reason to extract stones from an area which was going to be built up, so by LH IIIB2, this outcrop may not have contributed significantly to the large stone mass needed for the Lower Citadel wall (see also Brysbaert 2015), at least on its west side. Moreover, the stones used at the Lower Citadel wall do not correspond to the colour description of lithofacies A as being dark beige when freshly exposed and light beige when exposed for ages (Varti-Matarangas *et al*. 2002, 479). The stones employed are dark steel blue/grey and some are reddish (Grossmann 1967; 1980, 492; Wright 1978, 215–16). Those that were exposed in more recent excavations show both reddish and blue-grey hues, predominantly blue-grey. This fresh stone colour description fits well with lithofacies E and F, and partially with B. Until a more thorough (and petrographic) study of

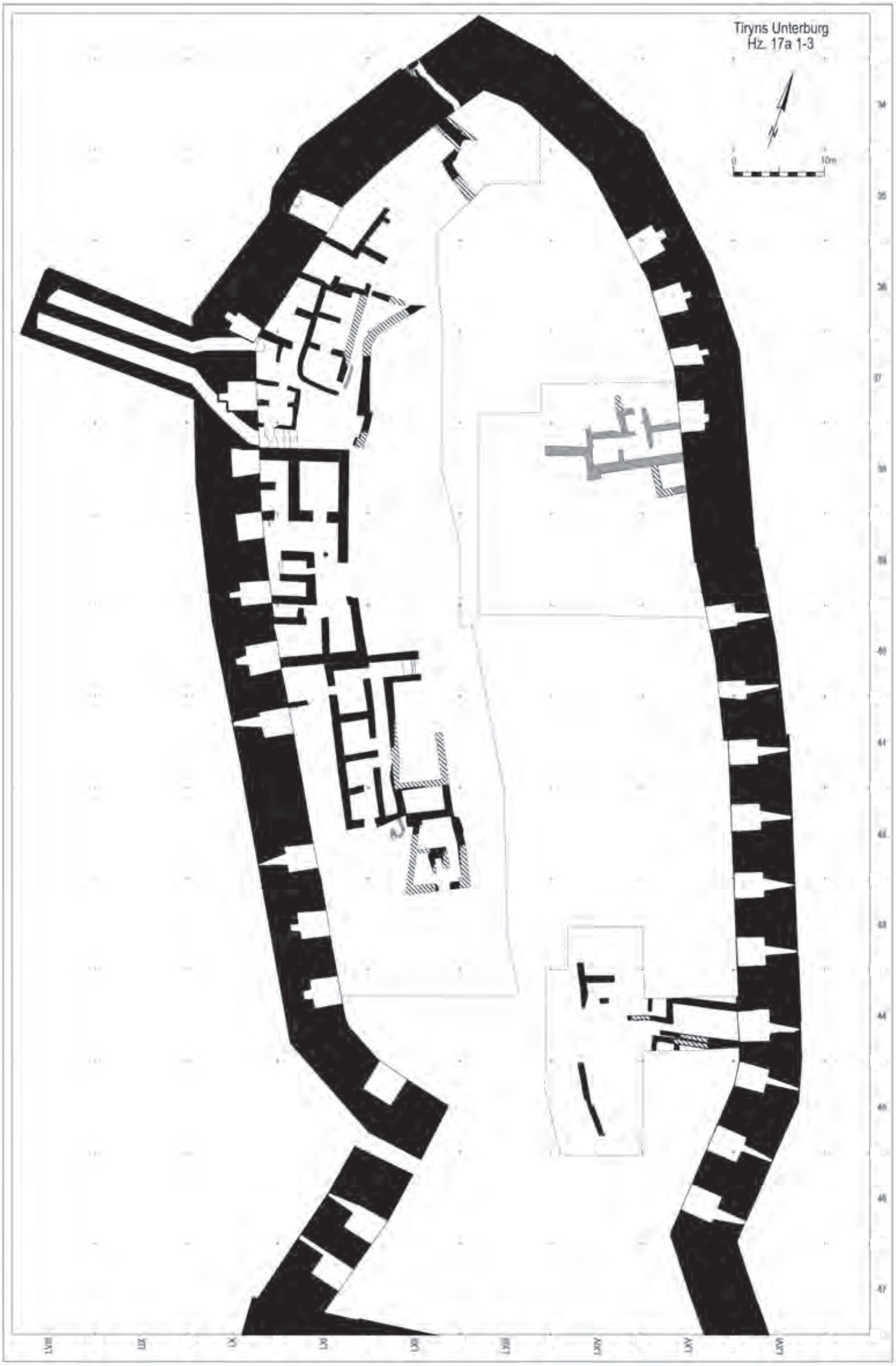

Figure 1 Plan of Tiryns' Lower Citadel wall (Hor. 17 a1–3) (with kind permission of Professor J. Maran and kindly provided by M. Kostoula)

Total length	350 m (T_15) [a]
Average thickness	7.5 m [b] (10 measurements) (T_8, T_76)
Average preserved height (W side)	6.5 m [c]
Limestone density factor	2,700 kg/m³
Large block size (0.8–5+ m³)	2–13 tonnes
Medium block size (0.2–0.8 m³)	500 kg–2 tonnes
Small block size (0.01–0.2 m³)	30–500 kg
Large block size average	2.5 tonnes
Medium block size average	1 tonne
Small block size average	250 kg
Large block size % of total wall	65% [d]
Medium block size % of total wall	25%
Small block size % of total wall	10%
Total volume of stone mass (17,060/21,000 m³) [e]	46,070/57,700 tonnes

Table 1 General information on the Lower Citadel wall, fot notes a–e: see endnotes, p. 103

the stones employed can be matched with specific extraction locations, the most likely scenario is that stones for the Lower Citadel wall may have come from lithofacies A and B, but many could have come from E and F, the latter originating from quarries in the hill adjacent to Profitis Ilias, about 1 km south-east of Tiryns.

In reference to the total volume in cubic metres or mass in tonnes (Table 1), the cost for quarrying the limestone can be calculated as follows (*contra* Loader 1998, 67 who thinks that it is impossible to calculate this). In his colossal work done at Petra, Bessac (2007, 136) suggests limestone extraction costs at 1.0 md/m³ (unworked blocks). He suggests that 1 man-day (md) entails 10 hours (Bessac 2007, 135, n. 495). This figure is similar to De Haan (2009, 3) who suggests 1.1 md/m³ for masonry blocks, based on a modern experiment with very experienced workers. Abrams (1994) worked with 1.1 to 2.2 md/m³ for unworked small stones based on modern experiments, while Pakkanen (2013) suggests similar numbers (1.1 to 2.2 md/m³) for Athenian limestone masonry blocks. For quarrying, Pakkanen calculated one skilled and one unskilled worker and added 0.2 unit for supervision, based on inscriptional evidence and ethnographical comparanda. Most of these authors use a 10-hour workday (also DeLaine 1997, 106; Hurst 1902, 376). This seems to be a realistic suggestion since it corresponds to the working days of agricultural workers (allowing for shorter days in the winter and longer ones in the summer). In following Bessac and De Haan, although the carefully cut corner blocks are not yet taken into account for these preliminary calculations, I employ one man-day per cubic metre (hereafter: md/m³) because mainly roughly worked or unworked blocks were employed throughout. While some of the blocks are larger than 2.5–2.7 tonnes and may thus have needed more effort (De Haan's 2009, 3, 6 refers to blocks of 2.5 tonnes), it is at this preliminary stage impossible to estimate how many such blocks left the quarries, so the average of 2.5–2.7 tonnes or 1.0 m³ is employed here. Moreover, no real difference in labour costs is to be calculated for quarrying large or medium-size blocks (but see Brysbaert 2013 on the bathroom floor block of 23 tonnes). The rubble that was used mostly inside the wall but also in between blocks on the outside of the facades, was likely collected from the waste incurred during quarrying itself and during the rough dressing of the blocks, carried out in the quarry or later. Grossmann (1980, 496) mentions that further stone dressing was rarely done for the Lower Citadel wall in comparison with the Upper Citadel materials, and that specific diorite stone pounders may have been employed for such a task. Such work has not been taken into the basic calculations presented here but is being incorporated as part of the larger project aims, together with the efforts involved in filling up the gaps between the larger stones with various materials, and covering the walls with mortar material (Grossmann 1980, 498).

For the total amount of 17,060/21,000 m³ limestone material (or 46,070/57,700 tonnes) at a rate of one md/m³, the same number in man-days would have been required in the quarries. This could translate into 100 men quarrying 171/210 man-days respectively. Since at least three different lithofacies may have been employed in the Lower Citadel wall, possibly three groups of 30 men could have been working in three different quarry areas simultaneously, assuming that the quarry location allows for this number of people to work alongside one other, an aspect currently under investigation. In contrast to this model, one group of 30 men may have gone from quarry to quarry, providing an ongoing stone supply *during* the actual construction activities, thus keeping the workflow steady and efficient, rather than causing massive amounts of stone to accumulate at the quarry or construction end. This would, independent of the economically efficient workflow, hinder and even endanger other day-to-day activities in and around the citadel. This model would spread the quarrying over longer periods of time but would have provided stone when and where needed, and it would reduce the number of people needed for the quarrying. It also corresponds better to the later Greek quarry practices of ordinary small numbers of blocks at a time.

3 Transporting from the quarry to the site

3.1 Transport options

Before any figures are given for transporting the stone from the quarries to the building site, the means of transport needs to be considered. Without coming to a definite conclusion, Loader (1998, 54-61) discusses this aspect in some detail and cast doubt over Wright's assertion (1978, 159, 229) that transport was not an important factor since most materials came from nearby. I agree with her that getting blocks of 2–5 tonnes from even as close as 50 m–1 km away poses logistic and practical challenges, and involves efforts which cannot be ignored for the sheer stone volume needed to construct the Lower Citadel wall (details in Brysbaert 2013).

Two options for transporting blocks can be considered here: manpower and animal traction, combined with wheeled vehicles or sledges. The Linear B tablets refer to the presence of draft animals in association with wall builders on major construction sites (Palaima 2010, 367; on wall-builders or masons: Pylos An series, An 35; Chadwick 1976, 138) and mention the ox as a working animal. Ventris and Chadwick (1956, 42), Killen (1992/3; 1998) and Halstead (2001) discuss how oxen spans in agricultural contexts seem to have been managed by the palatial administration, probably due to their high cost of maintenance, and seem to have been allocated to the *dāmos* for agricultural tasks while the body of the *dāmos* may have been providing the human labour for agricultural work (Killen's share-cropping model). Also De Fidio (1992, 183–4) discusses the allocation of working oxen by the Knossos palatial administration for ploughing purposes. One may wonder then whether a similar organization may have been set up and shared between palace and *dāmos* with its landholders when it came to organizing and recruiting both skilled and unskilled workers for construction purposes.

Since oxen were known in Mycenaean contexts and their use in the transport of such masses of stone would have severely reduced the needed human labour, I have calculated the man-day cost it would have taken oxen yokes to bring the required stone mass to the site, one kilometre away. The literature provides various numbers in relation to the weight one oxen pair can move. Burford (1960, 8) suggests that 19 yokes at full strength could have pulled 10 tonnes. DeLaine (1997, 99) suggests that 12–18 yokes are needed for 10–15 tonnes respectively (see also Mannoni and Mannoni 1984, figs 136–8). DeLaine's figures infer that one oxen yoke could move about 800 kg of material while Burford (1960, 3–6) suggests about 500 kg only; Burford revised this number in 1969. Heavier loads are carried, such as building blocks from 2 tonnes onwards, and up to 6–8 tonnes blocks are mentioned for Eleusis. The most realistic estimation is that one yoke could have transported 800 kg to 1 tonne which fits DeLaine's and Loader's (1998, 60) suggestions and this is also used here. Several painted ceramic oxcart figurines have been found in Kilian's excavations (1988) of the LH IIIB Middle Building in the southwest Lower Citadel. These date to the 13th century BC while an EH II example from Tiryns has been mentioned too (Brysbaert 2013, 62 with refs). The figurines indicate that oxcarts must have been an important resource to people all through the Bronze Age.

Table 1 shows the percentages of large, medium and small size blocks counted over half the length of the Lower Citadel wall. These numbers come into play for transport since a single pair of oxen or one yoke can only transport part of the medium to small size material. The large size blocks, minimally 2 tonnes with an average range of 2.5–3.5 tonnes, needed quadruple yokes, or eight oxen, per cart load or sledge. Loader (1998, 60–1) describes the average weight of a massive block at being under two tonnes using Wright's (1978) average block measurements, some of which actually add up to 4 tonnes. In my block calculations quite a few were larger than Wright's measurements for the Lower Citadel wall, with at least one dimension up to and more than 2–2.5 m. Furthermore, the difference between the use of a wheeled vehicle and sledge may result in different friction on the road surface, slowing the movement down. Consiglio (1949, 92) discusses the practical use of lubricants to transport the Carrara marble blocks and while calculating the friction coefficient (μ) is beyond this paper's scope its influence is under investigation at the moment of writing (see *e.g.* the water poured over the sand as lubricant in the transport of Djehutihutep's statue; Koutsoumpas and Nakas 2013).

The movement of the two different volume types (see Table 1) has been calculated separately and despite the logically suggested model of employing both single and quadruple yokes, it is, in effect, impossible to be sure of the size of load that would have been transported in one trip, or how many oxen pairs were used per trip. I have, therefore, employed the minimum rate of 0.7 md/tonne/km. Pakkanen (2013, n. 45) calculates this rate, based on Greek inscriptional evidence. It needs to be pointed out, however, that calculations of both oxen yokes and people involved in transport will depend on their availability at the given time of the year, especially during the periods where agricultural tasks also require the presence of oxen. Seasonality is thus a crucial factor to be taken into account and potentially conflicting activities may, therefore, have been spread out to ensure that they would not overlap, suggesting a well-organized body of people that played a pivotal role in forward planning (also Brysbaert 2013; Devolder 2015). The rate of 0.7 md/tonne/km number incorporates the number of oxen pairs needed related to the load carried.

3.2 Loading and unloading blocks

A crucial factor that has cost implications is the loading and unloading of the carts (table 2). Burford (1960, 12, 15, 17) indirectly points out the importance of this activity in Classical times by referring to the experience one needed in loading heavy blocks onto carts, the payments that were accounted for doing so, and the officials that were in charge of organizing such work, especially the unloading of heavy blocks (also Loader 1998, 65–73). De Haan (2009, 7) reports that the loading and unloading of 2.5 tonnes blocks can be done in a matter of 20 minutes. While this may well be the case, it still requires several people per large-size block and, as such, it involves labour input at a rather important scale for the Lower Citadel wall, considering its block size. Hodges (1989, 133, 139) refers to four men at the levers and two people inserting supports but we should not forget that the blocks here are regular and evenly weighted blocks each of 2.5 tonnes. The larger blocks at Tiryns are far more irregular, both in shape and size and will, in all likelihood, have required two extra people at the levers, thus a total of eight people per work team around one average block. The medium to smaller blocks may have been helped by four people per team (also Loader 1998, 67). Loading heavy blocks thus entails both levering and hauling efforts to be carried out by teams of well-coordinated people. If each block of 2.5–3.5 tonnes took 20 minutes to load in the quarry, and again to unload on site (De Haan 2009, 7), 65% of the Lower Citadel wall block volume falls in that category while 35% medium to small material can be handled in the same time by four people. Dorka (2002, 13, 21) halves this time because he allows the use of lifting devices with counterweights for this sort of work in Egypt. While there is no evidence for such devices the option of this method for lifting blocks is attractive and its possibilities will be explored in the near future. Based on this double task, an extra total amount of 10,700/13,400 md is required to fulfil this important step. In order to avoid strong people idling, the large loads may have relied on the four guides accompanying the quadruple yokes while relying on four quarrymen and four builders on either end of the transport trail and the same may have applied to the single yoke set-up.

Table 3 summarizes the calculations for the block transport activities with oxen. The speed of a yoke return journey is c. 2 km/h. According to DeLaine (1997, 108) such loads moved at 1.67 km/hour one way. So each yoke, single or quadruple, could have gone loaded and returned empty to the quarries in 1 hour, so, in an ideal 10 hour working day, 10 trips/day could be achieved. Loader (1998, 69) similarly refers to 1.8–2.5 km/h. The number of return trips that would have to be made sounds very high but this number would be decreased if several yokes, *e.g.* five groups, were set up to work in rotation to achieve a constant flow of stone provision to the construction site. Such work, however, may have become difficult, if not impossible, if rainfall turned some of the roads muddy and slippery, thus making transport work impossible during parts of the winter and early spring. Taking such environmental factors into account already indicates that constructing such large-scale works may not have continued uninterruptedly for years on end. Agricultural activities may have delayed this further (Brysbaert 2013).

65% large blocks: 30,000/37,500 tonnes	6 at levers + 2 inserting supports	20 minutes/action	**6,400/8,000 md** [f]
35% medium/small blocks	4 at levers and inserting supports	20 minutes/action	**4,300/5400 md** [g]
100% block loading and unloading	-	-	10,700/13,400 md

Table 2 Block loading/unloading, for notes f–g: see endnotes p. 103

65% large stones	30,000/37,500 tonnes	c. 3.5 tonnes/trip	8570/10,715 cart load trips/4 yokes
35% medium/small stones [h]	16,124/20,195 tonnes	c. 1 tonne/trip	16,125/20,195 cart load trips/single yoke
Total nbr of trips	-	-	24,695/30,900 trips
Total trip days	-	-	**2,470/3100 trip days**

Table 3. Block transport from quarry to site, for note h: see endnotes p. 103

Moreover, each oxen pair needed one guiding person alongside it and such a highly complex level of transport provision needed complex levels of organization and supervision throughout (Burford 1960, 16–17). The Società Editrice Apuana (1970, 147) published fascinating images of the multiple oxen yoke transport of an immense Carrara marble block where each yoke has a guide (*contra* Loader 1998, 69).

The figures given here did not take into account the quality of the road surfaces (and if repairs/reinforcements were needed), the time of year when this can be done (likely not in the rainy season), or any of the friction coefficients (*e.g.* Consiglio 1949, 90, 92) that play a role in the efficiency of the transport. These figures, although preliminary and indicating minimal efforts only (full economic costing is underway, see *e.g.* Brysbaert *et al.* submitted), clearly indicate that transport efforts, thus labour costs, cannot be ignored even if only one kilometre is to be covered (see also DeLaine 1997, 217). Blocks much larger than 3.5 tonnes and up to 13 tonnes, as a few are, would then need a different approach altogether. A minimum of 16 yokes would have been required for 13 tonnes (after DeLaine 1997, 99) or, if pulled by pure man power, it may have taken a similar collaboration as was required for the bathroom floor block (Brysbaert 2013). If one kilometre needed to be traversed, moving a 13 tonnes block may have taken 50 people 1.5–3 days to reach Tiryns.

4 Building the Lower Citadel wall

Extensive accounts of the building activities at the Tiryns citadel have been published but very few details cover the actual day-to-day process of getting the blocks there, lifting them and building them into the wall. Dörpfeld (1886) discussed many construction elements early on while Müller (1930), Grossmann (1967, 1980) and Schnuchel (1983) cover various aspects of the construction of the Lower Citadel. The most detailed account of construction techniques, tools and processes is Küpper (1996, 31–52) who includes a discussion of the term ‘Cyclopean’ and of the use of a binder material applied in the Tiryns walls. None, however, apart from Loader (1998), detail how the work may have been organized by actually looking at the builders and their supervisors. Küpper (1996, 33) does refer to the stepped wall construction in segments and to the high level of skill required to achieve perfect joints. Such display of skill confirmed, for him, the clear defensive purpose of the construction, next to how the construction symbolizes the power behind such works, a point I totally agree with (see discussion). Grossmann (1967, 98) agreed with both Dörpfeld and Müller that the Lower Citadel wall was constructed as one unit at one time and that the size of its stones by far surpassed those employed at Mycenae. He suggested that the wall was built up in horizontal courses over its entire thickness instead of in two faces with a space in between and filled later, since it would not have been possible to carry this out for the entire 350 m of the wall. It was, moreover, achieved in segments and the joints between such segments are visible in the outside façade. These joints do not pass perpendicularly through the wall thickness. Instead, they are stepped on the inside and thus form a stronger connection between each segment (Grossmann 1967, 100–1; Küpper 1996, 50).

4.1 Hauling up the blocks

The Lower Citadel wall was constructed on the bedrock: the foundation trench was cut through older settlement layers and the bedrock surface (Küpper 1996, 49–50 for details). Once the latter was ready, an earthen ramp has been postulated to facilitate the transport of blocks to the actual wall surface and to put them in place. While this point seems quite certain, Küpper did not agree with Grossmann’s suggestion of an orthogonal ramp, or several, which could be moved from segment to segment when needed, based on the fact that it was not economical given the amount of earth being moved, and such ramps would not have aided in constructing the niches. Instead, Küpper (1996, 50) argues that the ramp must have been at least 4.5 m wide to allow for the size of the transported blocks and workspace on either side. In relation to the ramp discussion, Maran (2008, 47-8) describes a stone platform found underneath Room 78c of Building XI in the northern tip of the Lower Citadel which, stratigraphically, dates between LH IIIB Developed and LH IIIB Final and is thus contemporary with the wall construction. He suggests its potential usage by the builders of the Lower Citadel wall as an option and this will be looked at in more detail in the near future.

Table 4 presents the calculated man-days for Grossmann’s ramp system; figures based on Küpper’s system are given in table 5 and are discussed below because the matter is crucial to the wall construction itself. The figures, based on DeLaine’s extensive research, and corroborated by Hurst (1902), indicate that one person could move c.1.8 m³ earth in one day, which is almost double the 1 m³ employed by Fitzsimons (2011, 80), who based his calculations on Wright (1987, 174).

According to Küpper who worked out the figures of Grossmann’s ramp, the initial volume of earth of 281.25 m³ needed to be doubled (i.e. 562.5 m³, see its costing as calculated in Table 4) when an inclination of 10% is used for hauling up the blocks. All factors for these calculations are based on DeLaine’s (1997, 107, 268) detailed work on soil movement. Hurst (1902, 377) provides the md rate for ramming earth in place, a factor not taken into account by Küpper’s calculations. If this ramp needed to be moved a minimum of four times, 2,250 m³ of earth would have had to

Digging soil and throwing behind	0.15 md/m³	42.2
Loading into baskets	0.06 md/m³	16.9
Carry 100 m: md/trip + md/m³	 0.0045 (x trip nbr) + 0.075 md/m³ (x volume)	 48.7 21.1
Ramming of earth	0.0367 md/m³	10.3
Supervision	10% of total md	
Total work for 281.25 m³		139 md (unskilled) 153 md (with supervision) [i]

Table 4 Cost calculations of Grossmann's ramp, based on 281.25 m³, for note [i]: see endnotes p. 103

Digging soil and throwing behind	0.15 md/m³	1,969
Loading into baskets	0.06 md/m³	788
Carry 100 m (md/trip + md/m³)	 0.0045 (× trip nbr) + 0.075 md/m³ (× volume)	 2,272 984
Ramming of earth	0.0367 md/m³	482
Supervision	10% of total md	
Total work		6,500 md (unskilled) 7,140 md (with supervision)
Total work (supervised) 6.5 m 8 m		 **4,640 md** **5,710 md**

Table 5 Cost calculations of Küpper's ramp, based on 13,125 m³ for 10 m height

have been moved. If the wall is taken to have been 10 m high, a volume of 9,000 m³ would have been required and if that needed to be moved four times, thus a volume of 36,000 m³ of earth, the cost would have been 19,600 md (based on Küpper 1996, 50–1). A hundred people would have been shifting just earth for 196 days.

Instead, Küpper suggested a 350 m long ramp all along the planned wall circuit starting on the south-east side, moving alongside the trajectory of the developing wall northwards and then to the west and south while sloping up. This ramp would also have allowed two groups of ramp builders either working towards each other or away from each other. Thus, fewer people would have been required since building would only have needed to be done day-by-day as the wall grew. When it reached a height of 10 m at one end, the inclination would only be 2.9 cm/m or c. 3 %. Küpper (1996, 50–1) suggests that the ramp started on the east side from where it climbs up counter-clockwise towards the north, then west and south, and the 2.9 % inclination is convenient for block transport. Once the first segment of the wall on the west side is constructed over a width of X m, that earth ramp section of 10 m high can be taken down and redistributed over the remaining 350 m – X m and placing the X m before the original zero point where the ramp started. That way, the ramp keeps its 350 m length which is the only prerequisite to maintain the 2.9% inclination on the ramp. This pattern is repeated until all segments of the wall are built to their full height which, in fact, means that the same volume as the initial 350 m of ramp was constructed, piecemeal, out of the same amount of initial earth volume of 6,562.5 m³. The total earth volume to be shifted would thus be double, i.e. 13,125 m³. The total volume of earth for this ramp would be 6,560 m³ but used twice.

Table 5 converts this part of the construction activities into costs. If again 100 people were working purely on moving this amount of earth, they would spend c. 72 days altogether. This stands in sharp contrast to the total of 196 days based on Grossmann's earth ramp model (see above and Table 4). What also makes Küpper's model more attractive than Grossmann's is that the former sees this work as integrated in the actual stone wall construction itself and, as such, no entire work group is solely moving earth around, and a more realistic inclination to haul blocks up is achieved.

As far as the actual stone wall construction itself is concerned Loader comments: 'Little consideration has been given to how the blocks were placed in positions in the walls.' She (Loader 1998, 61-9) gives examples of other cultural settings and worked out cost calculations for activities to be done by manpower and by animal traction. De Haan (2009) refers to pyramid building with standard blocks of 2.5 tonnes, all cut perfectly to the same size to be fitted tightly throughout. Without wanting to underestimate the work involved, construction with massive unworked boulders is to be seen as a far more irregular task, and exactly because of the irregular block size and shape, extra work/care needs to be provided in placing them as tightly as possible while providing a technically sound and strong wall. Loader's model of using a wooden roller ramp in combination with oxen to pull blocks up and place them in position is attractive. However, no evidence exists to prove that this system had been invented and used by the Mycenaean builders and it would have meant that turning points for oxen yokes would have been needed on the ramps.

4.2 Placing the blocks in the wall

So far, the blocks were already transported to the site and unloaded, but they still had to be moved up the ramp and be put in place. While constructing with irregular massive blocks cannot be quantified as easily as for the Egyptian masonry blocks the latter figures can be used as a guide and be modified. For this purpose, I have modified Atkinson's and Hodges' figures of human hauling labour and placing blocks by levering to fit the Mycenaean case as closely as possible. Atkinson (1961, 297) suggests that 2 men can haul 1 tonne on a sledge over a flat surface. If 2.5 tonnes is taken as an average for the massive blocks, 5–6 people would be needed. To further allow for a 3% inclination of the 350 m ramp, 6–7 people would be required to pull such a sledge up the ramp to its final location. Based on Atkinson (1979, 120–1), Loader (1998, 68) suggests that it took 4 men 11.19 hours to pull a 2.5 tonnes block from the quarry to the site, covering 1 km distance. Translating this into pulling this weight up the 350 m ramp with 3% inclination with 7/8 men at hand would reduce the time to just over 2 hours per block while, in reality, no ramp would be needed at the start and the full one would been needed only towards the end of the construction. Therefore, I worked with an average ramp length of 175 m throughout and one block per hour would be hauled up on average. The hauling of one 2.5 tonnes block up the ramp could be achieved by eight people in one hour, so eight md would have brought up 25 tonnes of stone material to the top of the wall under construction. Table 6 brings the total figures together.

These then need to be placed in the wall which can, in my view, only have taken place by careful and controlled levering (Loader 1998, 64 basing herself on Hodges 1989, 139; see also De Haan 2009, 7). For this task, I employ the same number of people as were required for levering the blocks during loading and unloading since placing each block from the sledge in the wall is a very similar action (see Table 2). Conveniently, c. 7/8 people, required to haul up each block, are needed to lever it in place. A 2.5 tonnes block can be moved horizontally 190 mm in 20 seconds by 6 people (Hodges 1989, 133–9). I employ 8 to account for more irregular blocks in size and shape, so a distance of c. 60 cm can be traversed in 1 minute. Over the thickness of the wall of 7.5 m the average distance for blocks to be moved is 4 m. Table 7 sums up the calculations done for this part of the construction.

Weight in tonne	people	Time
2.5	8	1 hr
25	8	10 hrs = 1 day
46,070/57,700	8	1,842.5/2,308 days
46,070/57,700	1	14,740/18,464 md
46,070/57,700	**8 × 5**	**368.4/462 days**

Table 6. Hauling blocks up the ramp, see also note j in the endnotes p. 103

Table 8 brings all costs together and shows that the man-day estimates for hauling the blocks up the ramp are high compared to other costs, as already noted by Loader (1998, 68-69). This is why she she reverted to using oxen to haul up the blocks on a hypothetical wooden roller system. However, these are based purely on human power, thus they are expected to be high.

5 Discussion

How should these calculations be understood? Relating them to each other is the most logical way of interpreting them since none of the tasks outlined were done in isolation or in a linear way. Abrams and Bolland (1999) developed a very convenient 'spread-sheet' model, adapted here for these preliminary results. DeLaine (1997, 105–6) suggests that a working year on the building site of the Caracalla Baths in Rome consists of 220 working days (April–November) and work outside, such as quarrying, could be conducted for 290 days per year. At Tiryns the quarrying was probably linked with directly transporting the blocks to the site, so I have used a maximum of 220 days for all activities. As already indicated, environmental and other factors, such as seasonal changes, and agricultural tasks of working the land with oxen and ploughs, may have had a direct impact on the number of days that people and animals could have been available to work in construction at *any* given season, unless certain agricultural and other craft tasks were temporarily taken over

	Horizontal speed	mass	Block type	People needed	Distance required
Giza pyramid	190 mm/20 m-sec.	2.5 tonnes	Masonry	6	-
Tiryns wall	190 mm/20 sec = 60 cm/m-min.	2.5 tonnes	Irregular	8	
Tiryns wall	6,666 m-min.	2.5 tonnes	Irregular	8	4 m (400 cm)
Full wall circuit volume	**204.7/256.44 m-days**	46,070/57,700 tonnes	Irregular	8	4 m
Total cost	1,637.6/2,051.5 m-days			1	

Table 7 Positioning the blocks in the wall, see also note k in the endnotes p. 103

Action	6.5 m wall	8 m wall	Team work nbrs for 6.5/8m wall
Quarrying	17,060 md	21,000 md	30 × 568.75/700 md
Loading and unloading:			
Large	6,400 md	8,000 md	8 × 800/1,000 md
Medium & small	4,300 md	5,385 md	4 × 1,075/1,346 md
Transport with oxen	2,470 trip days	3,010 trips days	
Ramp building	4,643 md	5,714 md	8 × 580/714 md 16 × 290/357 md
Hauling blocks up the ramp	14,740 md	18,464 md	8 × 1,842.5/2,308 md (8 × 5) × 368/462 md
Positioning blocks in wall	1,637.6 md	2,051.5 md	8 × 204.7/256.4 md

Table 8 The basic Lower Citadel wall operation summarized

by others. The need of oxen for ploughing, however, would have remained and while we cannot answer seasonality-related questions with any degree of certainty at this stage such considerations were explored elsewhere (Brysbaert 2013 and the ongoing work). Table 9 visualizes the different tasks spread over a specific time period.

Everything became more labour intensive towards the end of the construction: the ramp became higher thus more people were needed for hauling up blocks. Only the quarrying took up the full three years while other tasks started later, often with fewer people at the start than later on. All figures are thus locked into each other out of necessity: the rate of bringing blocks up should match the rate of placing them in the wall *and* the rate by which they are brought to the site, hence also quarried, in order to avoid accumulation of materials which could block construction and everyday life. For that reason, I suggest multiple teams of eight people hauling the blocks up the ramp, in a rotational chain, as was also suggested for the block transport by oxen yoke teams. Building the ramp and positioning the blocks in the wall are closely linked. Since these teams' maximum work rate is determined by the quarrying and transport rate, the tasks of constructing the ramp, hauling the blocks up and positioning them in the wall could have been done by the same shifting teams as three parts of one task.

With the data employed, Table 9 demonstrates that the Lower Citadel wall could have been constructed, by less than an average of 100 men and five teams of oxen, in about three years. This stands in contrast to Müller (1930, 208) who referred to several decades but that was commented upon by Grossmann (1967, 101).

My calculated statements reflect, first, the 'ideal sketch' of the basic wall construction produced here in calculating *minimum* numbers of people, animals and divisions per task over time. In this paper, no niches or any later alterations could yet be taken into account, (details in Maran 2010; and Schnuchel 1983, 404-410). The numbers may equally work for a more realistic picture whereby several external factors (*e.g.* seasonality) and internal factors (more or fewer workers and oxen available depending on the season) would be taken into account. These factors would necessarily stretch the numbers calculated, and would especially affect the suggested time lines. However, the number of 100 workers, referred to in relation to several tasks may have been higher or lower in reality, depending on many external factors, but would have to be somehow linked up to the real needs of the task at hand and all other embedded tasks. As such, drastically different numbers, especially when linked together as in Table 9, may not be that realistic either when seen from a purely practical viewpoint and based on the types of data

Activity	Year 1	Year 2	Year 3
Quarrying	36 × 220 md	30 × 220 md	30 × 220 md
Transport	5 oxen teams × 180 trip days	5 oxen teams × 220 trip days	5 oxen teams × 220 trip days
Loading/unloading:			
Large	13 × 175 md +	13 × 220 md	13 × 220 md
Medium/small	9 × 175 md	9 × 220 md	9 × 220 md
Ramp building + positioning blocks	8 × 175 md	12 × 220 md	17 × 220 md
Hauling blocks up	16 × 165 md	32 × 220 md	40 × 220 md
Total in man-years and oxen teams	82 men + 5 oxen teams (partial year)	96 men + 5 oxen teams	109 men + 5 oxen teams

Table 9 Activity time-line per year, expressed in man-days and trip days

that were used (see introduction). These strings, thus, of embedded activities (ramp and wall building, quarrying and loading, unloading and building, Table 9) indicate sophisticated levels of human resource management and planning (DeLaine 1997, 192-193) which are integral and embedded links in the construction activities themselves.

Some remarks are necessary: all figures given are *minimum estimates* and do not take into account certain aspects of working, as outlined above (*e.g.* niche construction, the slightly later North Gate alterations [Maran 2008, 88-91, 2010, 726-729], weight of carts). Further fieldwork will refine these minimum estimates by taking each factor, action and alteration into account. Especially the unskilled labour forces may have shifted from one task to another. Also these aspects are being quantified in the larger ongoing study now funded by an ERC Consolidator Grant (2015-2020). Finally, these numbers only refer to the workforces involved in pure construction processes per step, but nowhere are the people who support these workforces in terms of food provision, tool production, repair and provision calculated (but see Brysbaert 2013). To illustrate the sort of knock-on effect such large-scale building projects may have had on a living community, the archival records of Versailles during the periods of its large construction activities are particularly revealing (Lepetit 1978, 606–7).

Inefficiencies must have been present throughout the work too and detailed fieldwork aims at picking up on the material evidence for these. Grossmann already mentioned, for instance, that the offsets in the wall may have been caused by changing numbers of available workers, irregular available finances and other work interruptions. While some segments are constructed with high regularity, such as parts of the Upper Citadel, others, such as the Lower Citadel wall, are rather irregular, courses running in bends and with unequally thick courses (see already Müller 1930). According to Grossmann (1967, 101; 1980, 493), these irregularities were likely not the consequence of fast work done under time pressure but had to do with flaws in the delivery of materials. Finally, I also consider the effects of higher and lesser skilled labour involved in each task. Any inefficiency would have obstructed the workflow, causing delays and extra ‘costs’. These irregularities are documented in the ongoing work at Tiryns and are being investigated in terms of their potential causes.

Crucial to the smoothness of the workflow and its efficiency would have been the role played by the supervisors and managers who, when experienced, would know how to avoid obstructions or, when these occurred, would know how to restore the workflow. They would also be responsible for indicating when certain groups of people had to start working in order to provide a constant workflow and would thus necessarily have been socially close to them. Considering their potential social organization in terms of recruitment is thus important and can be usefully compared to contemporary work gangs both on construction sites and excavations. These usually work tightly together as one team under one master-builder/excavator, and have often built up solid work experiences together for years, sometimes for decades, in the same team, where recruitment of new members is carefully discussed by all. Finally, some sections of the Lower Citadel wall have been restored over time with blocks that were no longer *in situ*. (see Grossmann 1980, 477–8 with further references and personal observations on current conservation work on site). How such activities may have influenced the calculations presented here is being investigated and compared to field-based data collected (see Brysbaert *et al.* submitted).

6 Conclusions

This paper investigated the Lower Citadel wall construction and its logistics at Tiryns, as only one part of a much larger building programme conducted from the 14th into the second

half of the 13th century BC. This short study, selective of the basic shape of the Lower Citadel wall only, exemplifies how preliminary cost calculations can give an indication about the interactive involvement of different groups of people working closely together, the minimum time it took them, the organization it required and the socio-political and economic implications it certainly will have had on all involved.
I would like to reiterate that future considerations of the niche constructions and their subsequent infill will not only change and fine-tune the calculations presented here but will also tie in these features and the efforts made for military purposes into the social role that such constructions played at specific phases of the final palatial LH IIIB period (see Grossmann 1980, 489–90; Maran 2010).

That the wall was constructed for defensive purposes, among other reasons, cannot be doubted and much effort went into it, as I have aimed to show. However, if the minimum numbers calculated still required at least three years (and likely more, see Brysbaert 2013) for a substantial workforce to complete the basic task, the defensive nature of the construction cannot have been put in place to counteract or protect from *imminent* threatening danger. It was clear, however, that difficulties were on the horizon and this is also seen in the fact that in those last decades of the 13th century BC, efforts were made to bring craft activities of importance to the palatial administration under closer spatial and managerial control and thus within the LH IIIB citadel walls. Such examples are visible in Tiryns Lower Citadel North in Building XI (Maran 2008; Brysbaert and Vetters 2010), and indirectly through the intense recording in the Linear B tablets. A similar trend may be noted at Pylos in the activities of weapon and chariot production management in the northeast building during roughly the same period (*e.g.* Lupack 2008, 122–7), and at Mycenae where the LH IIIB wall now extended to surround the craft activities at the Cult Centre (Lupack 2008, 167).

Efforts in realising these citadel complexes came from several groups with likely different social status: the ruler who presumably ordered the task and may have checked it regularly himself or through supervisors/architects, the supervisors themselves likely present at each stage of the work to be done, the different groups of workers, some of higher specialization than others (both skilled and unskilled), and the people who provided tools, equipment, food and other necessities. In all calculations provided in the tables, I took the difference between skilled and unskilled labour (indirectly hinted at in the Pylos Linear B tablets) into account in the same way as DeLaine (1997, 104–7) does for her work which also includes figures linked to supervision of such work. It remains, of course, not easy to determine specific numbers relating to both skilled or unskilled workers but DeLaine bases herself on historical, ethnological and textual accounts to arrive at a ratio of 1:10, which is probably influenced by the nature of the task (also Pakkanen 2013, n. 27).

Of equal interest is that two types of economic strategies seemed to have been at work more or less simultaneously. On the one hand, we note the building of a formidable fortification wall, whose construction forms in itself a display spectacle, involving the mobilization of substantial work forces and bringing materials from several locations. Taking these factors together, building this wall cannot be considered a low budget undertaking and this was clearly not what elites tried to portray. On the other hand, the use of local stones and the efficiency with which many, if not all, tasks must have been organised to interlock into each other to achieve a smooth workflow, does show that these works, despite their overt display character, had to be carried out economically viable but without losing the rich possibilities to play out subtle messages in their stone choices and usages (Brysbaert 2015). As such, the Lower Citadel fortification wall fulfilled its defensive purposes preventively, by having been constructed, *and* through the way it was done. It may thus have created or enhanced a sense of community-belonging by having many people involved in this 'Cyclopean' task, but it had, at the same time, the power to intimidate. The wall's multiple meanings thus sat in the socio-political power display that went hand-in-hand with its construction from a socio-economic perspective, while employing and bringing together large human, animal and natural resources. Comparatively, the Società Editrice Apuana (1970, 146) shows a spectacle admired by onlookers while caravans of oxen, pulling the largest block ever quarried, pass through the village (also Mannoni and Mannoni 1984, fig. 137 and 248; see also Santillo-Frizell 1997–8 for such arguments).

The possible economic considerations for the wall construction itself then stand in contrast to the efforts and costs involved in, for instance, bringing in the conglomerate blocks for the entrance ways at the Upper Citadel, to be brought from a distance of 15–18 km away (Brysbaert 2015). Similarly, the quarrying, transporting and putting in place of the bathroom floor (Kilian 1988 suggesting that the date of laying this slab could have been earlier than LH IIIB2 and thus be part of an earlier palace phase), in itself a tour-de-force, consisted of an effort that did not follow the usual economic considerations at all. That task alone was performed purely to display power, to show who had it, to perform it, and to demonstrate it to all who were able to observe and admire it.

The quarry for this turbiditic limestone has not been not located yet (Varti-Matarangas *et al*. 2002, 480). However, if the quarry was, hypothetically, 10 km away – a number chosen to be in between the nearest quarries at 1 km distance of the site and the quarries for the conglomerate stone, *c.* 15–18 km away – the transport of this block, if done by pure and extremely well-coordinated human power, would have taken 200 people 17 to 33 days to move the block over 10 km. These figures reflect the efforts done in a recent experiment moving a 25-tonnes Egyptian obelisk, under the direction of Dr M. Lehner (Lehner 1997, 202-225 mentions the use of 6-8 men per tonne, arriving at 200 men for his 25 tonnes obelisk). DeLaine (1997, 100–1) contrasts strongly the bulk material extraction and transport which was done as cost-effectively as possible, versus the use, extraction and transport of, for example, marble, meant to form a display of imperial power, contributing to the overall 'magnificentia' of the construction. The sheer difficulties, in Rome, of moving such massive items around, made a public spectacle out of the generating process of public building. The activities around the bathroom floor thus will have produced an immense spectacle to be discussed and admired, and the contrast, then, between both economic strategies, for the Lower Citadel all and the bathroom floor, was likely intended.

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Notes in tables

[a] T_ nbr: refers to the drawings in the Tiryns Archive that were employed to produce calibrated measurements

[b] Compare to earliest published figure by Dörpfeld 1886, 203: 7.60 m.

[c] An original wall height of up to 10 m has been suggested (Grossmann 1967, 1969; Schnuchel 1983; Küpper 1996), even 12.5 m was mentioned: Loader 1998, 71.

[d] Based on block counts on the outside surface carried out over a length of c. 185 m out of the 350 m, so just over half. Grossmann noted that larger blocks were used more often on the outside versus the inside façade and even less in the centre of the wall. The percentages given here take this into account. This count was done combined on T_31, T_61, T_63, T_66, T_68, T_76, T_105

[e] For the volume and mass in tonnes two figures are given: the first corresponds to a wall height of 6.5 m, the second of 8 m as an average, see *e.g.* Loader 1998, 61, 72 for the latter figure. Both figures are used, as such, throughout the text.

[f] *E.g.* 30,000 tonnes divided by 2.5 tonnes = 12,000 tonnes. Each 2.5 tonnes needs 8 people for 40 minutes = 320 man-minutes or 5.333 man-hours × 12,000 = 64,000 man-hours or 6,400 md.

[g] *E.g.* 16,124 tonnes, loaded per tonne, need 4 people for 40 minutes = 160 man-minutes or 2.666 man-hours × 16,124 = 43,000 man-hours or 4,300 md.

[h] Medium and small-size stones are calculated together since they both can be transported by a single yoke.

[i] This figure is very similar to Küpper (1996, 50) who came to 150 working days but that did not include ramming the earth.

[j] Having compared this cost with the suggestion made by De Haan (2009, 6) and with reduced friction of 0.1 μ (see Consiglio 1949, 90, 92), a higher result, 2.4 hours employing 6 people, was achieved.

[k] I did not take the niches, ubiquitous in the Lower Citadel wall, into consideration for these preliminary construction calculations since Küpper's hypotheses (1996, 51-52) on their construction cannot, at this stage, be tested without further investigations at the site, if it is possible at all

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Ostia's visual connection to Rome

L. Bouke van der Meer

Several spaces, buildings, statues, images and inscriptions in Ostia, Rome's main port, refer to Rome or parts of Rome. They were created by Romans from Rome in order to strengthen the relation between the capital and the colonia.

Archaeologists (for example Boin 2013,1; Sewell 2010, 72-73; Steuernagel 2004, 68-69, 155) have often used a text of Aulus Gellius to suggest that Roman *coloniae* were *quasi effigies parvae et simulacra* ('as it were small replicas and images') of the their founding city, Rome (Appendix, text 1). According to Gellius, who wrote around AD 165, *coloniae* reflect 'the greatness and majesty of the Roman people.' Gellius, however, only deals with the rights and institutions of *municipia* and *coloniae*, not with their physical form. Nevertheless, we are entitled to interpret spaces and buildings as miniatures of Rome or parts of Rome since already Cicero (*Att*. 5.2.2; cf. *Pro Fonteio* 13) looked upon *Cumanum*, his villa between Cumae and Puteoli, as a *pusilla Roma* ('a very little Rome'). In addition, *regiones* and *vici* in some Republican colonies have been called after areas in Rome (Bispham 2000, 176 n. 5). Ausonius (*Ordo urbium nobilium* 6.61-63; 4.29; 4.74) calls Capua *Roma alter* ('the other Rome') and Arles *Gallula Roma Arelas* ('Arelas, the little Rome of Gaul'). So my questions are: does the *colonia ostiensis* show copies of parts of Rome? More broadly, what were Ostia's visual connections to Rome? Therefore, we have to look for spaces, buildings, statues, images and inscriptions which have a connection to the capital. It is interesting to see where the references are made, by whom and why.

Ostia as we see it nowadays, mostly dates to the second century AD (fig. 1; for Ostia in general see Meiggs 1973[2]; Pavolini 2006; http:\www.ostia-antica.org). It covers many spaces and buildings from earlier periods. It has only very partly been excavated as we know from Michael Heinzelmann's geophysical prospections (1996-2001).

First some words about Ostia's early development. According to Livy Ostia was founded as *urbs* and according to other ancient authors as *colonia* by Rome's fourth king, Ancus Marcius, between 640 and 616 BC. This is, however, not (yet) confirmed by archaeological evidence.

The first stone settlement was a rectangular stone fortification, a *castrum*, which was occupied by soldiers from Rome. It was built around 300 BC. Its foundation is not mentioned by ancient authors. It lost its function after the Second Punic War. From then on Ostia's river harbor, a square basin on the left bank, near the sea, got a more commercial function. It became of great importance for the storing and transfer of grain and other goods to Rome.

In the second half of the second century BC Ostia was still dependent on Rome as is testified by the *locus publicus* (usually incorrectly called *ager publicus*) between the Tiber and the *decumanus*, public land which was earmarked by travertine boundary stones (fig. 1, nos. 1 and 12; *CIL* XIV 4702; Cébeillac *et al*. 2006, 82-83, no. 4; 2010, 88-89 no. 5; Pensabene 2007, 9 (*c*. 150-125 BC)). The *cippi* or *termini* mention the name of Gaius Caninius, *praetor urbanus* of Rome (Cébeillac *et al*. 2006, 94-95 no. 10; 2010, 98-99 no. 10. Bargagli and Grosso 1997, 9 (*c*. 130-100 BC)). The public space was used for the storing of goods and grain in *horrea*. Rome had similar public spaces: the banks of the Tiber (Cébeillac *et al*. 2010, 135-136), *poemeria*, and the Campus Martius which lies between the Tiber and the so-called Servian city walls.

Probably at the end of the second century BC Ostia became independent from Rome (Cébeillac *et al*. 2006, 94-95 no. 10; 2010, 98-99 no. 10; Bargagli and Grosso 1997, 9 (*c*. 130-100 BC)). Rome, however, kept the supervision of the grain import and guaranteed Ostia's safety.

Ostia's earliest visual reference to Rome can be dated around 63 BC when Cicero, as consul, built and took care of the city walls and gates. His adversary, the *tribunus plebis* Clodius Pulcher, completed and approved these in 58 BC (Appendix, text 2). Fragments of two identical inscriptions from the attics of the Porta Romana mention the *Senatus Populusque Romanus* as donor and the *colonia Ostiensis* as recipient (fig. 1, no. 2; Cébeillac *et al*. 2006, 90-92, no. 8; 2010, 95-7 no. 8. Pensabene 2007, 184-191). The gate was restored around AD 100 but the inscriptions probably partly copy the Republican ones. Henner von Hesberg dates the marble statue of the winged Minerva, which was found behind the gate, to the time of Cicero (Von Hesberg 1998. Pavolini 2006, 53. Contra: Pensabene 2007, 190-191 dates Minerva as late Flavian). Therefore, Fausto Zevi assumes that it belonged to the Republican gate, also in view of Cicero's dedication of a statue of Minerva as *phylax* ('(city) guardian') on the Capitoline hill in Rome, in 58 BC (Plut., *Cic*. 31.5. F. Zevi, in: Gallina Zevi and Humphrey 2004, 30-31).

Other references to Rome are the marble *Fasti Ostienses* which have been displayed from at least 49-44 BC onward (Bargagli and Grosso 1997, 8-9). The year calendar mentions first the consuls and events in Rome, then the names of the *duoviri* and events in Ostia.

The man who gave Ostia some urban flavour was Augustus' general and friend, Marcus Agrippa. He built the Theatre (made of marble, travertine, brick and tufa) and its *post scaenam porticus* in the *locus publicus* along the *decumanus* between 18 and 12 BC (fig. 1, no. 6; *CIL* XIV 82 and a fragment: *[M(arcus) Ag]rippa, co(n)s(ul) [III, --- tribunicia] po[testate---]*. For comment see Cébeillac *et al*. 2006, 92-94, no. 9; 2010, 97-98 no. 9. Pensabene 2007, 284-290. P. Battistelli and G. Greco, in: Nicolet 2002, 391-420). The combination of theatre and *porticus* is recommended by Vitruvius (*De Architectura* 5.9.1) around 22 BC. He was inspired by the Theater of Pompey and its *porticus* in Rome, which were dedicated in 55 BC. Its plan is illustrated by the *Forma Urbis*, the Severan marble map of Rome. Agrippa built his monuments only in public areas, on the Campus Martius in Rome and on the *locus publicus* in Ostia. At the end of Augustus' reign the marble Temple of Roma and Augustus (Pensabene 2005, 512, 521-522 (late Augustan), 2007, 135-144 (late Augustan or *c*. AD 5/10 – 20); Geremia Nucci 2005, 230 (Tiberian)) was built on the place of the demolished southern gate of the *castrum* opposite two temples along the *decumanus* (fig. 1, no. 16). The two early Augustan temples would have replaced two Republican ones according to Pensabene (2007, 13, 123-128; Morciano 2012, 54-55). Its area became Ostia's Forum. The temple was incidentally used for political meetings (*CIL* XIV 353: *In aede Romae et Augusti placu[it] ordini decurionum…*) like the Temple of Mars Ultor on the Forum of Augustus in Rome. A colossal statue, found behind the temple, represents the personification of Roma as draped Amazon with her left foot resting on a globe (M. Loreti, in: *Archeologia Classica* 37 (1985), 176 n. 25 (first century AD). *LIMC* VIII, 1, Suppl., s.v. Roma, 59 (E. di Filippo Balestrazzi: second or third century AD)). We don't know who ordered the temple. According to Patrizio Pensabene it may have been the imperial house because of the lavish use of Luna marble (Pensabene 2007, 142).

Ostia's division into *vici* ('neighborhoods') was probably introduced by Rome. Augustus reorganized Rome's *regiones* and *vici* in 7 BC (Suet. *Aug.* 30: Puteoli was divided in seven *regiones* in the Augustan period. See also Steuernagel 2004, 43). Formerly the city had 4 *regiones* and an unknown number of *vici*. According to Pliny (*NH* 3.66) Rome had 14 *regiones* and 265 *compita Larum* in AD 73. The *vici* had *compita* (crossroad shrines: altars, *aediculae*) under supervision of *magistri vici*. We don't know when Ostia was divided into five *regiones* (*CIL* XIV 352 (AD 251)) but *vici* certainly did exist at Ostia in Augustus' time as is shown by the inscription on an *in situ* round marble altar standing on a marble and travertine base dedicated by a *magister* or *magistri* to the *Lares vicinales* (Appendix, text 3; fig. 1, no. 14; Lott 2004, 69 dates it before 7 BC; Pensabene 2007, 177 to 30-20 or 20-10 BC and Rieger 2004, 241 to *c*. 50 BC. *AE* 1945, 56 (from Otricoli) mentions a dedication to *Lares vicinales* by *IIIIviri iure dicundo*). Pensabene dates it for stylistic reasons before 7 BC, more precisely between *c*. 30 and 10 BC. In addition, the altar is not square and does not mention *Lares Augusti*. An inscription which is dedicated to the *Lares Augusti* dates to AD 51. So maybe Claudius, when he started his Portus project, reorganized Ostia's *vici* as Augustus had done in Rome (Pensabene 2007, 21 n. 85, 178-179. *AE* 1964, 151: (*Ti(berio) Cla[udio Caes]ar(e) August(o) Germanico / pont(ifice) m[ax(imo) tr(ibunicia) pot(estate) XI co(n)s(ule) V cens(ore) p(atre)] p(atriae) Laribus Augustis s[ac(rum)] magis[t]ri primi d(e) s(ua) p(ecunia) f(ecerunt)*).

During the early reign of Trajan who created the second *Portus*, Ostia's ground level was raised, the Porta Romana restored and a Basilica was built along the Forum (fig. 1, to the west of no. 16; Pensabene 2007, 212-217). Interestingly, a fragment of the sculptured friezes probably belonging to this building shows an episode from Rome's history: the Geese of the Capitol. The place of the Basilica and its decoration may have reminded passers-by of the Basilica Aemilia along the Forum of Rome which had internal friezes with similar historical themes. In addition, the Basilica has several architectural elements in common with the Basilica Ulpia along the Forum of Trajan in Rome. In both cases the central nave has 6 x 18 columns.

Some buildings of Hadrian who was twice *duovir* of Ostia, probably in 121 and 126, refer to Rome. He transformed Ostia in three areas (For Ostia's gratitude see *CIL* XIV 95 and VI 972: *colonia Ostia conservata et aucta omni indulgentia et liberalitate eius.* The *Serapeum* was dedicated on 24 January 127, Hadrian's birthday. See Bargagli and Grosso 1997, 43. Cébeillac *et al*., 2010, 152-153, no. 29). In the centre the very high, monumental Capitolium arose around 120 (fig. 1, opposite no. 16; see C. Albo, in: Nicolet 2002, 363-390; Pensabene 2007, 250-268; Morciano 2012, 53-59; Boin 2013, 140-144. *CIL* XIV 32 mentions an *aedituus Capitoli*). It was built in the spirit of Vitruvius' normative statement (*De Architectura* 1.7.1): '…for (the temple of) Jupiter, Juno, and Minerva should be on the very highest point commanding a view of the greater part of the city.' Interestingly, the altar in front of the Capitolium shows

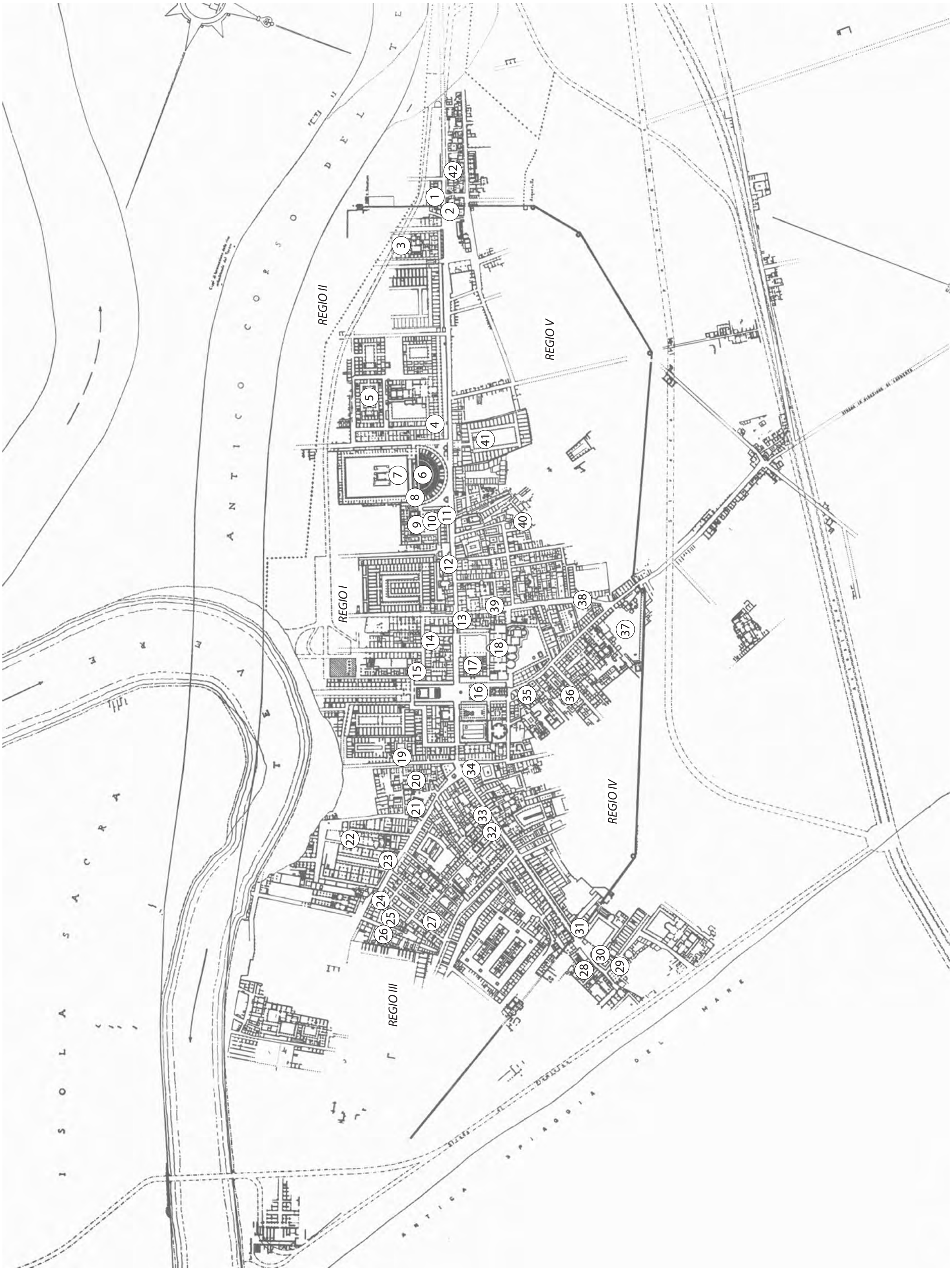

Figure 1 Map of Ostia (from: L.B. van der Meer, *Ostia speaks*. Leuven 2012, cover folder)

a shield with Gorgon's head and a helmet, again clear references to Minerva as guardian goddess of the city.

In the *locus publicus* the Barracks (*castra*) of the Firefighters (Pensabene 2007, 315-318) and the Baths of Neptunus were built; the latter were sponsored by Hadrian (fig. 1, no. 5). The inscriptions in and from the Barracks mention the *cohortes vigilum* from Rome. Inscriptions of *Ostienses* are lacking. So the building was probably not public. It was, as it were, a part of Rome in Ostia, including a Severan *Augusteum* with altars and statues dedicated to the emperors (until *c*. AD 250).

Symbolic references to Rome are present in Hadrian's period too. Its mythic history is shown by an altar with reliefs on all sides which originally stood in a public place which was given *decurionum decreto* (*LDDDP*). It was dedicated in AD 124. It was transferred to a *sacellum* in the *porticus* behind the Theatre between *c*. AD 150 and 200 (fig. 1, no. 8). There it was reused as base for a statue of Silvanus. The backside showing Romulus and Remus under the she-wolf was turned to the front, thus making a clear reference to the origins of Rome (Cébeillac *et al*. 2006, 266-268, no. 74; 2010, 175-177, no. 41. Pensabene 2007, 200 n. 655 relates the relief to the Lupercal on the Palatine, dwelling place of Faunus who could be assimilated with Silvanus). An inscription on a marble slab which mentions king Ancus Marcius as founder of Rome's first *colonia*, Ostia, probably belonged to a statue base of the king (Appendix, text 4). It dates to the Antonine period. Probably it stood on the Forum (Cébeillac *et al*. 2006, 73-74, no. 1; Cébeillac *et al*. 2010, 80-81, no.1). The inscription was an *elogium* comparable to inscriptions, dedicated to Aeneas and to Romulus, on the Forum of Augustus in Rome and on the Forum of Pompeii (*CIL* X 808 and 809).

Between *c*. AD 200 and 238-244 (the reign of emperor Gordian III) the most recent temple of Ostia, the *Tempio Rotondo II*, probably a *Templum divorum* or *Augusteum*, was built behind a large square to the west of the Basilica (Boin 2013, 90-97; Pensabene 2007, 296-315; Rieger 2004, 173-214). Its interior with niches and probably an *oculus* ('eye') in the dome must have recalled the Pantheon in Rome.

From late antiquity remains an epigraphic and possible symbolic reference to Roma. Just before AD 389 the *praefectus annonnae*, Ragonius Vincentius Celsus, placed a statue, probably of Roma, for Roma, on a reused statue base, in front of the Theatre, sponsored by the *civitas ostiensis* (Appendix, text 5; fig. 1, no. 6; *CIL* XIV 4716; Boin 2013, 148). The statue may have looked like a standing Amazon or like the enthroned Roma on the *Tabula Peutingeriana.*

To conclude, inhabitants and visitors of the *colonia Ostiensis*, Gellius included (*Noctes Atticae* 18.1-2), saw spaces, buildings, images, and inscriptions which would have reminded them of Rome or parts of Rome. Ostia was not an *effigies parva* of Rome. The visual references to Rome are mainly present in two public spaces: the *locus publicus* and the Forum area. Spatial and architectural imitations (*locus publicus*, *vici*, city gate, theatre, *porticus*, Basilica, Capitolium, Barracks and the Round Temple), though not exact copies, were made in the course of five centuries, from the second century BC until *c*. AD 250. Caninius, Cicero, Agrippa, Trajan and Hadrian created spaces and buildings with antecedents in Rome. So not the local authorities but Romans from Rome made visual connections in order to reinforce the relation between the capital and *colonia*. Some references were also meant as ostentation of Rome's power and past, self-representation and memorialization. Local magistrates, usually *duoviri*, preferred to invest in urban infrastructure, commercial buildings, and sanctuaries in the first century BC and first century AD. Their *modus donandi* differs, for example, from that of benefactors in Pompeii who dedicated buildings on their Forum to the cult of emperors.

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Appendix

1. Gellius, *Noctes Atticae* 13.16.8-9 (c. AD 165)

Sed coloniarum alia necessitudo est; non enim veniunt extrinsecus in civitatem nec suis radicibus nituntur, sed ex civitate quasi propagatae sunt et iura institutaque omnia populi Romani, non sui arbitrii, habent. Quae tamen condicio, cum sit magis obnoxia et minus libera, potior tamen et praestabilior existimatur *propter amplitudinem maiestatemque populi Romani, cuius istae coloniae quasi effigies parvae simulacraque esse quaedam videntur,* et simul quia obscura oblitterataque sunt municipiorum iura, quibus uti iam per ignotitiam noli queunt.

2. *AE* 1997, 253 (one of the two identical inscriptions from the attics of the restored Porta Romana (*c*. 100 AD), which probably partly copy inscriptions from 63-58 BC).

[SE]N[AT]U[S P]OPULU[SQUE ROMANUS] / CO[LON] IA[E O[STIEN]SIUM M[U]RO[S] E[T PORTAS DEDIT]. / M(arcus) [TULLIU]S C[ICE]RO C[O(n)S (ul) FECIT CURA]VITQU[E]. / P(ublius) CL[ODIU]S PULCHER TR(ibunus) [PL(ebis) CON]SUMMAV[IT PROB]AV[IT]. / PORTAM VETUS]TATE [C]ORRUPTA[M---] [OSTIENSES?]---[OMNI DECOR]E A [SOLO]--[REFECE] RU[NT]

From: M. Cébeillac-Gervasoni, M.L. Caldelli, F. Zevi 2010, 95-97 no. 8.

3. *CIL* XIV 4298 (altar dedicated to the Lares Vicinales, *c*. 30-10 BC)

[M]AG(ister/-istri) D(e) S(ua) P(ecunia) F(aciendam) C(uravit/-uraverunt) / LARIBUS / VICIN(alibus) SACR(am) / ARAM MARMOREAM

4. *CIL* XIV 4338 (marble slab, probably from a statue base on the Forum; Antonine period)

A[NCO] / MAR[CIO / REG[I ROM(ano)] / QUART[O A R] OMULO / QUI A[B URBE C]ONDIT[A] / [PRI]MUM COLONI[AM] / [C(ivium) ROM(anorum)] DEDUX[IT]

5. *CIL* XIV 4716 (reused statue base in front of the Theatre, AD 385-389)

RAGONIUS VINCENTIUS / CELSUS V(ir) C(larissimus) PRAEFECTUS / ANNONAE URBIS ROMAE / URBI EIDEM PROPRIA / PECUNIA CIVITATIS / OSTIENSIUM COLLOCAVIT

One day on the streets of Camelon: discarded shoes from a Roman fort

Mareille Arkesteijn and Carol van Driel-Murray

One day, in the middle of the second century A.D., a gathering of people on the streets of Camelon, Scotland exchanged their old, worn out winter shoes for the new summer collection, dumping the unwanted footwear into a convenient ditch. Is this what happened or are there other scenarios? Whatever the case, this snapshot of the clothing actually worn at a particular point of time, on the streets of a particular settlement is offered as a tribute to Willem Willems (1950-2014), friend, colleague and mentor, who never lost his delight in the by-ways of Roman material studies, and whose early recognition of the social implication of footwear was a great encouragement.[1]

1 Introduction

It is seldom that archaeologists can visualise the variety of clothing actually being worn by people at a particular time or place. And because textiles are such infrequent survivals, the view inevitably shifts to feet. Leather footwear survives in some quantity and, furthermore, shoes are exceptional carriers of information on age, gender and identity (Groenman-van Waateringe 1978; van Driel-Murray 2001b, 360-1). Roman footwear is particularly informative, especially since the recognition of well-dated sequences of quite rapid fashion change and the definition of specific short-lived styles that are characteristic for particular periods (van Driel-Murray 2001a; Volken 2014). On a practical level, the exact nature of these transitions is still a matter of debate. How were new styles introduced and what was the course of their take up? How did the knowledge about the latest styles reach the frontier provinces? Above all, why did people set such store on participating in an internationally orientated culture, expressed via footwear? Occasionally, a single-event deposit permits an insight into just who was wearing what, what was the most popular style of the moment, and what was coming in to – or going out of – fashion. The dump of footwear discovered at the Roman fort of Camelon, Scotland, gives us a gives us just such a momentary glimpse of people's choices and aspirations at this remote frontier posting.

2 Find Circumstances

Lying just to the north of the line of the Antonine Wall in Scotland, on a bluff overlooking the River Carron, the fort at Camelon is the most northerly permanently occupied Roman settlement in the Empire. There is some evidence for Flavian activity, but the main lay-out of the fort and its annexes dates to the Antonine occupation of Lowland Scotland (*c*. 142-160 A.D.; Tatton-Brown 1980; Cook 2012). In 2011, excavations of the south-western corner of the site were carried out by AOC Archaeology prior to development. The footwear discussed here was recovered from Area 2, which exposed part of the southern enclosing ditches of the annex (Cook 2012, 3). Only a thin deposit of natural silting had formed in Ditch 485 before a mass of footwear was tipped in, forming a thick, waterlogged organic deposit still about 1.20m deep. Subsequently, the ditch was re-cut and the lower deposits became sealed by a thick clay layer: this undoubtedly accounts for the excellent preservation of leather and other organic finds. Post excavation work is in progress and the exact sequence and dating of the annex ditches is still under review (Cook 2012, 30-32). However, given the short period during which the Antonine Wall functioned, the shoes can be securely dated between 142 – 160 A.D.

Conservation work began almost immediately, and the fine condition of the leather is certainly due to the care taken during recovery and the speed of the professional conservation treatment carried out at AOC. Enthused by reports of the shoes, Mareille Arkesteijn, then still a student, travelled to Scotland to assist with the work, and in February 2012 the shoes came to the Department of Archaeology Leiden University for documentation and analysis. This work is still on-going, but in advance of the final publication, a preliminary report is warranted by the exceptional nature of the complex and the chance to present Mareille Arkesteijn's snapshot of the "Antonine look" as displayed on the streets of Camelon (figs 1-3).[2]

3 The shoes

The excavated one-metre segment of Ditch 485 yielded no fewer than 78 shoes. This is but a fraction of what must originally have been a much larger dump, but still represents one of the largest single deposits of footwear from Britain. The 46 identifiable uppers could be grouped into named styles according to the fastening method and overall appearance, using the criteria set out in van Driel-Murray

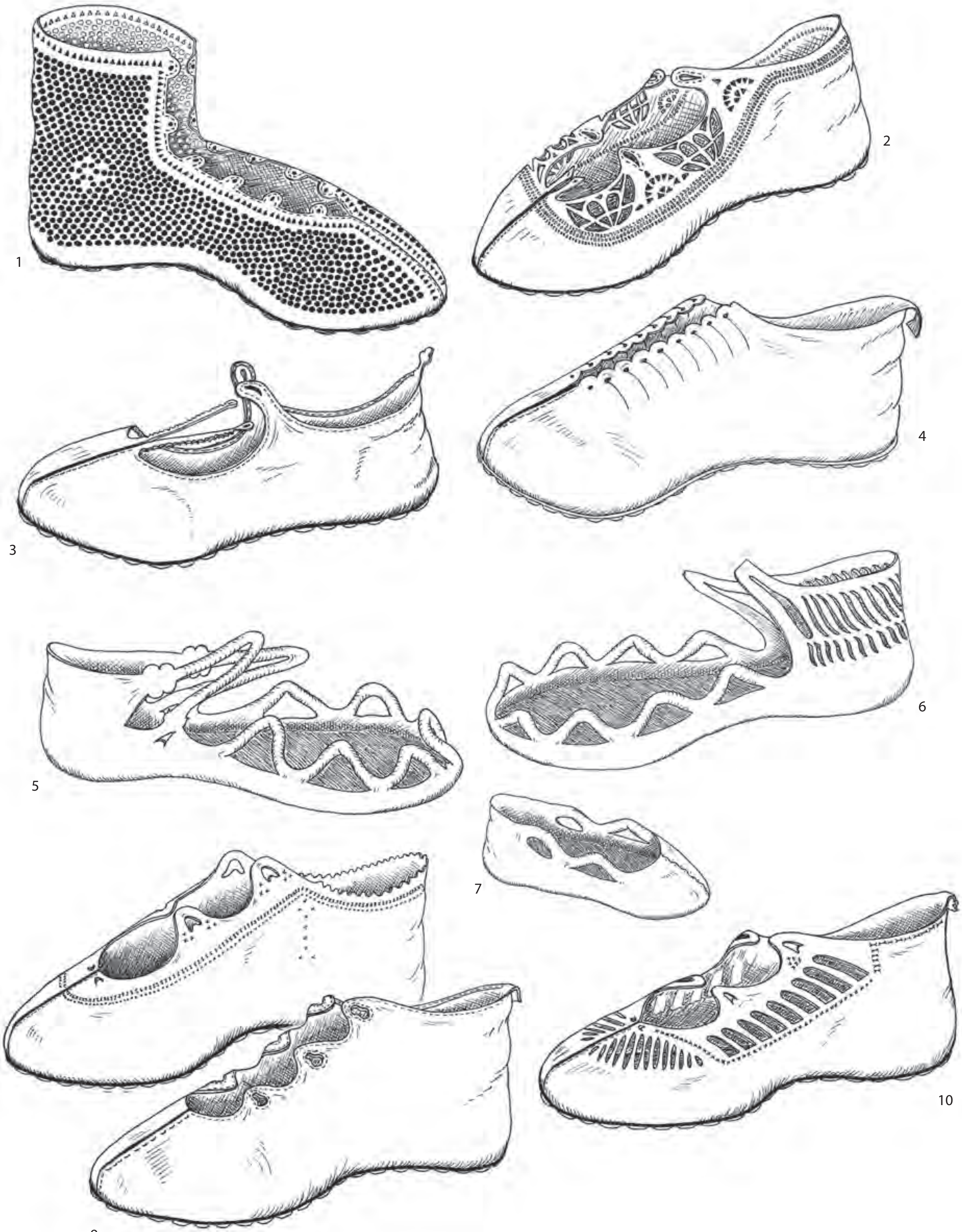

Figure 1 The Camelon footwear collection I (© Mareille Arkesteijn). 1. Camelon, 2. Hardknott, 3. Rosskopf, 4. Newstead, 5-7 carbatinae, 8-10 Carron

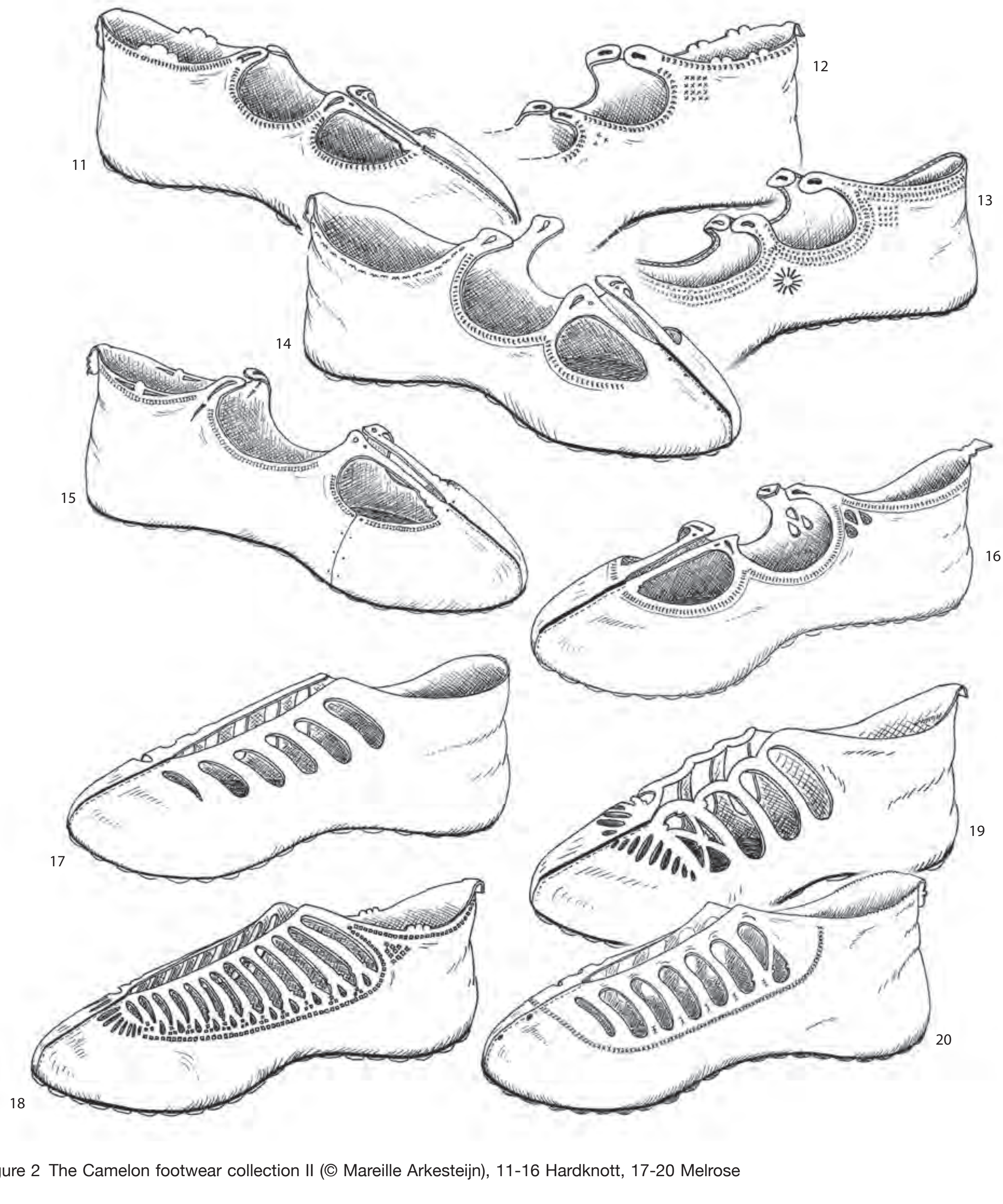

Figure 2 The Camelon footwear collection II (© Mareille Arkesteijn), 11-16 Hardknott, 17-20 Melrose

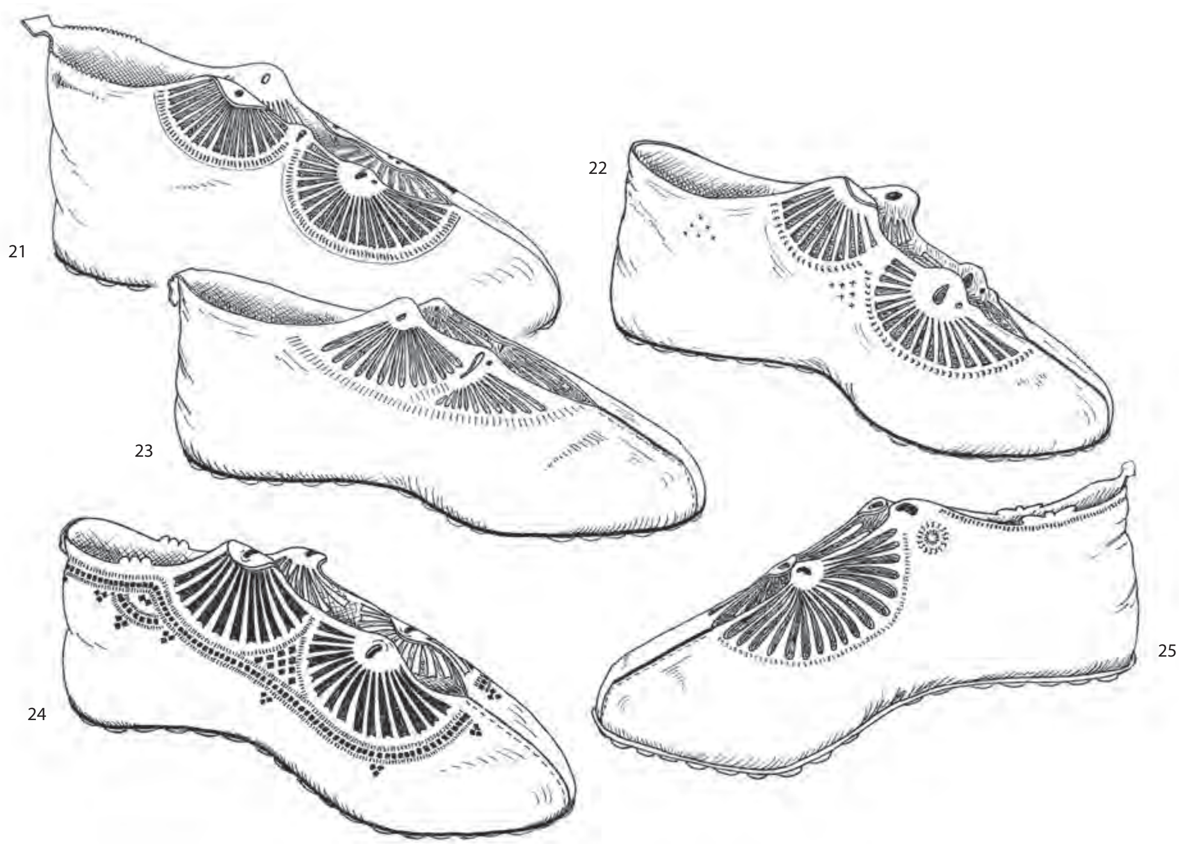

Figure 3 The Camelon footwear collection III (© Mareille Arkesteijn), 21-25 Zwammerdam

(2001a; 2001b) and expanded and systematized by Volken (2014, 78-9). There are in addition 8 single piece shoes (*carbatinae)* and a further 24 soles without surviving uppers, either as a result of general wear and tear, the use of thinner leather or because the upper was not made of vegetable tanned cowhide. Alternative skin processing methods, such as oil or mineral tanning, decay under waterlogged conditions, so that these finer, more supple leather types are absent from archaeological contexts in northern Europe (van Driel-Murray 2008). Other than their soles, some of the more classy shoes may therefore now be lost to view. All the soles and most of the uppers are made of cowhide, with only three of the surviving uppers employing goatskin: these are in noticeably poorer condition. In addition there are also a few re-use off cuts taken from unidentifiable stitched objects and these are also of goatskin.

Most eye-catching is the pair of lacy openwork ankle boots (style Camelon, fig. 4) but the overall picture is of serviceable shoes made from a strip of hide and sewn up over the toe (table 1). Except for three shoes with a sewn construction, all soles are hobnailed (for manufacturing details see van Driel-Murray 2001b, 349-50).

The most popular styles, Hardknott, Melrose and Zwammerdam (together almost 60%) form a familiar Antonine Wall association of forms, and though the Camelon is newly defined as a result of the three complete examples here, small fragments belonging to this shoe style can now be recognised amongst unpublished material from Newstead and Vindolanda.[3] At first, the Carron style was regarded as a variant of a relatively common late Antonine/Severan shoe with integral laces (e.g. Welzheim, van Driel-Murray 1999a, 64-6) but from its popularity at Camelon, it can now be seen to be an earlier precursor appearing regularly on other Northern sites (such as Newstead, Curle 1911, pl. XX.5). All these styles form a well-defined mid-Antonine association, well represented at other forts, such as Bar Hill and Rough Castle (Keppie 1975; Macivor *et al*. 1978/80, figs 15-16), but also Newstead and Hardknott (Curle 1911, pl. XIX-XX; Charlesworth and Thornton 1973). Parallels can sometimes be very close: the elaborate shoe fig. 1.2 is almost identical to one found at Newstead (Curle 1911, pl. XIX.15). Beyond Scotland, the same styles also appear on the Continent and indeed, everywhere where footwear of the mid Second Century survives (*e.g.* the Saalburg, Busch 1965, Taf. 11-15).

Figure 4 Openwork shoes style Camelon (photo © Mareille Arkesteijn)

Shoe style	Number	
Camelon	3	Including one pair
Carron	7	
Hardknott	10	
Melrose	8	
Rosskopf	5	
Zwammerdam	9	Including one pair
Other upper styles	4	Including one pair
Carbatina	8	Including one pair
Loose soles	24	
Total footwear	78	

Table 1 Variations in shoe styles: composition of the Camelon collection

Together they give an insight into the range of footwear available at any one time to people even on the fringes of Empire and the extent to which an international dress style had developed, influencing the choices made by both makers and customers.

To judge from dated occurrences elsewhere, the Melrose was quickly loosing popularity, while the Rosskopf was just coming into fashion: in this way, the finds from Camelon may assist in differentiating the largely undated finds retrieved from other northern forts. It is noticeable that except for certain decorative features (such as the lacy openwork) no trace of the characteristic elements of earlier Second Century footwear, familiar from Vindolanda (van Driel-Murray 2001a), is to be found in the typical Antonine designs. There seems to be a total break with past fashion, and the same holds true for the future: only a few of the styles popular at Camelon survive into the third quarter of the Second Century. Many fashions have a single-generation span.

Though sturdy and made to last, the shoes are carefully designed and a considerable degree of individuality was achieved within the basic outline by varying the number and shape of the fastenings. The Camelon bootees (fig. 4) illustrate well how a basic shoe style could be transformed into a status item. The network of holes was individually stamped, leaving a little rosette at the ankle, and although the delicate eyelets are backed by a reinforcement strip there is no indication that these fragile shoes were lined. This laborious technique is not confined to any particular shoe style or date, but is used to enhance whatever kind of shoe that is popular at the time (*e.g*. Schleiermacher 1982; Busch 1965, Taf. 15; van Driel-Murray 1993, fig. 19). Even though these delicate boots must have made quite an impression amongst the sensible shoes current at Camelon, most other shoes are embellished with more restrained decorative elements, such as openwork, stamps, frilling, rouletting or with shaped back tabs, so that no two shoes are alike. The extensive use of openwork rather implies the wearing of coloured socks and suggests that we should visualise this community as vibrantly colourful, the people fashion conscious and eager to distinguish themselves from their neighbours, men and women delighting in little playful touches to their essentially modest dress.

On the other hand, with only a few exceptions, the nailing of the soles is untidy, often random, and there are few of the decorative patterns that form such marked individuality on the soles at Vindolanda. The only re-occurring pattern – which may point to the hand of a particular shoemaker – is the additional U-shape at the seat of the sole (fig. 5).

Each shoe upper is different and, taken together with the great variation in the size and proportions of the soles, was evidently made to individual specifications: these are not mass-produced items churned out to be held in store till required. Even though we know nothing abut the use of standard sizes in Roman times, mass production would tend to result in more restricted size categories than are evident in size graphs (fig. 6) and there would be little encouragement to apply additional decorative elements.

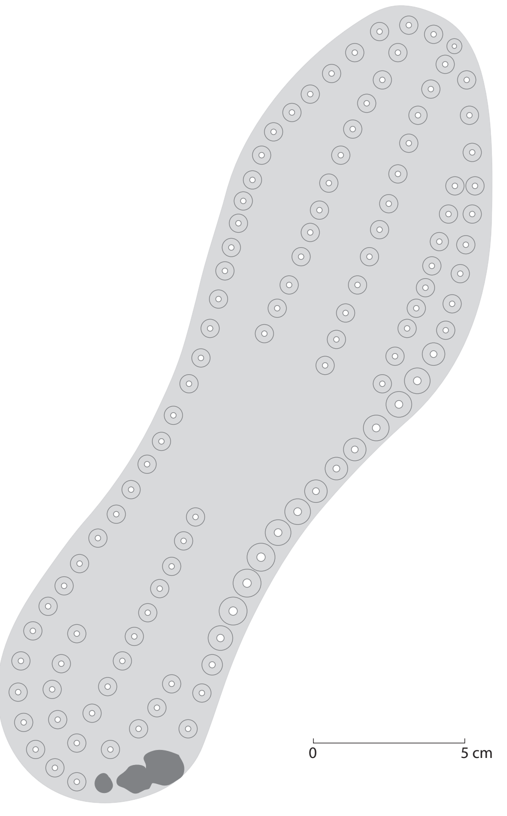

Figure 5 Typical nailed sole

4 The population: sizes

It was immediately clear that footwear belonging to men, women and children was represented in the complex, from a small carbatina, size 19 (appropriate for a child of 3-4 years of age, fig. 1.7)) to a couple of massive, heavy working shoes, size 42. Foot sizes trace the growth of children, and the consistent difference between aggregate women’s sizes and the larger male range make footwear a sensitive tool in the record of a living population (Groenman-van Waateringe 1978; van Driel-Murray 1993, 42-47). A clear dip in the graph (fig. 6) at 26 cm (continental size 39) marks the division between adult male (sizes 39-42) and adult female footwear (sizes 32-39). The short elapse of time between excavation, conservation and analysis is undoubtedly reflected in the noticeably larger size of shoes at Camelon when compared to soles from most other sites, where the

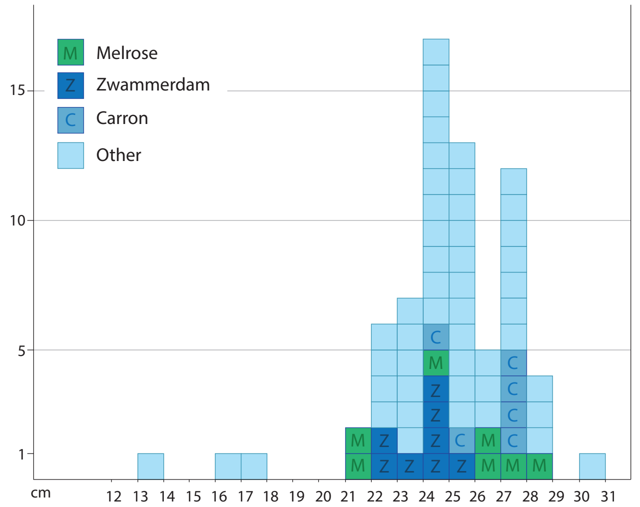

Figure 6 Graph of foot lengths (in cm.) Z = Zwammerdam; C = Carron; M = Melrose

female/male division usually lies around 23-24cm (size 35). This can now be seen to be in part a result of shrinkage following excavation, but it may also point to a relatively well-nourished population at Camelon, since the size distribution is not so very different from early 20th century records (Groenman-van Waateringe 1978). A feature of all graphs of archaeological footwear is the inflation of the 'female' range by the presence of growing youths and smaller men. So too at Camelon, where the footwear provides incontrovertible evidence for the presence of women, children and juveniles actually living in the annex. Both Newstead and Bar Hill show very similar patterns and it is evident that rather than being purely military areas, the annexes sheltered soldiers' families, as well as those engaged in crafts and other support services. Only the footwear is capable of revealing such a detailed view of the inhabitants (Curle 1911, 152; Keppie 1973, 80-82).

Archaeologically, juveniles or youths are even more elusive than women or children, but at Camelon the correlation between size and shoe style may enable us to catch a glimpse of this group. In general, Roman footwear is remarkably unisex, and at Camelon too, several popular styles occur in a range of sizes (such as the Hardknott). However, one style does seem to show up as being sex specific: all the Zwammerdam styles lie between continental size 33 and 38, indicating it was particularly favoured by women. Less clear is the case of the styles Carron and Melrose: since the majority of both lie at 38 and above (i.e. adult male), it is tempting to regard the occasional smaller examples as belonging to youths (21 and 24 cm, size 31.5, 35.5). Identifying individuals in this way is fraught with problems, and this observation does require corroboration from other locations. In comparison with the footwear complexes from Vindolanda and especially Welzheim, children's shoes are rather underrepresented at Camelon (van Driel-Murray 1993, fig 20; 1999a, 34-6, Abb. 33). Children may well have gone barefoot, as indeed they did in Ireland and Scotland till the 19th century – but this might also be the first indication of stress and shortages in the military supply of the fort.

5 A settlement under stress?

Although we were first mesmerised by the excellent preservation of the shoes and the simple beauty of the designs, it soon became apparent that though originally well-made and of good quality, many (though by no means all) shoes had been worn to the limit. Re-nailing was common, but eventually the nail heads wore down to the shafts and quite often the wearers continued to walk on the leather outer sole until that too wore through, exposing the lasting margins and even the insole. As the nails fell out, the uppers worked loose and were cobbled with rough strips of leather to keep the shoe serviceable and gaping seams were simply tied up together with string. Occasionally shoes were modified to relieve pressure on painful toes or to repair cracks caused by swollen joints (specifically *hallux valgus* fig. 2.15). Nevertheless, despite the worn soles and the scuffed hide of the uppers, it is remarkable that delicate features such as the fragile tongues of style Rosskopf and the lacy openwork of Camelon have survived well. This says a lot for the skill of the Roman shoemaker, who was able to distribute the stresses of gait evenly across the entire shoe. The character of the entire complex seems to be formed by the need to maintain possessions as long as possible, without the possibility of carrying out major repairs, though not reduced to extreme measures. There is for instance no sign of replacement soles, nor did the wearers resort to cannibalising other shoes to extend the life of their own possessions. This is the case at certain other highly stressed forts such as Castleford and Vindolanda period 2 (van Driel-Murray 1993, 33, pl. VII; 1998, 333-4). That supply lines could experience difficulties in winter is vividly displayed in letters from Vindolanda (Bowman and Thomas 1994, 321), and forts further north must have been even more vulnerable. A simple explanation for the dumping of this large collection of footwear is that supplies had been disrupted either by weather or by other external causes, and the population just had to make do with what they had till new leather was delivered. But does this do justice to the complex?

6 Shoe dumps: re-clothing, clearance or something worse?

While we were working on the shoes, we sometimes got the impression that several soles in the same find number, or adjacent numbers, were remarkably similar in size and proportions, as though a single individual had cleared out his/her wardrobe. Although well outside the scope of this study, forensic analysis of the foot impressions clearly visible on many soles might give an insight into individual ownership and choice, as well as shedding light on the formation process. Does the complex represent a few individuals gathering up their unwanted possessions in some sort of dumping ceremony prior to moving away, or is a larger group of people doing a simple exchange of old for new? If the former, this would also shed light on the accumulation of possessions and the social need for appropriate footwear. Shoes discarded by individuals in the normal course of things will tend to be scattered, ending up amongst other accumulated refuse in pits, ditches, rubbish heaps and odd corners. There is no compelling reason for collection, since neither leather nor worn hobnails were being recycled. Large scale discard of unwanted possessions is often associated with change of garrison and the need to travel light to a new posting, but this practical motive may be combined with more structured, collective dumping of pottery and other goods, such as the iron nails at Inchtuthil (Willis 1997, 46; Hanson and Maxwell 1986, 144). In view of the prominent role of footwear in ancient ritual, commemoration and symbolism, the Camelon dump may form yet another facet of the 'death assemblages' associated with the deliberate dismantling and burning of buildings during the occupation of the Antonine Wall (Dunbabin 1990; van Driel-Murray1999b; Hanson and Maxwell 1986, 144-5). Incidentally, such mobility and cross postings will be a major factor in the formation both of common dress styles and the rapid spread of information on changing fashions.

Entering the realms of fiction, more dramatic (or tragic) causes can also be imagined, but the possibility of a relationship between the construction of the deep V-shaped ditch with its ankle-breaker slot at the base and the massive dump of worn out shoes not long after does need to be considered. Post excavation work will no doubt shed light on some of these alternative explanations for the complex.

7 Conclusion

In preparing the UNESCO World Heritage nomination for the Lower German Rhineland frontier Willem Willems was increasingly faced with the shortcomings of present-day heritage legislation as regards the fate of organic finds and the waterlogged levels in which they have been preserved for so many centuries. The unique nature of the leather footwear from Camelon is a case in point: only a one-metre segment of the dump was excavated and information from the rest must be regarded as lost forever. In situations such as this, preservation *in situ* is merely postponement of destruction, since the removal of the clay seal inevitably means disturbance of the anaerobic conditions responsible for survival. Organic materials – leather, wood, textiles and botanical remains – are highly susceptible to changes in the water table, particularly following partial excavation or construction. The destruction of these valuable finds *outside* the immediate excavated areas needs to be considered in project proposals and management plans, as does the damage caused by piling and local fluctuations in the water table. It is to be hoped that fascinating find complexes such as this, with their potential for public outreach, will lead to changes in excavation and preservation strategies.

Although we don't even know what the new season's collection at Camelon looked like, we may close this view of the settlement's busy streets with their shoemaker's trademark, for all the world like the smiley that so often ended Willem's ever optimistic messages:

:)

Notes

1 The excavations were carried out by AOC Archaeology Group (North) in 2011 on behalf of Tesco Stores Ltd in advance of development at Glasgow Road, Falkirk, Scotland. The leather was conserved at the conservation laboratory of AOC Archaeology, and was sent to Leiden University under licence from Treasure Trove Scotland, National Museum of Scotland, Edinburgh. Mareille Arkesteijn studied the complex in detail for her MA thesis at Leiden University, which was submitted in 2014. We are grateful to Martin Cook and Ciara Clarke (AOC) for entrusting this material to us, for making all the necessary arrangements and for all their continuing assistance and support throughout this project. We also thank Ciara Clarke for permission to publish this account, in anticipation of the full report on the Camelon finds, which is in preparation.

2 We are deeply indebted to Mr. D. Van Wijk (Houston Texas) for a generous grant in support of these and other reconstruction drawings.

3 Characteristic are the small projecting roundels in which the lace holes are punched. These are usually backed by a separate lining. The non-descriptive nomenclature refers to the location of the first published examples, hence *Camelon* for this particular shoe.

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Clearance for a medieval *curtis*, Black Death and buckwheat (*Fagopyrum esculentum* Moench): vegetation history of the area around the confluence of the rivers Swalm and Meuse, the Netherlands, AD 800-1900

Corrie Bakels, Marijke Langeveld and Iris van Tulder

Two pollen diagrams obtained in the neighbourhood of Swalmen, a village in the southeastern part of the Netherlands, record a vegetation history ranging from c. 800 to c. 1900. The Swalmen diagram was obtained from an abandoned oxbow of the small river Swalm, a tributary of the river Meuse, and the other, the Syperhof diagram, from deposits in an oxbow of the river Meuse nearby. They reflect two important events. The Swalmen diagram displays the large-scale medieval clearance which led to a new parceling of the region, a parceling which is still functioning today. The Syperhof diagram shows the impact of the Black Death. Moreover, it prompts the suggestion that the start of buckwheat cultivation is somehow connected with the ravages of the Black Death. Initially buckwheat may have served as an emergency crop.

1 Introduction

In 2002 the Archeologische Diensten Centrum (ADC), Amersfoort, the Netherlands, excavated a terrain bordering the lower course of the river Swalm, a tributary of the river Meuse north of Roermond (fig. 1). The excavation preceded the construction of motorway A73. The site was named Swalmen-Nieuwenhof, Swalmen being the name of the nearest village and Nieuwenhof an important farm nearby. The excavation report appeared in 2013 (Vreenegoor and van Doesburg 2013).

Finds dated to the Early Middle Ages show that the area was inhabited during that period, but the most important finds are a set of buildings that belonged to a medieval site occupied between 950 and 1225. The buildings are interpreted as part of a major homestead, probably a *curtis*, a nobleman's estate. The site was abandoned as a residential site after 1225.

The Swalm is a relatively small meandering river with a source in Germany. Swalmen-Nieuwenhof is situated on its left bank at 1.5 km from the point where the river joins the river Meuse. Its valley has several oxbows filled with loamy and sometimes peaty sediments and one of these is situated close to the excavated area (fig. 1). Palynological investigations preceding the final excavation, and executed by Frans Bunnik (unpublished), suggested its value for vegetation reconstruction in connection with the medieval occupation. He also drew attention to an oxbow of the river Meuse close to the confluence of Swalm and Meuse.
As more elaborate research was not envisaged as part of the archaeological work, it was suggested that the Archaeobotanical laboratory of the Faculty of Archaeology, Leiden University, the Netherlands, might be interested in taking over.

Coring, by Corrie Bakels and Wim Kuijper, took place in October 2003. Both oxbows of the Swalm and the Meuse were sampled.

In 2004 both cores were analysed by students under close supervision by Corrie Bakels. The oxbow of the Swalm, named 'Swalmen', was the subject of the MSc thesis of Marijke Langeveld and the oxbow of the Meuse, named 'Syperhof' after a farm close by, was the basis for the BA thesis of Iris van Tulder. As BA work requires far less pollen counting than MSc work, the Syperhof diagram was finished by Corrie Bakels.

Figure 1 The location of the cores (black dots)

2 Material and Method

A side-filling corer was used for sampling the infill of the oxbows. The cores were taken to Leiden and cut into samples 1 cm thick. From the slices selected for pollen analysis, pollen was retrieved by the usual treatment with KOH, HCl, gravity separation sg 2.0 and acetolysis. Before treatment a tablet with *Lycopodium* spores was added following the method Stockmarr (1971). Identification was achieved by using the works of Faegri *et al*. (1989), Moore *et al*. (1991), and for cereals Grohne (1957). At the time identification of non-pollen palynomorphs and counting of charcoal was no standard procedure in the laboratory and was therefore not asked of the students.

The pollen sum aimed at was 300. It is a strictly upland (dryland) pollen sum, excluding wetland trees like alder (*Alnus*) and willow (*Salix*) and possible wetland elements like grasses (Poaceae) and sedges (Cyperaceae). The diagrams were produced using the programs Tilia and Tilia Graph (Grimm 1991).

Both cores were AMS ^{14}C dated at Groningen (table 1). The loamy infill of oxbows is notoriously difficult to sample, because of the risk of displaced material. Also samples near the surface of the infill may suffer from contamination with recent matter brought down by, for instance, small burrowing animals. One sample of the series of five submitted for Swalmen and another of the series submitted for Syperhof fall outside their ranges and expectation.

The Swalmen GrA-29855 sample provided a date which is far too old. This sample consisted of terrestrial seeds but also of a piece of charcoal. To include a piece of charcoal was obviously a mistake. The Syperhof GrA-29722 sample contained post-bomb material and was therefore younger than expected. This sample was a collection of very small seeds which must have been displaced from the surface of the infill. Both dates are therefore rejected. The samples belonged to a first batch sent in for dating. Sampling for the second batch avoided both charcoal and very small seeds. Their results do meet the expectations.

	GrA	Age BP	calAD 95.4%
Swalmen			
40 cm	59688	670 ± 35	1270 - 1394
48-50 cm	29855	1495 ± 40	430 - 645
67-69 cm	29857	985 ± 45	981 - 1161
75-76 cm	29718	1125 ± 35	777 - 993
125 cm	59690	1180 ± 35	725 - 967
Syperhof			
30-32 cm	29721	265 ± 35	1681 - 1930
60 cm	59691	295 ± 35	1485 - 1663
80-82 cm	29722	134.2 ± 0.5%	recent
180 cm	59692	570 ± 35	1300 - 1427
450 cm	59760	895 ± 45	1029 - 1221

Table 1 The 14C dates obtained from the cores Swalmen and Syperhof

3 Results and discussion

3.1 *Swalmen*

The oxbow Swalmen is the older of the two. Silting up started somewhere before 725-967. The core comprises 204 cm of infill on top of gravel. From the bottom to 18 cm below the surface the sediment consisted of sandy, humic loam, while the uppermost deposit consisted of peat. At 70-72 cm the loam was of a different character, namely more compact with less sand. At first sight the narrow band was interpreted as a serious hiatus in the deposition, but the ^{14}C dates reveal that this interpretation is false. A sudden, not very long-lived event is considered the true cause of the disruption of the usual sedimentation process.

Pollen curves show sudden changes after the event (fig. 2). The tree cover, expressed in arboreal pollen percentages (AP), decreases whilst the curves of rye (*Secale*) and other cereals (wheat/barley/oats, *Triticum/Hordeum/Avena*) show important rises. Pollen curves of cereal weeds such as cornflower (*Centaurea cyanus*) react in the same way. The category grasses (Poaceae, not included in the pollen sum) show a rise, but the tree cover in the wetter part of the landscape, witness the curve of alder (*Alnus*), suffers too. The event is contemporaneous with the early phase of the medieval *curtis* Swalmen-Nieuwenhof. Most probably it marks its foundation.

The presence of an earlier use of the land, as witnessed by some pollen of cereals and walnut (*Juglans*) tallies with the Early Medieval occupation mentioned in the introduction. The AP percentage suggests that this earlier use had less impact on the general vegetation characterized by a local upland woodland which consisted of oak (*Quercus*), some lime (*Tilia*) and ash (*Fraxinus*), with fringes of hazel (*Corylus*) and birch (*Betula*). However, the proportion of oak rises before the main clearance, reflecting increasing human interference with nature, sparing oak (and hazel to a certain degree), but no other woody species. Beech (*Fagus*) is another important upland tree, but is considered to represent the echo of forests at some distance from the area under review.

The location of the core is close to the place where several large barns belonging to the *curtis* were erected and it could be that the event recorded in the diagram was of very local importance. Even the cereal pollen may have an origin in activities carried out next to these barns. However, the medieval newcomers are known to have restructured

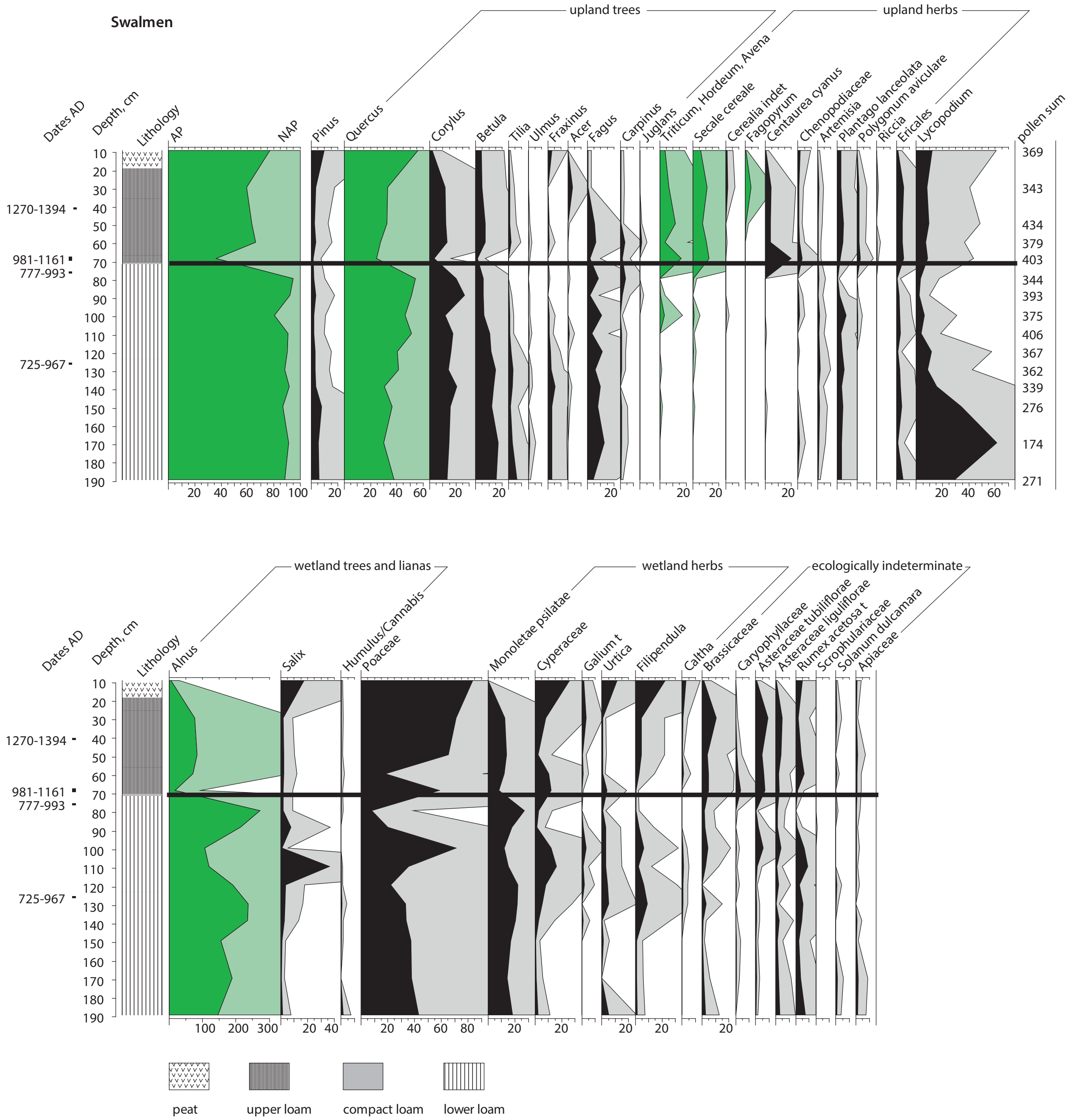

Figure 2 The pollen diagram Swalmen, selection of curves; curves discussed in the text in colour; exaggeration of curves 5x. A black horizontal line marks the level of clearance

the landscape in the wider surroundings. They are held responsible for the parceling of today (fig. 3). The rectangular system of rural roads dissecting the area goes back to their times. Excavation of one of these roads has proven this (Vreenegoor and van Doesburg 2013). This implies a large-scale opening-up of the landscape, and the decline in tree-pollen percentages most probably reflects not only the clearance made for building the homestead, but also clearance further away, including the wetter parts with alder carr. According to finds made during the excavation, the inhabitants of the farm bred horses, and for these animals pastures would have been needed. The low-lying land near

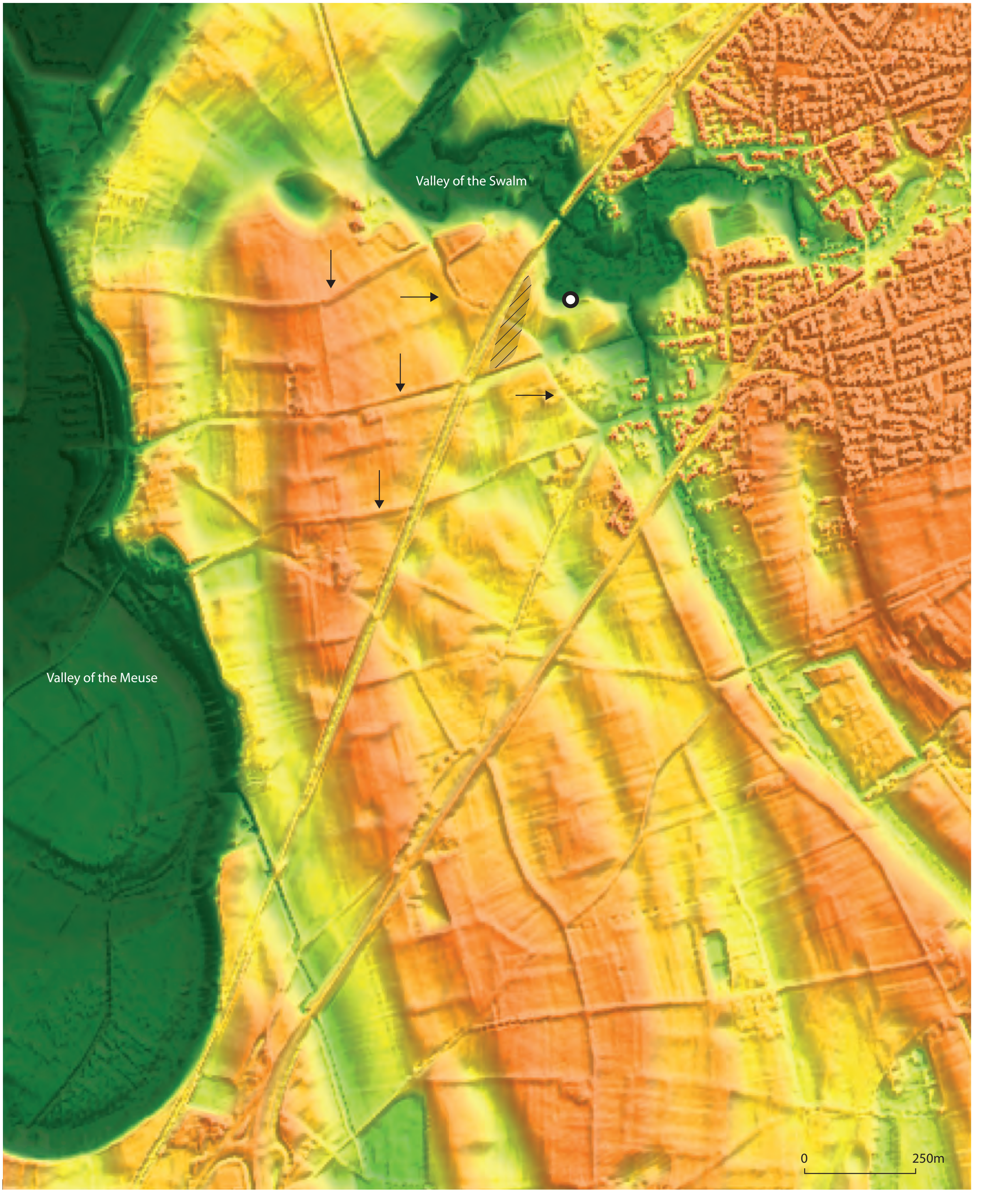

Figure 3 The Up-to-date Height Model of the Netherlands (AHN map) of the area south of the confluence of the rivers Swalm and Meuse. Elements of proven medieval origin are indicated by arrows, the excavation by hatching and the location of the core by a dot

the mouth of the river Swalm would have been perfect for that purpose. Today this land still serves as pasture land.

The botanical macroremains retrieved from the buildings included oats, rye, bread wheat and barley (van Beurden and Hänninen 2013) and pollen was counted of all four. In addition to cereals the pollen diagram shows walnut. Walnut shells have not been found, but as all macrobotanical material was charred, it would have been exceptional for them to have been found as they are commonly preserved waterlogged.

Another crop plant, buckwheat (*Fagopyrum*), appears in a later phase of land-use, dated to 1270-1394. As Swalmen-Nieuwenhof was abandoned as a residential site after 1225, to be reused as arable land, buckwheat growing would have belonged to this later activity. The crop plant is commented on below.

After this phase, rural activities slowed down. The deposition of loam in the oxbow stopped and the formation of peat was given a chance. The diagram does not suggest a serious hiatus between loam and peat. The tree pollen curves indicate that the local woods returned to some extent, with oak and ash on the dryer parts of the landscape, and willow (*Salix*) on the wetter parts. This return of trees may represent the same event as the rise of oak pollen in the Syperhof diagram discussed below.

3.2 Syperhof

At the location of coring, the former oxbow of the river Meuse revealed a 474 cm thick deposit of loam on top of gravel. According to the AMS dating, deposition started between 1029 and 1221 and continued to the twentieth century. The vegetation history reflected in its lower part should overlap with the history presented by the upper 50 cm of the Swalmen diagram. Some differences in pollen percentages may be expected, because part of the pollen in both Swalmen and Syperhof will have arrived by water transport and the Meuse is a much larger river than its tributary the Swalm. The Meuse has its a source in northern France and a large catchment area. The Swalm, and therefore the Swalmen diagram, provides a more local picture. Nevertheless, the general picture is the same (fig. 4).

The tree-herb ratio (AP-NAP) shows open landscapes with oak (*Quercus*) as the dominant tree. Hazel (*Corylus*) and birch (*Betula*) are prominent as well and represent the fringes of the woods. In the wetter parts of the landscape grasses (Poaceae) are more important than alder (*Alnus*), implying that wetland wood was at least partly replaced by meadows and pasture. Cereal pollen is rather dominant in the pollen rain released by the upland herb vegetation. During the counting of the Syperhof pollen the difference between cereal species was not systematically recorded, but rye, oats, wheat and barley were present with a dominance of rye.

From a depth of 300 cm upwards the tree cover steadily declines, whilst the cereals gain in importance. During this part of the Middle Ages rural activity was expanding and, if it is permitted to apply interpolation between the ^{14}C dates, this period has to be dated between 1150 and 1300-1427. It is followed by a rise in the upland tree (AP) curve, mainly due to a rise in oak (*Quercus*), but also in hazel (*Corylus*), and a decline in cereal pollen. This implies that rural activity changed, probably undergoing a setback. The onset of this phenomenon is also visible in the Swalmen diagram where it is dated later than 1270-1394. In the Syperhof diagram it ended before 1485-1663. The phase is marked in figure 4 by two horizontal lines.

The Swalmen and Syperhof cores are not the only providers of a pollen diagram reflecting the vegetation history of the region regarding this period. Van Hoof *et al*. (2006) published a diagram from an infill of an oxbow of the river Roer, also a tributary of the river Meuse and at nine km distance from the locations considered in this paper. There are eleven sound AMS datings for their core, which reflects the vegetation history and land use between 1000 and 1500. They conclude “the main feature of the analyzed pollen record is a long-term reduction of the arboreal component reflecting regional deforestation up to 1350 AD, parallel to the population increase during this period …”. And “woodland is exceedingly transformed to arable fields, grassland (pastures and meadows) and heath land”… “Following the period with maximum values for non-arboreal pollen… a period of prolonged and pronounced agricultural regression can be identified in the regional pollen record… (ca AD 1360-1440)” (van Hoof *et al*. 2006, 406).

The regression is also recorded elsewhere in western Europe (Yeloff and van Geel 2007; Lager s 2013) and has been linked to an agricultural decline that is also evident from historical sources. One of the features of this decline is abandonment of farms and rural settlements, leading to the ‘lost villages’ in England or the ‘Wüstungen’ in Germany (Bieleman 1992). Though true ‘Wüstungen’ are neither known from the Swalm-Roer region, nor from the adjacent part of Germany, it is quite possible that the area knew a less severe kind of ‘Wüstung’ in which not villages were abandoned but many fields were no longer tilled: the ‘Flurwüstung’ (Slicher van Bath 1963, 162).

In general the 14th-15th century crisis is considered to be due to a change of climate towards wetter conditions, but this change was already felt by the end of the 12th century (Lamb 1977; Buisman 1995). A more plausible reason is the ravages of the Black Death. The plague or Black Death arrived in the Swalm region in 1349 (Benedictow 2004). Though no chronicles are preserved to report on the number of victims in the villages around Swalmen, it is known that in cities not too distant, such as Cologne and Aachen in

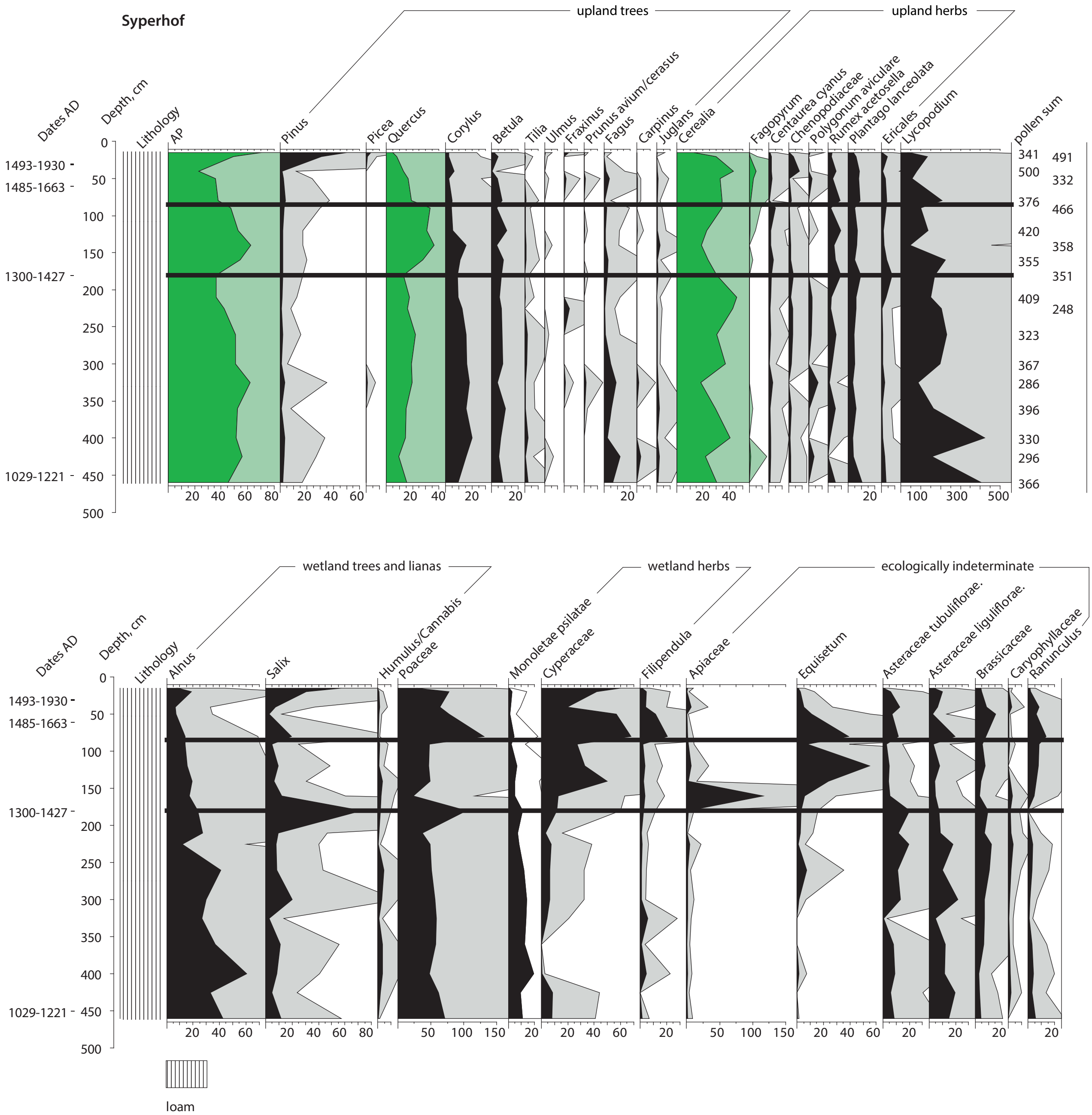

Figure 4 The pollen diagram Syperhof; selection of curves; curves discussed in the text in colour; exaggeration of curves 5x. Two black horizontal lines mark the beginning and the end of the agricultural regression

Germany, one third of the population perished (Creutz 1933; Schmitz-Cliever 1954). Such a decline in the population would have its effect on the extent of land under cultivation.

As cited above the agricultural regression recorded in the oxbow of the river Roer ended around 1440. In the Syperhof diagram it could not be pinpointed this sharply due to a lack of suitable material for dating, but the end occurred before 1485-1663. After that tree pollen percentages decrease and those of herbs, most conspicuously cereals, rise. Rural life had recovered.

The uppermost part of the diagram shows again a rise in tree pollen percentages, this time due to pine (*Pinus*). From historical sources it is known that pine was planted in the region between 1920 and 1950 (John Janssen, pers. correspond. with I. van Tulder 2004). The ^{14}C date allows this late arrival, but part of the pine pollen may have an extra-regional source, transported by air and/or river water. In the Southern Netherlands reforestation of sub-optimal soils with pine started already in the 19th century, to provide the coalmines with props. Therefore it is quite feasible that the uppermost spectra of the diagram reflect a longer period.

*3.3 Buckwheat (*Fagopyrum esculentum *Moench)*

Buckwheat appears in the Swalmen diagram between 1270 and 1394. In the Syperhof diagram the crop is already present at the start of deposition, 1029-1221, but this is not the start of a continuous presence. A period without buckwheat follows and its pollen reappear at 1300-1427. The Roer diagram reveals buckwheat in its upper part, deposited between 1430 and 1553 (van Hoof *et al*. 2006).

Buckwheat is a late addition to the range of crop plants cultivated in the Netherlands (fig. 5). Leenders (1996) writes "hard historical data show that buckwheat was introduced in 1389-1390 at at least two places: in Deventer on the river IJssel in the northern Netherlands and in the hinterland of Antwerpen in the southern Netherlands (Kempen-area). Within 50 years buckwheat was mentioned throughout the whole of the Kempen and also more and more in the IJssel valley and elsewhere in the northern Netherlands.". The dates provided by the Swalmen and Roer diagrams are in agreement with this history, but Syperhof is not. Some buckwheat is present before 1389. Four explanations can be offered: 1. the ^{14}C date is faulty, 2. the 'early' pollen grains were transported downwards from a higher level, 3. the 'early' pollen grains were brought in by river water from a region where cultivation started earlier, and 4. incipient cultivation is not recorded in the historical sources. A fifth possibility offered by Leenders (1996), namely that "buckwheat was always present as a weed" can be rejected because its pollen and macroremains are absent from prehistorical records before the Late Iron Age. The finds up to 1500, pollen and fruits together, are depicted in fig. 6 (RADAR 2010).

Figure 5 Buckwheat. Photo C. Bakels

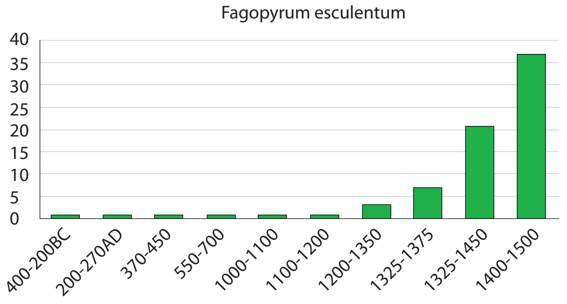

Figure 6 The occurrence of buckwheat (pollen and macroremains) in Dutch archaeological sites until 1500. The X-axis presents their date in chronological order; these dates are provided by their archaeological contexts which explains the hiatuses and overlaps on the time-scale. A site with buckwheat, irrespective of the numbers found, counts as one on the Y-axis. Before 1200-1350 the record mentions only six sites with buckwheat. After 1500 the plant is very common and this period is not depicted in the figure

A faulty ^{14}C date is always possible, but in the region immediately to the east/southeast, in Germany, buckwheat has been recorded from the second half of the 13th century (Bunnik 1999). An appearance before the first records in written sources should not be rejected off-hand.

The curve of buckwheat shows an interruption after the first appearance of the plant and therefore a downward transport is not very likely. The third possibility implies that buckwheat was cultivated in Belgium and northern France before 1300, but up to now no archaeobotanical finds have been recorded this early (Sigaut 2014, 110; Slicher van Bath 1963, 265). That leaves the fourth possibility: buckwheat as a crop of negligible importance.

Whatever its early appearances, buckwheat became only important as a staple crop from the second half of the 14th century onwards. Interestingly this is the period during which the Black Death struck the rural population. The contemporaneity may be coincidental, but could be just as well meaningful.

A buckwheat crop requires only three months from sowing to harvesting. The plant thrives on all kinds of soils, though in historical times it was mainly sown on sandy soils or on drained peat. In the Netherlands many varieties are known, grouped into two categories: sand buckwheat and peat buckwheat (Lenting 1853), but when these varieties came into existence is unknown. Regarding the sand buckwheats, the kind most likely sown in the medieval Swalm region as suitable peat deposits are absent there, three qualities stand out in addition to their short growing season: the crop requires little manuring, can be sown for several years on the same plot and represses weed growth (Lenting 1853). Therefore, it does not need much care. Of course there are disadvantages as well. Buckwheat does not survive frost and the plant requires loose soil. If the soil is not loose of its own, the field requires intensive ploughing. But except for the ploughing, buckwheat is a good emergency crop in times when labour is scarce. Therefore, it is quite feasible that buckwheat, possibly already known since late prehistory, but not much valued, was given a chance during a period of agricultural regression.

After that, the crop did not disappear, but gained steadily in importance instead. A document drawn up in 1635 concerning the output of the mill at Swalmen mentions 57 malder rye, 40 malder buckwheat, 20 malder malt, 4 malder wheat and 16 pounds of sugar (Ickenroth 1989). A malder is equal to 165 litres. The cultivation of buckwheat declined sharply in the 20th century because the adoption of artificial fertilizer made the growing of other crops more profitable. Indeed, in the Syperhof diagram buckwheat pollen are absent from the uppermost spectrum.

4 Conclusion

The Swalmen diagram clearly reflects the impact of land clearance connected with the foundation of a *curtis*, a nobleman's estate, around 950. Although the pollen diagram alone cannot assess the size of the area cleared and put into cultivation, archaeological research has shown that the clearance led to a considerable impact on the surrounding land. The parceling of an area of at least 2 km^2, still visible and functioning today, can be attributed to this medieval event.

Before this large-scale clearance the region was already exploited by a farming population, but to a much lesser extent. Intervention in the landscape grew from 725-967 onwards, but its effect is mainly visible in the growing importance of oak at the expense of other trees. After the abandonment of the large farm, around 1225, the region retained its use as agricultural land. After 1270-1394 the cultivation of wheat, barley, oats and rye was supplemented by buckwheat.

The Syperhof diagram reflects the same region. Its main feature is a rise in oak pollen percentages starting around 1300-1427, which is interpreted as the effect of the Black Death. The rise in oak pollen is matched by a decline in cereal pollen percentages. This reduction or change in agrarian activities may reflect a reduction in the overall population, but not to such an extent that the entire population was wiped out. At the same time the cultivation of buckwheat took hold and it is feasible that the two are connected. Buckwheat may have served as emergency crop.

Before 1485-1663 activities returned to normal. Only in the uppermost spectra the tree pollen percentages rise again, but that is due to the planting of pine to provide the nineteenth-twentieth century coalmines with props.

Acknowledgments

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Malaise and mosquitos: osteoarchaeological evidence for malaria in the medieval Netherlands

Rachel Schats

Malaria was an important disease in the history of the Netherlands. For the period after 16th century AD, there is solid documentation indicating the presence of the disease, specifically in the marshy areas of Holland and Zeeland. For the medieval period (AD 1000-1600), however, no such data exist which has resulted in the absence of malaria in discussions on past health and disease. Therefore, this article explores the possibility of medieval malaria by analysing the relationship between skeletal pathology and habitation in marshy areas. Results indicate that malaria was a highly significant illness in these regions of the Netherlands. This demonstrates that ignoring malaria as an important disease may result in wrong conclusions about the health status of medieval populations.

1 Introduction

Ziet ge muggen, lang van poot
Aarzel niet, maar sla ze dood!
Klein is de mug, maar groot het leed
Veroorzaakt door een muggebeet.
Beter dan chinine slikken,
Is het muggen dood te tikken!

A mosquito is neither friend nor pet
So don't hesitate and kill him dead
Small the bug but big the blight
Caused by a mosquito bite
Better than swallowing lots of pills
Is to give a mighty whack that kills

(translation Kelly Fennema)

Malaria, a debilitating and often chronic disease, is a major health problem in the non-western world. Although currently absent in the Netherlands, historical evidence suggests that malaria was endemic here as well, specifically in the marshy areas (Swellengrebel and de Buck 1938, 9; Van Seventer 1969, 9; Van der Heide 1988, 2374). This is demonstrated by the quote displayed above. The short poem encouraging people to kill mosquitos was displayed in the offices of general practitioners in the 1930s (Van der Heide 1988, 2372). This is a clear example of the fact that also in the Netherlands, malaria presented a health problem up to the 20th century. Unfortunately, in historical sources references to malaria concerning the period before the 17th century are scarce (Bruce-Chwatt and de Zulueta 1980, 106). While it is expected that the disease was also present in the medieval Netherlands based on the abundance of marshy areas in this period, the lack of solid documentation impairs the assessment of the impact and spread of malaria during this time.

Given the lacunae in our knowledge of malaria in the medieval Netherlands from historical records, we have to turn to archaeological data, specifically to human skeletal remains. The study of osteoarchaeology has proven an excellent source for knowledge about disease in the past. However, the fact that malaria does not result in specific skeletal lesions makes it difficult to study the disease in the archaeological record. Recently however, Gowland and Western (2012) were able to demonstrate a clear relationship between a pathological lesion called cribra orbitalia and regions they considered to be malarial (Gowland and Western 2012). This led them to conclude that even though malaria is not the only disease causing the orbital lesions, it can be used as an indicator for malaria in the UK. Therefore, building on research of Gowland and Western (2012), this paper aims to research the prevalence of cribra orbitalia in Dutch skeletal collections dating to the medieval period to investigate if a similar relationship between the pathology and possible malaria endemic areas exist. If so, this study will provide the first indirect evidence for malaria in the medieval period and will emphasise the importance of considering this aetiology in future skeletal research in the Netherlands.

2 Malaria: an overview

Malaria is an infectious mosquito-borne disease caused by parasitic protozoans of the *Plasmodium* genus. Only mosquitos of the *Anopheles* genus can transmit the malaria parasites: from the saliva, they are transferred to the circulatory system of the host where the parasites reproduce and mature (Sinden and Gilles 2002, 8). Of the approximately 200 species of the *Plasmodium* genus, there are currently four which directly infect humans: *P. vivax*, *P. falciparum, P. malariae,* and *P. ovale*. The *P. vivax* parasite is still the most globally distributed one. Since the *P. vivax* species is able to develop at lower temperatures than the other species and has a long incubation period, it was this species that was present in the Netherlands in the past, (Martens *et al.* 1999, S92). In contrast to the species prevalent in Africa (*P. falciparum*), the *P. vivax* malaria is considered to be less fatal (Warrell 2002, 200). The other two species have a limited distribution and are rarely associated with fatalities (Warrell 2002, 202).

One of the most important symptoms of malaria are the intermittent fevers, a feature of the disease also recognised throughout history, as will be discussed below. The fevers are the result of the typical life cycle of the parasites. Once they enter the human body, they invade the liver and red blood cells where parasite reproduction takes place. Once enough parasites are produced, which takes approximately 48 to 72 hours, the red blood cells burst releasing malaria organisms in the blood stream. This sudden increase of parasites in the blood results in an immune response of the body which is responsible for the fevers, but also for chills and muscle pain associated with malaria (Pinello 2008, 28). The symptoms are relieved when the parasites invade new blood cells, but will return once the cells burst again, explaining the intermittent fevers so well known for malaria. This destruction of red blood cells also results in another important symptom: anaemia. The cells are destroyed faster than the body can produce them, leading to a low red blood cell count. Although this does not have to be fatal, weaker individuals such as the sick, elderly or children can easily die as a result of anaemia (Douglas *et al.* 2012), which suggests that this could have been the case in the past as well.

3 Malaria in the past

Although it is difficult to identify malaria on the basis of past descriptions of symptoms, malaria appears to be a disease of great antiquity. Even though the name of the disease only dates to the 18th century, referring to the then assumed cause (corrupted air = *mala aria*) (van Seventer 1969, 9), references to seasonal and intermittent fevers are found much earlier in ancient Assyrian, Chinese, and Indian medical texts. Additionally, early scholars from Europe also seem to note the presence of the disease. Hippocrates, for example, described symptoms which can be associated with malaria (Gilles 2002, 1; Packard 2007, 37). In the third century BC, malaria appeared to have been omnipresent in Rome and its surroundings taking substantial numbers of lives (Packard 2007, 37). Plinius prescribed bread with woodlice as remedy for the fever that was plaguing the citizens (van der Heide 1988, 2372). From this period onwards, it is assumed that malaria spread to Northern and Central Europe. Historical documents indicate its presence in England in the 16th century AD. English marshlands were considered to be extremely unhealthy since inhabitants and visitors were plagued by *ague*, a term which refers to the high, intermittent fevers (Dobson 1989, 3). In the centuries that followed, references to what appears to have been malaria are regularly found throughout Europe, suggesting that it was a common disease. From the 19th century onwards, improved agricultural methods, medication, and other eradication techniques resulted in a decrease of malaria in Europe (Packard 2007, 37).

Malaria is also known to have had a long history in the Netherlands. From the 17th century onwards, references to symptoms which could be related to the disease are found in several historical documents. Sylvius de le Boë, a Dutch doctor and anatomist, describes an epidemic of fevers in Leiden in 1669 and the famous Dutch physician Herman Boerhaave also has written extensively about the fevers causing many deaths in the Netherlands (Bruce-Chwatt and de Zulueta 1980, 106). In 1826, a severe outbreak of fevers, apparently related to flooding of the North Sea, caused many deaths. In Amsterdam, for example, 2400 of the 200,000 inhabitants are reported to have died as a result of ‘malarial disease’. Several more outbreaks would plague the Netherlands in this century (Bruce-Chwatt and de Zulueta 1980, 107), although the infection rates became somewhat lower in this time. This was most likely as a result of the increased availability and reduced price of the medicine quinine (van Seventer and De Buck 1938, 24-26).

What is clear throughout time is the relationship between marshy areas, especially regions that were reclaimed from the sea, and the prevalence of malaria. The current provinces of Zeeland, Friesland, North-Holland, and Groningen appear to have been most heavily affected by ‘malarial disease’ (Bruce-Chwatt and de Zulueta 1980, 108). In the 20th century, it became clear that this is a result of the preference of *Anopheles atroparvus*, the mosquito species which was transmitting malaria in the Netherlands, for breeding in brackish water. In the peat and clay areas reclaimed on the sea, water salinity would have been high, creating the perfect breeding ground for malaria mosquitos. In these areas, mosquito density would be very high (fig. 1) resulting in a high prevalence of malaria. This is also why the damming of the Zuiderzee with the Afsluitdijk in 1932 reduced the disease rates in the Netherlands: the once large body of brackish water now became fresh water. Additionally, a combination of measures in the form of supplementary medication and treatment of houses (and stables) with insecticide (Dichloordifenyltrichloorethaan or D.D.T.) resulted in the disappearance of the disease in the 20th century (van der Heide 1988, 2374). After 1958, no patient with autochthonous malaria has been reported in the Netherlands (van Seventer 1969, 2055).

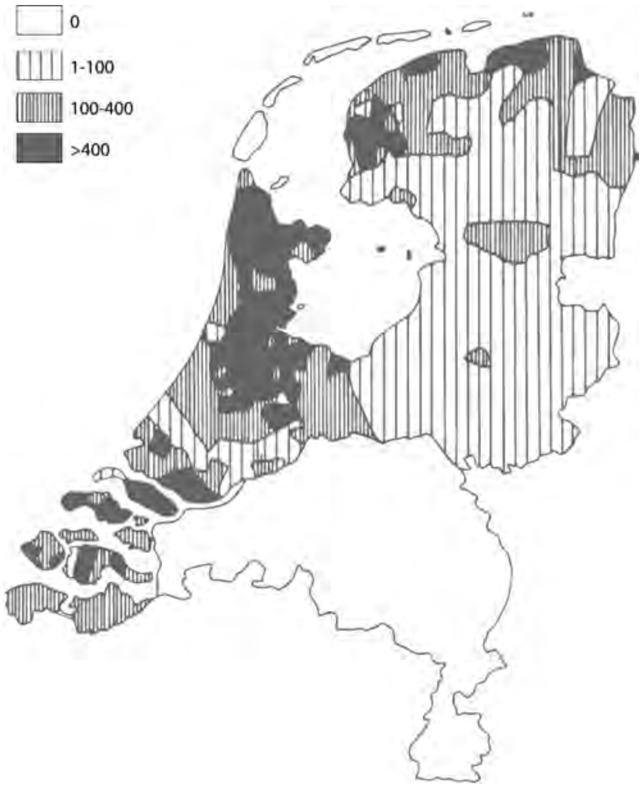

Figure 1 Map of the Netherlands indicating mosquito density as estimated by the number of mosquitos found in stables in 1938: black=more than 400 mosquitos, narrow lines=100-400 mosquitos, wide lines=1-100 mosquitos, white=0 mosquitos (adapted from Swellengrebel and de Buck 1938, 71)

Information on geology and climate from the medieval period suggests that malaria could have been prevalent during this time. Land reclamation was one of the most important activities in the medieval period in the coastal regions, starting around AD 1000, resulting in large areas of drained peat and clay surrounded by brackish water (Hoppenbrouwers 2002, 116). This would have created the perfect circumstances for endemic malaria in the medieval period. Since no historic documentation on malaria in this period exists, osteoarchaeological data from skeletal assemblages provide the only means by which evidence for this hypothesis can be gained.

4 Malaria in the skeleton

4.1 Direct evidence: biomolecular

Palaeopathology aims at diagnosing disease in human remains. Unfortunately, it is not always possible to identify the specific disease that is the cause of lesions observable in the skeleton through macroscopic examination alone. This is due to the fact that bone has a limited response to disease. As a result, skeletal lesions caused by a number of diseases are indistinguishable from each other. Recent advances in ancient pathogen research, however, have made it possible to identify ancient disease directly in bone, resulting in a definitive diagnosis. This approach worked particularly well for tuberculosis (*e.g*. Mays *et al.* 2001; Mays and Taylor 2003), leprosy (Donoghue *et al.* 2005) and the Black Death (Bos *et al.* 2012; Harbeck *et al.* 2013). However, identifying malaria parasites in ancient human remains proved to be more difficult. Parasite DNA has been successfully found in soft tissues of Egyptian mummies (Nerlich *et al.* 2008), however, the detection appears to be more challenging in skeletal remains. Although ancient malaria pathogen DNA was found in the skeleton of a child from Italy (Sallares *et al.* 2004), several other researchers failed to retrieve the parasite DNA from bone. For example, Pinello (2008) analysed over a hundred skeletons from malaria endemic areas in England but was unable to identify malaria DNA. The author hypothesises that this is most likely due to poor pathogen DNA survival or to inadequate detection techniques at the time (Pinello 2008, 12).

Other methods for identifying ancient disease in skeletal remains include lipid biomarkers analysis and antibody detection. Lipid biomarker research has shown to be valuable for diagnosis of tuberculosis and leprosy (*e.g.* Gernaey *et al.* 2001), however, this has not been attempted for malaria. The detection of antibodies has had some success in archaeology. Kolman *et al.* (1999) were able to detect syphilis antibodies, although other researchers were unable to confirm their results (*e.g.* Cattaneo *et al.* 1992). For the detection of malaria, this approach has proved to be successful in soft tissue samples from Egyptian mummy remains (Bianucci *et al.* 2008). Fornaciari and colleagues (2010) were able to detect malaria antibodies in members of the Medici family in Italy who were known to have died from malaria. Currently, Kendall and colleagues are working on improving the immunological assays to be able to apply this method on a more regular (cost efficient) basis in archaeology (Kendall *et al.* 2014).

4.2 Indirect evidence: skeletal

As direct detection methods for malaria in ancient skeletal remains are currently not providing clear and consistent results, indirect skeletal evidence for the disease has to be considered to be able to gain insights in the distribution in the past. Although malaria does not result in clear pathognomonic lesions in the skeleton, the fact that anaemia is one of the most common symptoms allows it to be studied osteoarchaeologically. Anaemia results in a deficiency of red blood cells which the body will try to replace by generating more. Most of the red blood cell production in the human body takes place in the bones, specifically in the marrow.

In response to the low red blood cell count, the bone marrow becomes enlarged in an effort to produce more cells. Occasionally, this expansion of the marrow can be seen macroscopically in the skeleton since it results in the disappearance of the outer layer of bone. Especially in places where the cortex is thin, such as the cranium, the effects of anaemia can be seen. The eye orbits are prone to show the lesions associated with marrow enlargement since the bone cortex is very thin. This marrow hyperplasia in the eye orbits is termed cribra orbitalia and gives the surface a porous, sieve-like appearance (fig. 2) (Aufderheide and Rodríguez-Martín 1998; Walker *et al*. 2009; Gowland and Western 2012).

It is, however, important to note that anaemia is not a specific disease, but a pathological symptom and can be related to many causal factors, not just malaria (Walker 1985; Walker *et al*. 2009, 110). The causes of anaemia in archaeology have been extensively debated over the last few years. Although controversy on the actual aetiology still exists (see Waldron 2009; Walker *et al*. 2009), cribra orbitalia is generally described to be the result of general nutritional stress (Waldron 2009). High prevalence of orbital lesions in a population will commonly lead to the conclusion that the individuals were deprived of certain nutrients. Although vitamin deficiencies are a good explanation for cribra orbitalia in areas without malaria, in regions where this disease was prevalent it has to be considered as possible cause for the orbital lesions as well. While the fact that anaemia is an important symptom in malaria would suggest that the disease is a likely cause of orbital lesions, due to its clinical insignificance and difficulty of observing this lesion radiologically, medical literature does not currently support this hypothesis (Gowland and Western 2012, 303). Recently, however, Gowland and Western (2012) were able to demonstrate a clear relationship between cribra orbitalia and marshy areas in Anglo-Saxon England. No such correlation was found with enamel hypoplasia, another skeletal stress marker, suggesting that the orbital lesions can be a good indicator for malaria in the archaeological record (Gowland and Western 2012, 309).

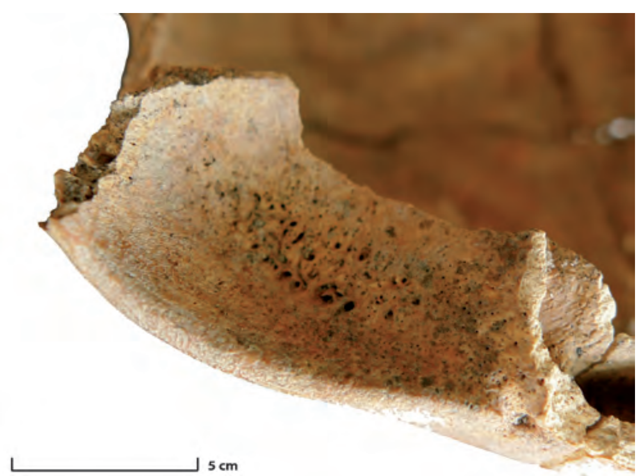

Figure 2 Healed cribra orbitalia in the left eye orbit of an adult female from the Paardenmarkt collection, Alkmaar

In Dutch skeletal collections, cribra orbitalia is a relatively common pathology. However, malaria is rarely mentioned as a possible cause for the orbital lesions in skeletal reports, even though it is possible that this disease is responsible for the observed cribra orbitalia, especially when individuals came from a region with malaria endemicity. Currently, however, there is no strong indication for malaria being present in the medieval period. Therefore, the relationship between marshy areas and the prevalence of cribra orbitalia is studied in an effort to provide indirect evidence for the presence of malaria.

4 Cribra orbitalia in Dutch skeletal collections

4.1 Materials and methods

For this study, the prevalence of cribra orbitalia in 13 urban and rural skeletal collections, a total of 1838 individuals, are compared. An overview of the collections and cribra orbitalia prevalence are shown in table 1. Unfortunately, the percentages of cribra orbitalia displayed in the table are crude prevalences which mean that all individuals in the collection are taken into account, not just the individuals with eye orbits. Ideally, a true prevalence, including only individuals with eye orbits, should be used for this kind of analysis. However, this was not available for all collections. If only assemblages for which a true cribra orbitalia prevalence was recorded were used, the sample size and geographic spread would become too limited for valuable analysis. Therefore, it was decided to use the crude prevalence, but it is important to keep in mind that this may have been influenced by post-mortem factors such as taphonomic alteration or destruction of bones.

The seventh column in the table indicates whether the collection came from an area considered to be high in malaria mosquitos. Since no direct evidence is available for the medieval period, the categorisation is based on counts from the 1930s. When the skeletal collection originated from an area with more than a hundred mosquitos in 1938, it is considered malarial. Although it is possible that mosquito density changed during time, information on past geological circumstances would suggest that areas classified as malarial in 1938 would have been preferred by malaria mosquitos in the medieval period as well. The skeletal assemblages classified as malarial according to the

Site number	Site	Dating	Number of individuals	Cribra orbitalia	Crude prevalence (%)	Malarial?	Reference
1	Beguinage cemetery, Breda	1267-1530	120	0	0,0%	No	Rijpma and Maat 2005
2	Blokhuizen, Niedorp	1000-1200	119	13	10,9%	Yes	Schats, in prep.
3	Catharinakerk, Eindhoven	1200-1500	186	3	1,6%	No	Baetsen and Weterings-Korthorst 2013
4	Cruyskerke	1200-1421	316	6	1,9%	No	Sannen 2010
5	Julianaplein, Wijk aan Zee	1420-1573	17	3	17,6%	Yes	Baetsen 2008
6	Klaaskinderkerke	1268-1573	54	7	13,0%	Yes	Schats, in prep.
7	Koningsveld, Delft	1450-1572	220	4	1,8%	No	Groen, in prep.
8	Minderbroeder-sklooster, Dordrecht	1275-1572	316	5	1,6%	No	Maat et al. 1998
9	Nieuwlichtklooster, Utrecht	1392-1580	57	8	14,0%	Yes	d'Hollosy 2012
10	Oude en Nieuwe Gasthuis, Delft	1265-1652	101	1	1,0%	No	Onisto et al. 1998
11	Paardenmarkt, Alkmaar	1448-1572	189	17	9,0%	Yes	Schats, in prep.
12	Stiftskapel, Maastricht	1070-1521	27	0	0,0%	No	Jansen and Maat 2002
13	Vroner Kerkhof, St. Pancras	1000-1297	116	8	6,9%	Yes	Alders and van der Linde 2011

Table 1 Prevalence of cribra orbitalia in the collections under study and corresponding 'malarial' or 'non-malarial' categorisations

20th century data are mostly from North-Holland and Zeeland where regions of peat and clay reclaimed on the sea were very common. Figure 3 shows the same map as above but now includes the skeletal assemblages used for comparison in this study.

4.2 Results

The comparison of the prevalence of cribra orbitalia between the areas considered malarial and those which are deemed non-malarial shows a marked difference. In total, 56 individuals (10.1%) showed orbital lesions in the malarial regions and in the non-malarial areas only 19 of 1286 (1.5%) individuals were affected by this pathology (table 2). This difference in prevalence between the malarial and non-malarial regions can be analysed using a chi-square test of independence to assess whether the difference also meets statistical significance. The results indicate that the difference is highly statistically significant (X^2= 74.131, df=1, p<0.001, N=1838), pointing to a clear relationship between cribra orbitalia presence and regions considered to be malarial.

5 Malaria in medieval Netherlands

The results indicate a strong link between areas deemed malarial and the prevalence of cribra orbitalia. Much higher frequencies of the orbital pathology are reported for the skeletal assemblages that originated from areas where malaria mosquitos are assumed to have been prevalent in the medieval period. This would suggest that cribra orbitalia, as was shown by Gowland and Western (2012) for the UK, is also a good indicator for malaria in the Netherlands. Consequently, while this was previously only assumed, the results of this study potentially provide evidence for the occurrence of malaria in the medieval period.

Even though sample size in this study is modest and the geographic spread does not cover the entire Netherlands, the results have important implications for the understanding of health and disease in the medieval period. This research has demonstrated that malaria is most likely a significant cause of cribra orbitalia in the regions where the disease was endemic, such as large parts of North-Holland and Zeeland. Ignoring malaria as a factor in the discussion of disease in a

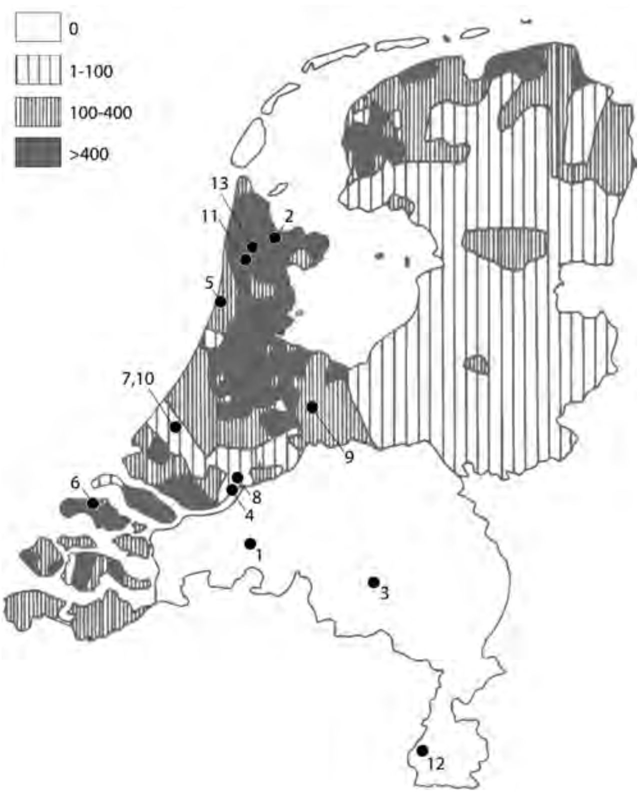

Figure 3 Map of the Netherlands indicating mosquito density in 1938 (adapted from Swellengrebel and de Buck 1938, 71) with the sites used in this study indicated as dots (numbers correspond with those in table 1)

population from these regions could potentially result in wrong conclusions. For example, the high prevalence of cribra orbitalia in the skeletal collection from Wijk aan Zee is explained in the skeletal report by high levels of nutritional stress (Baetsen 2008, 74). Considering that Wijk aan Zee was located in a region with high malaria endemicity, this disease should have been taken into account as a possible cause of the orbital lesions.

To conclude, this paper has demonstrated that malaria could have been an important disease in the medieval period in the marshy areas of the Netherlands. By showing a relationship between malarial areas and cribra orbitalia prevalence, this study has demonstrated the potential of using the lesions as malaria indicators in Dutch archaeology. Consequently, the results have significant implications for the interpretation of cribra orbitalia. Rarely malaria has been discussed as a possible cause, more often cribra orbitalia is associated with nutritional stress. Even though many factors can be responsible, not taking into account malaria-related anaemia can result in incomplete discussion on health and disease, specifically when dealing with skeletons from marshy areas. The incorporation of malaria in the differential diagnosis of cribra orbitalia could potentially completely change the interpretation of the health status of some archaeological populations.

In the future, more conclusive evidence could be provided through the incorporation of new biomolecular techniques. As discussed above, some studies focusing on malaria detection in skeletal remains using DNA techniques have been performed, unfortunately with limited success (*e.g.* Sallares *et al*. 2004; Pinello 2008). However, recently, new DNA techniques have been developed which may improve the detectability of the ancient pathogen in human bones (Kobolt *et al*. 2013). Additionally, the analysis of human dental calculus has shown to have great potential for the analysis of disease in past populations (Warinner *et al*. 2015) which may also be of use in the search for the malaria parasites. With these new methods, it will be possible in the future to gain a full and definitive understanding of the spread of malaria in the medieval period. The present study has created a starting point from which further research can be undertaken.

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	Number of individuals with cribra orbitalia	Number of individuals without cribra orbitalia	Total number of individuals	Crude prevalence
Malarial	56	496	552	10,1%
Non-malarial	19	1267	1286	1,5%

Table 2 Prevalence of cribra orbitalia in malarial and non-malarial areas

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Shipwrecks in Dutch Waters with Botanical Cargo or Victuals

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This article gives an overview of the botanical finds made during surveys, assessments and excavations of shipwrecks in the Netherlands. The wrecks date mainly from the period 16th to 18th century. Both samples of the cargo and loose botanical finds are mentioned. In addition to cultivated plants we also identified (collected) wild plants and their seeds. This last group concerns especially the arable weeds between grain cargoes. The finds are reported in relation to the wreck they were found in and all economically important species found are recorded in a catalogue.

1 Introduction

Since the early 1980s archaeological research in Dutch waters is carried out by the state, mainly on shipwrecks. This is due to the fact that from that moment on it was understood that a rich cultural heritage under the water surface is still largely undiscovered. And it is precisely this heritage that tells us about Dutch maritime history, the cultural contacts and commercial relationships that have been built up around the world for centuries. The botanical remains that have been found during these researches reflect this image.
The research initially came under the responsibility of the Department of Archaeology under Water (A.O.O.) of the then Ministry of CRM/WVC. In 1995 this section officially changed into the Dutch Institute for Ship- and Underwater Archaeology becoming part of the State Service for Archaeological Heritage (N.I.S.A./ROB). Later on the ROB merged with the RDMZ into the RACM. Since 2009, this is the Cultural Heritage Agency of the Netherlands (Rijksdienst voor het Cultureel Erfgoed, RCE). The Cultural Heritage Agency's Maritime Programme performs research on shipwrecks, bridges, harbours and other maritime landscapes. Its aim is to provide firm foundations for knowledge, research, policy, collaboration and education on the maritime cultural heritage in the Netherlands.

The first author regularly collected botanical material of wrecks during diving. The second author has identified the material. In addition to the research carried out by us, we have added the finds mentioned in various publications and reports with other botanical finds from ships in the Netherlands.

The aim of the article is to present an overview of what has been found in shipwrecks in the Netherlands (fig. 1) over the last 30 years and to provide some reflection on these finds. The authors have made an effort to bring many finds together in order to present this overview. It has not been the aim to be exhaustive in the listing of finds.

2 Shipwrecks

A wrecksite contains often not only the construction parts of the former ship, but also the remains of the cargo, victuals (food), the inventory and personal belongings (see also

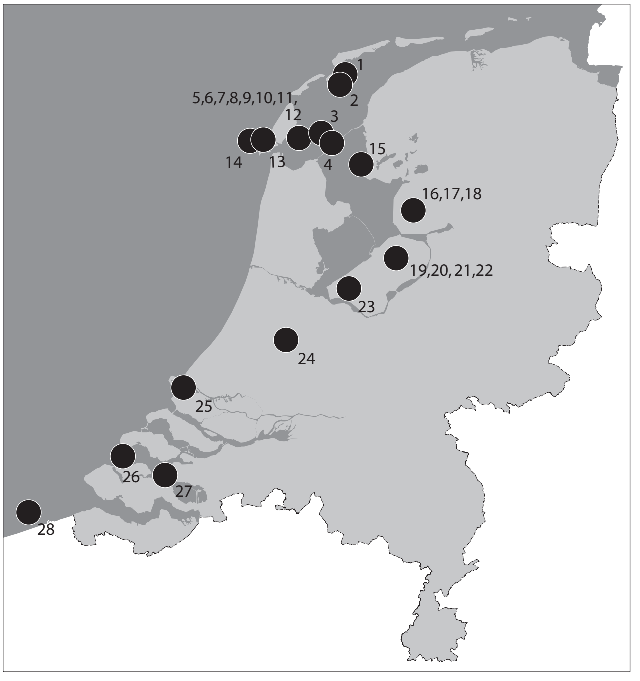

Figure 1 Location wrecks, mentioned in this contribution, in the Netherlands
1 = Wrak op de Pannenplaat, 2 = Vliestroom, 3 = Scheurrak SO1, 4 = Doove Balg 1 (Buytensorgh), 5 – 12 = Burgzand: BZN 2, BZN 4, BZN 8, BZN 9, BZN 10, BZN 14, BZN 15, Scheer 1, 13 = Aanloop Molengat, 14 = Noorderhaaks 10 (Sophia Albertina), 15 = Hindeloopen, 16, 17, 18 = Noordoostpolder: NG 29, NG 35, NB 6, 19 – 22 = Oostelijk Flevoland: OF 34, OA 35, OF 3, OL 79, 23 = Zuidelijk Flevoland: AZ 105, 24 = Woerden 1, 25 = Oostvoornse Meer 8, 26 = Roompot, 27 = Brabants Vaarwater (François Narp), 28 = 't Vliegent Hert (drawing RCE)

Reinders 1988). Many of these objects are made of organic material. Plants play a major role. Just think of the hemp- and flax-fibre that was used for ropes and sails, or rush mats which were used to separate different cargoes of grain, like those found on the 16th century grain trader Scheurrak SO1 (Manders 1996). This article will not deal with these kinds of finds, not even with the moss that was used for caulking (an article on this subject is Cappers *et al*. 2000). An important question we will refer to is which plants or plant seeds were transported as cargo or victuals. In addition, we were curious about the state of the finds, particularly in comparison with the conservation of material from excavations on land.

So far, very little attention has been paid to botanical finds in wrecks. An exception is the research of building timber of the ships. The wood is often identified and then dated by means of tree-ring research. This tells us about the felling date of the wood, its provenance and also indirectly about the time when the ship was built and/or repaired.

Excavations on land are not identical to research under water. The procedure from inventory to research may be the same but because of its location, visibility under water and for example the limitations in communication, the execution is often much more difficult. Observations are therefore often more difficult to make. Time is another limiting factor. A diver can only stay underwater for a short period of time. Each time the researcher has to record small amounts of information that have to be put together like a giant jigsaw puzzle in order to create an overview. Due to the constant dynamics (tides and currents) of the seabed, objects can temporarily surface and later be again buried in the soil. Each time objects are surfacing from the seabed, they will be vulnerable to fast deterioration processes (Manders *et al*. 2014, 26). The quantity and quality of the finds, however, can be excellent because the presence of oxygen in the seabed is almost always low (Huisman *et al*. 2008). Also unique is the fact that the botanical material had a function at the moment of the ship's sinking. This could be for example cargo or food, and was not deposited as waste as is usually the case when found on land (*e.g.* in cesspits). When studying the cargo of sunken ships, a useful source may be archive material and various historical publications in which, sometimes casually, the cargo is mentioned. An example is that of the flute ship 'Zeehond' that was with a cargo of flax seed en route from Bordeaux to Amsterdam, and shipwrecked along the Texel (Wadden Sea) coast between 1662 and 1668 (Hell and Gijsbers 2012). These sources are not included in this article.

3 Collecting, method, storage

Two types of finds can be distinguished: loose finds and samples of larger quantities of botanical cargo and victuals. The loose finds are usually larger seeds, for example coconuts and stones of olives. In the case of larger samples, we collected a part of layers deposited in the wreck, often the botanical cargo, or the content of an object, often a cask or pot. The samples are a representation of the cargo or food of which more was present.

For some wrecks we were able to collect soil samples (sediment, layers of plant debris). Under water the material was put into plastic bags that can be sealed and above or below water the sample was provided with metadata (code, date, name diver, etc.). Most samples have been taken consciously and planned in advance. As a result, the sample methods were prepared, locations were planned and find labels were written before the sampling was executed. During the research of the BZN 4 we managed to dig up a whole cask (figs. 2 and 3).

In the laboratory the samples were carefully rinsed with tapwater on a sieve with apertures of 0.5 mm and 0.25 mm. After a division into different size classes, the residue was analysed in water with the aid of a microscope. The number of botanic remains was noted and in the case of large numbers the quantity was estimated in tenths, hundreds or thousands. The complete identification lists of some shipwrecks are too long to mention here. It concerns for example, the seeds of wild plants that have grown between the cereals. The full reports are available at the National Service for Cultural Heritage.

The identifications were carried out with the help of the literature and reference collection of the botanical laboratory of the Faculty of Archaeology of Leiden University. Sometimes the help of colleagues/specialists was invoked in case of 'difficult' seeds. Also old books and paintings give a hint of which products we can expect (fig. 4). Not all finds could be identified. The finds are stored, in a preservation liquid (formalin or a mixture of water, alcohol and phenol) or

Figure 2 Cask with coffee in the wreck BZN 4 (photo RCE)

Figure 3 Cask from the BZN 4 during transport (photo RCE)

dry, and deposited in the maritime depot of the Cultural Heritage Agency of the Netherlands in Lelystad.

4 Examined wrecks and their botanical finds

An overview of the location of the wrecks in the Netherlands is given in fig. 1.

4.1 Waddenzee

Special attention was paid to the shipwrecks in an area east of the island of Texel. This is the old Texel roads with as centre the area Burgzand Noord (Manders 2003). In earlier times many ships were waiting here for good conditions to be loaded or unloaded or to wait for the right wind to sail out to the West Indies, East Indies or other market places in Europe. The cargo of large sea-going ships was brought in with smaller barges to the ports around the Zuiderzee, especially the important staple market of Amsterdam. Although relatively well protected against the prevailing northwestern winds, many ships wrecked during storms in this part of the Wadden Sea, especially if these storms came from other directions like the southwest.

The Wadden Sea has been declared a World Heritage site in 2009. The Burgzand Area, with 15 known wrecks, is a National Monument (Nr. 15660).

Burgzand Noord 2 (BZN 2) – Polish Canon wreck
Archaeological assessment and additional research: 2000, 2005.
Ship type: Armed (Baltic?) merchantman, c. 28 m long.
Age: Built in second half of the 17th century, wrecked circa 1670 – 1675.
Note: this ship was supposed to come from the Baltic area and with a load of among others discarded bronze cannons for re-melting.
References: Vos 2012.

Two samples of the BZN 2 are respectively from a thin (up to 1 cm thick) compact peat-like material found in an excavation trench and a compact peat-like material found in an excavation pit between wooden panelling. The analysis showed that this material consists for almost 100% of cerealia epidermis. The cereal species are not easy to

Figure 4 Painting by Abraham Breughel: Vruchten en bloemen. Circa 1675. Museum Boijmans Van Beuningen, Rotterdam (photo Studio Tromp, Rotterdam)

identify. As an admixture we see hundreds of seed fragments of corn cockle (*Agrostemma githago*) and a single fragment of cornflower (*Centaurea cyanus*), black-bindweed (*Fallopia convolvulus*), swine's succory (*Arnoseris minima*), chess (*Bromus secalinus*) and sheep's sorrel (*Rumex acetosella*).

The conclusion is that the samples were that of milled grain. This is used to bake bread or to make porridge. In between the cerealia epidermis, seed fragments of some wild plants that grow mainly in grain fields and harvested with the grain were found. One of it is corn cockle, which is toxic. Because it wasn't sieved out of the flour, the poison of the seeds accumulated in the human body. It is not clear how many people must have died due to this poisoning. More on this in Manders (1992). The other botanical material collected from this wreck consists of single finds. In four cases these were pieces of grass-like material. This may have been used for many purposes like animal food or stuffing. Buckwheat chaff (*Fagopyrum esculentum*) may have served as packing for a cargo of clay pipes, which probably were packed in barrels. During a dive on 4 September 2001 an oval box was salvaged. In this box we found some cubic centimetres of sand with fine plant remains. These plant remains were all shorter than 1 cm, and were comparable to recent tobacco (see catalogue). It is therefore likely that in this box tobacco (*Nicotiana tabacum*) was present and that it concerned personal use. It may have been smoking or chewing tobacco, which was often on board in large quantities. Not only the frequency in which tobacco boxes are found in wrecks, but especially the large numbers of (used) clay earthen pipes are an indication of this (Krook 1986; Troostheide 1995).

Burgzand Noord 4 (BZN 4)
Archaeological assessment and inspections: 1999 - 2005.
Ship type: Large heavily-built sea-going vessel with a length of more than 35 m. West Indiaman.
Age: Built mid 18th century, wrecked 3rd quarter 18th century.
Comment: The BZN 4 wreck was probably a Dutch ship that arrived with a cargo from South America or the Caribbean. It was found on the Texel roads and was probably waiting for good winds to sail away. Kuijper and Manders (2009 [2011]) focuses on this wreck and the botanical content.
References: Kuijper and Manders (2009 [2011]).

After her discovery in 1984 local divers called this ship the "Watervatenwrak" (water cask wreck). In 1999 and 2001 a diving team of the RCE examined the ship through an archaeological assessment, with the use of trial trenches. The ship was probably built around 1750. Dendrochronological research dates a piece of wood at 1744 ± 6 years (Hanraets 1999). During the investigation it turned out that a lot of material, which later turned out to be coffee (fig. 5c and 5e), was present in and nearby casks. It became clear that these casks (figs. 2 and 3) were filled with (unroasted) coffee beans and that this was an important part of the cargo. The wood from which the casks were made comes from the northeastern part of South America: Andiroba (*Carapa* sp.), Bacuri (*Platonia insignis*), Vinhatico (*Plathymenia reticulata*), Wallaba (*Eperua falcata*) (Luckers 2002). For the escape of gas from the casks, produced by the coffee beans, an ingenious system was constructed with sugar cane stems through the lid (Kuijper and Manders 2009 [2011]).

A total of 41 samples was examined with a total volume of more than 19 litres. The entire content of one cask was salvaged and at random analysed. It was calculated that each cask could contain approximately 500 litres. At seven places in the wreck loose botanical objects were collected. Some objects are fragments of sugar cane stems (*Saccharum officinarum*) (fig. 5a). In addition to the main cargo of coffee

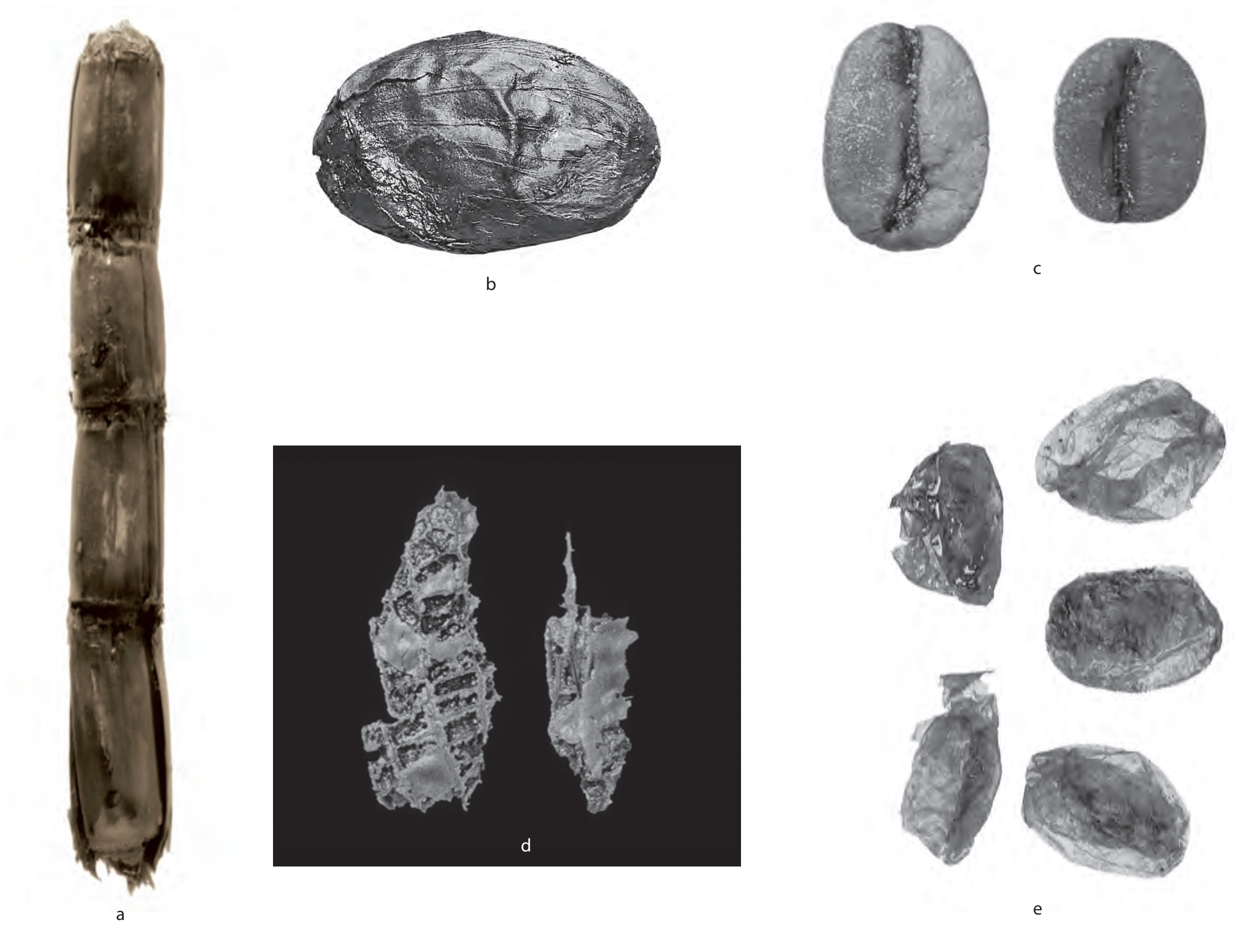

Figure 5a Saccharum officinarum (length 24.5 cm); b Theobroma cacao; c and e Coffea arabica; d Arachis hypogaea. BZN 4 (photos J. Pauptit)

Figure 6 Periplaneta americana, egg cases of cockroaches, inside above, outside below. BZN 4 (photo J. Pauptit)

we also found – in small numbers – seeds of cacao (*Theobroma cacao*) (fig. 5b). Also the seedwall of buckwheat *(Fagopyrum esculentum*), fragments of (horse)beans (Fabaceae: cf *Vicia faba*), a piece of chaff of oat (*Avena* sp.) and two fragments of a pod of a peanut (*Arachis hypogaea*) (fig. 5d) were found. The peanut remains were collected in the remains of a broken barrel, but can be an intrusion.

Noteworthy were the many remains of cockroaches (*Periplaneta americana*) and their egg cases (fig. 6). On the basis of the coffee beans themselves, the origin cannot be determined. The wood of the casks and stowing wood have a Central and South American origin. The marking 'SD' on one of the casks may relate to Santo Domingo. It would appear that the area of origin of the cargo is the Caribbean (including the northeastern part of South America).

Burgzand Noord 8 (BZN 8)
Archaeological assessment including trenches and inspection: 1998, 2002 - 2005.
Ship type: Medium sea-going armed ship, 30 – 35 m long (South European?).
Age: Built mid 17th century, wrecked 3rd quarter 17th century.
Comment: The BZN 8, as well as the BZN 10 nearby, was in the past associated with the shipwreck 'Lelie' that wrecked in 1654. This is however not correct. On BZN 8 a Jacob staff was found dating to 1653.
References: Vos 2012.

Some loose objects were salvaged from the wreck. In a copper kettle, seeds attached by oxidation were found. The dozens of well-preserved grains belong to black mustard (*Brassica nigra*). Remarkable were the finds of a nutmeg (*Myristica fragrans*) (fig. 7a) and 11 kernels of almond (*Prunus dulcis*) (fig. 7b). Noteworthy is that a part of the seeds were damaged (see figure), gnawed by rats or mice.

Because it concerns single finds we can not make any estimation of the quantities of the species on board. They may have been products from the galley or private stock. See catalogue for more information.

Burgzand Noord 9 (BZN 9)
Archaeological assessment: 1998 , 2000 – 2005.
Ship type: A large armed sea-going ship, carvel built, 40 – 45 metres long. A Dutch trading ship.
Age: Built mid-17th century and wrecked in the 3rd quarter of the 17th century.
Comment: Known as 'Twee kanonnenwrak' (two-canon wreck). The kind of pottery and the ship construction suggest that the most likely provenance is the Netherlands. On board was also found a large quantity of pottery (Italian marbled and Italian grafitto tarda from Pisa) and a (relief) tile from Saintonge (Frankrijk). The ship may have been involved in trade with the Mediterranean.

For the botanical research six samples were collected: two from a tar barrel and four from a layer of epidermis of cereals above a layer of straw. The samples from a small barrel contained in both cases half a litre of tar with seeds and some sand. The tar was hard to handle. However, the seeds found in there were excellently preserved. No doubt this was caused by the tar. Many seeds still retained their original shape. The species composition of the two samples is the same. In both cases, it consists of hundreds of grains of rye (*Secale cereale*) and several dozen horse beans (*Vicia faba*) (fig. 8d), the smaller form of the large beans we consume nowadays. Also some peas (*Pisum sativum*) (fig. 8c) were identified. A second species of cereal found was a grain of barley (*Hordeum vulgare*) (in a husk). Very special was the find of eight cowpeas (*Vigna unguiculata*, synonym *Vigna sinensis*) (fig. 8b) and a seed of the green gram (*Vigna radiata*) (fig. 8a), also called mung bean. These two species of beans have never been found in the Netherlands and also outside Europe we know of hardly any finds.

Figure 7a Myristica fragrans; b Prunus dulcis. BZN 8 (photos J. Pauptit)

The cowpea is a crop that is known to have been consumed in Germany in the Middle Ages (Körber-Grohne 1987). This plant was domesticated in Africa, and spread to the Mediterranean and Central Europe. It is one of the oldest known human food crops. Today, cowpeas grow in many tropical and subtropical areas. Both the seeds and the green parts are eaten (Kalkman 2003). The green gram originates from India and its surrounding areas and has been grown there for thousands of years. Much later this bean also became cultivated in Eastern Africa, Australia and America. Both the beans and the plant (just-germinated seeds, pods, young plants) are used. The young sprouts of the plant only a few cm in height are known as bean sprouts or tauge. The cooked beans are whole or halved eaten as “dhal” in India, but may also be roasted or ground. This finds prompts the question of what the beans were doing in the wreck. Their use in 17th century Europe is not confirmed by archaeological finds. Never have any finds from this period been reported. The sample consisted mainly of rye, but the beans will not have grown in a rye field. Maybe the two bean species came on board during a trip to Africa or Asia. It may have been food for the crew or was cargo. This remains unclear. It is also striking that the samples were rather clean. This means that there were few arable weeds between the cereals. Only eight other species were present in small numbers.

The remaining four samples were collected from a layer of compressed cereals, found in the aft and bow of the ship, just below the second deck and on a layer of straw and wood. Analysis showed indeed that the compact layers consisted of epidermis of cereals. The content of the seeds has disappeared over time, only the very thin seed wall remained (flattened, but complete). A sample taken at random turned out to be almost 100% rye (*Secale cereale*). There are a lot of arable weeds present between the cereals, but compared to the many tens of thousands of rye grains this is a low number. One single epidermis resembles that of wheat. In the samples also a few seeds of linseed (*Linum usitatissimum*), hemp (*Cannabis sativa*) and gold-of-pleasure (*Camelina sativa*) were present. The seeds are mostly well preserved and complete. From the species list (about 100 species) and the numbers (many hundreds) of herbs, we can draw the conclusion that the composition of the four samples is more or less identical and so probably they originate from the same cargo (see Appendix 1). With few exceptions, most of the plant species grow in cereal fields. They were harvested with the rye. The rich diversity of flora in the cereal fields was common at that time. We can visualise an image of these fields with pink red corn cockles (*Agrostemma githago*), oxeye daisies (*Leucanthemum vulgare*) and blue cornflowers (*Centaurea cyanus*). The few species usually not growing in cereal fields, like bogbean (*Menyanthes trifoliata*), blueberry (*Vaccinium* sp.), raspberry (*Rubus idaeus*) and heather (*Calluna vulgaris*), may have arrived on board in dried peat used as fuel or from the bottom of the Wadden Sea (from eroded peat layers). Norway spruce (*Picea abies*) with one needle and baneberry (*Actaea spicata*) with one seed would likewise not have grown between the cereals. How these species ended up between the cereals is unclear. Baneberry is a plant about half a metre high, which grows in moist, calcareous slope forests. It is an European species from hilly and mountain areas. A seed of this species was not expected on board.

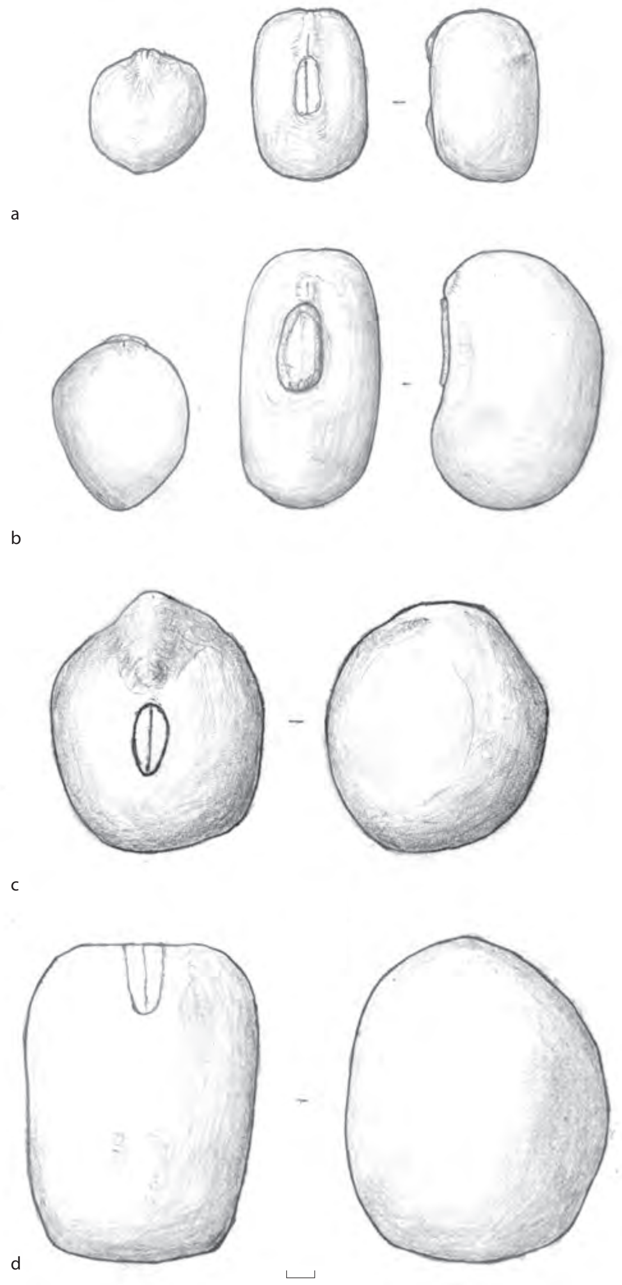

Figure 8a Vigna radiata; b Vigna unguiculata; c Pisum sativum; d Vicia faba. BZN 9 (drawing W.J. Kuijper)

Due to the fact that the rye was found in large quantities in the aft and bow of the ship we can assume that it was part of the cargo and that the BZN 9 was on its way with this cargo and possibly also a cargo of Italian pottery. A weevil beetle (*Sitophilus granarius*) lived between the grains. The larvae eat the grains and can, if they occur in large numbers, seriously affect the quality of a cargo.

The species composition of the cereal samples indicate that the fields were located in a not too wet but also not too dry area, with lime-poor to lime-rich, nutrient-rich sandy loam or loamy sand. The plants that were identified belong to the communities of the so-called class of arable field communities (Stellarietea mediae). Between the cereal, seeds occur of arable weeds that are limited in their distribution. They may therefore give a clue to the origin of the rye. Most of the plants found in our samples have a large range. This is often the whole of Europe, with sometimes even areas in North Africa. Some species are even growing in other parts of the world. However, there are plants with a narrow distribution. For example the Venus' looking glass (*Legousia hybrida*) does not grow in northern and eastern Europe. The yellow chamomile (*Anthemis tinctoria*) is absent in southwest Europe and England. When looking at the present distribution (Kästner *et al*. 2001) of all species, then mainly areas in western France, Germany and Italy qualify as origin of the cereal cargo. Some eastern European countries, however, are not entirely excluded. In addition, we can say that some typical species with a southern distribution are missing, such as white lace flower (*Orlaya grandiflora*), small bur-parsley (*Caucalis platycarpos*) and shepherd's-needle (*Scandix pecten-veneris*). There are also species that surprisingly are missing in our samples, such as poppies (*Papaver* sp.) and wild radish (*Raphanus raphanistrum*).

Burgzand Noord 10 (BZN 10)
Archaeological assessment: 2000, archaeological field work 2005-2014.
Ship type: Large sea-going ship (about 35 m), heavily armed merchantman, of possible north German origin.
Age: Built in the 2nd half of the17th century, wrecked probably before 1700.
Comment: The find of a palm (*Orbignya* sp. or *Attalea* sp.) seed in this wreck was published by Kuijper and Manders (2003).
References: Vos 2012.

The ship's main cargo consisted of hundreds (maybe thousands) of Iberian jars that supposedly were filled with alumina and uric acid, a mixture that was used in the wool industry. Also casks with grapes and anchovies were discovered. Four botanical samples were taken from the casks spread throughout the ship. Together a total of 250 cm^3 wet material was sieved. The residues consisted for almost 100% of grape remains (*Vitis vinifera*). These remains were very well conserved and consisted of hundreds of pips (immature and mature), dozens of whole skins of grapes with the seeds still inside, many fragments of skins, pieces of branches of the bunch of grapes and stalks of the berries (fig. 9a). The quantity and spread of the casks with the

a b

Figure 9a Vitis vinifera; b Orbignya sp./Attalea sp. BZN 10 (photos J. Pauptit)

grapes suggest that they were part of the cargo. In one of the samples we found a large seed of melon (*Cucumis melo*). A striking find was a seed of a palm (*Orbignya* sp. or *Attalea* sp.) (fig. 9b). The origin of the palm is Central or South America (Kuijper and Manders 2003).

Burgzand Noord 14 (BZN 14) - Potterwrak
Archaeological assessment and partial excavation: 1999, 2000, 2002, 2004, 2005.
Ship type: A large, probably armed, sea-going merchant ship of Dutch origin, 35 – 40 metres long.
Age: Built mid 17th century, wrecked 2nd half of 17th century.
Comment: Moolhuizen (2009 [2011]) has focused on this wreck and its botanical content. The popular name used by divers for the wreck is the 'potter wrak'. It refers to the large number of large loadstones that were found on this wreck.
References: Vos 2012.

The sampled botanical material was found during a partial excavation of the stern part of the ship. Of thirteen samples, eleven contained remains of black pepper (*Piper nigrum*) (fig. 10). It mostly concerned large quantities, up to several hundreds or even thousands of corns per sample, with remarkable preservation. Small stalks with unripe berries of pepper were also present. The total number of pepper corns from the samples lies somewhere around 6000. One of the samples (PW-328) came from inside a small beech wood barrel.

Other finds concern cereals, beans (*Vicia faba*) and peas (*Pisum sativum*), rice (*Oryza sativa*) (chaff) and a seed of cucumber (*Cucumis sativus*), buckwheat (*Fagopyrum esculentum*), linseed (*Linum usitatissimum*) and hemp (*Cannabis sativa*). On a single epidermis of grain in a cask the cell pattern of rye (*Secale cereale*) could be recognised. Between the cereals the seeds of approx. 35 arable weed species were present (see table 2 in Moolhuizen 2009 [2011]). Again, especially the large quantities of pepper were remarkable. As it turned out, for example, a small sample of approximately one sixth of a litre from the contents of a cask almost entirely consisted of peppercorns. It concerns hundreds of seeds and their outer layer ('epidermis') and dozens of stalks to which the seeds would have been attached. Besides the large amounts of pepper, some other evidences indicate an Indian, or at least a tropical connection of the ship. Coral blocks were found between the ballast stones, and during the archaeological assessment also a double layer of pinewood planking (doubling, see Van Duivenvoorde 2012, 8) was identified. Was this an East Indiaman, with casks of black pepper, cereals and beans or peas on board? It is a peculiar combination of luxury spices from the colonies with common European food. The pepper may well have been the cargo – maybe even private trade – while the beans and cereals were probably food on board.

Burgzand Noord 15 (BZN 15)
Archaeological assessment: 1999, 2000, 2002, 2004, 2005.
Ship type: Carvel built merchantman.
Age: Mid-17th century, wrecked second half of 17th century.
Comment: The popular name 'Fragment near Potter ' suggests that BZN 14 and 15 belong to the same ship. So far

Figure 10 Piper nigrum. Corns and stalk. BZN 14 (photo corns J. Pauptit, drawing stalk M. Oberndorff)

this remains unclear. However, a heavy load of iron bars and copper wires and sheeting suggests that the fragments belong to two different ships. This cannot be confirmed.
References: Vos 2012.

Two samples were taken from this wreck for botanical research. An iron concretion contained dozens of hemp seeds (*Cannabis sativa*). The use of hemp seeds on board is unclear. The seeds may have been used as bird food. A second sample was taken in fine laminated clayey sand with small plant debris. In 1/5 litre of sediment we found remains of plants of watersides and fresh water, and a seed of eelgrass (*Zostera marina*) (see Appendix 1). In addition there were many remains of marine animals (especially shells) in the residue. It is clear that this sample was taken from a natural deposition, developed after the sinking of the ship.

Scheurrak SO 1
Archaeological excavation: 1989 - 1997.
Ship type: More than 30 metres long, carvel built Dutch merchantman (flute-like construction).
Age: Built about 1580, possibly wrecked on Christmas night 1593.
Comment: This wreck has been fully excavated. Tens of thousands of objects have been brought up and the construction has been investigated and recorded.
References: Manders 1992; 1993; 2003.

In 1984 the wreck was detected at approximately nine nautical miles northeast of Oudeschild (Texel) in the Wadden Sea. It turned out to be a late 16th century grain ship. The cargo mainly consisted of a very large quantity of bread wheat (*Triticum aestivum*). Compact layers at various places (24 samples) consisted of the epidermis of this cereal. These clearly were part of a bulk cargo in the hold, which had been transported on a layer of bundled straw (fig. 11). Striking, but for that time quite common, was the presence of many seeds of arable weeds between the cultivated cereals. Between the wheat, the seeds of corncockle (*Agrostemma githago*), cornflower (*Centaurea cyanus*), brome (*Bromus* sp.), wild radish (*Raphanus raphanistrum*), knotgrass (*Polygonum* spp.), charlock/mustard (*Sinapis arvensis/ Brassica* spp.), cleavers (*Galium* spp.), nipplewort (*Lapsana communis*), fat hen (*Chenopodium album*), mouse-ear chickweeds (*Cerastium* spp.), hemp-nettle (*Galeopsis* spp.), corn gromwell (*Buglossoides arvensis*), black bindweed (*Fallopia convolvulus*), black medick (*Medicago lupulina*), vetches (*Vicia* spp.), forking larkspur (*Consolida regalis*), docks (*Rumex* spp.), grasses, mayweed (*Tripleurospermum/ Matricaria*), chickweed (*Stellaria* spp.), oraches (*Atriplex* spp.) and many others were identified. A total of about 46 species. From seven samples the seed composition is noted (see Appendix 2).

Other cultivated crops between the wheat are turnip rape (*Brassica rapa*), rye (*Secale cereale*), barley (*Hordeum vulgare*), emmerwheat (*Triticum dicoccum*), millet (*Panicum miliaceum*), oat (*Avena sativa*), horse bean (*Vicia faba)*, buckwheat *(Fagopyrum esculentum*) and garden cress (*Lepidium sativum*). Single seeds found were a pine cone (*Pinus* cf *sylvestris*) and a hazelnut (*Corylus avellana*).

Another kind of material consisted of lumps of fibres. Analyses revealed them to be the roots and leaves of harestail cotton-grass (*Eriophorum vaginatum*). This material can be recognised by the presence of the characteristic scerenchymatous spindles. In between also seeds of cross-leaved heath (*Erica tetralix*) were present. Various other plant parts were not identified, like grass-like material or a clod of sedge peat. This material may have originated from the soil (peat) of the Wadden Sea, peat for fuel on board or may have been caulking material.

Analysis of the weeds that were harvested with the wheat showed that a large part of the southern Baltic Sea region

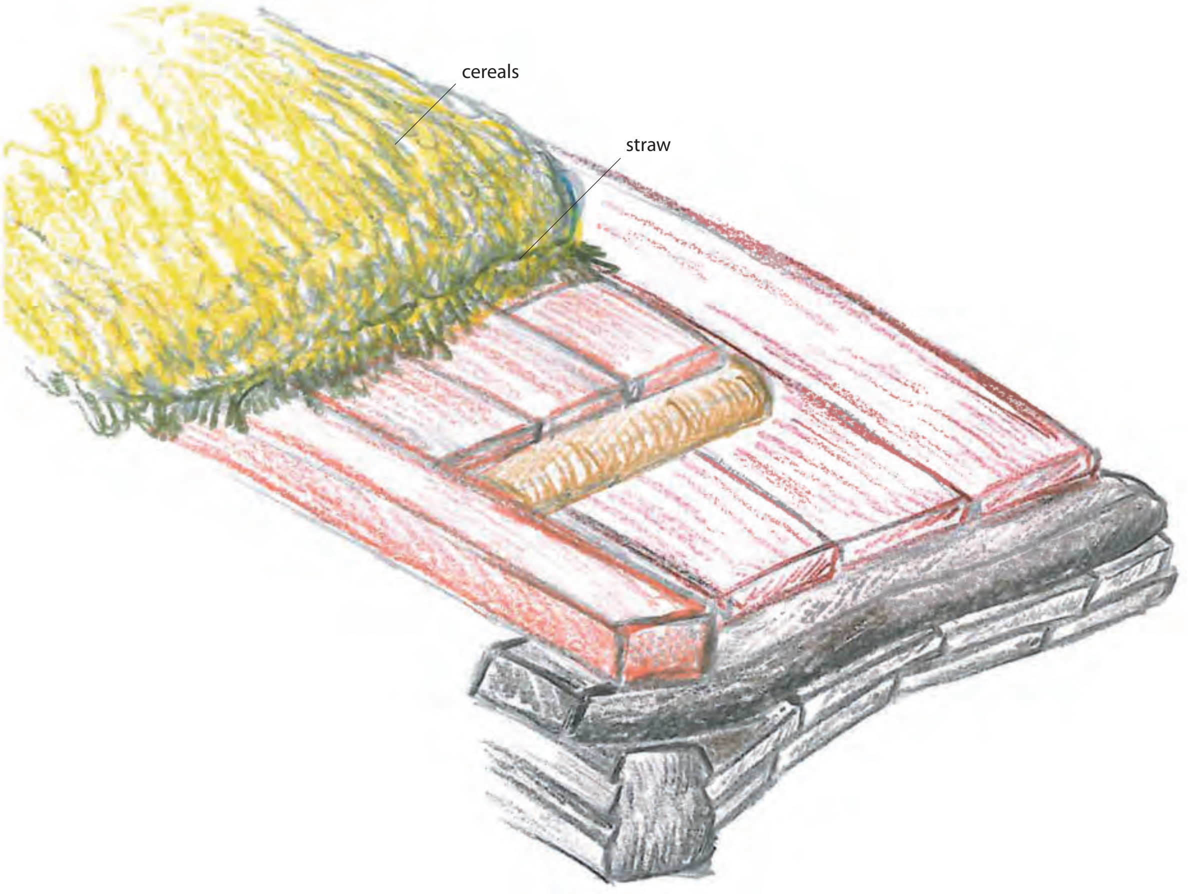

Figure 11 Scheurrak SO 1. Reconstruction of the situation of the cargo (breadwheat) in the hold (drawing M.R. Manders)

qualifies as origin (Manders 1993). This corresponds with the so-called granaries of Europe: Europe's main cereal production area along the Vistula River in Poland. The trade of the cerals was called the 'mother trade'. It refers to the successful role the Dutch played in the trade of this important source of food in Europe and the enormous wealth it created in the country. The destination of the cargo is unknown. The ship was lying on the Texel roads and Amsterdam was the staple market for grain in Europe. From here most of the grain was traded and often also transported to many other markets. To do this, the load would not have been unloaded, but its quality would have been inspected and the load sent elsewhere. Southern Europe and Italy in particular were a good option. At the end of the 16th century famine often struck this region and prices of grain were high. A trumpet found in the Scheurrak SO 1 wreck was made in Genua and the armament of the merchantman indicates a working area where some individual ship protection was needed: the trade to southern Europe. From historical sources we know that often several grain ships were waiting on the Texel roads, for a successful outcome of the price negotiations between the Dutch traders and the Italian consumers (with the result that the Italians had to pay astronomical prices for the grain), before sailing out to the Mediterranean.

A number of other botanical finds on board were straw, rope and sail of hemp, mats and baskets from willow, small heather brooms and birch logs, which was probably firewood for the galley.

Scheer 1
Survey: 1975 – 1977.
Ship type: Merchantman.
Age: Late 16th – early 17th century.
Comment: Cargo of, amongst others, wheat and lead ingots (probably ballast blocks).
References: Manders 1992; 1993.

About 4 nautical miles northeast of Oudeschild (Texel) in the Wadden Sea lies the wreck Scheer 1. Already in the

years 1975 – 1977 samples were collected from Scheer 1 by amateur divers. Two examined samples are very similar to those of the Scheurrak SO1 wreck. Interesting are the samples that show some differences (see Appendix 1). One sample comes from a compressed layer of epidermis of cereals with lots of weed seeds. Another sample consisted of loose grains with virtually no weed seeds. In the latter case the grains were very well preserved: the shape still retained its original form with the presence of starch. The identification of the grains was not difficult: bread wheat (*Triticum aestivum*) (fig. 12d and 12e). Through geographically pinpointing the natural area of the weed seeds (c. 54 species), it was possible to trace the origin of the cargo, which was an area in the Baltic Sea region (Manders 1993, see also above under Scheurrak SO1).
In addition to bread wheat some poppy seeds (*Papaver somniferum*), oat (*Avena sativa*), rye (*Secale cereale*) (fig. 12b), barley (*Hordeum vulgare*) (fig. 12c), hemp (*Cannabis sativa*), turnip rape (*Brassica rapa*), linseed (*Linum usitatissimum*) and buckwheat (*Fagopyrum esculentum*) (fig. 12a) were found. Between the cereals remains of insects, including weevils, were present. The larvae of these weevils consume cereals and they can seriously affect the condition of the cargo.

Vliestroom (VLS)
Archaeological assessment: 1995. In 1988 reported by dive team Caranan.
Ship type: Small to medium sized sea-going ship, about 35 m long.
Age: Construction 1st quarter 18th century.
Comment: Built in the Netherlands or in England.
References: Akker *et al.* 1996.

During a dive on this wreck a concretion was found. In this material, wickerwork (a mat) was visible, with 37 grape pips (*Vitis vinifera*) entrapped. The avocational dive team Caranan had already salvaged some with grape twigs, grape pips, peppercorns and cloves (*Syzygium aromaticum*) (identification by A. Duijf, Dive team Caranan).

Doove Balg 1 - Buytensorgh
Salvaging operations: in 1958 and 1964, archaeological survey 1986.
Ship type: East Indiaman of the VOC.
Age: Built in 1753, wrecked in 1760.
Comment: due to the fact that the ship arrived in 1754 in Batavia and only returned to the Netherlands in 1757, we can assume that in these three years the ship also took part in the Inter-Asiatic trade.
References: Braven *et al.* 2003.

Figure 12a Fagopyrum esculentum; b Secale cereale; c Hordeum vulgare; d and e Triticum aestivum. Scheer 1 (photos J. Pauptit)

When the ship came back from Batavia in 1759, a part of the cargo was unloaded on the Texel roads. The cargo included pepper, sugar and tea. In January 1760 the Buytensorgh wrecked at the height of the Javaridges in the Wadden Sea. Many pepper seeds (*Piper nigrum*) were found in the wreck during the salvaging operations, as well as sappan wood (*Caesalpinia sappan*). Pieces of ferric oxide glued together with sand and wood from the site also contain pepper seeds.

Wrak op de Pannenplaat
Research: 1988.
Ship type: Possibly a small galjoot.
Age: 18th century.
Comment: Has been researched by avocational dive team Caranan.
References: Duikteam Caranan 1988.

The amateur archaeologists of dive team Caranan have intensively researched an 18th century shipwreck in the Wadden Sea. Amongst many finds, of which its main cargo of roof tiles and bricks, they report the findings of ". . . well preserved peas, coffee beans, a stone of a prune, straw and tobacco". . . (Duikteam Caranan 1988, 39). Regarding the latter, they also noticed little wooden sticks to keep the tobacco leaves together. Unfortunately we do not know any more information and no samples of these finds were kept.

4.2 IJsselmeer (Zuiderzee)
The ships listed below were all excavated under dry conditions (except for the Hindeloopen 3). The methodology of doing research and sampling of the ships therefore differs from submerged sites, in that visibility and currents are not a problem here. The ships often have been under water for many centuries. As a result of land reclamation of the Noordoostpolder and Flevoland, however, they are now on 'dry' land.

IJsselmeer – Hindeloopen 3
Archaeological survey: 2006, archaeological assessment: 2010.
Ship type: Tjalk-like carrier, approximately 21 m long.
Age: Second half of the 17th century.
References: Beurden 2006; Kroes *et al*. 2013.

An archaeological survey followed by an assessment have been carried out on a 17th century shipwreck in the IJsselmeer near Hindeloopen (Nijefurd). The contents of a kettle, found during the survey, was examined by Van Beurden (2006). It turned out that 70% of the material in the kettle consisted of the remains of rye (*Secale cereale*): thousands of complete seed walls (epidermis) and a few chaff remains (rachis segments). Between these rye grains some other crops and collected species were present: seeds of barley (*Hordeum vulgare*), linseed (*Linum usitatissimum*), hemp (*Cannabis sativus*) and hazelnuts (*Corylus avellana*). In addition to these species, there are hundreds of seeds of a few dozen species of wild plants present. These plants grew in different places, like cereal fields. Some seeds from the surroundings have been washed into the wreck (van Beurden 2006). During the research many hazelnuts were found, which may indicate that this was part of the cargo (Rijksdienst voor het Cultureel Erfgoed 2010).

Noordoostpolder (NG 29)
Excavation: Explored in 1969.
Ship type: Probably fishing boat with keel, length 17 m.
Age: Presumably 17th or 18th century.
Comments: The identification of this being a fishing boat was made based on the net weights that were found. The exact location of the wreck is unknown.
References: CMA (central archives Maritime Heritage, RCE) M12532NG.29.

A sample of half a litre of plant material was collected. After sieving, about 80% of the sample was left. In the residue many fine plant remains were present and some pieces of wood, stem and fiber. The analysis showed that the plant remains consisted of well-preserved leaves and seeds of peatmoss (*Sphagnum* sp.), sedge (*Carex* sp.), cottongrass (*Eriophorum* sp.), common spike-rush (*Eleocharis palustris*), cross-leaved heath (*Erica tetralix*) and heather (*Calluna vulgaris*) (see Appendix 2). Some remains are carbonised. All the material comes from wild plants and the origin is probably a bog. It is possible that peat was on board as fuel for the oven. It may also have been a sample of peat that washed up in the wreck after the wreckage.

Noordoostpolder (NG 35)
Discovered: 1956, archaeological assessment: 1999.
Ship type: Heavy fully clincker built vessel of approximately 19 m long and 5 m wide. Possible foreign origin.
Age: Probably mid 16th century.
Comment: The age of the ship has been based on the type of caulking cramps (sintels). One dendrochronological sample of a loose plank gave a *post quem* date of 1422.
Reference: CMA (central archives Maritime Heritage, RCE) M12531NG.35.

During the investigation of this wreck at Emmeloord, three small samples were collected for botanical research (see Appendix 2). The analysis showed that the material consisted mainly of oats (*Avena sativa*). The grains, reduced to the squashed grain wall (epidermis) only, were to a large extent still in the chaff. Incorporated were the food crops barley

(*Hordeum vulgare*), rye (*Secale cereale*) and linseed (*Linum usitatissimum*) (See Appendix 2 for all identifications). Also a number of arable weeds and seeds of water and marsh plants were present. Of these last two groups the seeds originated from the sediment or were washed in by river water from the mainland.

If the samples are representative of an important part of the cargo, we can assume that the ship was on its way with a cargo of oats.

Noordoostpolder (NB6)
Discovered: 1952, archaeological excavation: 1955.
Ship type: Groninger tjalk.
Age: Wrecked in 1787.
Comment: Transported besides cargo (tiles and tiling) also soldiers from Muiden to Hoorn when it sank.
References: CMA (central archives Maritime Heritage, RCE) NB 006 54847. http://www.verganeschepen.nl/schip.php?wrakid=43

At the bottom of the wreck buckwheat (*Fagopyrum esculentum*) was found.

Oostelijk Flevoland (OF 34)
Survey: 1964, archaeological excavation: 1972.
Ship type: Tjalk 13,4 m long and 4 m wide.
Age: Mid 17th century.
Comment: During the excavation (near Lelystad), many finds related to the inventory and personal belongings were found, which makes a reconstruction of past life on board possible.
References: CMA (central archives Maritime Heritage, RCE) OF 034 55065. http://www.verganeschepen.nl/schip.php?wrakid=16

During the excavation a seed of a palm (*Orbignya* sp.) was found in this ship (Kuijper and Manders 2003). See catalogue.

Oostelijk Flevoland (OA 55)
Survey: 1963, archaeological excavation: 1970, 1982.
Ship type: Large seaworthy cargo ship, about 40 metres long.
Age: Second half of the 17th century.
References: CMA (central archives Maritime Heritage, RCE) M 12554 OA.55 (van der Velde 2012).

During the investigation a seed of a palm (*Orbignya* sp.) was found in this ship (Kuijper and Manders 2003). See catalogue.

Oostelijk Flevoland (OF 3)
Archaeological excavation: 1972.
Ship type: Groninger tjalk.
Age: Built in 1878, wrecked in 1886.
Comment: Known as 'De Zeehond'.
References: Oosting and Vlierman 1990; van Holk 1994.

During the investigation buckwheat (*Fagopyrum esculentum*) was found in the forecastle of the ship. This material was possibly the filling of a mattress.

Oostelijk Flevoland (OL79)
Survey: 1959. Archaeological excavation: 2013.
Shiptype: Small trading vessel (approx. 16.5m by 4.5m).
Age: End of the 18th century.
Comment: Excavations were carried out in the International fieldschool for Maritime Archaeology Flevoland (IFMAF) setting. Botanical sampling was carried out randomly in the wreck.
References: Filatova and van Popta 2014.

During the excavations carried out by IFMAF, the domesticated plants buckwheat (*Fagopyrum esculentum)*, plum (*Prunus domestica)*, coriander (*Coriandrum sativum*) and anise (*Pimpinella anisum*) were identified together with many wild plants. These wild plants very probably were deposited from the peaty environment in the ship after the wrecking.

The buckwheat only consists of a large amount of chaff fragments. In combination with the many clay pipe fragments, this suggests that the buckwheat was used as packing material.

Zuidelijk Flevoland (AZ 105)
Archaeological assessment: 1974.
Ship type: Carvel built trader.
Age: Second half of the 17th century.
Comment: After the assessment the site at Almere has been covered with an additional layer of soil to protect it in situ.
Reference: CMA (central archives Maritime Heritage, RCE) M12311 ZA.105.

During the investigation buckwheat (*Fagopyrum esculentum*) was found.

4.3 North Sea

Aanloop Molengat (AM)
Archaeological excavation: 1985 – 1999.
Ship type: A large merchantship of at least 32 m long.
Age: Wrecked mid 17th century off the west coast of Texel.
Comment: This was together with the Scheurrak SO1 wreck, the first archaeological excavation carried out under water in the Netherlands. It has now been nominated to be protected as a national monument.
References: Maarleveld and Overmeer 2012.

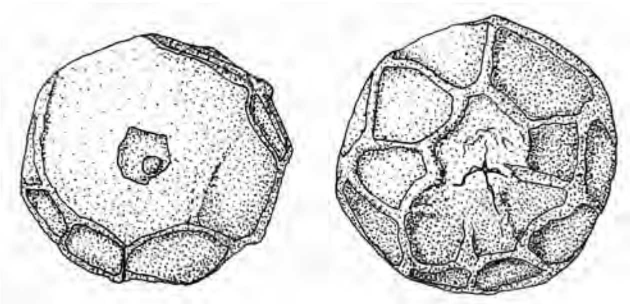

Figure 13 Piper nigrum. 2 views of a corn. Aanloop Molengat (drawing M.R. Manders)

Aanloop Molengat is the wreck of a ship with onboard a main cargo of half-finished products like tin, lead ingots (eastern Europe) and iron bars (possibly from Sweden). Also elephant tusks (Africa), cannon balls, cloth seals (Leiden, the Netherlands and Mons/Bergen, Belgium) and pins to hold the cloth together were discovered, as well as quicksilver and a stock of cow hides. During the investigation some seeds of black pepper (*Piper nigrum*) (fig. 13) were discovered between the hides. In addition, there are the imprints of peppercorns and cereals found in concretions at various places in the wreck (Manders 1992). The shape of the grain impressions is similar to that of bread wheat (*Triticum aestivum*). Pepper and cereals may have been part of the cargo, but could just as well be on board for personal use. A third species, corncockle (*Agrostemma githago*), was also present in small quantities. This plant grows in cereal fields. The diversity of the cargo suggests that it was an outgoing ship laden with goods from the staple market of Amsterdam.

Noorderhaaks 10 - Sophia Albertina (SA)
Archaeological assessment: 2004.
Ship type: Swedish warship (first-rate ship), 48 m long.
Age: Wrecked in 1781 in the North Sea near Texel (Noorderhaaks).
References: Overmeer 2012.

In 2004, a part of a coconut (*Cocos nucifera*) was found in the wreck of the Sophia Albertina (Overmeer 2012). It concerns the top part of the nut. In this case it is almost certainly a utensil. The top section of the nut looks like a dish and can be used for all kinds of purposes. On the base a stain of rust is visible. The whole object (inside, outside, edge) is covered with marine organisms (barnacles, seamats, polyps). This means that the nut has been on the seabed surface for quite a while. Unfortunately this makes its relation to the wreck weaker. There is a possibility the seed entered the site after wreckage.

4.4 North Sea Delta area, Zeeland

De Roompot
Archaeological assessment: 2005.
Ship type: Merchantman of the Nederlandsche Handels-maatschappij (NHM).
Age: Mid 19th century.
Comment: The wreck was first identified as the Anna Katharina. This proved to be incorrect.
References: Overmeer in prep.
The Roompot was a Dutch East Indies ship of the NHM, built in the period 1841-1844, with as home port Zierikzee. In 1852 it sailed to pick up a cargo of rice in Burma. After a six months journey the ship struck a sandbank off the coast of Vrouwenpolder, a few miles from home. This happened in June 1853. The ship went adrift on the Oosterschelde and sank in a navigation channel, which, coincidently like the ship bears the name “Roompot”. The wreck was discovered by chance in 1992. At that time it was reported to be in extremely good condition, with the decks still in place. In 2005, during the archaeological assessment, the wreck turned out to have deteriorated into a bad state of preservation, only 10 years after its discovery.

Single grains of rice (*Oryza sativa*) were sampled from the wreck, but much more was observed by the divers. Knowing the history of the ship, it is clear the grains were part of the cargo of the Roompot.

Oostvoornse Meer (OVM 8)
Archaeological excavation: 1988 - 1989, archaeological shipwreck recording 2014.
Ship type: Merchantman, c. 30 m long.
Age: Late 17th – early 18th century, wrecked first half of the 18th century.
Comment: These are the remains of a Dutch ship with a cargo from the Mediterranean area (southern Spain).
On board among others were mortar bombs and cannons.
References: Kleij 1993.

Some plant remains were salvaged from the wreck. These are the remains of olive (*Olea europaea*) and grape (*Vitis vinifera*). Hundreds of olive stones were observed near Spanish or Portuguese jars. The olives may have been stored in these jars. The olive stones are twice the size of those usually recorded (for sizes: see catalogue). The wreck also yielded a bunch of grapes. Unfortunately after salvage only some fruit skins and 4 pips remained. Kleij concludes that the grapes were probably present as raisins (Kleij 1993), however, we have some doubts whether this conclusion is correct, as the pips and skins were found in a bunch. It seems to us therefore more likely that the ship transported whole grapes. Both grapes and olive originate from the Mediterranean area.

Oosterschelde, Brabants Vaarwater – François Narp
Survey by sports divers. Discovered: 1975, after which various dive actions were conducted.
Ship type: Merchantman, with a diverse cargo of tiles, earthenware, bottles of wine and much more.
Age: Mid 18th century.
Comment: Due to a name – François Narp – on a bell, including a date of 1739, it has been suggested that this is the name of the ship. Other finds in the wreck confirm the mid-18th century dating. The wreck has been completely salvaged between its discovery in 1975 and 1982, when it was investigated by an underwater archaeologist.
References: Maarleveld 1982.

Sports divers have mentioned the discovery of two wooden chests with iron fittings. In one of the chests was found a bag with spices (cloves - *Syzygium aromaticum*, nutmegs - *Myristica fragrans*). Because no value was attached to this find, it was thrown away. The second chest has also been destroyed (Maarleveld 1982).

4.5 Other areas

Rijn – Woerden 1
Excavation: 1978, 1979.
Ship type: Roman barge, 29.6 m long.
Age: Early 3rd century AD.
References: Haalebos 1997; Pals and Hakbijl 1992.

During excavations in the town of Woerden, one of the towns with a Roman fort situated at the northern border of the Roman empire, a ship was discovered in a former riverbed of the River Rhine. The bottom of this Roman ship was covered by a compressed layer of plant material. The original thickness would have been approximately 70 cm (Haalebos 1997; Pals and Hakbijl 1992). A sample of the layer was analysed by Pals. It consisted of a dark brown, compact mass of waterlogged, mostly dehusked cereal grains. Some of the epidermis of the seeds and chaff (spikelet forks) permitted an identification as emmer wheat (*Triticum dicoccum*). The cargo was infested with *e.g.* beetles (grain weevils: *Sitophilus granarius*). Between the cereals seeds of dwarf elder (*Sambucus ebulus*) were present (as whole berries). Other species found were corncockle (*Agrostemma githago*), white lace flower (*Orlaya grandiflora*), sorrel (*Rumex* sp.), creeping thistle (*Cirsium arvense*), coriander (*Coriandrum sativum*) (one) and hazelnut (*Corylus avellana*) (one fragment). It has been suggested that the cargo probably originated from Belgium (Pals and Hakbijl 1992) with a destination of one of the castella/harbours along the last part of the River Rhine.

Westerschelde – ’t Vliegend Hert
Excavation: 1981 - 2000.
Ship type: Dutch East Indiaman of the VOC, c. 30 m long.
Age: Built in 1729 - 1733 at Walcheren (Southwest Netherlands) by the Dutch East India Company. Wrecked on 3rd February 1735.
Comment: Shortly after departure from Vlissingen for a trip to the East the ship struck a sandbank. A storm with strong waves made it sink in the border area Netherlands-Belgium (Vlakte van de Raan). It is actually lying in Belgian waters.

The North Sea Archaeological Group has salvaged, amongst others, five lead containers from the wreck. They turned out to contain tobacco (*Nicotiana tabacum*). Pollen analysis of a tobacco sample indicated an origin from South America (Troostheide 1995). On some pipe bowls buckwheat seeds were attached. It is assumed that these served as packing material of the pipes (Krook 1986).

4.6 More wrecks

More shipwrecks in the Netherlands are known to have contained botanical finds. Some even derived their local names from it, like ‘rice wreck’ or ‘chestnut wreck’ (T24 II, Kastanjevatenwrak). Unfortunately, no samples have been taken of these wrecks and therefore no official identification was done. On the other hand, from other wrecks, like the supposed Juffrouw Maria-Agnes (sunk 1735) samples were taken (bread wheat) by local divers and analysed at the University of Wageningen (Duikclub Texel 1983), but no position and no positive identification of the wreck is known. Therefore samples like these lack context and were disregarded for this overview.

5 Conclusion

The research of botanical material in shipwrecks has yielded an enormous variety of finds. For some shipwrecks it is clear that the (main) cargo was sampled. These are: the BZN 4 (coffee), BZN 9 (rye), Scheurrak SO 1 (bread wheat), Scheer 1 (bread wheat), Buytensorgh (pepper), Noordoostpolder (NG 35) (oat) and the Roompot (rice). However, many observations concern small quantities. Often the context (besides knowing they come from a particular shipwreck) is unclear. Did the sample come from a main cargo? Or only a small part of the overall cargo? Or was it just taken from one jar or cask and was it for personal use or food on board? This is the case for the wrecks BZN 2 (flour), BZN 4 (cacao), BZN 8 (black mustard), BZN 9 (rye, horse bean, pea), BZN 10 (grape), BZN 14 (black pepper), Aanloop Molengat (bread wheat, pepper), Oostvoornse Meer (olive, grape), Hindeloopen 3 (rye, barley, flax, hemp, hazelnut). For some finds we can assume that these are relatively unique objects (in singular or small quantities). This is the case for the BZN 2 with the tobacco leftovers in a box, in BZN 4 the sugar cane and the peanut, in BZN 8 almond and nutmeg, in BZN 9 cowpea and green gram, in BZN 10 a melon pip and a palm fruit, in BZN 14 amongst others cucumber, in Scheurrak SO 1 amongst others garden cress, in Vliestroom grape, in Eastern Flevoland on two sites a palm fruit (identical to the one found on BZN 10) and in the Sophia Albertina a fragment of a coconut. Due to the sampling conditions – for example improper methods for sampling in an underwater environment – but also due to the fact that not all samples were taken during archaeological research, much information that is important for the understanding of the meaning has been lost for ever. Another limiting factor in the comprehension of the samples is that fact that only few of the above observations and samples have come from extensive excavations. Most came from salvage operations, archaeological surveys or at the most an archaeological assessment.

Generally, the conservation of the plant remains was good. In a single case even the content of cereals was still present and the shape of the grain remained (Scheer 1). Nevertheless in many cases the characteristic cell pattern of cereals could no longer be observed. The preservation of many finds, compared to land excavations, is often excellent. This is caused by the (sea) water and the anoxic environment in the seabed. Unfortunately material also disappears during a continuous process of sea currents, damage by fishing and looting.

Through research of botanical material in shipwrecks an image can be obtained of what was used and transported as cargo, and which can also be compared with the written (archival) sources.

6 The sampling of botanic finds in shipwrecks

The Quality Norms for Dutch archaeology (KNA landbodems 3.3, protocol opgraven, 46-48) contains in the chapter on excavation a subchapter on sampling, including botanical macro remains. An adaptation for underwater sampling is being prepared. This will be a big step forward in the research of botanical finds in shipwrecks, including the remains of cargo and victuals. Even the use of the procedures executed on land is better than how most of the above-mentioned sites have been sampled in the past. This lack of systematic sampling often makes not only identification, but also analyses of the former function of the botanical finds difficult. For these it is important to take representative samples and to know where these samples come from. Only analyses of the type of species is not enough. A diver usually is the only person to see the context of the finds first hand. Therefore recording of everything he or she does is important.

Improper sampling may result in the loss of information or even the whole sample. Samples dissolve easily in water and for example small seeds may become separated from the sample if not taken properly.

Many of the botanic macroremains described above were discovered incrusted in or attached to other objects. They were noted long after they were salvaged from the wreck. Other (larger) seeds have been picked up from the wreck because they were easy to identify. In these cases often no surrounding sediments were lifted. This may have deprived them of a vital context, and thus another piece of evidence on former use. From the above descriptions of sites where botanical remains were found, it also becomes clear that this kind of material is not highly valued by everybody. Often botanical remains are overlooked, are thrown away after salvaging or will be lost due to improper (or no) conservation. Finally, sampling is important, but as the word sample implies, it should be a representation of what is present on the site. This means that it is important to report what it represents, hence to get a (rough) overview of how big the layers or areas are of which these samples form a representation. We will here not go into the best ways on how to sample botanical remains, as these will already be described in the Quality Norms. However, it is important to realise that botanical remains are often very well preserved in shipwrecks. They represent an important category and are a source for research of life on board, trading, medical use in the past and much more. Cargo was on its way still waiting to be used. Grain for example had not been turned into flour or bread yet. The cargo often still contains large amounts of impurifications, like weeds and insects. These also can say something about the provenance of the cargo and about the process of harvesting, transporting and the quality of goods shipped and traded. These are often impossible to research in botanical samples from land sites. When found there, these were often already discarded as food leftovers.

At least when doing any sampling underwater, divers should keep in mind that they have to take a representative sample, having to note the place of sampling, record the context and sample surrounding sediment if possible.

7 Catalogue of cultivated and collected plants found in the shipwrecks

Almond (*Prunus dulcis* (Mill.) D.A. Webb, synonym *Prunus amygdalus* Batsch) – fig. 7b
In wreck BZN 8 we found 11 fruits:
dimensions: 35x25x18 (*c*. 1/5 part gnawed); 32x24x19.5 (*c*. ¼ part gnawed); 31.5x25x20 (c. ¼ part gnawed); 30x25x17 (*c*. 1/5 part gnawed); 25x18x15.5 (*c*. 1/5 part gnawed); +23x24x17 (upper half gnawed); 35x24x17 (*c*. ¼ part gnawed); 32x22x15 (*c*. 1/5 part gnawed); 32x21x17 mm (*c*. ¼ part gnawed).

Almond is a rare species from archaeological sites in the Netherlands. We know of 13 sites which are dated between 1400 and 1820, and mostly there is one fruit present (van Haaster and Brinkkemper 2010).

Anise (*Pimpinella anisum* L.)
Reported from a small trading vessel in Oostelijk Flevoland (OL79).
Anise in not very often reported, it is known from a dozen sites from the Roman Period to post-medieval times in the Netherlands (van Haaster and Brinkkemper 2010).
The seeds are used as a flavouring in drink (milk, liqueur), pastries and meat (Kalkman 2003).

Barley (*Hordeum vulgare* L.) – fig. 12c
A grain in chaff in BZN 9; some grains (with chaff) in Scheurrak SO 1 and Scheer 1; dozens in G 35; some in Hindeloopen 3.
Barley is a well-known cultivated cereal. Recorded from many archaeological sites in the Netherlands which date from prehistoric times to post-medieval times.

Black mustard (*Brassica nigra* (L.) W.D.J. Koch)
In the BZN 8 wreck, a copper kettle was found on which, by oxidation, black grains were glued. This turned out to be dozens of seeds of black mustard. In BZN 9 dozens of the same seeds were found.
Black mustard is a well-known species from archaeological sites in the Netherlands.

Bread wheat (*Triticum aestivum* L.) – fig. 12d and 12e
Some possible grains of this species were found between many grains of rye in BZN 9. Research of the Scheurrak SO 1 and Scheer 1 showed that these ships had a main cargo of bread wheat. The imprints of cereal grains in glued material at various places in the wreck Aanloop Molengat point to bread wheat. Bread wheat was used to make ‘white’ bread. This was considered to be the luxury bread, in comparison to rye bread.
Bread wheat is a well-known cereal, mainly recorded as carbonised material from archaeological sites in the Netherlands.

Buckwheat (*Fagopyrum esculentum* Moench) – fig. 12a
The solid seed walls (‘chaff ‘) of buckwheat have been found occasionally. These pieces may have been used as packaging material. For example, in the wreck of the Dutch East India Company ship ‘De Vergulde Draeck’ that wrecked in 1656 on the Australian west coast, a box was found with clay pipes. The box was filled with buckwheat to protect the clay pipes (Krook, 1986). These buckwheat chaffs were the waste of food preparation, and were re-used as packing material. In wreck BZN 2 buckwheat was also present as packaging material. Moreover buckwheat was found in: BZN 4 several dozen seeds, BZN 14, one seed, Scheurrak SO 1 and Scheer 1 both one seed, two shipwrecks in Eastern Flevoland OF 3, (mattress filling?) and OL 79 (packing material?), Southern Flevoland (AZ 105), Noordoostpolder (NB 6), ‘t Vliegend Hert (glued together to pipe bowls).
Buckwheat is a well-known species from archaeological sites in the Netherlands which date from the Full Middle Ages and post-medieval times (van Haaster and Brinkkemper 2010). It was an important foodstuff for many people and the ‘chaff’ had many uses (Kok and Kuijper 2001). Nowadays it is no longer an important food in the Netherlands.

Cacao (*Theobroma cacao* L.) – fig. 5b
The beans in BZN 4 are about 25 mm long, 15 mm wide and 10 mm thick. A seed consists of 2 cotyledons with lobes. Fragments of the contents were regularly found in the samples. The fragile beans were probably broken during the sampling and recent transport. The seed wall is thin, and impressions of veins are visible on its surface. Remarkable is that the contents of the seeds is still present. This was probably caused by the high fat content of the seeds.
Dimensions in mm of (whole) cacao beans that could still be measured are:
28x17x10; 27x15x10; 26x14x8; 23x16x10; 23x15x11; 23x15x10; 23x14x11; 22x16x11; 22x15x11; 22x11x11; 18x12x9.
flattened seeds (length x width):
27x16; 24x14; 24x12; 23x13; 23x13; 22x14; 22x13; 20x12; 20x11; 19x14; 19x12.
Cacao has never found before in landexcavations in the Netherlands. The species is only mentioned from wreck BZN 4. Also in Europe archeological finds are rare. In Ireland a seed was collected from the bottom of a cellar foundation of an eighteenth-century house in Dublin (Geraghty 1996).
Originally the plant comes from the tropical rainforests of the Amazon and Orinoco Basins in South America. During the Spanish conquest of Central America, it was noticed that the local people drank a liquid with cocoa. In 1528 Hernando Cortez brought the first cacao beans from Mexico to Spain. In the middle of the 17th century, there were coffee and chocolate houses in Holland where this drink could be bought. In the Netherlands cacao has been traded since the end of the 17th century (Wennekes 1996).
The plant was cultivated in Africa from the end of the 19th century. More data in Kuijper and Manders (2009 [2011]).

Cereals (Cerealia)
Regularly we have found cereals (fragments) on board the ships. When it is milled and corrosion has occurred the characteristic cell pattern on the wall is often no longer

visible. It is probably mostly rye and bread wheat. Large amounts of grain were found in the ships BZN 2, BZN 9, BZN 14 (whole epidermis and in one sample as fragments), Scheurrak SO 1, Scheer 1, Noordoostpolder NG 35, Aanloop Molengat, Hindeloopen 3 and Woerden 1.
Cereals are frequently reported from archaeological sites in the Netherlands which date from all periods. Especially in cesspits 'thousands' of fragments are present.
Whole grains in large numbers usually relate to cargo. When the grain is milled to small fragments it is possibly intended for bread and porridge for the crew.

Clove (*Syzygium aromaticum* (L.) Merr. & L.M. Perry)
This species was reported by amateur divers from the wreck of the François Narp. There is also a report from amateur divers of cloves found in concretions from the Vliestroom wreck.
Clove is a very rare species in archaeological sites. In the Netherlands only finds of pollen are known from circa 100 sites in the period between 1325 and 1900 (van Haaster and Brinkkemper 2010).

Coconut (*Cocos nucifera* L.)
The find in the Sophia Albertina belongs to the top part of the innerpart of a coconut with the three ridges on the outside that meet each other in the middle. The fragment is 9 cm in diameter and 3 cm high, the wall thickness is 3 - 4 mm. Few archaeological finds of coconuts are known from the Netherlands (period 1500 – 1900), some are carved (Rijkelijkhuizen and van Wijngaarden-Bakker 2006).
Coconuts grow in tropical areas. Both the nuts and the milk are commonly eaten and drunk, and used by man. Nowadays, the nuts are traded all over the world.
Coconut is very rarely (six finds) collected from archaeological sites in the Netherlands. They are reported from the period 1500 – 1800 (van Haaster and Brinkkemper 2010).

Coffee (*Coffea arabica* L.) – fig. 5c and 5e
Coffee is a relatively rare appearance in an archaeological context, especially in Europe. The authors know of some finds only. In the Netherlands coffee beans were found in an 18th century cesspit in Amsterdam (van Haaster 2010) and in a dump from the New Time period in Gouda (Botermans and van Malssen 2010). In the Wadden Sea the species is reported from the 18th century 'Wrak op de Pannenplaat'. There is a find of *Coffea arabica* in a cannon at the bottom of the sea near Padstow, England. By oxidizing of the bronze the seeds were well preserved. The cannon is dated in the 17th century, the coffee beans themselves are not dated (Greig 1991). From the Goose Rock site on the south coast of England there is a mention of coffee in the wreck of HMS Pomone from 1811 (Tomalin *et al*. 2000). In Bremen in Germany four coffee beans were found in the fill of a cesspit. The dating is late 18th century (Rech 2000). Coffee beans were found in a shipwreck at the bottom of the Red Sea (Sadana Island) in Egypt. The date of the cargo is around AD 1700 (Haldane 1996; Ward 2001). The Vrouw Maria on the south coast of Finland (Dutch merchant ship, wrecked in 1771) had a cargo, including coffee beans (Lempiäinen-Avci 2013).

Coriander (*Coriandrum sativum* L.)
One seed was found in the Roman ship Woerden 1 and several in the 18th century OL 79 wreck.
Coriander is regulary found in settlements in the Netherlands which date from the Roman Period, Middle Ages and post-medieval times (van Haaster and Brinkkemper 2010).
It is used as a spice in meals.

Cowpea (black-eye pea) (*Vigna unguiculata* (L.) Walp., synonym *Vigna sinensis* (L.) Savi ex Hausskn.) – fig. 8b
In BZN 9 ten seeds were found. Dimensions (N = 10): 8.9(8.1–9.8)x5.8(5.2–7.0)x4.8(4.3–5.7) mm.
Cowpea has never been found in sites in the Netherlands and also outside Europe we know of hardly any finds.
The plant was domesticated in Africa, and spread to the Mediterranean and Central Europe. It is one of the oldest known human food crops. Today, cowpeas grow in many tropical and subtropical areas. Both the seeds and the green parts are eaten (Kalkman 2003).

Cucumber (*Cucumis sativus* L.)
One seed was found in wreck BZN 14.
Cucumber is known from some dozens of sites in the Netherlands which date from the Middle Ages.

Emmer wheat *(Triticum dicoccum* Schrank*)*
The main cargo of the Roman ship Woerden 1 consists of emmer wheat; one seed in was found in Scheurrak SO1.
There are many records available of emmer wheat in the Netherlands; they date from the starting of agriculture. In the post-medieval period the species is rare (van Haaster and Brinkkemper 2010).

Garden cress (*Lepidium sativum* L.)
Some seeds in a sample from Scheurrak SO 1. Originally this is a crop from the eastern part of the Mediterranean. It is grown for use in salads or as a vegetable.
Only a few records of garden cress are available from archaeological sites in the Netherlands, which date from the Middle Ages and the post-medieval times (van Haaster and Brinkkemper 2010).

Gold-of-Pleasure (*Camelina sativa* (L.) Crantz)
In BZN 9 some seeds and the caracteristic pod in one of the samples.
The first finds of gold-of pleasure are from Bronze/Iron Age settlements, the species disappeared at the end of the Middle Ages. It is used for the production of oil.

Grape (*Vitis vinifera* L.) – fig. 9a
In BZN 10 four samples were taken from casks. The material turned out to consist for almost 100% of remains of grapes. These remains were excellently preserved and consisted of hundreds of pips (unripe and ripe), dozens of whole epidermis of grapes with the seeds still in it, many fragments of epidermis, pieces of branch of the bunch of grapes and stalks of the berries. Also in the wreck in the Oostvoornse Meer (OVM 8) the remains of a bunch of grapes were present. In the Vliestroom some dozens of grape seeds were found in iron concretions. One possible seed was found in OL79.
Grape is a well-known species from archaeological sites in the Netherlands which date from the Middle Ages and post-medieval times.

Green gram (mung) (*Vigna radiata* (L.) R. Wilczek) – fig. 8a
In BZN 9 a seed of this species was found. Size: 5.8x3.8x 4.0 mm. Entire surface with well visible length rows of rectangular cells.
Green gram is not known from archaeological sites in the Netherlands.
The green gram originates from India and its surrounding areas and has been grown there for thousands of years. Much later, this bean became cultivated in Eastern Africa, Australia and America. Both the beans and the plant (just germinated seeds, pods, young plants) are used. The young sprouts of the plant of a few cm high are known as bean sprouts or tauge. The cooked beans whole or halved are eaten as 'dhal' in India, but may also be roasted or ground.

Hazelnut (*Corylus avellana* L.)
In wreck Scheurrak SO 1 one whole hazelnut was discovered. Some whole hazelnuts were found in a kettle in a wreck (Hindeloopen 3) in the IJsselmeer and the many hazelnuts observed further in this wreck point to cargo. In the Roman ship Woerden 1 one fragment was found.
Hazelnuts are many times reported from archaeological sites in the Netherlands which date from all periods.

Hemp (*Cannabis sativa* L.)
In BZN 9 a seed was found between the large quantities of rye and other plants. In BZN 14 there was also a seed between many other species. A concretion of the BZN 15 contained dozens of seeds. In a kettle in a wreck in the IJsselmeer (Hindeloopen 3) some hemp seeds were found between the rye grains. In Scheer 1, three seeds.
Hemp seeds were eaten and oil was pressed from the seeds. Of the fibres of the stems ship ropes were made (Kalkman 2003). It is also known as a food for birds.
Hemp is a well-known species from the Netherlands which date from the Roman Period to post-medieval times.

Horse bean (Broad bean, Celtic bean) (*Vicia faba* L.) – fig. 8d
This is the smaller form of our current large broad bean. These beans were found in BZN 9 (55 seeds) and dozens of fragments with hila in Scheurrak SO 1. In BZN 14 many fragments of beans or peas, in BZN 4 some fragments of cf *Vicia faba*. If there is no hilum present on pieces of the epidermis, the identification is not certain and the material is listed as cf *Vicia*.
Horse bean is regulary found, mostly in low quantities and carbonised. The sites in the Netherlands date from the Bronze Age to post-medieval times.

Linseed (Flax) (*Linum usitatissimum* L.)
Some seeds in BZN 9; in wreck BZN 14 one seed was found and in a wreck in the IJsselmeer (Hindeloopen 3) some seeds in a kettle were found; in Scheurrak SO 1 and Scheer 1 both two seeds; in G 35 two seeds.
Flax or linseed is a common species, found from the starting of the agriculture in the Netherlands until the present. The seeds are pressed for oil (paints, varnishes), or used for medicinal purposes, as bread addition, *etc*.

Melon (*Cucumis melo* L.)
Burgzand Noord 10 yielded, between the many grape seeds, one seed of a melon. The dimensions are 14.5x5.1x3.1 mm. The cell pattern, with strongly wavy cell walls, corresponds to that on the pips of melon.
Melon is a rare species (c. 20 recordings) from the Netherlands which date from the end of the Roman Period until post-medieval times (van Haaster and Brinkkemper 2010).

Millet (*Panicum miliaceum* L.)
In Scheurrak SO 1 single pieces of chaff between the cereals.
Millet is a wellknown species with hundreds of records from circa the Bronze Age until post-medieval times (van Haaster and Brinkkemper 2010).

Nutmeg (*Myristica fragrans* Houtt.) – fig. 7a
In BZN 8 one seed was found: 25x20 mm. In the wreck of the François Narp the species was mentioned by amateur divers.
Nutmeg, as well as mace, is a spice derived from the nutmeg tree (*Myristica fragrans*), which in rainy tropical coastal

regions is cultivated for the nuts. The nut is grated before use. In Europe it is used in the kitchen since the 16th century. The tree was originally cultivated only on the Banda Islands (Indonesia).
We know of no archeological finds from the Netherlands.

Oats (*Avena sativa* L.)
In the ships Scheurrak SO 1 and Scheer 1 several dozen oat grains (as epidermis with chaff) were found between the wheat. A ship in the Noordoostpolder (NG 35) contained many oats (*Avena sativa*). In the BZN 4, and also OL79, a piece of chaff of *Avena* sp. was found.
If no chaff remains are present, it is not possible to identify the seeds as cultivated oats. It can also concern wild oats. Some hundreds of records of oats are known from archaeological sites in the Netherlands which date from the Bronze Age until the post-medieval period (van Haaster and Brinkkemper 2010).

Olive (*Olea europaea* L.)
Found in the wreck in the Oostvoornse Meer. Remarkable were the olive stones, 5 measured seeds (length x width x thickness): 22.5x10.5x9; 23x11x11; 25x11x10; 25x12.5x10; 28x12x10.5 mm. With these dimensions these seeds are remarkably large.
In the Netherlands there are 25 recordings of samples with olive stones. They date from the Roman Period, Middle Ages and post-medieval times (van Haaster and Brinkkemper 2010).

Palm (*Orbignya* sp. or *Attalea* sp.) – fig. 9b
In wreck BZN 10 the seed of a palm was found. This find was published by Kuijper and Manders (2003). The species belongs to the family Areacaceae and the genus *Orbignya*. *Attalea* is a synonym. This palm genus contains dozens of species whose seeds are similar to each other. The identification is therefore *Orbignya* spec. The species grow in Central and South America. The seed is 82 mm high and 53 mm in diameter. Weight (after freeze-drying) 118.9 grams. Also in two excavated ships in Eastern Flevoland (OF 34 and OA 55) a seed of this species was found.
Rijkelijkhuizen and van Wijngaarden-Bakker (2006) report the use of these nuts for the manufacture of buttons and other objects in the Netherlands in the 16th to 19th century.

Pea (*Pisum sativum* L.) – fig. 8c
Four peas in BZN 9. The seeds are round to angular, measuring 7.4x6.2x6.0; 8.1x7.5x6.9; 9.8x9.0x7.0; 10.0x8.0x8.3 mm. Many fragments of beans or peas in BZN 14. Also reported from the ‘Wrak op de Pannenplaat’.
Pea is a regularly mentioned species: carbonised, mineralised or waterlogged in the Netherlands, from prehistoric until post-medieval times. It is a common legume, used as food.

Peanut (*Arachis hypogaea* L.) – fig. 5d
Only in a sample from a large cask of BZN 4 were two fragments of a pod found. (Kuijper and Manders 2009 [2011]). Unfortunately it cannot be ruled out that the material came into the wreck from outside, because the pod remains were found at the top layer of the seabed.
One seed was reported from Amsterdam, dated between 1700-1900 (van Haaster and Brinkkemper 2010). Other archeobotanical finds are unknown to us.
The peanut comes originally from Brazil. About 800 B.C. the peanut was already known from Peru. Via Mexico and the West Indies the species reached North America. In the 16th century the Portuguese brought peanuts to West Africa. Nowadays the plant is cultivated in all tropical and subtropical countries.

Pepper (*Piper nigrum* L.) – figs. 10 and 13
Many seeds in the Buytensorgh and in the wreck Aanloop Molengat and packed in casks in the BZN 14 wreck. Also mentioned from the Vliestroom by divers. Especially in the BZN 14 large quantities of pepper were found. For example, a sample of approximately almost one sixth of a litre of a barrel consists of peppercorns. It concerns thousands of grains and their outer layer (epidermis) and dozens of stalks (fig. 10) to which the grains have been attached (Moolhuizen 2009 [2011]). Pepper has been a key-trade for the Dutch East India Company (VOC). It has been found in more wrecks outside the Netherlands, like the VOC ship Mauritius (wrecked 1609, l’Hour and Rieth 1989), possibly also in the Kennemerland (wrecked 1664) and in the Portuguese Nossa Senhora dos Mártires (wrecked 1606), also called the ‘pepper-wreck’ (de Castro 2005).
Pepper is fairly rare in archaeological finds, due to its high value. Black pepper was expensive since the Roman Age. It was only for the very rich during the Dark Ages. Its purpose was to disguise the smell of meat gone bad (Moolhuizen 2009 [2011]).
Black pepper is a tropical climber. The berries are green when unripe, then turn red. They are harvested at different stages and processed accordingly. The unripe berry is salted or pickled to preserve its colour, resulting in green pepper. Black pepper is obtained by drying and smoking the reddening berries, and white pepper by removing the mesocarp of fully ripened berries. The latter was the most expensive because it was the most labour-intensive, which is why trading companies focused on black pepper.

Plum (*Prunus domestica* L.)
Reported from the Oostelijk Flevoland (OL79), a small trading vessel. A ‘plum’ was seen in the ‘Wrak op de Pannenplaat’.

Plums (with varieties) are well-known species from archaeological sites in the Netherlands, especially the Middle Ages and post-medieval times (van Haaster and Brinkkemper 2010).

Poppy seed (*Papaver somniferum* L.)
In a grain sample of the wreck Scheer 1, 11 seeds were found.
Poppy is a well-known species from sites in the Netherlands which date from prehistoric and historic times. The small seeds are used as spice (on bread and in pastry) and to press into oil.

Rice (*Oryza sativa* L.)
In the Anna Katharina, BZN 14 (six, in chaff) and in the Roompot rice grains were found.
Rice is not a common species in the Netherlands. There are some tens of sites known which date from circa 1250 - 1950. It concerns chaff or seeds.
Rice is grown in the tropics and subtropics. The species was and is an important cereal for much of the world's population. In Europe, however, it was hardly eaten. Rice was an important food for the staff of the VOC in the areas where this company was active. Rice was mainly transported within Indonesia.

Rye (*Secale cereale* L.) – fig. 12b
We have found rye in the BZN 9 (cargo); in BZN 14 just a single epidermis was suitable for identification, resulting in rye; in Scheurrak SO 1 and Scheer 1 several dozen epidermis; one in the Noordoostpolder (G 35); thousands and some chaff in a kettle in the Hindeloopen 3.
Rye is a common species from archaeological sites in the Netherlands, especially from the Middle Ages and until post-medieval times. It is used for bread, porridge etc.

Sugar cane (*Saccharum officinarum* L.) – fig. 5a
Sugar cane was present in wreck BZN 4 as culm fragments and parts of stems. The sugar cane was used as a ventury system in the coffee casks. These fragments measured 7, 12, 12, 16, 16, 25, and 28 cm. The diameter was circa 2.5 cm. There were joints (nodes) every 5-6 cm in the culm fragments (Kuijper and Manders 2009 [2011]).
Sugar cane comes originally from New Guinea. In Polynesia possibly for the first time the plant was used by man, from here it came to India and China. Already in 327 BC Alexander the Great reported the cultivation of sugar cane in India. Via Persia and Egypt the plant was introduced in Morocco, Sicily and Spain. In 1520 the cultivation started in Mexico. It was gradually introduced in many areas and nowadays it grows in all tropical areas (*e.g*. Kalkman 2003). There are no other archaeological finds known from Europe.

Tobacco (*Nicotiana tabacum* L.)
In a small box from the BZN 2 sand with fine plant remains was present. These plant remains were all shorter than 1 cm. Under the microscope bundled spiral cells were visible. These cells are comparable with those of recent tobacco. It is therefore likely that this box yielded tobacco (*Nicotiana tabacum*). Smoking or chewing tobacco is both possible.
The five lead containers from 't Vliegend Hart contain tobacco. From the 'Wrak op de Pannenplaat' leaves of tobacco are mentioned.
Tobacco was probably present on all ships. On the one hand as a cargo on VOC or WIC (West Indian Company) ships, on the other hand, as personal stock of the crew during the trip. Prior to the start of their journey, the sea men received a ration of tobacco (Krook 1986; Troostheide 1995).
Tobacco is a rare species in archaeological sites in the Netherlands (Middle Ages).

Turnip Rape (*Brassica rapa* L.)
Two seeds in Scheer 1 and 63 seeds in Scheurrak SO 1.
Turnip rape is a well-known species from archaeological sites in the Netherlands which date from the Middle Ages until post-medieval times. It is mainly used to extract the oil.

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Appendix 1

SEED ANALYSIS SAMPLES WRECKS BZN 9, BZN 15 and Scheer 1

wreck	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 15**	**Scheer 1**	**Scheer 1**
findnumber	60	61	267	268	276	283	422	1	2
volume in cm3	500	500	500	500	250	500	500	-	-
date	8/02/2000	8/02/2000	7/04/2002	8/04/2002	31/07/2003	16-6-2004	30-8-1990	1975-1977	1975-1977
cultivated plants									
Secale cereale	xxx	xxx	xxxxx	xxxxx	xxxxx	xxxxx	-	-	xx
Triticum aestivum	-	-	-	-	-	-	-	xxx	xxx
cf *Triticum* sp.	-	-	x ?	?	?	?	-	-	-
Hordeum vulgare	1	-	-	-	-	-	-	-	3
Avena sativa	-	-	-	-	-	-	-	30	-
Linum usitatissimum	-	-	x	x	1	x	-	2	-
Vicia faba	18	37	-	-	-	-	-	-	-
Pisum sativum	1	3	-	-	-	-	-	-	-
Vigna unguiculata	8	-	-	-	-	-	-	-	-
Vigna radiata	1	-	-	-	-	-	-	-	-
Camelina sativa	-	-	-	-	-	+ 1 pod	-	-	-
Brassica rapa	-	-	-	-	-	-	-	2	-
Cannabis sativa	-	-	-	-	1	-	-	3	-
Fagopyrum esculentum	-	-	-	-	-	-	-	1	-
Papaver somniferum	-	-	-	-	-	-	-	11	-
wild plants									
Achillea millefolium	-	-	1	x	-	1	-	-	-
Actaea spicata	-	-	-	-	-	1	-	-	-
Agropyron repens	-	-	-	-	-	-	-	cf 2	-
Agrostemma githago	1	-	xx	xx	xx	xx	-	xxx	37
Agrostis sp.	-	-	x	-	-	x	-	-	-
Alchemilla vulgaris	-	-	-	-	-	1	-	-	-
Anchusa officinalis/arvensis	-	-	-	-	-	x	-	-	-
Anthemis arvensis	-	-	x	1	-	2	-	-	-
Anthemis cotula	-	-	-	x	-	-	-	23	-
Anthemis tinctoria	-	-	x	x	1	x	-	-	-
Anthriscus sylvestris	-	-	1	x	-	x	-	-	-
Arctium cf *lappa*	-	-	1	-	-	-	-	-	-
Arenaria serpyllifolia	-	-	-	x	-	1 capsule	-	-	-
Artemisia cf *vulgaris*	-	-	-	-	-	1	-	-	-
Atriplex patula/prostrata	-	-	x	x	-	x	-	2	-
Avena fatua	-	-	-	-	-	-	-	1	1

wreck	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 15**	**Scheer 1**	**Scheer 1**
findnumber	60	61	267	268	276	283	422	1	2
volume in cm3	500	500	500	500	250	500	500	-	-
date	8/02/2000	8/02/2000	7/04/2002	8/04/2002	31/07/2003	16-6-2004	30-8-1990	1975-1977	1975-1977
Betula sp.	-	-	-	-	-	-	1	-	-
Boraginaceae ?	-	-	2	x	-	x	-	-	-
Brassicaceae ?	-	-	1	-	-	-	-	-	-
Brassica nigra	-	2	xx	xx	-	x	-	2	-
Bromus secalinus type	xx	xx	xx	xx	xx	xx	-	-	xx
Bromus sp.	-	-	-	-	-	-	-	2	-
Buglossoides arvensis	-	-	-	-	-	-	-	-	2
Calluna vulgaris (twig)	-	-	1	-	-	-	-	-	-
Campanula rapunculoides type	-	-	1	x	-	x	-	-	-
Capsella bursa-pastoris	-	-	x	x	-	x	-	1	-
Carex sp.	-	-	-	2	2	1	2	1	-
Centaurea cyanus	-	-	xx	xxx	xx	xxx	-	16	1
Centaurea scabiosa	-	-	-	-	-	x	-	1	-
Cerastium sp.	-	-	-	x	-	-	-	-	-
Chara sp.	-	-	-	-	-	-	1	-	-
Chelidonium majus	-	-	1	-	-	-	-	-	-
Chenopodium album	-	-	xx	xx	x	xx	-	3	1
Chenopodium rubrum	-	-	-	-	-	-	-	cf 1	-
Cirsium arvense	-	-	-	-	-	1	-	-	-
Clinopodium acinos	-	-	1	5	-	-	-	-	-
Conium maculatum	-	-	x	x	-	x	-	-	-
Consolida regalis	-	-	x	x	-	x	-	1	1
Convolvulus arvensis	-	-	-	-	-	-	-	3	-
Cuscuta epilinum	-	-	-	-	-	1	-	-	-
Erodium cicutarium	-	-	-	-	-	1	-	-	-
Fallopia convolvulus	-	-	xx	x	x	x	-	8	2
Fallopia dumetorum	-	-	-	-	-	1	-	-	-
Festuca ovina	-	-	-	-	-	-	-	cf 1	-
Fumaria officinalis	-	-	2	-	-	1	-	-	-
Galeopsis bifida/speciosa/ tetrahit	-	-	xx	xx	x	xx	-	6	-
Galeopsis ladanum/segetum	-	-	x	1	-	x	-	-	-
Galium aparine	-	-	1	-	-	-	-	17	4
Galium palustre	-	-	-	-	-	-	-	2	-
Galium spurium	-	-	xx	xx	x	xx	-	cf 1	-
Galium cf *verum*	-	-	-	-	-	x	-	-	-

wreck	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 15**	**Scheer 1**	**Scheer 1**
findnumber	60	61	267	268	276	283	422	1	2
volume in cm3	500	500	500	500	250	500	500	-	-
date	8/02/2000	8/02/2000	7/04/2002	8/04/2002	31/07/2003	16-6-2004	30-8-1990	1975-1977	1975-1977
Geum cf *rivale*	-	-	-	-	-	1	-	-	-
Heracleum sphondylium	-	-	-	-	-	x	-	-	-
Hieracium sp.	-	-	-	-	-	3	-	-	-
Humulus lupulus	-	-	-	1	-	-	-	-	-
Hydrocotyle vulgaris	-	-	-	-	-	-	1	-	-
Hypochaeris cf *glabra*	-	-	1	x	-	-	-	-	-
Juncus sp.	-	-	-	-	-	-	-	1	-
Knautia arvensis	-	-	x	x	x	xx	-	-	-
Lapsana communis	-	1	xx	x	-	x	-	1	-
Legousia hybrida	-	-	1	-	-	-	-	-	-
Leontodon autumnalis	-	-	-	-	-	1	-	-	-
Leontodon hispidus	-	-	-	-	-	-	-	1	-
Lepidium campestre	-	-	x	x	-	-	-	1	-
Lepidium ruderale	-	-	2	-	-	-	-	-	-
Leucanthemum vulgare	-	-	xx	xx	-	xx	-	-	-
Lithospermum arvense	-	-	-	-	2	-	-	-	-
Lolium temulentum	-	-	-	-	-	-	-	8	-
Lotus sp./*Trifolium* sp.	-	-	-	-	-	1	-	-	-
Medicago lupulina	-	-	2	x, in pods	2, in pods	x, in pods	-	2	-
cf *Melampyrum arvense*	-	-	-	-	-	2	-	-	-
Mentha sp.	-	-	-	-	-	1	-	-	-
Menyanthes trifoliata	-	-	-	1	-	-	-	-	-
Myosotis arvensis/palustris	-	-	x	xx	1	xx	-	-	-
Neslia paniculata	-	-	-	-	-	-	-	1	-
Odontites sp.	-	-	2	2	-	1	-	-	-
Persicaria hydropiper	-	-	-	-	-	-	-	1	-
Persicaria lapathifolia	-	-	2	1	-	x	-	3	-
Phleum pratense	-	-	xxx	xxx	3	xxx	-	-	-
Picea abies	-	-	-	-	-	1 needle	-	-	-
Picris hieracioides	-	-	-	-	-	-	-	1	-
cf *Pimpinella saxifraga*	-	1	x	xx	1	x	-	-	-
Plantago major	-	-	x	x	-	x	-	1	-
Poa annua	-	-	-	-	-	-	-	1	-
Poaceae	-	-	xxx	xxx	x	xxx	-	-	-
Polygonum aviculare	-	-	xx	x	-	x	-	5	1
Potamogeton sp.	-	-	-	-	-	-	1	-	-

wreck	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 9**	**BZN 15**	**Scheer 1**	**Scheer 1**
findnumber	60	61	267	268	276	283	422	1	2
volume in cm3	500	500	500	500	250	500	500	-	-
date	8/02/2000	8/02/2000	7/04/2002	8/04/2002	31/07/2003	16-6-2004	30-8-1990	1975-1977	1975-1977
Potentilla supina type	-	-	3	2	-	1	-	-	-
Prunella vulgaris	-	-	x	-	1	-	-	-	-
Ranunculus acris	-	-	1	1	1	1	-	-	-
Ranunculus aquatica type	-	-	-	-	-	-	x	-	-
Ranunculus repens type	-	-	-	1	-	2	-	-	-
Ranunculus sardous	-	-	-	-	-	-	-	1	-
Raphanus raphanistrum	-	-	-	-	-	-	-	1	-
Rhinanthus cf. *minor*	-	1	xx	xx	x	xx	-	-	-
Rubus idaeus	-	-	-	-	-	1	-	-	-
Rumex acetosella	-	-	xx	xx	-	xx	-	2	-
Rumex crispus	-	-	-	-	-	-	-	2	-
Rumex sp.	-	-	x	x	x	x	-	-	1
Sagina sp.	-	-	-	-	-	2	-	-	-
Senecio cf *vulgaris*	-	-	-	-	-	1	-	-	-
Silene cf *vulgaris*	-	-	xx	xx	x	xx	-	16	1
Sinapis arvensis	-	-	xx	xx	x	xx	-	7	-
Sinapis/Brassica sp.	-	-	-	-	-	-	-	-	4
Sisymbrium officinale	-	-	-	xx	-	x	-	-	-
Sonchus asper	-	-	-	-	-	1	-	1	1
Spergula arvensis	-	-	x	x	-	x	-	-	-
Sphagnum sp. (leaf)	-	-	-	-	xx	-	xx	-	-
Stachys palustris	-	-	-	1	-	-	-	-	-
Stellaria graminea	-	-	x	x	2	x	-	cf 1	-
Stellaria media	-	-	xx	xx	-	xx	-	2	-
Thlaspi arvense	-	-	x	x	4	x	-	1	-
Torilis arvensis	-	-	-	-	-	-	-	8	cf 1
Trifolium pratense	-	-	-	2	-	-	-	-	-
Tripleurospermum maritimum	-	-	x	3	-	x	-	1	-
Urtica dioica	-	-	-	1	-	-	-	-	-
Vaccinium sp.	-	-	-	1	-	-	-	-	-
Veronica chamaedrys	-	-	-	2	-	1	-	-	-
Veronica serpyllifolia	-	-	-	1	-	-	-	-	-
Vicia cracca	-	-	-	-	-	-	-	cf 1	1
Vicia sativa	-	-	-	-	-	-	-	-	cf 1
Vicia hirsuta	2	2	2	x	1	x	-	xx + x pods	24
Vicia tetrasperma	3	2	-	-	-	-	-	-	-

wreck	BZN 9	BZN 9	BZN 9	BZN 9	BZN 9	BZN 9	BZN 15	Scheer 1	Scheer 1
findnumber	60	61	267	268	276	283	422	1	2
volume in cm3	500	500	500	500	250	500	500	-	-
date	8/02/2000	8/02/2000	7/04/2002	8/04/2002	31/07/2003	16-6-2004	30-8-1990	1975-1977	1975-1977
Viola arvensis	-	-	xx	x	-	x	-	-	-
Viola sp.	-	-	-	-	-	x	-	-	-
Zostera marina	-	-	-	-	-	-	1	-	-
Claviceps sp. ?	-	-	x	x	x	xx	-	-	-
Sitophilus granarius (weevil beetle)	-	-	-	-	1	x	-	-	-
analysis:	W.J. Kuijper, 2004							M.R. Manders, 1991	

Legend: x = some, xx = tens, xxx = hundreds, xxxx = thousands, xxxxx = tenthousands, fr = fragment

Appendix 2

SEED ANALYSIS SAMPLES WRECKS Scheurrak SO 1, NOP G 29 and NOP G 35

wreck	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**NOP G 29**	**NOP G 35**	**NOP G 35**	**NOP G 35**
findnumber	SO 1 - 1	SO 1 - 2	SO 1 - 3	SO 1 - 4	SO 1 - 5	SO 1 - 6	SO 1 - 7	50	2	2A	6
volume in cm3	-	-	-	-	-	-	-	500	200	5	200
date	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1969	1999	1999	1999
cultivated plants											
Secale cereale	x	4	-	13	-	-	2	-	-	-	1
Triticum aestivum	xxx	xxxx	xxx	xxx	xxx	xxx	xxx	-	-	-	-
Triticum dicoccum	-	1	-	-	-	-	-	-	-	-	-
Hordeum vulgare	-	1	-	-	-	1	-	-	xx	xx	xx
Avena sativa	2	5	3	1	1	-	-	-	xxx	xxx	xxx
Linum usitatissimum	-	1	-	1	-	-	-	-	1	-	1
Brassica rapa	2	44	3	-	-	13	1	-	-	-	-
wild plants											
Agropyron repens	-	1	-	-	1	-	-	-	-	-	-
Agrostemma githago	5	114	23	55	107	41	13	-	-	-	-
Alisma sp.	-	-	-	-	-	-	-	1	-	-	-
Alnus glutinosa	-	-	-	-	-	-	-	1	1	-	-
Anchusa officinalis/arvensis	-	-	-	-	-	-	-	-	-	-	-
Andromeda polifolia (leaf)	-	-	-	-	-	-	-	1	-	-	-
Anthemis cotula	-	2	4	1	1	1	1	-	-	-	-
Atriplex patula/prostrata	-	1	-	1	1	-	-	-	-	-	x
Avena fatua	1	3	-	1	3	1	-	-	1	x	1
Betula sp.	-	-	-	-	-	-	-	-	-	1	-
Brassica nigra	-	5	-	1	1	2	1	-	-	-	-
Brassica rapa	-	-	-	-	-	-	-	-	1 cf	-	-
Bromus mollis	x	-	-	-	-	-	-	-	-	-	-
Bromus sp.	x	31	-	18	2	xx	11	-	-	-	-
Buglossoides arvensis	-	3	1	3	3	1	2	-	-	-	-
Calluna vulgaris (twig)	-	-	-	-	-	-	-	x	-	-	-
Capsella bursa-pastoris	-	-	-	-	-	3	-	-	-	-	-
Carex sp.	-	-	-	-	-	-	1	xx	xx	1	-
Centaurea cyanus	-	-	-	1	4	3	-	-	-	-	1
Cerastium sp.	-	-	-	-	-	-	-	-	-	-	x
Chara sp.	-	-	-	-	-	-	-	-	x	-	-
Chenopodium album	-	1	-	-	-	3	-	-	xx	1	xx
Cladium mariscus	-	-	-	-	-	-	-	1	-	-	-

wreck	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**NOP G 29**	**NOP G 35**	**NOP G 35**	**NOP G 35**
findnumber	SO 1 - 1	SO 1 - 2	SO 1 - 3	SO 1 - 4	SO 1 - 5	SO 1 - 6	SO 1 - 7	50	2	2A	6
volume in cm3	-	-	-	-	-	-	-	500	200	5	200
date	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1969	1999	1999	1999
Eleocharis palustris	-	-	-	-	-	-	-	xx	x	-	-
Erica tetralix	-	-	-	-	-	-	-	x	-	-	-
Euphorbia helioscopia	-	-	1	-	-	-	-	-	-	-	-
Fallopia convolvulus	2	7	2	2	3	-	-	-	2	2	xx
Galeopsis bifida/speciosa/ tetrahit	-	-	-	-	2	-	-	-	-	-	1
Galeopsis ladanum/segetum	-	-	-	-	-	-	-	-	-	-	-
Galium aparine	-	18	5	2	3	2	1	-	-	-	1
Galium palustre	-	-	-	1	-	-	-	-	x	-	-
Galium spurium	-	-	cf 1	-	cf 1	-	-	-	-	-	-
Cladium mariscus	-	-	-	-	-	-	-	-	xx	-	-
Hippuris vulgaris	-	-	-	-	-	-	-	x	-	-	-
Hordeum murinum	-	cf 1	-	-	-	-	-	-	-	-	-
Hydrocotyle vulgaris	-	-	-	-	-	-	-	x	-	-	-
Juncus sp.	-	-	-	1	-	1	-	x	-	-	-
Lathyrus sp.	-	1	-	1	-	-	-	-	-	-	-
Lemna sp.	-	-	-	-	-	-	-	1	-	-	-
Lepidium campestre	2	-	-	-	-	1	-	-	-	-	-
Lychnis flos-cuculi	-	-	-	-	-	-	-	-	1	-	-
Medicago lupulina	-	1	-	3	13	5	1	-	-	-	-
Menyanthes trifoliata	-	-	-	-	-	-	-	x	xx	-	-
Myrica gale	-	-	-	-	-	-	-	x	-	-	-
Nymphaea alba	-	-	-	-	-	-	-	-	x	-	-
Odontites sp.		-	-	-	-	-	1	-	-	-	-
Oenanthe sp.	-	-	-	-	-	-	-	1	-	-	-
Oxycoccus palustris (leaf)	-	-	-	-	-	-	-	2	-	-	-
Persicaria hydropiper	1	1	1	-	-	-	-	-	-	-	-
Persicaria lapathifolia	-	2	2	3	1	1	2	-	xx	3	xx
Persicaria minor	-	-	-	-	-	-	-	1	-	-	-
Plantago major	-	-	-	-	-	-	-	-	-	-	1
Poaceae	-	1	-	-	-	1	-	-	xx	-	1
Polygonum aviculare	-	10	1	12	17	8	1	-	-	-	1
Potamogeton sp.	-	-	-	-	-	-	-	x	2	-	-
Potentilla anserina	-	-	-	-	-	-	-	x	-	-	-
Ranunculus aquatica type	-	-	-	-	-	-	-	-	1	-	-
Ranunculus flammula type	-	-	-	-	-	-	-	-	1	-	-

wreck	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**Scheurrak**	**NOP G 29**	**NOP G 35**	**NOP G 35**	**NOP G 35**
findnumber	SO 1 - 1	SO 1 - 2	SO 1 - 3	SO 1 - 4	SO 1 - 5	SO 1 - 6	SO 1 - 7	50	2	2A	6
volume in cm3	-	-	-	-	-	-	-	500	200	5	200
date	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1986-1997	1969	1999	1999	1999
Ranunculus repens type	-	-	-	-	-	-	-	1	-	-	-
Ranunculus sceleratus	-	-	-	-	-	-	-	x	-	-	-
Raphanus raphanistrum	-	-	1	-	1 + fruit	-	-	-	-	-	-
Rubus idaeus	-	-	-	-	-	-	-	1	-	-	-
Selaginella selaginoides	-	-	-	-	1	-	-	-	-	-	-
Sinapis arvensis	4	5	6	-	3	26	1	-	-	-	1
Sinapis/Brassica sp.	-	-	-	28	50	-	-	-	-	-	-
Sonchus arvensis	-	-	-	-	-	-	-	-	-	-	x
Sonchus asper	-	-	-	-	-	-	1	-	-	-	1
Spergula arvensis	-	-	-	-	-	1	-	-	-	-	x
Sphagnum sp. (leaf)	-	-	-	-	-	-	-	xxxx	xx	1	-
Stellaria media	-	-	-	-	-	1	-	-	1	-	-
Thlaspi arvense	-	-	-	-	-	-	-	-	x	1	x
Vicia cracca	-	-	1	-	-	-	-	-	-	-	-
Vicia sativa	-	1	-	-	xx	xx	-	-	-	-	1
Vicia hirsuta	-	1	-	100	xxx + x pods	xx	-	-	-	-	-
Vicia sp.	22	-	3	-	-	-	-	-	-	-	-
Viola sp.	-	-	-	-	-	-	-	-	-	1fr capsule	-

analysis: M. R. Manders, 1991 W.J. Kuijper, 1999

Legend: x = some, xx = tens, xxx = hundreds, xxxx = thousands, xxxxx = tenthousands, fr = fragment

‘A day in the Life’ – *Cannerberg (the Netherlands), August 2nd 5045 calBC*

Luc Amkreutz and Ivo van Wijk

Reconstruction drawings offer great potential for involving the public and “translating” the past. However, their conception and execution point out many areas for discussion and leave much for debate. In this contribution two reconstruction drawings, or rather impressions, of the recently (2013) excavated site of Cannerberg are discussed. It is argued that while attempting to approach reality, the scientific value of these productions lies exactly in what we don’t know. As such visualizing the past may underline those areas where further research is needed and reconstruction drawings may become both a means of communicating with a wider audience as well as a tool for further research.

1 Introduction

The excavation of the Cannerberg Linearbandkeramik (LBK) settlement near Maastricht (The Netherlands) in the summer of 2013 drew much attention. Within the project plan it was clear that next to the actual excavation of the site it was also a primary goal to involve and inform the public, in particular the inhabitants of Maastricht. The LBK had hitherto been mainly associated with the occupation of the Graetheide plateau; however, from very early on Bandkeramik settlements on the west bank of the Meuse, such as the Caberg settlements, had been excavated (Van Wijk and Amkreutz 2014). This approach was of course in line with article 9 of the Treaty of Valetta (Malta), but also was a particular goal of the municipality of Maastricht and the contractor (A2 project bureau) aiming to involve citizens in their early past while creating positive revenue for a construction site.

A number of different mechanisms were implemented by Archol (Archaeological Research Leiden), in cooperation with the RMO (National Museum of Antiquities), to maximize public outreach. This involved the active incorporation of volunteers in the excavation campaign, the repeated communication of new discoveries through local newspaper articles, a blog and an exhibition in the municipal heritage centre and library (Centre Céramique) immediately following the excavation. What made the greatest impression on the public however, was an artist’s reconstruction of the Cannerberg settlement by Mikko Kriek (BCL Archaeological Support). This bird’s eye perspective of the site was developed and adjusted directly alongside the field campaign and could be presented at the exhibition. Meanwhile a second impression zooming in on a detail of the site has been developed as well. The positive acclaim of the illustration at the Euregional LBK conference in Sittard (November 2014) inspired us to publish it here. It appears that artist’s impressions remain one of the foremost methods to translate archaeological finds and features into something the wider public can relate to. Since there are many of these impressions around and not all of them are equally accurate (see De Grooth 2005), we feel the need to write a brief description and “disclaimer” introducing this particular impression.

2 Excavating on the Cannerberg

In the summer of 2013 a large excavation campaign revealed the layout of a late Bandkeramik settlement (Van Wijk and Meurkens forthcoming) on the Cannerberg, just south of the city of Maastricht. The Cannerberg is situated on a loess-covered upper terrace formed by the River Meuse during the Pleistocene. The Cannerberg is bordered on its eastern side by a steep drop (height difference of 50 metres) to the valley of the Jeker/Geer and on the western side the upper terrace gently merges with the middle terrace (fig. 1). The geographical location of the settlement is atypical, since most of the Dutch LBK settlements are situated on the middle terraces, with the exception of several younger ones on the eastern side of the Meuse (Van Wijk 2014).

Based on test trenching (Van Wijk and Meurkens 2014) the structure of the settlement was thought to have an open layout. This contrasts with most Dutch LBK settlements such as Elsloo, Stein and Sittard. These are “high density” settlements that were inhabited from the early LBK onwards and yielded many house plans.

The indications for a more open distribution of houses at Cannerberg made it a fine example for focusing on the house yards and settlement structure.

In total 3.5 ha were excavated, revealing the outlines of a small Bandkeramik village, encompassing at least 26 house yards. Based on the pottery chronology it is thought that 4 to 5 house yards where present during each (ceramic) phase. The house yards cluster and move across the settlement area.

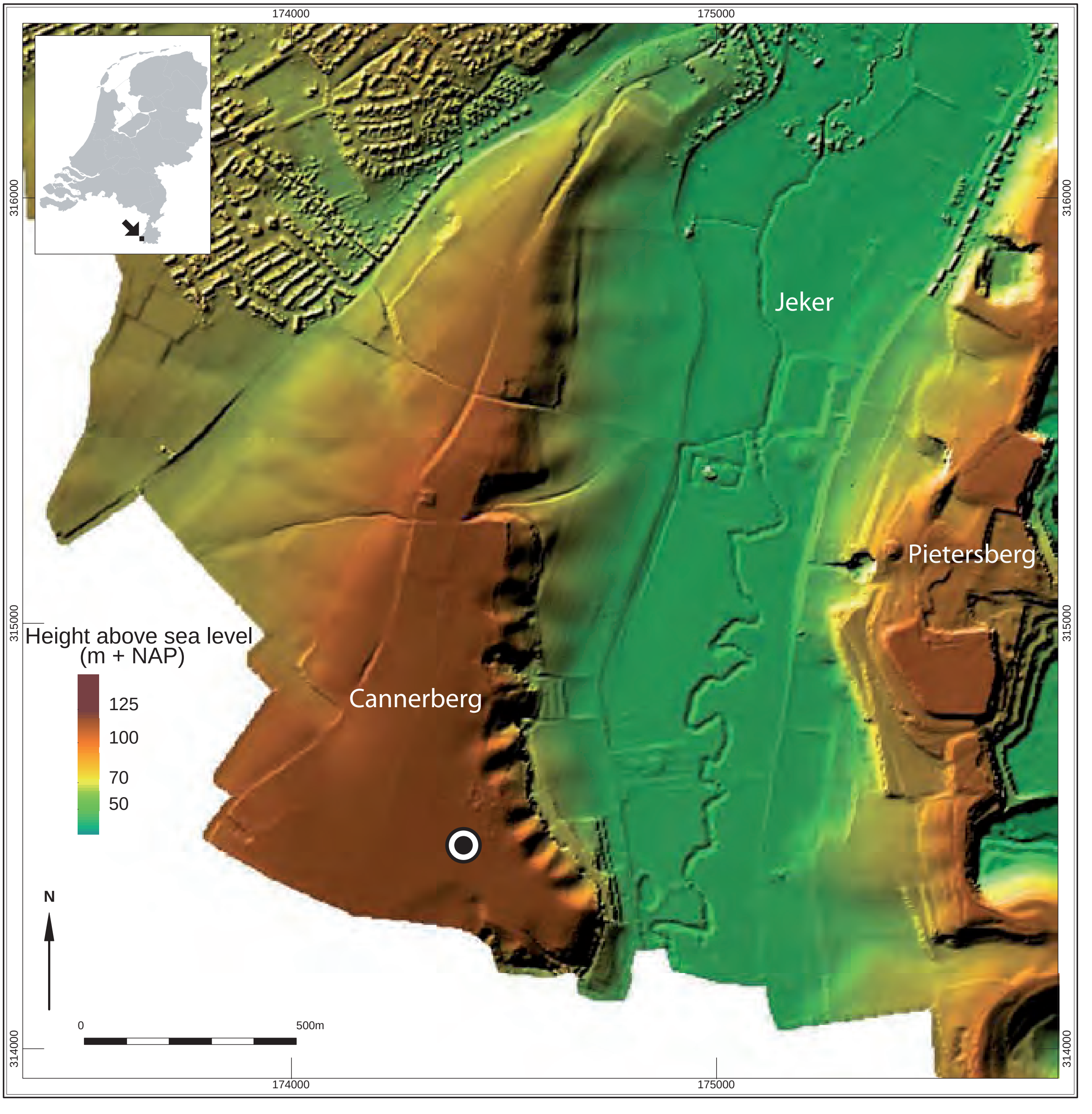

Figure 1 LIDAR image of the Cannerberg and its surroundings (© ARCHOL, Leiden/Drawing Walter Laan)

The house structures themselves are oriented east to west and consist mainly of Modderman Type 2 houses (Modderman 1970). These are two prominent features that distinguish this site from other known settlements in the Netherlands, since most Dutch LBK settlements have a wider range of house types and most of the houses are orientated north-east to south-west. Regarding the material culture there hardly seems to be any difference in comparison to other sites. Pottery, flint and stone tools typically conform to regional LBK standards. What was most striking, however, was the enormous amount of flint that was present within three large refuse pits. They resemble the flint blade production workshops from Verlaine-Petit Paradis (Allard 2005; 2007; Burnez-Lanotte and Allard 2004; Allard and Burnez Lanotte 2007; 2008) and the settlement therefore may have played a comparable important role in social and economic distribution networks. One of the main research questions focused on the origin of the flint raw material. The nearby valley of the Jeker/Geer came into view as a possible location for raw material. Research involving GIS and stratigraphical plots could establish if flint-bearing outcrops, now covered by deposits of the Geer, were accessible during the early Neolithic. A coring campaign was therefore initiated to determine the fluvial stratigraphy. It also offered the possibility to propose a reconstruction of the vegetation around the site. While the research for the publication of the site is still ongoing, it is clear that the Cannerberg settlement already holds a special place within the Dutch Bandkeramik. This is not only based on its flint blade industry, but also because of its striking geographical position, settlement structure and occupation dynamics. This inspired us to create two reconstructions of the settlement: one a bird's eye view of the settlement within its environment and a second one focusing on the individual house yards.

3 Illustrating Cannerberg

The illustration of Cannerberg was based on results coming directly from the field campaign. These were used by artist Mikko Kriek for the production of both impressions. The use of computer software and techniques, in this case 3d Max and Vue, in the creation of these digital impressions has the big advantage that the images are not static. Within certain limits there is room to adjust previous versions. This is crucial, since in most cases the artist is not archaeologically schooled (in this case he was), nor will have been present at the excavation. The process of translating is as such often hindered by archaeologists speaking a different language than the artists. The remaining product then is usually a compromise between time, budget and communication. With digital drawings, however, time is bought to a certain extent. This enables the commissioning party to have details changed. In this case, the ongoing analysis of the excavation, the consultation of recent literature on comparable LBK settlements and the information provided by (archaeobot-anical) specialists could be incorporated and altered the images considerably before the final version was produced. Arguably, with these images there maybe is no final version, as it is always possible to add or alter detail. Finally, there is another big advantage to these digital drawings and that is that they are in fact not a fixed image, but a 3D recreation. This enables the artist to not only introduce or remove elements, but to change perspective, "camera-position" and lighting altogether. This makes a drawing not just an image, but perhaps also a tool to explore a past world or environment and to visualize what may be abstract points of discussion. In the following section both plates will be presented and briefly described.

3.1 Overview 1: The Cannerberg settlement complete (fig. 2)

The image shows the Cannerberg settlement from an elevated bird's eye perspective. It is mid-summer at the end of a hot day and clouds are gathering above the site for yet another thunderstorm. Visible to the right are a number of east-west oriented houses, widely spaced, characterised by smoke coming from their roofs. In between the houses there are small garden plots bordered by hedges and fencing that were used for crops such as lentils and peas. Several tracks indicate the most used routes. The area is partly cleared and covered with shrubs and weeds. Individual trees remain, providing shade. The house furthest on the right is under construction, several trunks and planks are visible. Cattle are herded to the fallow fields in the foreground and a big fire is burning in an open area to the left of the houses. The nearer settlement area is separated from a second part of the village by a narrower corridor which is visible to the back. In the centre of that ward a house yard has been abandoned and is recognisable by its charred post stumps and the gradual reclamation of the area by weeds.

To the west of the settlement and separated by a narrow band of trees, several fields are visible; they are bordered by trees and shrubs. The fields are yellow from the ripe emmer and einkorn, while some lie fallow. In the open spaces cattle can graze. The tree stumps of the vast Atlantic forest are still visible. The forest itself, largely consisting of lime and oak trees, covers most of the landscape like a blanket. Towards the river valley it diversifies and develops into more swampy open patches near the water. Also visible are several clearings in the forest (Kreuz 2008). They may have developed naturally or by human intervention, but according to the latest views characterise the Atlantic forest. Some of the clearings in the distance are definitely of anthropogenic nature. They represent actual nearby settlements, as can be seen by the smoke on the horizon.

To the east the valley of the Jeker/Geer is visible. It was a small stream, but offered a diversification of the landscape. In the distance it merges with the Meuse at the current location of Maastricht. It was a source location for (lithic) raw material in the Cannerberg settlement. Clearly visible beneath the tree cover are the limestone "cliffs" of the Pietersberg. The slopes to the east and west of the Cannerberg have become steeper, as the Cannerberg only later gained its undulating appearance due to erosion caused by large-scale Roman and Medieval deforestation.

Figure 2 Bird's eye perspective, facing to the north, of Maastricht-Cannerberg and its surroundings, including the Jeker and Meuse valley (© Rijksmuseum van Oudheden (National Museum of Antiquities), Leiden/Drawing Mikko Kriek)

3.2 Overview 2: The Cannerberg settlement in detail (fig. 3)

This image provides a somewhat adjusted close-up of the northern part of the Cannerberg settlement. It depicts four Type 2 houses. Two of these are functioning, one is being built, and another one has burnt down: some of the roof-bearing poles have been removed and the remnants of the house are slowly taken over by the undergrowth. The functioning houses have painted façades (Lichardus and Lichardus-Itten 1985) and are bordered by wall trenches or pits that are filled with muddy water, due to an intense thunderstorm that passed earlier that day. Clearly visible are also the other pits, some of which have gradually filled again, scattered across the open space. A number of well-trodden paths cross the small shrubbed area; tree stubs, occasional trees and weeds remain. In the direct vicinity of the houses there are small garden plots, while in between the two houses there is an open space with fire and some logs. Clearly visible is the impressive forest edge and the tall trunks of lime and oak. In front of these, shrubs delineate the zone between forest and clearing (Salavert *et al.* 2012). To the left one of the fields is visible with ripened emmer or einkorn, as well as a corner with some flax shimmering bluish in the distance. In the foreground a number of people are visible. One is knapping flint on the edge of a large pit. This corresponds with the enormous amount of knapping debris, blades and cores found in three of the Cannerberg pits.

4 Between fact and fiction

Behind the creation of these two images there stands of course a vast amount of discussion. Some of the information provided was inaccurate, or some of the initial suggestions

Figure 3 Close-up of the Maastricht-Cannerberg settlement, including four houses, fields and the forest edge (© Rijksmuseum van Oudheden (National Museum of Antiquities), Leiden/Drawing Mikko Kriek)

by the artist were off the mark. For instance the buzzard in the foreground on image 1 originally was a South American condor; a choice in the drawing program and certain (financial) limits only yielded one bigger bird of prey, which upon more close perusal appeared to be an American condor. However, most discussion revolves around the tension between knowledge and assumption, between fact and fiction. There are a number of examples. For instance some of the house plans in the overview are actually too large for the Type 2 houses that were found, but they were not removed because of the generic value of the image in functioning as an image of a LBK settlement. As not the entire settlement was excavated the possibility remains that type 1 houses were present. Other aspects up for discussion involved the number of simultaneous houses and what houses in decline or under construction actually look like. The existence, number, location and size of the garden plots formed another point for discussion, as did the use of the open area between the houses on figure 3. Such open areas have been found at Cannerberg and at Elsloo (Porreij-Lyklema and Van Wijk forthcoming), but whether they functioned as communal gathering places is not clear. Also the number, size and depth of the open pits threw up questions. The landscape soon looked as if littered with bomb craters, so a number were removed again. All these aspects for which presence is attested, but location and contemporaneity are problematic, remain speculative. They are educated guesses at best.

In view of recent discussions of LBK reconstructions in particular (see De Grooth 2005; Röder 2010), it is clear that there is not one valid method or approach, and that there is a large difference in quality, public and intentions of the commissioners. Some reconstructions of settlements, techniques and houses are clearly based on the available archaeological material, but this does not automatically yield the best result. For instance the choice to base LBK clothing, hairstyle and headdresses on the decoration patterns and shape of figurines yields spectacular, but rather peculiar results (see Lüning 2005). Whereas very glossy and smooth impressions on the other hand may look spectacular, yet remain uninformative. Of course there is also the tension between an overview, which remains to a sense abstract and the inclusion of detail in the form of people and activities, which increases the margin for error.

For the creation of the Cannerberg images it is convenient that in the past much has been written and reconstructed about LBK settlements. This tried and tested information provides a solid base for a settlement reconstruction to which "local details" may be added. A good example of such a base is the scale model of the village of "Elsweiler" designed by Corrie Bakels, based on Langweiler and Elsloo (De Grooth and Verwers 1984, 68). For the Cannerberg the terrain was altered, as were the places and size of the houses, the number of pits and the location of the fields. As argued above, to a certain extent this remains speculative, but the chosen method allows for the inclusion and removal of elements until a credible image remains. Of course credible from our reasoned perspective. As such the most important aspect is that we realise that the eventual image is a compromise between excavation and imagination and as much a product of the excavated settlement remains and associated data as it is a product of its time of creation.

5 Hoogcanne: a day in the life

If we can come to terms with the fact that the impression offered is exactly that: not a reconstruction of an LBK settlement, but rather an image of it based on archaeological information and informed extrapolation, then its creation becomes positive in two ways/areas.

With respect to the public, it provides a welcome image of something that is difficult to visualize by archaeological finds and excavation plan drawings alone. Also it becomes something people identify with and that creates a sense of familiarity and realism, hence the title. In the case of the Cannerberg excavation, Maastricht citizens, who are rather familiar with their Roman heritage, now also included their early farming roots as something to be proud of, as part of their identity. The LBK settlement on top of the Cannerberg was soon dubbed "Hoogcanne" as a counterpart of the 17th century castle and associated village of Neercanne at the foot of the hill. Furthermore, posters and postcards of the impression were ordered by the A2 project bureau for use in public relations. The excavation in fact took place within the scope of nature compensation for the development of the A2 motorway tunnel through Maastricht.

With respect to archaeology, or science, the image is positive because in its creation one tries to approach reality. The title of this contribution suggests exactly that. At the same time it is clear that this is not a photograph, let alone reality, but an impression. However, since one has to recreate reality, many details are added that are in fact assumptions, or extrapolations, based on excavated evidence, anthropological comparison, other images and imagination. At best the result is close to the unknown truth, but if it is not, it remains valuable in that it forms a starting point for discussion, disagreement and eventually consensus and a furthering of knowledge.

As such we hope that, despite the positive acclaim so far, these images will not become textbook figures of an LBK village, but rather stepping stones in an ongoing discussion.

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Uncovering Roman fort Matilo in Leiden, 70-250 AD

Jasper de Bruin

The passing of my dear colleague and friend Willem Willems on December 13, 2014, is the immediate reason for writing this article, that was originally intended for a liber amicorum on the occasion of his 65th birthday on July 19, 2015. Willem had been appointed as professor in Provincial-Roman archaeology in Leiden in 1991. In the autumn of 2006, freshly starting work at Leiden University, I took over the course of Provincial-Roman archaeology, that Willem had successfully taught for so many years. Being occupied with the Faculty's annual field school for our first year's students, research in the field of Provincial-Roman archaeology was not an integral part of my appointment, but this changed when Willem became not only the supervisor of my dissertation, but also my direct supervisor at work. Apart from being dean of our Faculty, Willem was very ambitious about setting up a full course in Provincial Roman archaeology in Leiden. In order to do so, attractive research projects, including excavations, were part of the strategy.

In 2008, the Municipality of Leiden approached Willem with a request for assistance in an excavation. In the coming years, the site of the Roman fort within Leiden's boundaries and its immediate surroundings were to be redeveloped as an archaeological park, with the outline of the fort forming the base of the park's design. In order to do so, the south-eastern corner of the fort had to be located by means of an excavation. The question was whether the Faculty wanted to participate in this research. Willem took up the challenge as an opportunity to gain more insight in the lay-out of one of the last unexplored Roman forts in the Netherlands. The fact that a substantial heritage element was involved in the project, was also right up the street for Willem. In 2009, the excavation was carried out and we were able to resolve the long lasting discussion of the location and lay-out of the fort. In this article, the main results of this research are presented. I am glad that Willem got to know the results of our excavation and that he was able to see the reconstruction in the park for himself in 2013. Looking back, I can say I was honoured that I could work with Willem, even though this proved to be of rather short duration.

1 Introduction

In the south-eastern part of the modern city of Leiden lies a Roman fort that was part of the Lower Rhine Frontier of imperial Rome. According to the Peutinger Map, the fort was called Matilone, but was probably called Matilo (fig.1).
In Roman times, the site was located on the western bank of the river Rhine. The northern border of the site consisted of a wide gully, formed by the mouth of the Corbulo canal, which at this point flowed into the Rhine. The canal, dug around 50 AD (De Kort and Raczynski-Henk 2014, 63), connected the river Rhine with the Meuse estuary. The site was declared archaeological monument in 1976 and in 2008 the protected area of the monument was enlarged (de Vries 2008, 64-69). Despite reports of archaeological finds from the early sixteenth century onwards and several years of extensive archaeological research in the twentieth century, the exact location of Leiden's Roman fort remained unknown. Only in 1999 the north-western corner of the fort was discovered, although the exact dimensions of it remained unclear (Polak *et al*. 2004a). In 2008, the Municipality of Leiden approached the Faculty of Archaeology to participate in the search for the south-eastern corner of the Roman fort.

2 Research methods

Because the site is a protected archaeological site, the first step was to investigate whether it was possible to locate the forts' contour in a non-destructive way. Therefore, accessible parts of the site were examined using a Groundtracer, a geophysical survey method (fig. 2). The most important feature that was detected was a zone orientated northwest-southeast that might be the remains of the eastern wall of the fort or one or more of the fort's debris filled ditches (de Bruin *et al*. 2009, 14-17). This interpretation, however, had to be verified, because there was a possibility that the observed features were of a later date. A borehole survey by the Cultural Heritage Agency of the Ministry of Education, Culture and Science confirmed that the debris was of possible Roman date, but the context of the material could not be identified. In the end, excavation became inevitable.

Figure 1 The place Matilone on the Peutinger Map. The site is situated between Praetoriu Agrippine (Valkenburg) and Albanianis (Alphen aan den Rijn). Picture courtesy of the Österreichische Nationalbibliothek / Vienna Cod.324, segm.1

To limit the extent of the disturbance of the archaeological monument, a small trench of 25 metres long and two metres wide would be dug, perpendicular to the northwest-southeast orientated zone with debris. If the debris zone was indeed the fort's wall, then it could be unearthed right in the middle of the trench. The possibility to dig a second trench, if required, was included in the research design.

Figure 2 Surveying the site with a groundtracer. Photo: author

At first, the trench was planned on the site of the local community gardens, but this caused too much protest by the owners. More to the south of the gardens, a disused greenhouse became the only possible location for the excavation. The excavation was carried out by a combined team of archaeologists from the Municipality of Leiden and the Faculty of Archaeology. A group of five students participated in the project as well (fig. 3). Even though excavating in a greenhouse seems very attractive considering the rainy Dutch climate, the weather during the excavation was sunny and fairly warm. Because the greenhouse had previously been heated, there were not many windows and in combination with the weather outside, the temperature regularly rose above forty degrees Celsius, even, in one occasion, causing the mechanical digger to fail because of the heat. The topsoil in the greenhouse was completely dried out, creating a very dusty environment for the research. Despite these difficulties, the excavation in the greenhouse can be regarded as successful.

3 The excavation

From 7 to 25 September 2009 the first trench (trench 1) was excavated, running across the width of the greenhouse. On 5 and 6 October 2009, a second trench was dug (trench 2), in order to locate the southern wall of the fort. Trench 1

Figure 3 Students participating in the excavation. Photo: Erfgoed Leiden en Omstreken

yielded the most information, and is, therefore, discussed in more detail.

3.1 *The fort's wall*

Because of the complex stratigraphy Trench 1 (fig. 4) was excavated in seven levels. The first level merely removed the dusty topsoil as the first in situ finds and features were recorded directly under the topsoil, only fifty centimetres below the surface level. Instead of the expected robber trench of the fort's wall, a broad zone of Roman debris was found in the centre of trench 1. Apparently, the wall of the fort was located somewhere else. Yet, in the most western part of the trench, the edge of a robber trench was observed (fig. 5, A). After permission by the Cultural Heritage Agency to enlarge the trench here by 4,5 metres, a broad robber trench was exposed. During the course of the excavation this structure turned out to be the wall of the fort, because the characteristic postholes and wooden piles emerged from under the robber trench (fig. 5, A; fig. 6). The same situation was found in trench 2, making it possible to reconstruct the dimensions of the stone built fort.

In the north profile of trench 1, it appeared that the robber trench of the fort's wall was much broader, as if there was another robber trench attached to the remains of the wall of the fort. In the most north-western corner of the trench 1, a small part of this other robber trench was found at right angles to the fort's wall (fig. 5, B). No driven poles were found under this shallow feature, suggesting that this structure was less heavy constructed than the wall of the fort. Although a latrine could have been placed near the forts' wall, such a structure should be founded much deeper, because it had to be connected to a sewer. Therefore, it is possible that this robber trench marks the foundation of a tower that was bonded to the wall. It is known that towers were not founded as deeply as the walls of the forts itself, as has been observed in Utrecht (Kloosterman 2010, 21, with references to other examples).

3.2 *Ditches of the fort*

A series of ditches were found to the east of the fort's wall. The oldest ditches, consisting of a ditch that was exposed under the later fort wall (fig. 5, C) and another one located

Figure 4 Overview of trench 1, located in the greenhouse. Photo: Erfgoed Leiden en Omstreken

more to the east (fig. 5, D), were filled up in the first, maybe even in the first quarter of the second century AD. The western ditch, located under the later fort's wall, was filled up in at least two stages. Because of the lack of well-dated finds from the bottom of the ditch, it is unknown when it was dug, but a date in the first century seems plausible. This ditch was cut by a V-shaped ditch that was filled up in two phases (fig. 5, E). The oldest phase yielded a fragment of a *terra sigillata* bowl that can be dated between 60 and 85 AD (identification Ryan Niemeyer). However, this fragment could have been redeposited from the earlier ditch that was cut by the V-shaped ditch. In the second filling of the ditch a fragment of pottery was found that could be dated from 150 AD onwards, together with a concentration of construction rubble. According to inscriptions from Matilo constructions in stone were undertaken in 103-110, 196/198 and 198-205 AD (Brandenburgh and Hessing 2014, 30-31). Thus, the filling of the second phase of this ditch could have taken place in the second century.

Another V-shaped ditch (fig. 5, F) was situated too close to be contemporary with the first mentioned V-shaped ditch. No datable finds could be obtained from this ditch. Next to the ditch, a third ditch was located (fig. 5, G). This ditch, with a flat bottom, may have been contemporary with the first V-shaped ditch, but this is not clear. This flat-bottomed ditch was filled up after 100 AD. The two V-shaped ditches could have succeeded each other, while the ditch with the flat bottom may have been contemporary with the first, most western V-shaped ditch. All three ditches were filled up in the second century and this process was finished around the end of this century, when a new ditch was dug (fig. 5, H). This ditch was more U-shaped and much broader than the

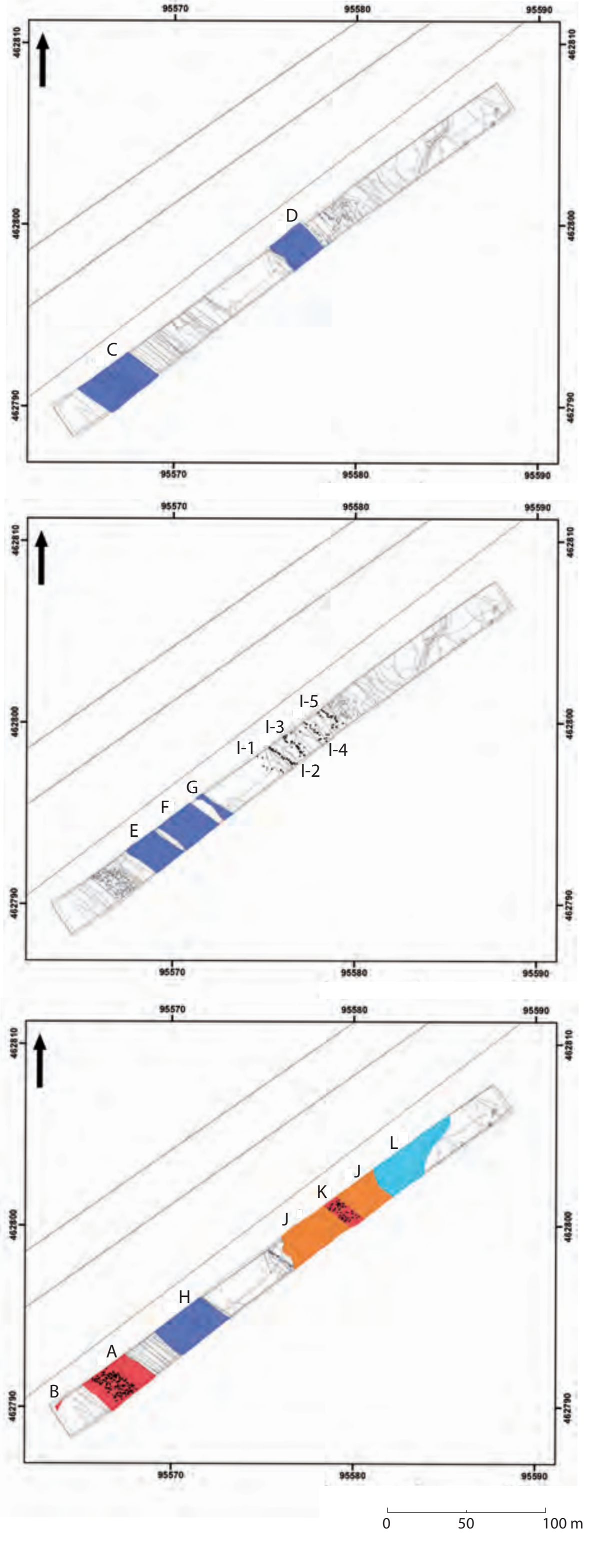

Figure 5 Trench 1 with the main features, numbered A-L. The features are pictured by Phase. Picture: Erfgoed Leiden en Omstreken and author

Figure 6 Postholes under the fort's Stone wall. Photo: Erfgoed Leiden en Omstreken

previous ditches. Find material from the ditch can be dated between the end of the second century and the middle of the third century AD. It belonged to the last building phase of the fort and is associated with the stone wall.

3.3 The river bank

The biggest surprise of the excavation was the former bank of the River Rhine, which appeared more or less in the middle of Trench 1. Apparently, the builders wanted to place their fort as close as possible to the river. As a result, an early ditch (fig. 5, D), located on the edge of the higher ground, was eroded. Possibly as a reaction to this, several rows of thin wooden posts ware erected parallel to the course of the river (fig. 5, I, rows numbered 1 to 5). These rows of poles probably formed fences of wattle that could contain soil, as a sort of bank protection. At the end of the second century, additional measures were necessary to stop the eroding force of the Rhine. In several phases, layers of highly fragmented rubble were laid to protect the vulnerable bank of the river (fig. 5, J). These layers were the features that had been detected by the Groundtracer and were at first mistakenly interpreted as remains of the forts' wall. Layers of rubble, that served as a bank reinforcement, were also found on the site along Corbulo's channel (Hazenberg 2000, 35; Polak and De Groot 2009, 11), and also along the Roman fort of Zwammerdam (Haalebos 1977, Beilage Ia, g).

Another measure to protect the bank of the river was the construction of a riverside wall, 70 centimetres wide and constructed on a foundation of poles (fig. 5, K). This wall does not define an annex, because it comprises an area that was too small to serve as a temporary enlargement of the fort. Additional layers of rubble were necessary to protect this wall from erosion. These layers were, in turn, affected by water. A depression situated directly to the east of these layers was probably responsible for the continuous risk of erosion, because it carried water during floods (fig. 5, L). In this depression, fragments of at least five Roman shoes were found, dating to around the end of the second or beginning of the third century (identification Carol van Driel-Murray).

4 The results of the excavation in relation to other excavations of Matilo

Although the area around the position of the fort has been excavated quite extensively, the site of the fort itself has not been thoroughly investigated. Trenches 1 and 2 were excavated in 2009. The other trenches are numbered 3-6 (fig. 7). In 1927, Jan Hendrik Holwerda from the Dutch National Museum of Antiquities excavated to the west of the fort (trenches 3) . He was able to locate the U-shaped ditch that belonged to the stone built phase of the fort (Polak *et al*. 2004a, 66). In 1999, a geophysical survey and small excavation uncovered the north-western corner of the Roman fort (Polak *et al*. 2004a, trench 4 and coloured area). In the excavation (which was actually a small trench, comparable to Trench 1 from the 2009 campaign) finds and features from earlier fort phases could also be documented. Additional information was obtained from two trenches in 2011 and 2012 during the construction of the park (Van der Feijst and Brandenburgh in prep., trenches 5-6). Combining the evidence from these fieldwork campaigns, it is possible to outline the construction history of Matilo. Also, an attempt

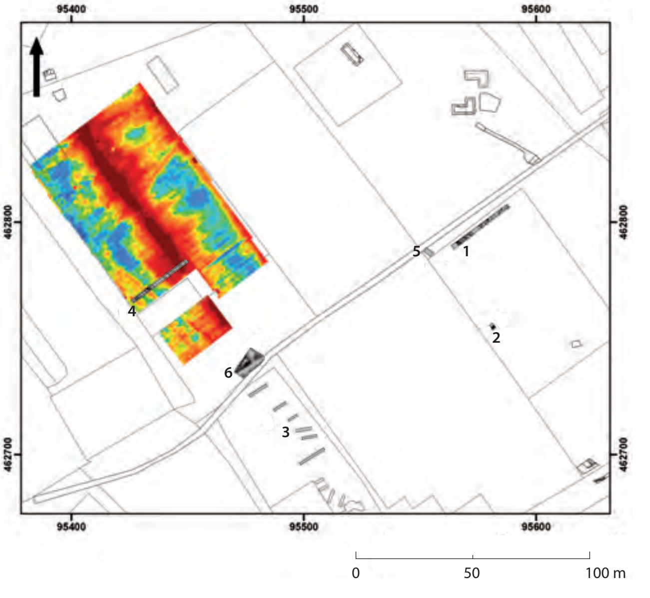

Figure 7 Trenches, dug on the site of the fort, numbered 1-6 (shaded), the area that was researched by means of a geophysical survey is coloured. Picture: author

can be made to reconstruct the plan of the fort during the different phases.

4.1 Phase 1 (around 70 AD-around 100/125 AD)

The ditches from the oldest fort were found in trench 1 and 2. This ditch was located under the later fort wall. A second ditch, found more to the east in trench 1, probably dates from the same period. This ditch was only observed in trench 1. To the west side of the fort, two ditches from the same building phase were excavated in trench 4 (Polak *et al*. 2004a, 33-37, ditches A-B). The western of these two ditches, resembles the eastern, oldest ditch in trench 1. Since this is the outer ditch, it can be assumed that a second ditch was present more to the west of trench 1. Because the outer ditch of the oldest fort was also found in trench 2, it is possible to reconstruct the dimensions of the first fort in Leiden (fig. 8). Remarkably, the ditch yielded several artillery balls, in both trench 1 and trench 4. The ditches of this fort were filled up in the (late?) first century or first quarter of the second century. Pottery collected at several locations in and around the fort suggests a starting date of the occupation before 70 AD. In trench 5, the only trench dug in the inner area of the fort, a *terra sigillata* bowl from the type Dragendorff 24/25 was found that could be dated between 40 and 80 AD (van der Feijst and Brandenburgh in prep). However, it is possible that before the construction of a fort, only a small military post was present. Therefore, it is possible that the fort itself was constructed around 70 AD and that it could have been used until around 100 AD. Nevertheless, it remains possible that the fort could be dated earlier.

4.2 Phase 2 (2nd century AD)

In the next building phase, two V-shaped ditches and a ditch with a flat bottom were dug on the eastern side of the fort. In trench 4, a single V-shaped ditch can also be dated around the same period; this ditch cuts an older one that might be dated from an earlier period (Polak *et al*. 2004a, 37-38, ditch D) . The ditches from this new phase are located on the same spot as the ditch from the stone-built phase. Presumably, the fort was enlarged around this time, almost to its final dimensions. However, the reconstruction of this phase (fig. 9) remains more hypothetical than the others, as the ditches on the north and south side of the fort were not excavated. This second building phase can be dated in the second century.
A building inscription, dating between 103 and 111 AD, suggests the first occasion for construction with stone (Brandenburgh and Hessing 2014, 30). Evidence for building in stone in this second phase of the fort was also found in the form of building debris, in the western V-shaped ditch in trench 1 (see paragraph 3.2).

4.3 Phase 3 (end of 2nd-3rd century AD

In the final phase, a broad ditch was dug around the fort and a stone wall was built. The ditch has been found in trench 1

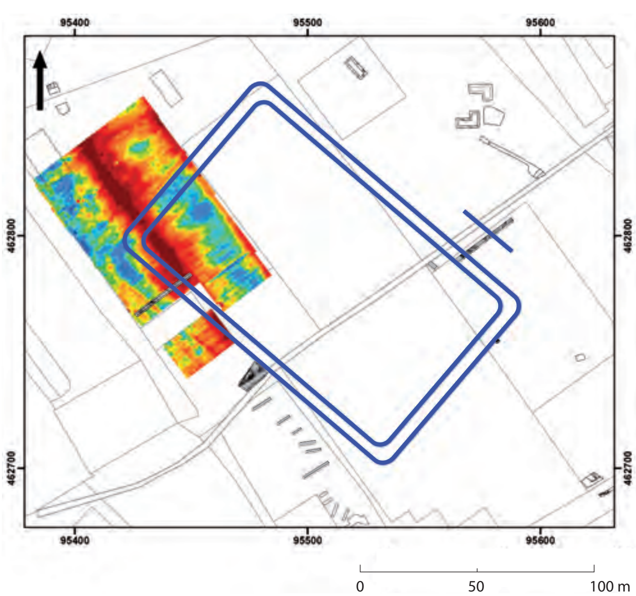

Figure 8 Reconstruction of the dimensions of the two ditches (blue lines) of the first fort phase (around 70-around 100/125 AD). A third ditch was only found on the east side of the fort. Picture: author

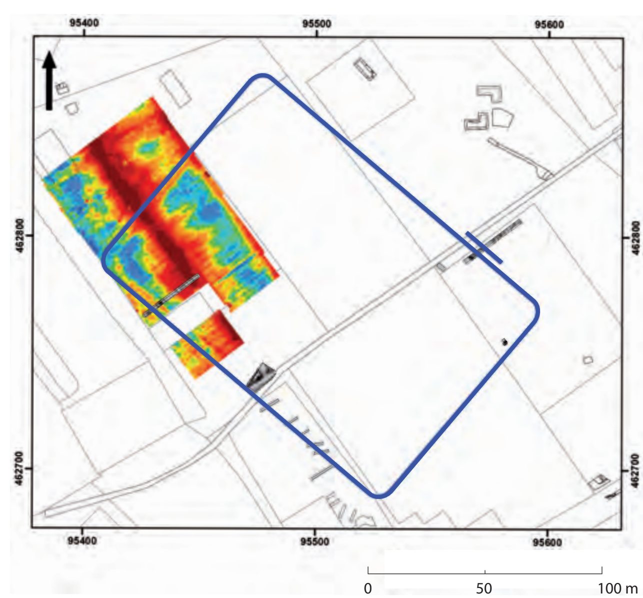

Figure 9 Reconstruction of the dimensions of the V-shaped ditch (blue line) of the second fort phase (2nd century AD). A second, contemporary, flat-bottomed ditch was only observed on the east side of the fort.. Picture: author

and 4, but was also revealed in the 1927 excavation by Holwerda (trenches 3). The fort's wall appears in trenches 1, 2 and 4. In trench 1 there is evidence for a tower, that was attached to the wall. In trench 6, parts of the western gate of the fort, the so-called *porta decumana*, were found (van der Feijst and Brandenburgh in prep.). If the evidence is combined, it is possible to reconstruct the dimensions of this third phase of the fort (fig. 10). Because the location of one gate and a tower were found, it is possible to reconstruct the plan of the fort in more detail (fig. 11). The building of the stone fort of Matilo started around the end of the second century. Two building inscriptions, dating in 196/198 and 198-205 AD, suggest building activities in the fort (Brandenburgh and Hessing 2014, 30-31); this might be the starting date for the stone-built phase. The fort was probably in use until 250 AD.

5 Matilo: size and location

The Roman forts along the western part of the Lower Rhine Frontier are characterized by their small size when compared to other forts on the Roman Frontier. This was a deliberate adjustment to local circumstances, because the forts were built to supervise the Rhine river and its many tributaries in the area (Graafstal 2002, 19; van Dinter 2013, 25). This made a spread of the available troops at multiple strategic locations necessary. However, if the stone built fort in Matilo is compared to the other stone forts in the area, it appears to be one of the biggest (Table 1). Maybe the fort housed somewhat more soldiers or it fulfilled a special purpose. Yet, without any knowledge of the fort's interior, it is impossible to make any statements about the purpose of the fort in Matilo. Being one of the bigger forts in terms of dimensions, its extended design is aberrant, but may have been dictated by local circumstances. In other respect the Matilo fort resembles the position of the others forts in the region with the long side of the fort located parallel to the river.

Matilo was located in close proximity to the river Rhine and the Corbulo channel. Sporadic flooding occurred, as is reflected in the measures to protect the bank of the Rhine (paragraph 3.3). For a long time, it wasn't clear why these forts were built on such unsuitable natural locations. However, the discovery of artillery bullets in Leiden and the other forts in the region indicates that the forts were equipped with artillery. Some of the towers (in Leiden up to seven) of the longest side of the forts, were in fact artillery towers from which boats on the river could be targeted. Evidence from excavations in Utrecht suggests that the artillery had a range of 150 to 160 metres, so that the bullets could reach the opposite bank of the Rhine (Dielemans 2012, 260). The location of the fort in Leiden shows that supervising of the river, the Corbulo channel and other waterways was its primary function. Monitoring of water transport was carried out by soldiers who were on watch in the towers, of which some were equipped with artillery.

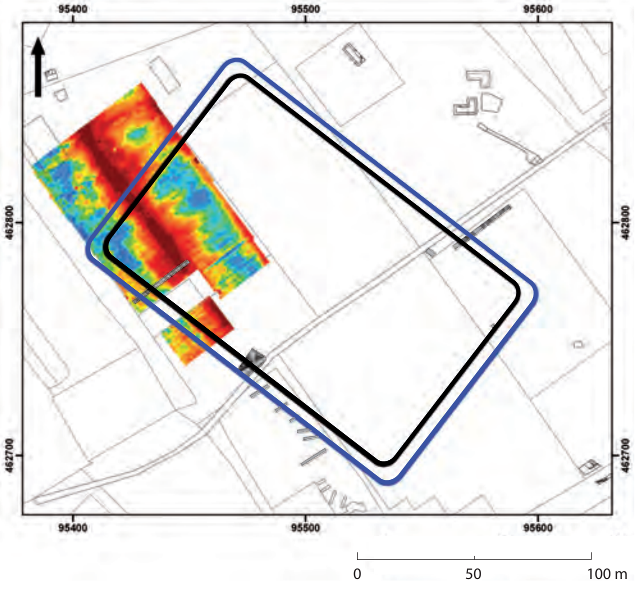

Figure 10 Reconstruction of the dimensions of the wall (black line) and ditch (blue line) of the third fort phase (end of 2nd-3rd century AD). Picture: author

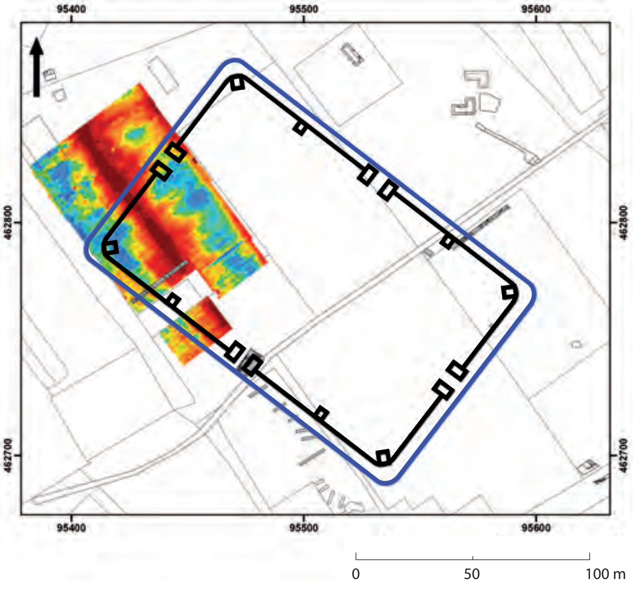

Figure 11 Hypothetical reconstruction of the of the third fort phase (end of 2nd-3rd century AD), with towers and gates. The dimensions of the towers and gates are derived from the fort of Valkenburg 6 (Glasbergen 1972, 145). Picture: author

Fort name	Square Meters	Acres	Literature
De Meern	9200	2.3	Langeveld 2010, 16
Alphen aan den Rijn Period 3	9750	2.4	Polak et al. 2004b, Kaart B1
Woerden IV	10406	2.6	Haalebos & Lanzing 2000, 19, Afb. 13
Zwammerdam Period III	12408	3.1	Haalebos 1977, Beilage Ia
Roomburg Phase 3	14725	3.6	This article
Valkenburg 6	16080	4.0	Glasbergen 1972, 145
Utrecht Period V	18710	4.6	Ozinga & De Weerd 1989, 54
Vechten Period III	27000	6.7	Zandstra & Polak 2012, 258

Table 1 Dimensions of the stone built phases of Roman forts along the Lower Rhine Frontier in the Netherlands

The threat of being hit by these bullets was probably enough to minimise the chance of disturbance.

6 The park Matilo

The results of the excavations of 2009 will be published in the foreseeable future (Brandenburgh and De Bruin in prep.) Shortly after the excavations ended the results were shared with the designers of the park. Since the excavation yielded the location of the south-western corner of Matilo , it became possible to reconstruct the outline of the stone-built fort and the construction of archaeological park Matilo could begin. The whole site was covered under a 50 centimetres thick layer of soil in order to preserve the site. In September 2013, the park was officially opened. The fort itself is visualized by an earthen rampart 3 metres high, and three gates are visualized by cuts through the rampart flanked on each side by towers (fig. 12). The fourth gate, the *porta decumana*, is visualized by a tunnel, in which graffiti refers to some of the finds that were collected on the site. Outside the fort, two parallel ditches have been reconstructed, although, from an archaeological point of view, this particular phase was equipped with only one (U-shaped) ditch. Nevertheless, the reconstruction provides a good notion of the dimensions of a Roman fort along the Lower Rhine Frontier. Moreover, it is the only Roman fort in the Netherlands that is not only located in the residential area of a town, but is it also almost completely preserved *in situ*. Therefore, Matilo is one of the key-sites of the UNESCO nomination of the Roman Frontier of Lower Germany (see also Willems *et al*. this volume).

Figure 12 The reconstructed fort in archaeological park Matilo, seen from the northeast. Photo: Buro JP

Acknowledgements

I would like to thank Chrystel Brandenburgh for allowing me to use the information from our report in preparation. Lourens van der Feijst provided the data from his excavations in Leiden and we productively discussed the preliminary results of his project. I would like to express my gratitude to Mathias Böhm of the Österreichische Nationalbibliothek in Vienna, who helped me to get an original scan of the Tabula Peutingeriana, that is used in Figure 1. Furthermore, I would like to thank JP Witteman for the use of his beautiful picture of the reconstruction of Matilo, as shown in Figure 12. Carol van Driel-Murray corrected the initial draft of this paper, for which I am very grateful. Any mistakes are my own.

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A pearl necklace: the Lower German Limes World Heritage nomination

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In the first half of 2014, two of the key documents for the proposed Lower German extension of the Frontiers of the Roman Empire (FRE) World Heritage Site were drawn up by the first two authors: the Statement of Outstanding Universal Values (SOUV) and the Comparative Analysis (CA). Both are formally required by Unesco as part of the nomination dossier. In the case of serial, transnational World Heritage properties like the Frontiers of the Roman Empire site, all the different parts need to comply with an overarching SOUV. The SOUV and CA for Lower Germany emphasise (1) the longevity and integrity of the military complex which included a series of major legionary bases, fleet installations, command posts and industrial facilities; (2) special aspects of a river frontier like transport logistics, harbour works and water management; (3) the wealth and special nature of the archaeological information contained in the waterlogged contexts of a lowland river, notably ecological find materials, ships and votive depositions. This paper reproduces the text of the SOUV and CA, as well as the set of site selection criteria and principles for the definition of buffer zones that was derived from the SOUV and CA. These documents are preceded by an introduction by the third author sketching the formal Unesco context of the nomination process and outlining the steps taken so far.

1 Introduction (TL)

In 1992, the Netherlands ratified the World Heritage Convention of 1972. With this ratification, the Dutch government stated that they will contribute to the warranty of natural and cultural heritage sites that are of universal importance to the history of humankind. The ratification also gives states the possibility to nominate new sites for UNESCO's World Heritage List. In the Netherlands, there are currently ten sites[2] on this list. A place on the World Heritage list can impart considerable added value since it means worldwide recognition of the Cultural or Natural values of an object or an area. Research has shown that for certain sites the benefits are relatively obvious – thus World Heritage Site status can act as a catalyst for more effective conservation, partnership working, civic pride, social capital, learning and education and additional funding and investment. But there may also be significant economic or social benefits for the nominated sites, as James Rebanks concluded in his study on the potential social and economic benefits from WHS inclusion, which was based on a comparison of 878 WH sites[3]. A nice example in this respect is the conclusion reached in the framework of the nomination of the Waddensea: having the World Heritage status for cultural heritage is like having a Michelin Star for restaurants.

1.1 Tentative list

In order to be nominated, properties first have to be placed on the so-called Tentative List. State Parties need to re-examine and re-submit their Tentative List at least every ten years.
In 2007 the Netherlands started with the review of the Dutch Tentative List, following the Global Strategy and using typical Dutch themes, like water management, civil society and design. The assessment and the selection of properties were made by an independent committee[4]. In 2010, this committee offered her advice to the responsible State Secretaries for Culture and Environment. The committee advised the State Secretaries that ten properties in the Netherlands fulfil the criteria of Outstanding Universal Value and comply with the Global Strategy and the selected Dutch Themes. The Dutch Part of the Limes took a remarkable place in this advice. Although it fulfilled the criteria of having an Outstanding Universal Value (OUV), the committee concluded that there was no possible siteholder for this section of the Roman Frontier, and therefore advised not to place the Dutch part of the Limes on the Tentative List.

As a direct result of this advice, the three provinces Gelderland, Zuid-Holland and Utrecht initiated an agreement on future cooperation regarding the Limes. This agreement, also signed by the Cultural Heritage Agency, included the statement that the three provinces were willing to prepare the nomination file and declared that they have the ambition to become siteholder once the Limes has become an UNESCO World Heritage site. Based on this agreement, the State Secretaries decided to place the Dutch Limes on the tentative list (which includes nine other sites)[5]. The new tentative list was adopted by UNESCO on August 17 2012. The cooperation document, signed by the three provinces and the state Cultural Heritage Agency, forms the framework for the Dutch Limes Association, which is preparing the World Heritage Nomination.

1.2 *The Limes as an extension of the Frontiers of the Roman Empire*

Within the system of UNESCO World Heritage, two types of nominations can be distinguished: new nominations and extensions of existing World Heritage sites. In the case of the Dutch Limes, the nomination would involve an extension of the existing World Heritage site “Frontiers of the Roman Empire (FRE)”. In both Britain and Germany stretches of the FRE have already been placed on the World Heritage List. Hadrian’s Wall in Great Britain was the first part to be listed in 1987. In 2005 the Upper German-Rhaetian Limes was also added, followed in 2008 by the Antonine Wall. When the Upper German-Rhaetian Limes was added to the FRE, the World Heritage Committee recommended ‘that the nomination be seen as the second phase of a possible wider, phased, serial transboundary nomination to encompass remains of the Roman frontiers around the Mediterranean Region’[6].

Given this recommendation, it seems a logical step to add the Lower German Limes to the existing ‘Frontiers of the Roman Empire’ World Heritage Site (fig. 1). Interesting is that other Limes countries are now also working on the nomination of the Roman Frontier. Besides the Netherlands, Austria, Croatia, Hungary, and Slovakia in Europe as well as Tunisia in North Africa have also placed their sections of the Limes on their Tentative Lists. In the long term, nomination of all these stretches could lead to a single serial transnational Frontiers of the Roman Empire World Heritage Site encompassing all relevant component parts of the “Roman Limes” at the height of the Empire in the 2nd Century CE. In this period the Limes stretched almost 6,000 km from the Atlantic coast of northern Britain, through Europe to the Black Sea, and from there to the Red Sea in the Near East and across Northern Africa to the Atlantic Coast.

1.3 *A transboundary nomination*

From the beginning of the process, it was clear that the nomination of the Dutch part of the Limes would be a transnational nomination together with the German states North Rhine-Westphalia and Rhineland Palatinate. Together, the German states of North Rhine-Westphalia and Rhineland-Palatinate and the Dutch provinces of Gelderland, Utrecht and Zuid-Holland cover the entire area of the Lower German Limes, featuring forts, ships, roads and civilian settlements along the river Rhine. There are three important reasons for a transnational nomination. Firstly, during the Roman era, this area formed a single administrative entity: the province of Germania Inferior. Secondly, by nominating the German and the Dutch part together, the entire gap between the existing parts of the FRE is closed. Thirdly, this increased the possibility for a successful nomination.

In 2014, the three Dutch provinces, the Cultural Heritage Agency and the two German States drew up an agreement on how to cooperate in the nomination process, how decisions will be made and what decision-making structures will be formed. Also included in the cooperation document is the formation of an advisory board to incorporate scientific knowledge in the nomination process.

Besides an agreement with the German states, the Dutch Limes Association also drew up an agreement with 25 Dutch Municipalities, which was signed in January 2014. The parties committed themselves to the common goal of placing the Dutch part of the Limes on the UNESCO World Heritage List and, furthermore, agreed on the processes involved in the preparation of the nomination (who is responsible for which part of the process).

1.4 *Defining the OUV’s as a starting point for the nomination*

Two key documents in the UNESCO World Heritage nomination process are the comparative analysis (CA) and the description of the Outstanding Universal Values (OUV’s). The CA aims to demonstrate that there are no comparable World Heritage sites with similar values on the list or likely to be nominated in the future, while the OUV demonstrates why a site is outstanding and unique and why it should be placed on the list.

The Dutch Limes Association asked Leiden University to formulate these documents. In defining the OUV’s, they were required to comply with the existing criteria of the FRE-WHS and take in to account the so-called Koblenz Declaration (2008), that defines the principles for the FRE-WHS as agreed by all member states of the Bratislava Group[7].

In the process of the World Heritage Nomination, the decision to involve Leiden University was in fact a logical one. Under the late Willem Willems, the University was able to access considerable experience, not only concerning Roman History and the Limes, but also about preparing World Heritage Nominations in general. Furthermore Erik Graafstal, being an associate researcher of Leiden University, added expertise in the field of comparative research of Roman Frontiers. Also including Carol van Driel, chairwomen of the Lower Rhine Limes Seminar, an excellent team was formed to define the OUV’s together with our German colleagues.

2 Statement of Outstanding Universal Values (WW)

2.1 *A very brief synthesis*

The part of the Roman Frontier known as the Lower German Limes (*Niedergermanische Limes*) ran for 380 km from

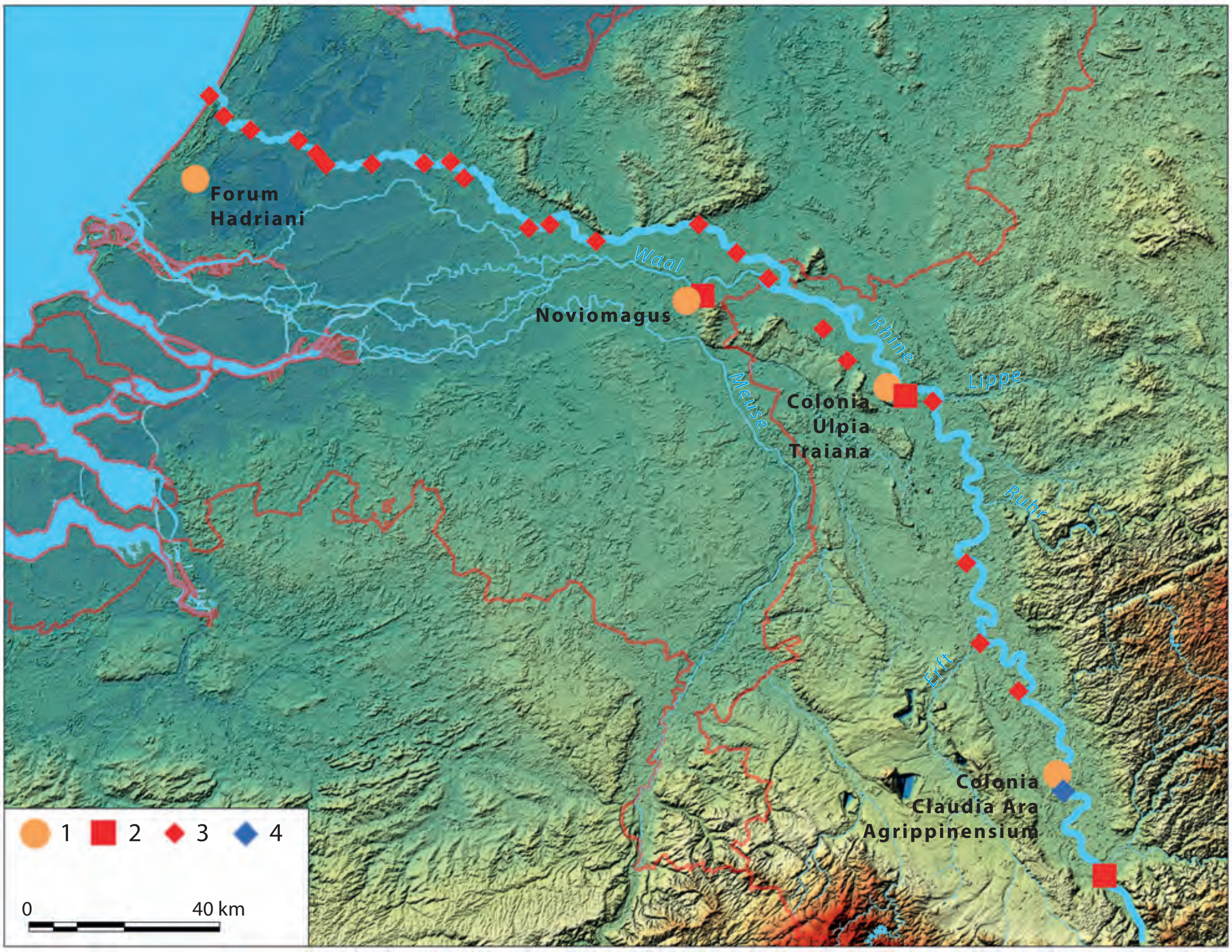

Figure 1 Elevation map of the Lower Rhine region showing the *civitas* capitals and main military installations of the Lower German frontier zone in the 2nd century; 1 *civitas* capital, 2 legionary fortress, 3 auxiliary fort, 4 fleet base (Menne Kosian, Rijksdienst voor het Cultureel Erfgoed)

Katwijk aan Zee at the mouth of the Rhine in the Netherlands to Remagen in Germany. It was established gradually, following the Caesarian and Augustan campaigns of conquest that led to its initial infrastructure. Some of the camps that were situated south of the river Rhine as part of the military support infrastructure for the conquest, subsequently became the springboard for the construction of additional forts and fortlets along the left levee of the Rhine from 40 AD onwards. These were supplemented with watchtowers near river bends, a clear indication that the system was intended to create a line to control movement and transport both across and along the river. This system was more or less completed before the 2nd century AD, the main period of the frontier at the height of the empire and remained in use in later years.

This part of the Limes was not a military bulwark in the sense of a closed and interconnected system of walls, towers and forts along more or less 'straight' line. Instead, it consisted of more loosely connected forts on the left bank of the Rhine, like a necklace consisting of pearls on a string, with legionary fortresses in between or in the immediate hinterland. Many military installations were strategically placed in relation to the junctions of major tributaries upstream and branch channels downstream, to control movement over water as well as over land for military as well as economic purposes.

Following a temporary breakdown in the last decades of the 3rd century, this system remained in use during the 4th and the first quarter of the 5th century as the forward part of a defence system that in this period relied on an infrastructure reaching deep into the hinterland over a wide area in Northern Gaul. Some new forts were constructed and some existing facilities were partially or completely refurbished while others were abandoned. Downstream, especially in the wetlands of the western part of the Rhine delta where habitation conditions had deteriorated significantly, the system may have served mostly to protect the trade route over the Rhine to the province Britannia.

This infrastructure continued to influence the development of the area long after the demise of the Roman Empire and some "pearls on the necklace" became important Merovingian centres and later the basis for the ecclesiastical and administrative infrastructure of the Carolingian empire.

2.2 The Outstanding Universal Value

In order to be admitted as World Heritage properties, nominations to the list must demonstrate the presence of Outstanding Universal Value as well as meet the conditions of integrity and authenticity. In addition, they must have an adequate protection and management system in place. This is reflected in the scheme.

The World Heritage Committee considers a property as having Outstanding Universal Value (OUV) if the property meets one or more of ten predefined criteria: six for cultural properties, and four for natural properties. Three of these six criteria have been found relevant by the Committee for the parts of the "Frontiers of the Roman Empire World Heritage Site" (FRE-WHS) that have been nominated and inscribed so far. The criteria that have been found relevant are criteria II, III and IV. This means that for new additions such as the Lower Rhine Limes, these same criteria are appropriate. They should be defined in such a way that they illustrate clearly what this part of the frontier adds to the FRE-WHS as a whole.

Therefore, the OUV of this part of the Frontier is expressed as follows:

Criterion ii

Definition: to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design.

The Lower German Limes formed part of the frontier throughout the entire existence of the Roman Empire and as such reflects the development of Roman military and related civilian facilities and infrastructure from its earliest beginnings in the last decades BC until the mid-5th century (the building programmes of the Roman emperors from Augustus to Valentinian III). It is also illustrative of the development of all successive phases of its military strategy from a period of conquest through a phase of stabilization and forward defence and ultimately to a system of defence-in-depth. In addition, its built legacy served as a backbone that shaped early Medieval civil and religious infrastructure.

Criterion iii

Definition: To bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared.

The Lower German Limes is the only area that formed part of the frontier throughout the entire existence of the Roman Empire, with an unbroken occupation. It is at the same time unique because of the presence of all elements that the military occupation could encompass, from legions in early and late forms to regular as well as irregular auxiliaries in addition to the fleet. It is also a prime example of a river frontier with exceptional (underground) preservation of wooden riverine infrastructure such as quays and ships.

Criterion iv

Definition: *to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history*.

As a river frontier which – in the delta area as well as the lower Rhine terrace upstream – has always been a wetland, the Lower Rhine limes exhibits unique testimonies of water management strategies and constructions, in addition to holding an extremely varied dataset encompassing organic materials and artefacts bearing unique information on frontier life and on vanished traditions such as notably that of river boat building.

2.3 Integrity and Authenticity

2.3.1 Integrity

Definition: Integrity is a measure of the wholeness and intactness of the cultural heritage and its attributes. Examining the conditions of integrity, therefore requires assessing the extent to which the property:

- *is of adequate size to ensure the complete representation of the features and processes includes all elements necessary to express its Outstanding Universal Value;*
- *which convey the property's significance;*
- *suffers from adverse effects of development and/or neglect.*

In contrast to several other parts of the Limes, the Lower German Limes is a river frontier that was never a closed line. The system was designed much as a necklace with strategically placed "pearls on a string" and irregularly sized stretches of river in between. There will have been a path, succeeded by a properly built road in between, but the river was itself part of the system. Of course the design was such that the system ideally must have been closed in the sense that all movement along, but also across the Rhine, could be controlled.

Nevertheless, it was never a single structure but a system with cleverly arranged, individual parts. This approach has also been chosen for the inclusion of parts in the World Heritage site and no attempt has been made to physically connect the constituent parts because they were never connected as one structure in the past either. Moreover, as the Rhine is a living river, ending in a wide delta and, until recently, still meandering, certain sections of the Roman Rhine have obviously not survived to the present day. Indeed, some parts disappeared – or rather: changed course – already during the Roman Period.

Nevertheless, geological and archaeological research has revealed that the Roman period river system is largely extant, along with most of the infrastructure on the south-western levee that is preserved below ground. Due to this location the preserved remains also include very high quality organic remains much of which has not been excavated. This provides for a very high level of archaeological integrity, with finds and features preserved in their original context in the soil matrix.

This despite the fact that sites when excavated regularly show evidence of original layers having been washed out and redeposited by the river, both during and after the existence of the Frontier. This is considered to be a normal part of any riverine site. It is a matter for discussion in an expert meeting if completely washed out sites should be considered. An example in case might be *Carvium*/Bijlandsche Waard, where large masses of stone indicate the presence of an eroded military establishment at the famous moles, the dam built by Drusus that Tacitus writes about. The remains are still present at the original location, but redeposited at a lower level, and they constitute a well-preserved and authentic deposit containing extremely valuable historical material such as the gravestone dredged up in 1938 belonging to the soldier Marcus Mallius from Genua, who according to his will, *Carvio ad molem sepultus est*, 'has been buried in Carvium, at the mole'.

The Lower German Limes does not have many standing remains preserved above ground. Some remains have been brought to light during archaeological excavations or other works, but wooden structures have only survived in the soil or under water level and in general, visible stone-built elements have been torn down in the Middle Ages and later to re-use the stone in a region that was for the most part a stoneless landscape. These fragments can be traced in many early- and late-Medieval structures, adding another layer to the history of the Lower Rhine region. Architectural elements of stone as well as foundations have been preserved below ground, imparting additional significance to the high scientific value of the organic remains. These form archaeological reserve areas all along the length of the river.

The World Heritage property is constituted by a selection of these areas along the Rhine, as well as some elements of supporting infrastructure in the immediate hinterland. In that way, the component parts represent the pearls on a necklace that accurately reflects the structure of the past.

Elements from the hinterland comprise *only* those elements that can be directly and exclusively related to the military infrastructure of the second century that embodies the concept of forward defence. Military works from the later period defence-in-depth system in the hinterland have been excluded. No elements from beyond the limes have been included, although a case could be made for those structures that belong to the second century, the period chosen to define the frontiers of the Roman Empire as a whole. It would thus not be appropriate to include military installations from an earlier time period (*e.g.* Velsen or Haltern and the other Lippe forts), but it would be possible and in line with the nomination to include military structures from the forward defence system in the second century, such as marching camps (*e.g.* Ermelo). This remains to be discussed in an expert meeting.

Particular areas have been chosen for inclusion in the nomination for the contribution that they make to the specific criteria for OUV in this part of the Roman limes as outlined above. Care has been taken to include the full variety of elements that is so typical for this part of the limes, both in a chronological sense as in covering the full range of variability. In that way, the wholeness of the property is adequately represented and its intactness is further supported by the fact that only sites with substantial archaeological integrity have been chosen.

The buffer zones around the proposed constituent parts need to be adapted to local circumstances and it should be stressed that buffer zones can be vertical as well as horizontal. In situations where individual components are preserved as elements of the landscape, buffer zones normally serve to control visible impacts of development. However, in situations where large scale organic deposits and materials are present or suspected below the surface, the buffers serve to maintain the physical integrity by controlling the groundwater table, as well as any urban development above the Roman remains. Buffer zones may also be extended over areas where archaeological substance in the ground is expected on the basis of scientific considerations, but for which there is as yet no firm evidence.

2.3.2 Authenticity

Definition: *Depending on the type of cultural heritage, and its cultural context, properties may be understood to meet the conditions of authenticity if their cultural values* *(as recognized in the nomination criteria proposed) are truthfully and credibly expressed through a variety of attributes including:*

- *form and design;*
- *materials and substance;*
- *use and function;*
- *traditions, techniques and management systems;*
- *location and setting;*
- *language, and other forms of intangible heritage;*
- *spirit and feeling; and*
- *other internal and external factors.*

The Lower German Limes is an archaeological property, and its location and setting are fully authentic. Virtually all of the component parts that have been included in the nomination are underground and remain unexcavated. They are the original remains and as such not only exhibit a high degree of integrity but also complete authenticity. A few parts have been excavated and have then been properly conserved and presented. All these elements retain their authenticity.

Because the Lower Germans limes is special also in that its authentic remains are almost all below ground and hence invisible, their value needs some form of translation in order to be understandable for the general public. This need has led to some reconstructions but also to a number of innovative projects to convey these values. Several sites are presented symbolically by expressing their boundaries on the ground surface in some way, while protecting their authenticity as well as the setting and integrity of the surroundings (fig. 2). Such symbolic representations are well suited to create a minimum level of public experience of the limes without resorting to reconstruction in its classical form.

The authenticity of the nominated property is ascertained in that it is truthfully and credibly expressed through incorporation of the full variety of Roman military and related civilian facilities. In form and design as well as function all elements from the chronological stages of military deployment are represented at their original location. In many areas, organic remains are demonstrably or plausibly present, so that here too the authenticity is credibly expressed in materials and substance.

Figure 2 Visualisation of the headquarters building of the fort at Arnhem-Meinerswijk by means of gabions (DaF-architects, Rotterdam)

3 Comparative Analysis (EG)

3.1 General description

In Roman times, the Lower German limes (LGL) marked and defended the outer boundary of the province of Lower Germany (Germania Inferior), physically defined by the river Rhine. From the late 1st century, this frontier was held by a cordon of *c*. 30 major military installations sitting of the left bank between Katwijk and Remagen. The forts were fairly evenly dispersed along a 380 km stretch of river – at an interval of 10 km on average, making this one of the more densely held frontiers of the Roman world. A little upstream from Remagen, the provincial boundary between Lower and Upper Germany was formed by a little brook named the Vinxtbach, a name that harks back to the Latin finis for 'border'. At this point, the imperial frontier crossed the river Rhine to continue as an artificial barrier mostly right down to the Danube – the Upper German-Raetian limes, protected as part of the Frontiers of the Roman Empire WHS since 2005.

3.1.1 Physical setting

In terms of natural geography, the Lower German frontier can be roughly divided in three compartments. Not surprisingly, these coincide with the administrative boundaries between Rheinland-Palatinate, Nordrhein-Westfalen and the Netherlands – the partners in the proposed extension of the FRE WHS. But the subdivision would have been very real and relevant for the Romans as well.

Lower Germany was very much a geographical theatre in its own right, being effectively separated from Upper Germany by the Rheinisches Schiefergebirge. Here, the 'Middle' Rhine is mostly confined in a steep-sided valley, which made river traffic difficult in pre-modern times. The first 10 km stretch of the LGL downstream Remagen really belong to this landscape. Then, at Bonn, the Lower Rhine plain (Niederrheinebene) of Nordrhein-Westfalen opens up. Here the Rhine meandered more freely migrating within its band of holocene sediments, about 3 km wide, sometimes eroding the edges of the glacial Lower Terrace (Niederterrasse). This terrace was normally flood-free, and with few exceptions the Romans planned their military installations at the edge thereof, preferably at points where a river bend touched it.

Just past the German-Dutch border, the river delta is announced by the bifurcation of the Rhine and Waal. Here a more marginal landscape of sandy, elevated channel-belt and levee deposits (Dutch: stroomruggen) took over, largely determining where habitation and cultivation was possible – and where not. For the Dutch sector, there is a relevant further subdivision between the Nederrrijn, which has remained an active river since the Roman period, and the Kromme Rijn and (west of Utrecht) Oude Rijn that have largely silted up since the 3rd century. This subdivision neatly coincides with the provinces of Gelderland on the one hand, and Utrecht and Zuid-Holland on the other.

The river Rhine, even the residual gully of the Kromme and Oude Rijn, is a majestic feature of the historic environment. However, it is important to realize that the Roman riverscape would have looked incomparably different from our experience. The 19th- and 20th-century campaigns of river regularization have completely changed its aspect. Recent research in the Dutch river delta as well as Nordrhein-Westfalen has shown that in Roman times the river plain would have been a complex, constantly rejuvenating system of main beds, older channels and cut-off oxbows slowly silting up, providing shelter and harbourage at many points.

Of the stronger terrain features, the ice-pushed ridges in the Xanten, Kalkar, Kleve and Nijmegen areas deserve mention, as they have demonstrably influenced the positioning of military installations from the very first stage (*c*. 19 BC-AD 14). Further south, the anatomy of the Mittelrheintal clearly determined the planning of installations like the fort at Remagen which was placed at a marked 'bottle-neck' position.

3.1.2 Historical and archaeological resources

One of the special aspects of Lower Germany is the very dense coverage of its history, geography and peoples by Roman geographers and historians. This holds particularly true for the formative stages of the province and its frontier. This is in large part explained by the involvement of prominent members of the Augustan dynasty, like Drusus, Tiberius and Germanicus, in the attempted conquest of Germany. More coincidentally, the historian Tacitus had stayed in Belgian Gaul and the Rhine districts when his father was head of financial administration for these provinces. This explains his intimate knowledge of the tribes and histories of the area, culminating in his famous account of the Batavian revolt of 69. Pliny the Elder, writer of the Natural History, had served as a cavalry officer at Xanten (a piece of horse gear inscribed with his name was found there!) and taken part in a campaign to the Frisian coast in 47. Later prominent visitors include Trajan who received the news of his election as heir presumptive to the purple while residing in Cologne as governor of Lower Germany. In 122, Hadrian – a former commander of the 1st Legion in Bonn – passed through the province on his way to Britain, where he was to inspect the construction of his famous Wall in Britain. On this trip, incidentally, Hadrian was accompanied by his secretary Suetonius, the famous biographer.

A different type of written evidence is provided by inscriptions, graffiti and stamps. Some of these, like military brick-stamps and bronze diploma's issued at honourable discharge, belong to the regular stock of Roman provincial archaeology, but they are essential for reconstructing the military occupation of the frontier installations. While Lower Germany is well provided with this material, its collection of early Roman military tombstones, notably from the Bonn-Nijmegen sector (the so-called Rheinische grabstelen), is something special in northwest Europe, both in numbers and quality.

The LGL boasts an excellent research tradition and a staggering mass of excavation data mostly accumulated since the late 19th century. Some of the great advances in the study of Roman fortifications originated here, like the groundbreaking work of Lehner at Xanten, Koenen at Neuss, and Van Giffen at Valkenburg. This research tradition has resulted in a particularly strong infrastructure of universities (U) and museums (M) at Bonn (U/M), Cologne (U/M), Xanten (M), Nijmegen (U/M), Amsterdam (U) and Leiden (U/M). In more recent times, the Bodendenkmalpflege offices of the respective German Länder have taken up a crucial role in research and documentation. In the Dutch situation, part of this has fallen to the responsibility of the State service (formerly ROB, now RCE) and the municipal services of, for instance, Nijmegen, Utrecht, Leiden and The Hague.

As both the German Rheinland and the central/western Netherlands continue to be very dynamic areas, the LGL has seen a surge in developer-funded archaeology in the last two decades, resulting in a spate of excavation reports. A final positive element is the long gestation of this nomination, which has been fermenting since the late 1990's. As a result, up-to-date inventories are now available, for Nordrhein-Westfalen through the project Bestandserhebung Niedergermanischer Limes (since 2005), for the Netherlands through ongoing digital documentation at the RCE.

3.1.3 Historical outline

The first Roman military presence on the Rhine is now understood to date back to *c.* 19 BC, when a two-legion force was based on the Hunerberg at Nijmegen, soon to be followed by another major base at Neuss (*c.* 16 BC) and smaller installations at Bonn and Moers-Asberg. The precise purpose of this first disposition is still hotly debated. It certainly served to monitor the German tribes that had been recently allowed to settle on the left bank, most famously the Ubians and Batavians, as a measure to secure the northern periphery of Gaul. However, this tribal reshuffling appears to have elicited raids by others, like the Sugambri in 16 BC. Whether planned or not, the punitive campaigns that followed soon developed into a major military commitment in Germany. For a while (*c.* 7 BC-AD 9), it looked as though a great-German province roughly defined by the rivers Lippe and Lahn was underway, with its capital at Cologne. This perspective was shattered by the massacre of Varus with three of his legions in the Teutoburger forest in AD 9, and could not be reversed by the punitive campaigns of Germanicus (AD 14-16).

Interestingly, when the Roman army redeployed on the left bank of the Rhine after AD 9, it largely reverted to the bases that had served the German campaigns. In Lower Germany, two legions were based at Xanten, opposite the Lippe, thus controlling the major tribes of the North German plain, while another army group settled at the old logistic base of Neuss. The first deployment on the Lower Rhine shows a marked preference for concentrating forces at a few main bases (*Schwerpunktlager*), with a number of minor installations providing local security, logistic support etc. With four legions and some 30 auxiliary units, totaling *c.* 40.000 soldiers, the Bonn-Nijmegen area retained the largest concentration of military forces in the Roman world up to the late 1st century.

Feeding this force posed an enormous challenge. It has been calculated that nearly 2,000 shiploads of grain a year were needed to meet its needs (not counting fodder for horses), while the dependent communities of servants, soldiers' families and traders go a long way to double that figure. If we add staple items like wine, olive oil, beer and meat it is clear what the river Rhine must have meant to the Romans: a vital transport corridor to link up with crucial areas for army supply ranging from southern Spain to Britain. Recent research has suggested that the earliest forts in the western Netherlands were planned and manned with the specific purpose of securing and supporting the supply traffic that passed through the Rhine delta.

There were other non-defensive purposes, like monitoring the integration process of recently resettled tribes on the left bank. The Roman army can be shown to have been involved in the development of the capitals of the administrative districts (civitates) of the Ubii, Cugerni, Batavi and (later on) the Cananefates, at Cologne, Xanten, Nijmegen and Voorburg, respectively. The internal peace-keeping role of the army is highlighted by Roman responses to the Gaulish rebellion of 21 and the Batavian revolt of AD 69, which brought a legion back to Nijmegen (*c.* AD 70-104).
The involvement of the Tenth Legion in building the civic infrastructure of the Batavian civitas is a particularly fine example of the integrative role of the Roman army and frontiers.

By the early 70's, a dense chain of military installations had gradually clustered along the Lower Rhine for a number of reasons (warding off external aggression, internal security and development, supply logistics), resulting in the most strongly held line in the Roman world at that point. After the institution of the province of Lower Germany *c.* AD 85, a few changes were made in the positions and sizes of forts, and the last gaps plugged. The LGL thus was the first frontier of the Roman world to reach the fully-fledged form of the classical stage of limites as defined by the FRE WHS. Few changes occurred thereafter, except for the gradual rebuilding of most forts in stone in the course of this ‘happiest age of mankind’ (according to Edward Gibbon in his famous book Decline and Fall of the Roman Empire 1776-1788). An interesting development is the coastal extension of the LGL south of the Rhine debouchment in the mid-2nd century, reflecting increasing concerns for seaborne raiding.

Fundamental changes occurred after the middle of the 3rd century, when the Roman provinces periodically suffered from a vicious circle of economic decline, external aggression and internal strife. In the late Roman period, exposed frontier provinces sometimes moved to the centre of politics, with their populations and armies supporting imperial candidates who seemed better placed to serve their interests, like the self-proclaimed emperor Postumus who ruled the northwestern Roman provinces from Cologne (AD 260-268). The answer to this was a partition of imperial power, with junior-emperors often administering the northwest, usually from Trier, like Constantine the Great (AD 306-312).

Constantine’s presence here *c*. 310 marks the first of a series of reinstatements of the much-exposed Rhine in the course of the 4th century. Forts were rebuilt, sometimes reduced, but with much stronger defences, while completely new types of installations were also developed, like the bridgehead-fort at Köln-Deutz. The ability of self-contained defence appears to have gained in importance, while elements of a system of ‘defence in depth’ along the penetration axes to the interior seem to acknowledge the increased threat of Germanic incursions. While most of this investment is clearly concentrated on the old core sector upstream of Nijmegen, the area downstream reverted to its role of a transport corridor catering between England and the Continent, with Valkenburg and Brittenburg as the main hubs in the Rhine estuary.

3.2 Key features and values

3.2.1 Chronological span

The key feature of the LGL clearly is its early origin and longevity. Ranging from *c*. 19 BC to about AD 440, when the capital of Cologne was taken and occupied by the Franks, the cordon of frontier installations in Lower Germany encapsulates the complete development of Roman frontier policies and dispositions as briefly outlined above. From all main stages, various types and sizes of installations are included in the proposed nomination. From the classic age of limites, in particular, the complete spectrum of frontier installations is represented, ranging from the stone-built watchtower at Neuss-Grimmlinghausen to the legionary fortresses at Bonn – a difference of scale of 1:30.000 in terms of internal space. Together the successive military dispositions reflect the changing Roman policies and attitudes towards the populations under their control on the fringes of their Empire. Contained in several of the proposed sites is evidence of events that shaped the frontier’s history, like the destruction layers of the Batavian revolt found in most Lower Rhine forts and the victims of the first great Frankish incursions in 259/60 at Krefeld-Gellep.

Given its longevity, the LGL illustrates the complete evolution of Roman military architecture and infrastructure up to the late 4th century. In fact, Roman archeologists are largely confined to Lower Germany (together with Augustan Germany) when it comes to studying the development of the ‘classic’ Roman forts, recognizable by their playing-card shape, their typical defenses, and regular internal plan. This is particularly true of early legionary bases at Nijmegen, Xanten, Neuss and Bonn, where the internal accommodation appears to reflect a highly stratified view of human society, with the officer’s mansions mimicking the luxurious homes of the Mediterranean municipal elite. At the same time, the translation of received forms in local materials, like timber and wattle and daub, is evidence of the Romans’ pragmatism and adaptability to different circumstances. Another aspect of this is the way Roman military planners used the local terrain to stage their monumental gestures, as expressed, for example,in the fort frontages and prominent structures erected in Cologne, Xanten and Nijmegen, sending their messages into Germany.

Perhaps under-estimated as a cultural resource is the late Roman period. Recent research at Krefeld has shed light on a complex 4th-century development, while Dormagen and Kalkar have provided evidence for the fort reductions known from elsewhere. This period also saw new foundations like Qualburg, and innovative designs like the small installation at Haus Bürgel or an apparent trapezoidal fort at Alpen-Drüpt strongly resembling Altrip in Upper Germany. Several forts, like Bonn and Utrecht, remained in use in the early medieval period, thus laying the foundations for the first stage of urbanisation in Lower Rhine area.

3.2.2 Systemic integrity

Because of the multiple functions of the river Rhine as a defensive barrier, a formal boundary and a logistic feeder, most elements of the military system of Lower Germany were confined within this single narrow strip on the left bank of Rhine. On most other Roman frontiers (and this goes for the early Roman disposition in the Danubian provinces as well), the legionary bases, the Empire’s ‘main strength’ (Tacitus, Ann. IV.5), were kept in a rearward position, as a strategic reserve. This is why the artificial frontiers lack this important element, the nearest legionary fortress in England sitting 120 km south of Hadrian’s Wall.

For the same reason, the Lower German river frontier has this additional element of the Roman fleet, the Classis Germanica, based at Cologne-Alteburg. Furthermore, because the governor of Lower Germany also acted as commander in chief of the forces in his province, he chose to reside close to the main legionary bases in the German Rheinland, *i.e.* at Cologne – adding his imposing palace (praetorium) to this proposed extension of the FRE WHS. The dossier thus uniquely includes the complete hierarchy and diversity of Roman military installations.

With the legions so well represented, the LGL illustrates the remarkable range of activities performed by the Roman army in provincial and frontiers settings. Some of these pertain to the army's own needs, logistic or training facilities. A spectacular recent discovery are the scatters of practice camps in the environs of Bonn and Xanten, the bases of Legio I Minervia and XXX Ulpia Victrix, illustrating the proverbial discipline of the Roman army. Interestingly, the first specimens have now also turned up at auxiliary forts, like Till-Steincheshof.

However, the Roman army is culturally relevant to us not just as a military institution but as a living community of peoples of diverse backgrounds. This is why the extensive extra-mural settlements of traders, artisans, shopkeepers and military families (called canabae and vici in the case of legionary fortresses and auxiliary forts, respectively) are an indispensable mirror element in the present nomination, as are the extensive cemeteries that girded these conurbations. Equally important for understanding the cultural exchange and syncretism in Roman frontier communities are the cult sites that attracted a specifically military following, like the sanctuary of Vagdavercustis at Kalkar.

A recent study of the Thirtieth Legion based on inscriptions from all over Lower Germany and beyond, shows the sheer scale and diversity of its employment. Thus, detached personnel of the legions of Lower Germany can be seen at work at military brickworks at Dormagen, Xanten and Holdeurn, stone quarries like the Drachenfels, and the lime kilns of Iversheim. The fleet was deeply involved in this industrial-logistic complex, as is illustrated by its role in supplying the stone material for the forum of the civil town at Xanten. The Lower German dossier singularly charts the role of the Roman army as a default development force, also of basic civil infrastructure, as is illustrated by the strong military element in the peripheral town of the Cananefatians at Voorburg.

3.2.3 A special aspect: river transport and water management

The LGL presents us with a special aspect of river frontiers: the interconnection between military infrastructure and security arrangements on the one hand, and logistics, river transport and water management on the other. The choice of sites for the forts in the western Netherlands suggests that the control of the local maze of waterways, notably the side-rivers that exposed the Rhine corridor to waterborne raiding from the north, was a key consideration for Roman military planners. The provision of closely supervised harbourage at regular distances also clearly played a major role here.

With few exceptions, the forts in Lower Germany appear to have been provided with timber quays and strong revetments over hundreds of meters. In contrast to other FRE WHS stretches, well preserved wooden structures are a familiar feature for Dutch archaeologists digging at sites such as Vechten, De Meern, Woerden and Valkenburg. More recently, a similarly elongated riverfront has been documented at Moers-Asberg, while there is every reason to believe that things are no different at Krefeld-Gellep, Kalkar and Till-Steincheshof. Of a different order would be the artificial harbour basin suggested by remains of a stone mole in front of the legionary fortress at Bonn, and the harbour construction at Voorburg.

A similar stone mole, known from literary and epigraphic sources, was constructed at Herwen at the bifurcation point of the Waal and Nederrijn, in order to increase discharge via the latter branch. At the base of the Rhine delta, a canal was dug between the Rhine and Meuse estuaries in the early Roman period, the so-called fossa Corbulonis, 'in order to avoid the dangers of the sea' (Tacitus, Ann. XI.20.2). A second artificial canal is suspected south of the De Meern, connecting with the Hollandsche IJssel.

The importance of the Rhine as a trade axis is clearly indicated by the remarkable cache of votive offerings dredged up at Colijnsplaat in the Oosterschelde, on the route to Britain. The role of Trier and Cologne in this largely civil trade in wine, fish sauce, pottery etc. comes out clearly. Watchtowers placed at propitious points in river bends would have surveyed this traffic, while the arrangement found at a tower at Xanten-Lüttingen is suggestive of controlled use of the tow path that would have been continuously provided on the left bank.

3.2.4 A rare resource: the materialities of a river frontier

Being largely a lowland river, and feeding one of the largest troop concentrations in the Roman world, the Lower Rhine was the natural habitat of a specific type of transport vessel: the river barge. Some 18 of these, of a distinctly regional design (Prahme rheinischer Bauart), have been found, mostly accidentally, the majority of them in the harbour fronts of forts (fig. 3). Dozens of these must still await discovery in the river beds adjacent to forts, particularly in the western Netherlands where the fossilization of the river has prevented erosion of the ship remains. However, the same conditions

Figure 3 The Roman barge De Meern 1 under excavation in 2003. Note the preserved cabin walls (left). To the right a selection from the unique cache of wood-working and other implements found in the cabin: a plane, a hand saw and a *dolabra* (Rijksdienst voor het Cultureel Erfgoed)

probably apply to the oxbows and residuals channels on which several forts in Nordrhein-Westfalen are situated (*e.g*. Moers-Asberg, Kalkar, Till).

Apart from ships, the Lower Rhine area is also famous for the practice of votive offerings of prestigious items of military equipment in aquatic contexts, a regional tradition going back to the Bronze age. Roman helmets, swords and horse gear have been dredged up at a number of places along the rivers Lower Germany, with marked concentrations as at Nijmegen, suggesting established cult sites. A less well-known aspect of the Roman military sites in the Lower Rhine area is that the same type of weapon depositions regularly occurs along their river frontage as is illustrated by finds of helmets and/or swords at, for instance Roomburg, Woerden, De Meern and Vechten (fig. 4). Dozens, if not hundreds of such votive offerings are probably still to be found along the river frontages of all LGL forts.

For the same reason, the silted-up river-beds in front of the forts are veritable archaeological treasure chests in general – not because of individual spectacular finds but because of the masses of mundane material. These contexts literally functioned as the rubbish-dumps of the local garrisons and settlements, accumulating sewage and kitchen waste, broken vessels and other discarded items, as well as cuttings and offal of small industries, like butcheries, tanneries etc. The waterlogged conditions and clay sediments typical of residual river channels virtually guarantee the perfect preservation of perishable materials like leather, wood, seeds etc. (fig. 5). These deposits are a unique of source of information on the economy and material culture of the military settlements in the frontier zone and the extended communities that depended and fed upon them.

Figure 4 Bronze parade-helmet mask from Leiden-Roomburg, *c*. AD 80-125. The piece was ritually deposited in the Corbulo canal next to the Roman fort (Rijksmuseum van Oudheden, Leiden)

Furthermore, the lowland and wetland settings of most LGL sites mean that the soil conditions (mineralogical composition and position in relation to groundwater table) of 'sealed' archaeological contexts like wells, deep pits and ditches contain a wealth of environmental and nutritional information, like well-preserved pollen, seeds, pits and small animal and fish bones. A recent Dutch research project has demonstrated the potential of this material for reconstructing the natural environment of the forts as well as food procurement strategies of the Roman army.

There are two categories of perishable materials which the Roman army used in great quantities that deserve special mention: leather and wood. In normal circumstances, both decay within a matter of years or decades, leaving many Roman fort sites in Europe bereft of these materials. Along the LGL, in contrast, especially in the Dutch river delta, organic materials have been preserved in abundance. Due to the high ground water tables in the western Netherlands, it is common for military timber structures to have survived in the subsoil. Thus, the foundation posts of the defences, roads and internal buildings of the first installation at Alphen have

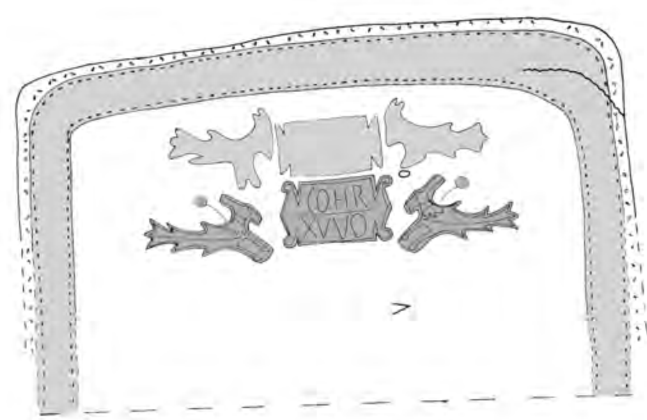

Figure 5 Leather shield cover with cartouche of the owner's unit, the *Cohors XV Voluntariorum*, recovered from a pit in the vicus area of the fort at Leiden-Roomburg (drawing by C. van Driel-Murray)

allowed a year-by-year reconstruction of the building process of a Roman fort (*c*. AD 41-43). Similarly, extensive year-ring analysis of timber revetments of the limes road in the western Netherlands has resulted in a detailed picture of successive construction and repair campaigns. Recent analysis of the ship finds from the Netherlands has proved the existence of local ship yards and identified sources of timber supply sometimes a 100 miles away. Leather, like wood, is an incomparable source of information about local industries, clothing and the composition of the population. Not surprisingly, some of the most important recent advances in environmental reconstruction as well as Roman military provisioning strategies have come from this area.

A paradoxically positive aspect of the townscapes that have developed in much of the Lower Rhine area is the protective cover provided by post-Roman construction layers. At places as different as Remagen, Bonn, Dormagen, Utrecht and Valkenburg post-Roman deposits sealed by occupation levels can be shown to have prevented these sites from being extensively damaged by ploughing, clay-digging, etc. At Bonn, a recent inventory has shown that *c*. 85 % of the former Roman fortress has been preserved between the foundations and cellars of modern building – and most of this surprisingly well at that (fig. 6). Similarly, the fort at Utrecht, under the Medieval cathedral, has recently been confirmed as one of the best preserved forts of the LGL.

3.3 Comparison and discussion

3.3.1 The LGL as a complement to existing parts of the FRE WHS

In assessing the particular contribution of the LGL to the transnational FRE WHS site, it is important to realise that the earlier nominations of Hadrian's Wall (1987), the Upper-German/Raetian limes (2005) and the Antonine Wall

Figure 6 Excavation of the legionary bathhouse at Bonn in 2012, showing the excellent state of preservation of the Roman remains under the modern townscape (LVR-Amt für Bodendenkmalpflege)

(2008), all represent a specific stage and special variant of Roman frontiers: the 'artificial' barriers of the 2nd century. This means that there is a difference in chronological scope. While the Hadrian's Wall complex contains a few late 1st-century forts and remained in operation in the late Roman period, the German limes essentially dates from the early 2nd century and was given up in AD 254 (Raetia) and AD 260 (Upper Germany). The Antonine Wall functioned for two decades at most (*c*. AD 142 – 158).

Perhaps more importantly, the artificial frontiers represent just one element, if a particularly manifest one, of the larger military disposition, the 'preclusive' security cordon watched by a continuous series of towers and backed up by auxiliary forts. The British and German parts of the FRE WHS do not comprise the legionary bases which figure so prominently in the proposed Lower German extension, nor the wider logistical infrastructure that supported the army in the frontier provinces. In the Lower German situation, all elements are superimposed on the left bank of the Rhine and represented in the nomination. The foregoing survey has highlighted various aspects of the Lower German army's involvement in mining, industry, logistics, building activity. In contrast to the British and German frontiers, the towns of the Lower German frontier districts were very much part of the same military cordon on the left bank. Although they are not normally included in this nomination (except for military-promoted Voorburg) urban communities, and therefore military-civilian interactions, are firmly part of the frontier landscape of the LGL.

There are also differences between the proposed Lower German nomination and that of the middle Danube. Here, the Roman military disposition was much slower to concentrate on the line of the river Danube. Until the late 1st century, most of legions and a good part of the auxiliary units were stationed in the interior of the provinces of Noricum, Pannonia and Dalmatia. As a consequence, the crucial formative stages (*c*. 5 BC-AD 85) are less completely covered in the Middle Danube nomination. If we compare the resources of the constituent and proposed parts of the FRE WHS, the narrative and future study of early Roman military architecture will largely focus on Lower Germany, while the Middle Danube is clearly the leading area when it comes to late Roman military architecture. So far, rather less evidence of the resources and aspects covered in 3.2 has come to light in the middle Danube area. In these fields, the LGL, and the Dutch river area in particular, possesses an unrivalled potential.

The particular contribution of LGL, then, is that is encompasses the complete evolution, from the very earliest stage, of the Roman military disposition in the widest sense, including the legions and their manifold activities, the fleet, the command structure, etc. Of the classic 2nd-century frontiers, the LGL had most of its hardware in place shortly after AD 70, making this one of the earliest linear arrangements in the Roman world with the potential performance of a 'prelusive' frontier. Of particular interest is the system's adaptation to a complex and dynamic natural environment, notably in the Rhine delta, and its symbiosis with the water infrastructure generally. This is reflected in specific elements like harbour installations and water works which figure prominently in the proposed nomination.

3.3.2 The LGL (and wider FRE WHS) in comparison to other fortified boundaries[8]

Perhaps surprisingly, fortified boundaries are a much under-represented category on the WH list. According to the thematic framework of the Filling the gaps report by The International Council on Monuments and Sites (ICOMOS, 2005), this category consists of the Great Wall in China (property nr. 438), the fortifications of Derbent (1070), and the Defense line of Amsterdam (759). The latter, however, is of a totally different nature. Like the New Dutch Waterline (Dutch tentative list) and the Ligne Maginot (France, 1928-1936), it served as a linear bulwark, designed to withstand attack in force by modern armies with heavy firepower. The Roman Limes, in contrast, was never meant as a line of static defense, with the Roman army entrenched behind a river or a physical barrier. By their organization, equipment, tactics and training, Roman legions and auxiliary units were specialists in mobile, offensive warfare. If 'defensive' in any meaningful way, Roman frontiers served as jumping-off points for interceptive pursuit or punitive reprisal, or, ideally, pre-emptive strikes far beyond the limes.

There is a second crucial difference with most fortified boundaries in recent history in that limites were not understood to mark the extent of Roman rule – they weren't territorial boundaries in the modern sense. Rome always controlled a wide buffer of polities and tribes beyond the limes through formal agreements of client-rule or 'friendship' backed up armed suasion, money and occasional punitive campaigns. In this game, the physical demonstration of Roman power as expressed in the forts and towers placed on the edge of Empire was a crucial element, their monumental stone facades showing Rome's mastery over terrain, natural resources and peoples alike.

An authentic aspect of the LGL and the Danube limes (such as the Austrian Tentative List) is that they represent a special variant of fortified boundaries: the 'river frontier'. Throughout history, rivers have been used by empires to stake claims of hegemony – the very origin of the Rhine and Danube limites goes back to precisely such claims by Caesar and Augustus, respectively. However, as fortified boundaries river frontiers are scarcely represented in the human cultural record (and are absent from the WH list). For all their attraction as markers of space, rivers really are poor separators of human communities, their valleys often functioning as zones of exchange rather than cultural divides. This is certainly true for the LGL, the tribal communities on both sides of the Rhine sharing much the same material culture and values originally.

In functional terms, the limes provided a line of control to monitor cross-frontier movement and trade, and ward off small- and medium scale security threats in the range of brigandage and raiding. The preclusion of raiding was important, as this was an endemic and potentially escalating element in the martial culture of the tribal societies that lived beyond Rome's frontiers. This aspect invites comparison with early medieval barrier systems like the Dannevirke (Schleswig-Holstein) and Offa's Dyke (Wales), or perhaps the medieval Landwehre that surrounded some of Germany's early polities. However, these earthworks are generally less elaborate and articulate, and therefore less informative, while there are also issues with their integrity and state of documentation. Perhaps more importantly, they are incomparable to the frontiers of the Roman Empire in that their extent was local and they divided essentially similar communities.

More directly comparable would be fortified boundaries that monitored the edge of other pre-modern empires that were exposed to nomadic infiltration or raiding. In the geo-cultural regions spanned by the former Roman Empire, the closest parallels are the barriers in the ancient Near and Middle East (*e.g.* Amurrit wall, Cappadocian Wall); the various barriers built in Central Asia between the 2nd century BC and the 6th AD, notably the Sassanid Wall; and the Anastasius Wall that protected the Byzantine Empire.

As a cultural monument and resource, the Frontiers of the Roman Empire are far more complex than the cited examples because of the sheer variety of physical and human geography negotiated, and the corresponding variety of installations, barrier elements and deployment patterns designed to meet specific challenges. The archaeological resources contained in this serial property are unsurpassed in their varied content and staggering mass, opening up endless possibilities for the comparative research of every thinkable aspect of life in and around the military frontier communities. This is complemented by a range of historical sources and documentary evidence that directly pertains to the conditions of life and service on the frontiers, such as discharge diplomata, countless inscriptions, and even parts of military archives as preserved in the Vindolanda tablets on Hadrian's Wall or papyrus records in arid regions.

Perhaps, the principal contribution of the Roman frontiers to the collective human experience resides in values signaled as under-represented in the existing WH list by the 'Gaps' report. On a practical note, the Roman frontiers represent an impressive series of 'creative responses' to natural and cultural challenges (terrain, building materials, food supply, local security issues, etc.). The 'utilization of natural resources' by the Roman military in a pragmatic and often sustainable fashion is a quality that keeps surprising even the most experienced student of Roman frontiers.

Roman frontiers are all about 'movement of peoples', another criterion underlined by the 'Gaps' report. What is important here is not so much the obvious regulatory function of limites, as the ongoing process of incorporation of indigenous communities through service in the Roman army. Through recruitment, occasional redeployments, trade and marriage, the imperial frontiers continuously circulated and integrated people, material goods, cultural forms and spiritual ideas, to form that wonderfully syncretistic culture known as provincial Roman civilization.

Also among the under-represented qualities are monuments as 'expressions of society'. One of the functions of Roman limites was to send a powerful message to the amalgam of provincial populations. Orators like Aelius Aristides likened the frontier works to a giant city wall, guaranteeing the security of the Empire's citizens. In a wider sense, the frontiers of the Roman world have been seen as answering 'a need to define the limits of a hybrid and transformational Roman identity in the particular context of territory outside imperial control that was occupied by 'barbarians''. The transcending cultural meaning of Roman limites perhaps ultimately resides in the frontier communities, military and civilian, developing and expressing their own identities and couleur locale in dialogue with ideals of civilized life summed up in the Roman term *humanitas*.

4 Boundaries and selection criteria (WW)

Definition: For nominated properties, boundaries should be drawn to include all those areas and attributes which are a direct tangible expression of the outstanding universal value of the property, as well as those areas which in the light of future research possibilities offer potential to contribute to and enhance such understanding.

The nomination of the Frontier of *Germania Inferior* (Lower Germany) is not one single property, but it is a *serial* nomination consisting of a number of spatially separated component parts in two countries, which makes it *transnational* as well. It is intended to become part of an even larger serial transnational property, the Frontiers of the Roman Empire World Heritage Site.

As such, it is thus not an independent nomination, and the rules of UNESCO's World Heritage Committee require that it should add something to then existing World Heritage Site. What is so special about the Lower German Limes has been outlined in the previous sections. The next step is to identify which sites in the Netherlands and in Germany should be selected as component parts of the nomination, because they contain the elements or attributes that add something new. In addition, they must be linked. The *Ittingen Recommendations* (WHC-10/34.COM/9B, 2010) clearly state a serial nomination must not "lead to a mere catalogue of sites without an adequate definition of the functional links between the component parts". For cultural sites they require that "component parts should reflect clearly defined, cultural, social, historical, or functional links over time".

4.1 Selection criteria for properties to be included as component parts in the nomination

It is crucially important that taken together, all aspects that have been highlighted as being of specific importance for the Lower German Frontier, the specific OUV (as opposed to the general OUV of the Limes as a whole that is currently being revised), are represented on one or more component parts. Looking at the OUV as described in chapter 1, sites should be selected on:

- Representation of all elements of the Roman Frontier, to illustrate the great diversity
- Time depth, to illustrate the long period of use, and
- Preservation, to illustrate the exceptional preservation conditions that are the reason for the survival of certain types of sites constructed from wood and other organic material,.

Given the aspect of time depth, it is important to include sites from the conquest phase, the limes phase proper, as well as elements from the late Roman defence system, so that the nomination includes examples from all different elements of the limes system. It is therefore necessary to select one or more sites of the following types:

- Relevant part of the provincial capital (*i.c.* the *praetorium* in Cologne)
- Early Roman legionary camp
- Legionary fortress
- Late Roman legionary fort
- Canabae legionis
- Early Roman auxiliary camp
- Auxiliary fort with a well preserved timber phase
- Auxiliary fort with a well preserved stone phase
- Vicus adjacent to fort (*Militärvicus*)
- Fortlet
- Watchtower
- Practice camp cluster
- Fort across the Rhine
- Late Roman fort
- Late Roman burgus
- Some unexcavated cemeteries associated with one or more of the above
- Military sanctuary
- Naval base/harbour/quay
- Ships
- Elements of infrastructure: limes road (wood, metalled), bridge, causeway, culverts and the like
- Water management: dug canal, water supply system, dams and moles
- Sites with potentially well preserved domestic organic remains such as leather, textiles and wood.
- Military industrial facilities: lime kilns, pottery kilns, tile kilns, quarry?

Some features should be noted about these site types. First, all should be included by at least one example, preferably the prime exponent. In specific cases, such as the famous canal that was dug under general Corbulo to connect the Rhine and the Meuse behind the dunes, the *fossa Corbulonis*, care should be taken to ensure that the best surviving parts are included in the nomination.

It is of course not necessary that these are all represented in each country separately, so if we have at least one, that is fine. On the other hand, it is to be recommended that where more examples are included it should be ensured that the sites are evenly distributed between Germany and The Netherlands.

Secondly, as these elements are drawn from different periods, they may occur in a single location, associated stratigraphically or spatially. Obviously, such associations are advantageous for inclusion in the nomination.

Thirdly – while including evidence of time depth is important, this evidence should *only* contain those sites that are actually more or less on the line of the limes of the second century AD. In order to stick to the principles of the Koblenz declaration, it should *not* be "diluted" by including inappropriate sites such as Roman military camps from the conquest phase in what later became the foreland of the Limes (such as the camps along the Lippe or Oer-IJ), or post-Limes fortifications from the late-Roman defence-in-depth system in the hinterland.

On the other hand, there are indeed sites in the foreland and hinterland that do date to the second century and that beyond any doubt belong to the military infrastructure. Examples would be the marching camp at Ermelo in the Netherlands or the industrial facility at Iversheim in the Rhineland. These elements perhaps require discussion at a separate expert meeting.

There is no obligation to be complete, with an endless repetition of similar sites. Indeed this is *not* appreciated by UNESCO and here too the saying applies that *in der Beschränkung zeigt sich der Meister*. So there should be a selection of the best-preserved examples, with limited destruction by development or excavation. Extensively excavated sites should be avoided.

In addition, wherever possible clusters of component parts should be chosen that can be joined by a common buffer zone, to ease the management and monitoring.

Another criterion for selection is the presence of sensible and clearly defined modern boundaries for the nominated properties as well as the buffer zone, with respect to spatial planning control and management (vertical as well as horizontal).

In conclusion: the idea is to incorporate in the nomination at least one example of all the elements that have been defined in the OUV as of specific value in the Lower German limes, and then to reduce the number by being practical and selecting only well protected sites with good conservation and situated in more or less equal numbers in both countries and in contexts that allow easy clustering in common buffer zones with as little foreseeable risks as possible.

4.2 Logical principles for the buffer zone

Definition: A buffer zone is an area surrounding the nominated property which has complementary legal and/or customary restrictions placed on its use and development to give an added layer of protection to the property. This should include the immediate setting of the nominated property, important views and other areas or attributes that are functionally important as a support to the property and its protection. The area constituting the buffer zone should be determined in each case through appropriate mechanisms. Details on the size, characteristics and authorized uses of a buffer zone, as well as a map indicating the precise boundaries of the property and its buffer zone, should be provided in the nomination.

Buffer zones can therefore only be delineated more precisely once a choice has been made as to which attributes need to be protected.

It is very important to realise that while the boundaries of nominated component parts always refer to the past (they must reflect where authentic remains with sufficient integrity are present), the boundaries of the buffer zone always refer to the present. They may be used to include areas of high potential value, but they must be defined with an eye to modern boundaries relevant in spatial planning.

Whenever possible, a single buffer zone should be used around a cluster of component parts and narrow unprotected areas between adjacent buffer zones should be avoided as these will inevitably lead to serious questions. Unless, of course, there are strong and convincing reasons to do so.

In consultation with the German partners and taking into account the decisions about buffer zones that have been taken for the already inscribed parts of the Frontiers of the Roman Empire World Heritage Site, the following types of buffer zone can be discerned:

4.2.1 The urban buffer zone

There is no need to try and connect all nominated parts in a single uninterrupted buffer zone. The river Rhine itself sufficiently represents its Roman predecessor as the connecting medium in the "pearl necklace" model. Therefore, unlike in Britain there is no need to use the buffer zones to create the continuity of the frontier. This provides a high level of flexibility and room to choose, and thereby assures a degree of 'governance comfort' for authorities. Some alternatives for types of sites that need to be included in the nomination (cf. above) but are situated in urban context can be found in the surrounding countryside.

Where this is not the case, buffer zones can be restricted to areas directly surrounding component parts of the nominated property and cover areas adjacent to such parts if there is a reasonable expectation of organic deposits and/or remains in these areas or an otherwise high archaeological potential.

4.2.2 The rural buffer zone

In rural areas the buffer zone may sometimes have a role to protect the landscape context and the visual setting of nominated component parts, a prime example being Vetera near Xanten, where the landscape has survived as described by Tacitus (*Hist.* IV, 23).

Because the limes in Lower Germany has for the most part been preserved almost exclusively underground, the visual setting is not always of primary importance. Buffer zones in this context therefore serve not only the control of development with adverse impact in a horizontal plane, but also in the vertical plane. They should be extended over areas adjacent to nominated component parts if there is a reasonable expectation of organic deposits and/or remains in these areas, for example fossil river channels. In so far as secure evidence exists of such deposits and remains, the area should preferably be included in the nominated property.

This principle should also apply to sites: if their extent is known, they should be included in the nominated property, if not – or to the extent they are not – they should be part of the buffer zone.

It is permissible, and has been accepted for the Obergermanisch-Raetischer Limes, to use the buffer zone to include areas with a high expectation but uncertain value. In these cases, there may be areas designated as buffer zones without a 'core' that is part of the nomination.

5 The follow-up (TL)

In the Netherlands, an assessment of all the Dutch sites on the Tentative List is currently taking place. Based on this assessment, the Dutch National Government will decide in April 2015 which property can be nominated in which year. The German National Government has already stated that it will also nominate its part of the Lower German Limes in the same year. Dependent on the decision of the Dutch National Government, we will probably start this year with writing the nomination file, including the management plan. The first step in this process is to define which sites will be part of the property. In this process the OUV is of great importance: it defines the criteria to select sites and whether or not to add sites to the nomination file.

Parallel to this process, on the European Level a discussion is going on about defining an overarching OUV for all the countries of the Frontiers of the Roman Empire, including the already inscribed parts of the FRE. When accepted by the World Heritage Committee, the nomination of the Lower German Limes will have to comply with this overarching OUV.

This is in fact a very complex process. The FRE, being a so-called serial transnational property, will need to have a single OUV, to which the different components make a substantial contribution. The various components in each European country are however very different from each other, and it will become difficult to make a single overarching SOUV (statement of Outstanding Universal Value) that will fit all the parts of the FRE. Furthermore, in managing the FRE on the long term an OUV that is too general makes it difficult to adequately protect the property from development and other pressures. In order to overcome this problem, the Bratislava Group suggested defining one overarching OUV, with an additional "Contributory Statement" for each component part. This would identify very clearly how the property will contribute to the OUV of the whole FRE as defined in the SOUV. If the World Heritage Convention accepts this approach, the OUV as now defined by Leiden University for the Lower German Limes will become a so-called contributory statement. The decision on this approach is expected at the World Heritage Convention 2015 in Bonn (Germany).

Notes

1 The late Willem Willems (1950 – 2014), holder of the Chairs of Archaeological Heritage Management and Provincial-Roman Archaeology at Leiden University, was the driving force behind the Statement of Outstanding Universal Values and strove to perfect the joint Lower German Limes submission. The text was substantially complete at his untimely death and we offer it as a tribute to his memory. Erik Graafstal, municipal archaeologist of the city of Utrecht and associate researcher of Leiden University, was responsible for the Comparative Analysis. Tamar Leene, National Program Manager Limes on behalf of the provinces of Utrecht, Gelderland and Zuid-Holland, wrote the introduction on the nomination process. We would like to thank Carol van Driel-Murray for her contribution to the completion of this article.

2 The term property refers to the area that is nominated. This can be a single area, or a series of loose components/sites. The word site is often used for the same concept as property.

3 In order to create these benefits, the report states that sites need to formulate and implement a clear marketing strategy and opportunities for benefits depend on the implementation of this strategy and the scale of the WH site. Rebanks Consulting & Trends Business Research (2009) "World Heritage Status: Is there opportunity for economic gain?"

4 Commissie Herziening Voorlopige Lijst Werelderfgoed.

5 Kamerbrief Voorlopige Lijst, 4 april 2011.

6 Decision WHC – 05/29.COM 8B.46.

7 The Bratislava Group is a group of experts from all European Limes Countries. On its meeting at Koblenz of 23.6.2004, the Bratislava Group formulated as a general guideline that the Frontiers of the Roman Empire World Heritage Site should consist of the line(s) of the frontier at the height of the Empire from Trajan to Septimius Severus (about 100 to 200 AD), including military installations of different periods which are placed on that line. These installations can include fortresses, forts, towers, the limes road, artificial barriers and immediately associated civil structures.

8 For the Comparative Analysis a desktop comparison has been made with a number of fortified boundaries and barriers across the world, with a special emphasis on Europe and the Near and Middle East. This included notably the ancient and early medieval barrier walls and fortified boundaries listed in A. Nunn (ed.), *Mauern als Grenzen*, Mainz 2009, 25; the defensive circuits of Greek city states; the earthen barriers of the Anglo-Saxon and Viking worlds, like Offa's Dyke and the *Dannevirke*; the Anastasian Wall of Byzantium; later medieval *Landwehre* in Germany.

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HERCULES: studying long-term changes in Europe's landscapes

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This paper presents the outlines of a new EU-funded research program for the long-term history, present-day management and further development of the European landscapes, including their natural and cultural heritage: HERCULES. One of the subprojects of this program (Work Package 2) links archaeological, historical and historical ecological data to the analysis of geo-information in order to develop models of long-term landscape change in three carefully chosen study regions in the Netherlands, Sweden and Estonia. This is framed theoretically by integrating insights from landscape biography, historical ecology and complex systems theory. The linking and analysis of data will be done using a Spatial Data Infrastructure and by means of dynamic modelling.

1 Introduction

In December 2013 a new large-scale program was launched for the research, protection and management of the European cultural landscapes within EU's Seventh Framework Programme: HERCULES (Sustainable Futures for Europe's Heritage in Cultural Landscapes). The major aim of HERCULES is "to empower public and private actors to protect and sustainably manage cultural landscapes that possess significant cultural, socio-economic, historical, natural and archaeological value, at a local, national and Pan-European level" (www.hercules-landscapes.eu). This will be achieved through academic and applied research by a network of 13 partners from 11 countries, including European universities and research institutes, small and medium-sized enterprises and non-governmental organisations. Together they will develop an integrative approach that incorporates diverse stakeholder perspectives to appropriately address landscapes changes. The University of Copenhagen and the Humboldt-Universität zu Berlin act as the coordinators of the program.

HERCULES includes no less than 10 work packages *e.g.* for case studies of short-term developments in the European landscapes, landscape typologies, broad and fine-scale modelling (scenarios) of future landscapes, the re-coupling of social and ecological landscape components, building a Knowledge Hub for landscape research and best practices in management, etc. The research will focus on a selection of nine case study landscapes in the UK, Sweden, Finland, Estonia, The Netherlands, France, Switzerland, Spain and Greece.

In this paper we present an overview of Work Package 2, as it brings together archaeological, historical and ecological data and insights in order to reconstruct the changes that have taken place in the European landscapes from earlier prehistory (the Neolithic) up to the present. In many ways, these changes are still operating as landscape forming processes in the European landscapes we live and work in today. This is the case, for example, where water management and land use had long-term or delayed effects, such as in the extensive water management systems in the Netherlands, in Mediterranean landscapes that suffer from erosion, 'desertification' and loss of biodiversity, in urban areas with long histories of 'path-dependent' trajectories of urbanization, etc. The research in Work Package 2 is coordinated and conducted by an interdisciplinary team of archaeologists, geographers, experts in geo-information science and land use managers from the Netherlands (Spatial Information Laboratory, VU University; Faculty of Archaeology, Leiden University), Sweden (Dept. of Archaeology and Ancient History, University of Uppsala), Estonia (Estonian Institute of Humanities, Tallinn University) and the UK (Forest Communication Network Ltd.).

2 Studying long-term changes in Europe's cultural landscapes

Within HERCULES, Work Package 2 (from now on 'WP2') specifically addresses the long-term changes in the European landscapes. Its objectives are:

1. To define an innovative theoretical framework for understanding the long-term development and transformation of landscapes, drawing on recent insights from geography, landscape archaeology, (historical) ecology, anthropology and information science.

2. To develop and test an infrastructural facility for retrieving and linking archaeological, historical and ecological data and geo-information (SDI) to support the interdisciplinary study of landscape change.

3. To develop dynamic and interpretive models for analysing long-term trends in landscape history in three

case study regions: the river landscape of the central Netherlands, Uppland in the eastern part of central Sweden, and Kodavere/Vooremaa area in the south-eastern part of Estonia.

In the process, WP2 tries to tackle a number of key issues in current landscape research and applied landscape assessment. Thus a major issue is how to practically envision future landscapes on the basis of a more sound understanding of landscape changes that already started many centuries or even millennia ago, such as increased human intervention in river and lake systems and shoreline dynamics. This fits in with the overall aim of HERCULES to contribute to future management aspects by enhancing the role of long-term thinking and analysis in Geo-design, urban planning, landscape design, and stakeholder involvement.

Current historic landscape assessments are often poorly matched with the needs of planners, policy makers and public interest groups. Such knowledge communities actively contribute to the further development of landscapes and regions, including their heritage (Fairclough and Grau Moller 2008; Janssen *et al*. 2014; Kolen *et al*. 2014). WP2 wishes to introduce these important knowledge communities to new possibilities for understanding complex interactive processes over the long term by clarifying the powerful roles of narrative, social memory, and practical experience (from the past and the present) in collaboration and design.

In WP2, landscape will be conceived of as being both a socially constituted and meaningful whole and a dynamic system that enables people to adapt to changing climatic and environmental conditions. Starting from this broad definition, the work package explores the methodological potential of historical ecological and biographical approaches to landscape (Crumley 1994; 2015; Kolen *et al*. 2015; Meyer and Crumley 2011; Roymans *et al*. 2009). In order to assess the long-term interactions between social and natural drivers more accurately and systematically, the concepts of historical ecology and landscape biography will be integrated with a complex systems approach (see 3. Theoretical framework). This has resulted already in a protocol for studying long-term landscape dynamics (Crumley *et al.* 2014), which will now be tested and applied in some of the HERCULES study landscapes, more particularly in the river delta landscape (including the Holocene peat area) of the central and western Netherlands, the Uppland area in Sweden and Kodavere/Vooremaa in south-eastern Estonia. The technical aspects of the research, which involves the building of dynamic models and a Spatial Data Infrastructure (SDI), will be done in collaboration with the Knowledge Hub of the program and a core team of WP3, which explores the possibilities of dynamic modelling for understanding short-term and current changes in the landscape.

3 The theoretical framework: integrating landscape biography and historical ecology

In 1996, The Danish-American geographer Kenneth Olwig tried to synthesize ecological/environmentalist and cultural/social science approaches in landscape research, based on a thorough investigation of the origins of the landscape concept, by re-introducing what he calls the ‘substantive’ nature of landscape (Olwig 2002; 1996). Although such a synthesis of paradigms, if possible at all (as many researchers oppose the idea of paradigms itself), is not an explicit goal of the integrated long-term approach to be developed in HERCULES, there is certainly a link between WP2 and Olwig’s endeavour. WP2 too aims at developing an integrated approach to the study of landscapes, combining the long-term perspective of archaeology and history with recent insights from cultural ecology, anthropology and geography. To achieve this goal, elements of recent ‘landscape biography’ and ‘historical ecology’ will be used as theoretical building blocks. Landscape biography and historical ecology are among the prominent emerging approaches to the study of long- term landscape history, and are now being combined and integrated with a complex systems approach to human-land and human-nature interactions.

Landscape biography studies the long-term transformations in landscapes, preferably from prehistory to the present, viewing landscape at each point in time as a complex interplay between social and economic developments, culturally specific perceptions of the environment, the history of institutions and political formations, and ecological dynamics (Kolen 2005; Roymans *et al*. 2009; Kolen *et al*. 2015). As a historical research strategy, it expresses a strong sense of the multi-layered nature of landscapes. It acknowledges the non-linear and path-dependent character of landscapes and the active role they play in the life histories and social memory of people (cf. Ingold 2000). This means that landscapes are not only seen as the (interim) outcomes of drivers, but in themselves are considered drivers for social, economic and climate change as well.

Historical ecology, which emerged in the US within the Boasian paradigm, developed a practical framework of concepts and methods for studying the past and future of the relationship between people and their environment (Balée 1998; Balée and Erickson 2006; Crumley 1994; 2012; Hornborg and Crumley 2007; Meyer and Crumley 2011). While historical ecology may be applied to spatial and temporal frames at any resolution, it finds particularly rich sources of data at the ‘landscape’ scale, where human activity and cognition interact with biophysical systems, and where archaeological, historical, ethnographic, environmental, and other records are plentiful. The term historical ecology draws attention to a definition of ecology that includes humans as a component of all ecosystems and to a definition of history that goes beyond the written record to encompass both the history of the Earth system and the social and physical past of our species. It provides tools to construct an evidence-validated, open-ended narrative of the evolution and transformation of specific landscapes, based on records of human activity and changing environments at many scales. Historical ecology offers insights, models, and ideas for a sustainable future of contemporary landscapes based upon this comprehensive understanding of their past.

Being complex systems, landscapes are self-organizing and exhibit what are known as 'emergent properties', which cannot be deduced from the individual natural or cultural components of the system. Agent-based perspectives on complex systems (cf. Van der Leeuw and McGlade 2013; Bentley and Maschner 2003) combine the principles of complex systems theory with the concept of interacting agents. Dynamic modelling allows to study whether developments inevitably lead in a certain direction (path dependence), and whether different scenarios will produce similar outcomes (equifinality). By this, it is very suitable for exploring long-term developments in cultural landscapes, allowing to test different hypotheses of the development of the cultural heritage embedded in these landscapes. As dynamic modelling may also be explored to create insights on how micro-scale processes give rise to macro-scale phenomena, it is of great interest to landscape archaeology, where we can usually only observe the macro-scale results of micro-scale actions in the past. Several archaeological studies have used dynamic modelling for this purpose (Kohler *et al*. 2007; Wilkinson *et al*. 2007).

Together, these frameworks encompass the range of variation that is currently found in international landscape studies. While the frameworks largely overlap, landscape biographic approaches focus on the regional scale of analysis and are more explicitly phenomenological and aimed at heritage studies, while historical ecological approaches are multi-scalar and are more comprehensive and explicitly empirical. Both frameworks embrace the stakeholders, planners, and managers of landscapes. For the first time, the HERCULES program aims at integrating the so far separate concepts of landscape biographies and historical ecology with a complex systems-based perspective on cultural landscapes. With spatial dynamic models specifically designed for the needs of interdisciplinary study of landscape change, HERCULES intends to provide landscape researchers with new tools to understand long- term developments in European landscapes by more effectively linking archaeological, historical, ecological and social data.

By integrating landscape biography, historical ecology and complex systems theory, WP2 wishes to realize a trans-temporal approach to landscape, treating epochs, periods, and other temporal divisions as ripe for research and not firewalls that protect temporal specialties. Such a trans-temporal approach has several advantages. Particularly important for planning and heritage, the coupled human/environment system can be analysed with regard to effective management strategies under specific (local, regional) social and environmental conditions and the results used to formulate future scenarios.

In order to tackle these challenges, the protocol for understanding long-term landscape dynamics produced by the WP2 team (Crumley *et al.* 2014) starts from 15 premises. Here we present only a selection thereof:

- *Much of what we know about landscape changes in the past cannot be based on extrapolation from present conditions.* Yet initial conditions of landscape systems are a strong predictor of later states. Past decisions shape and constrain subsequent ones and small differences are disproportionately the cause of later circumstances. This is called *path dependence*. Thus physical infrastructure, social practices, and other conditions can impede necessary system-wide change.
- *Knowing a landscape's history can be seen as using completed experiments undertaken in the laboratory of the past.* Most (pre-)historic forms of land use have proven not to be sustainable, but it is true that their persistence is, at least in part, witness to their utility.
- *Landscapes have their own temporalities and rhythms*, in relation to but distinctive from individual and community life cycles. The past is also always present in the landscape of 'today'. All landscapes incorporate "the powerful fact that life must be lived amidst that which was made before" (Meinig 1979, 44). Thus landscape biography and historical ecology view landscapes as palimpsests that are transforming continuously, both through conscious interaction by people with the material past in the environment and through less conscious forms of agency. This again illustrates that landscapes cannot simply be seen as the outcomes of drivers, but that landscapes themselves are also drivers of social, political and economic change.
- *Historical ecology and landscape biography both study long-term transformations in landscapes* from prehistory to the present (Crumley 1994, 2015; Kolen *et al*. 2015; Meyer and Crumley 2011; Roymans *et al*. 2009). It is important to realize that the disciplines contributing to this exercise, like landscape archaeology, historical geography, historical anthropology and palaeo-ecology, explore quite different datasets covering different time-intervals and aspects of landscape change. These datasets and the methods used to analyse and interpret them must be related and integrated in systematic ways in order to synthesize long-term changes.

- *Together, historical ecology and landscape biography can link social memories to the long term, connecting the micro-histories of places to broad-scale developments, and integrating experience and process*. One of the routes to this end is by the study of how, in different mnemonic, religious and social systems, memories, values and ideas concretely interact with the material world of which landscapes are an integral part (*e.g*. Küchler 2002).

Taking the above set of premises as its methodological starting point, HERCULES will not produce a single paradigm but rather offers a toolbox of concepts and competencies (cf. De Kleijn *et al*., 2014; Kolen *et al*. 2015; Meyer and Crumley 2011; Crumley 2015). At the same time, the premises can be chosen as explicit theoretical guidelines for research projects that tackle long-term changes in cultural landscapes.

4 A Spatial Data Infrastructure (SDI) for landscape research

The availability of digital tools and data to study long term changes in the landscape has, over the last decade, grown tremendously. Landscape scholars and landscape practitioners are more and more digitally skilled and the use of geospatial technologies has grown significantly. Landscape research is nowadays unthinkable without the use of Geographic Information Systems (GIS) software to analyse, and Spatial Data Infrastructures to systematically store and share digital spatial information. The theoretical framework proposed in WP2 promotes the integration of data and perspectives produced by academics and land management practitioners.

Given their explicit multidisciplinary aim, studies of the long-term history of landscapes and ecosystems make use of datasets from various sources. Optimally, these will include a combination of the following data:

- Data and information that (can) inform landscape researchers and stakeholders (spatial planners, landowners, heritage managers, local interest groups etc.) about the *natural characteristics and physical properties* of the landscape, both past and present, like geological and soil data, soil maps, digital elevation maps, palaeo-geographical maps, botanical data, data on climate and climate change, etc.;
- Data and information that (can) inform landscape researchers and stakeholders about *social economic land use and land use systems*, both past and present, like archival sources, cartographical databases, archaeological databases (*e.g*. large-scale vectorised excavation plans and survey databases), specific soil data and botanical data, databases for historical landscape features, monuments and historical urban structures, etc.;
- Data and information that (can) inform landscape researchers and stakeholders about the *political (territorial) and religious aspects* of past landscapes, like archaeological databases (burial sites, ritual depositions), archival sources (monasteries, parishes, manorial estates, etc.), cartographical databases (historical maps), databases for specific monuments and religious architecture (like churches), etc.;
- Data and information that (can) inform landscape researchers and stakeholders about *past experiences and meanings of landscape*, like databases for field and place names, oral history databases, cartographical databases (historical maps), visual databases for landscape painting and historical photography, etc.

It has been acknowledged recently that in order to explore and combine multidisciplinary datasets optimally these kinds of data could best be organized by means of a so-called Spatial Data Infrastructure or SDI (De Kleijn *et al*. 2014). The core function of an SDI is to enable users to share geospatial information beyond the level of a single institute or organization. This need is generally found in landscape research. In understanding what an SDI encompasses we make a distinction between the user objectives, technological components, Geospatial Information (GI)-literacy, content and governance (De Kleijn *et al*. 2014). The combination of the GI-literacy and the objectives determine the extent to which the technological components need to be developed and the content to which access is needed.

At the core of an SDI lies the technical infrastructure of services, varying from data viewing services to download and more complex processing services. On top of these services applications can be built with which users, with different objectives and GI-literacy levels, can perform their tasks. The applications through which the services can be accessed vary from web viewers for users to view and validate data, to dedicated GIS software with which modelling experts can perform complex analyses (*e.g*. ArcMap, Quantum GIS, GeoDMS, MapINFO, etc.).

For governance of an SDI three aspects can be distinguished. First, a party coordinative institute has to take the on leadership and ensure long-term viability and educate where necessary users how to use the tools. Second, the users' requirements for functionality and content have to be closely looked at in order to ensure that their needs are translated to (technical) requirements for the SDI and the applications that are implemented on top of it. Third, considering the content, the management of who can use what information for which purposes is also a fundamental part of SDI governance. Although the current trend is to publish data in the public domain as open data, to which the HERCULES project also strives to, some data cannot be put in the public domain due to privacy issues and restrictions of the data providers.

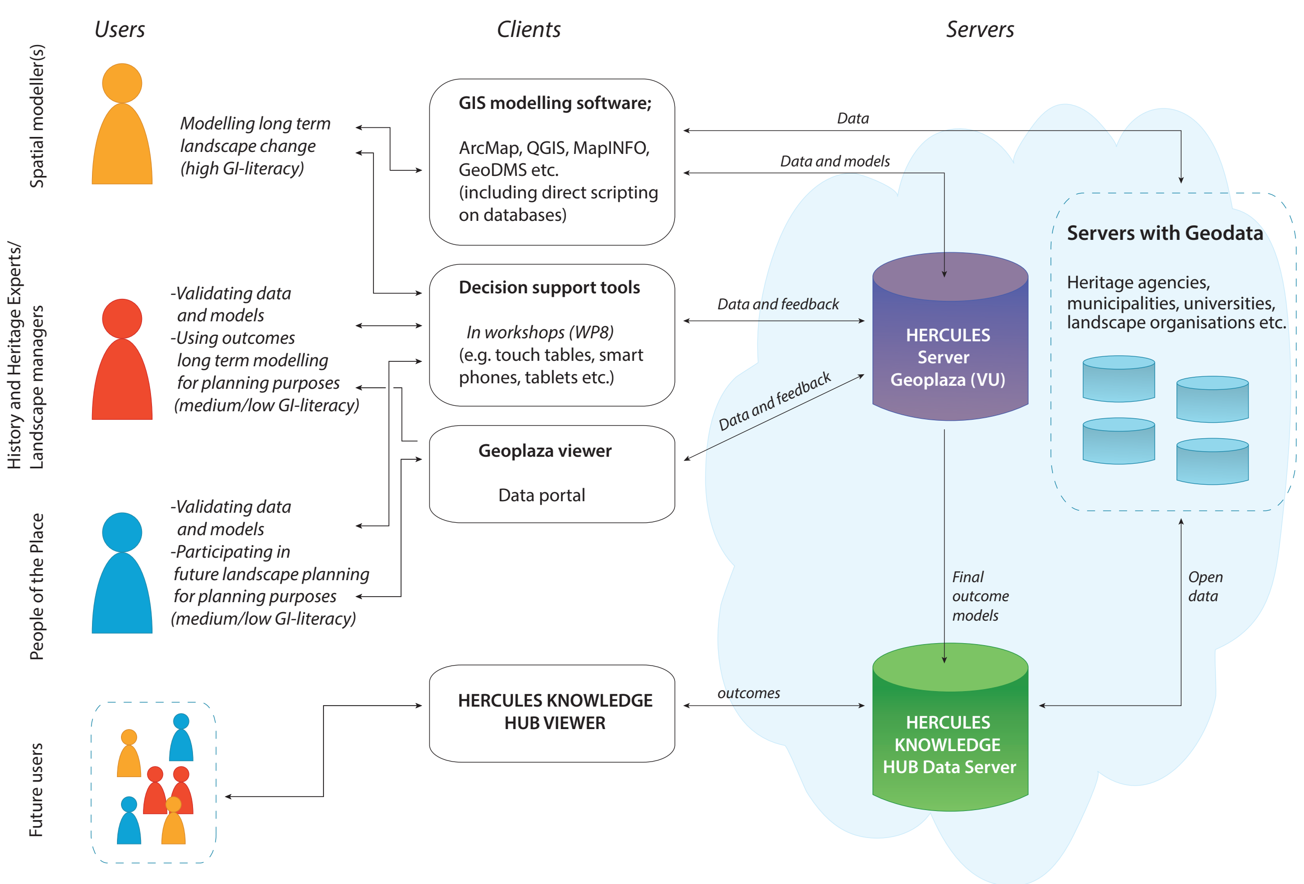

Figure 1 Schematic overview of a Spatial Data Infrastructure (SDI)

The study of long-term landscape change would benefit considerably from improved availability of data about the history and heritage of the landscape and functionalities with which the data can be processed and shared through an SDI. In the process of studying long-term landscape change, five areas in which an SDI has the potency to play an important role can be distinguished.

First, an SDI offers functionalities to integrate digital spatial data (also from different repositories *e.g.* different universities, governmental institutes etc.) in structured ways enabling users to work systematically.

Second, an SDI offers functionalities to communicate historical and heritage data to various stakeholders ranging from landscape historians and heritage experts to the people of the place for purposes of validation.

Third, an SDI offers functionalities to process and/or download data into specialist software with which complex long-term landscape change models can be developed and executed.

Fourth, an SDI offers functionalities to share the models and the outcomes of landscape research dynamically, allowing changes to the data to automatically update the model.

Fifth, an SDI offers functionalities to disseminate the research results as services that can be part of the Knowledge Hub developed in HERCULES or existing local heritage management data infrastructures.

The areas/themes identified above, except for the fifth, are not to be seen as separate phases, which follow up on each other, but are to be approached as stages through which long term landscape modelling goes through in several iterations.

A schematic overview of the SDI is shown in figure 1. It shows how the data servers are related to the clients and shows how the SDI aids landscape change modelling. It also shows how the SDI components are related and how the SDI interacts and can be integrated with HERCULES' Knowledge Hub developed in WP 7. The spatial modellers work foremost with professional GIS software, whereas the past-oriented and future-oriented landscape professionals and local stakeholders provide feedback through workshops using decision support tools. These last-mentioned groups are also providing feedback, making use of custom-made data viewers. Finally the project outcomes and results will be transferred to the HERCULES knowledge hub, providing insights in best practices for future landscape research.

5 Modelling landscape change

As stated above, the SDI is essential for giving stakeholders access to relevant spatial information and validate outcomes of spatial models about the past and current landscape. However, in itself, it will provide nothing more than a framework to accommodate the management and visualization and exchange of spatial data sets. Current approaches to mapping and visualizing landscapes of the past can be described as predominantly static. Typically, they only offer snapshots of archaeological or historical periods, showing the places where people settled and used the landscape, as well as the environmental setting itself (notably in the form of palaeo-geographical, or better said palaeo-geomorphological reconstructions). Predictive models (which are essentially statistical extrapolations) are then applied to predict the possible distribution of archaeological remains (see *e.g.* Kamermans *et al*. 2009; Verhagen and Whitley 2012). In this approach, time periods are lumped, and the dynamics of landscape transformation are obscured, tacitly assuming that in each period people were experiencing the landscape as a kind of tabula rasa.

Approaches to overcome this static approach are now emerging in geographical and archaeological landscape research. Notably, techniques like Agent-Based Modelling (*e.g.* Kohler *et al*. 2007; Wilkinson *et al*. 2007) and Dynamical Systems Modelling have great potential for better understanding the observed patterns of settlement and land use, and the processes that led to these patterns (cf. Bentley and Maschner 2003; McGlade and van der Leeuw 2013). Such models are designed as heuristic tools, for example to build scenarios of population development or to develop more sophisticated theories of human (spatial) behaviour and practices, but the outcomes should not primarily be seen and used as accurate predictions of for example past land use. It can therefore be doubted whether these models, in their current state of application, would be of much use to heritage professionals. From their point of view, information needs to be accurate and usable, rather than multi-interpretable explorative.

For these reasons, WP2 will not adopt ABM as a core modelling technique, despite its high potential for academic analysis. The outcomes would not, at this stage, be able to inform heritage policy, and hence not serve the overall aims of HERCULES. WP2 will therefore adopt and further enhance models that are able to close the gap between static mapping aimed at heritage professionals and dynamical modelling designed for academic research. This will be done by developing models that link path dependencies in (pre) historic land use to predictions and mappings that will make sense in a heritage context.

Within WP2 the concrete possibilities of dynamic modelling will be explored by adopting a case study approach. This will be done for three different case study landscapes, each being representative for more widespread environmental and climatic conditions within Europe: Atlantic (the river landscape of the Central Netherlands), Boreal (the Uppland area, Sweden) and continental European conditions (Kodavere/Vooremaa, Estonia). A Mediterranean area (Puglia, Italy) will be used for comparison. All case studies, most notably the Dutch and Swedish ones, will start from the premises defined in the protocol (see 3. Theoretical framework). For each of the three study regions a somewhat different modelling approach will be adopted to achieve this aim. Therefore, we will briefly introduce each of the case study landscapes below.

6 Case study landscapes

6.1. The Dutch river area

Parts of the Dutch river landscape were occupied already during the Mesolithic and Neolithic. Initially, land use will have been limited to the stream ridges of the rivers and the adjacent parts of back swamps, as well as on Pleistocene river dunes and their surroundings. In the Middle and Late Bronze Age significant sections of the stream ridges were transformed into true rural landscapes, with scattered (and roaming) farmyards with associated burial mounds, gardens, field systems and roads (Arnoldussen 2008). This rural landscape was part of a mosaic environment with forest, wetlands and more open cultivated areas. In the Roman Period, the study region formed the north-western part of the Roman frontier on the continent. By then, land use had been intensified considerably, creating a more open landscape with an increased human impact on the water system.

In about 1000 AD, the inhabitants of the river villages in the study region began building embankments along major rivers like the Rhine and Meuse (Van de Ven 1993; Harten 2000). Along with the villages themselves, fields and gardens occupied the highest parts of the banks, while the slopes down to the flood basins behind the banks were used as communal meadows and pastureland. In the period from 800 to 1250 AD, towns in the Dutch river area expanded significantly and there was growing demand for agricultural products. To satisfy this demand, the agricultural land area had to be extended to the low-lying peat areas and river basins (Harten 2000; Renes 2005). But before these areas could be drained and reclaimed, embankments had to be built along the river courses and any obstructing ones had to be dammed. Several centuries later, the still remaining open spaces between the village embankments were closed off and long, uninterrupted dikes were built. This process was completed in most parts of the Dutch delta by about 1300 AD. Inside the dikes, where in winter especially the river water could dam up to a significant extent, river forelands were created.

Thus over the course of five centuries, from 1000 to 1500 AD, the Dutch delta changed dramatically (Van de Ven 1993; Renes 2005). It was transformed from an open delta where the rivers had free reign and where large areas were taken up by fens and marshes to a tightly ordered agricultural territory under human control. With their far-reaching interventions such as dike building, the inhabitants of the Dutch river landscapes unconsciously reset the environmental agenda for themselves. In the long run, their reshaping of wetlands and stream valleys had unexpected repercussions, like dike breaches and large-scale floods.

In the Dutch river delta, the so-called Land Use Scanner (LUS) will be deployed to model land use changes (Hilferink and Rietveld 1998; Koomen *et al*. 2011). This modelling framework was originally designed for predicting land use development in the near future, based on information about the current situation and the hypothesized development of future land use demand. The allocation methods applied in LUS are the logit-based model to determine probabilities and a discrete allocation method to generate an allocation that is optimal given the suitability of different plots within the region. A major advantage of this approach is that it shifts the pervading focus in archaeology from local settlement sites to various landscape scales as the object of interest. It also looks at the landscape from the angle of its use, rather than from the dominant, geomorphologically based point of view aiming at predicting the landscape's suitability for settlement – which is of course only one aspect of what people did in the past. The LUS is particularly suitable for the Dutch river delta, given the very extensive data available on settlement distribution and palaeo-geographic reconstructions for the area over long periods of time.

6.2. Uppland, Sweden (figure 2)

Since the regressive shoreline displacement in Uppland, like elsewhere in Sweden, changed the landscape considerably over millennia and offered new land for occupation, it is necessary to examine how the changing topography influenced the choice of locations for settlement and land use.

A strategy to reconstruct this aspect of regional landscape change is to take the physical characteristics of the landscape into account, such as the presence of fresh water. Proximity to fresh water is important in the choice of settlement locations. Streams, lakes and rivers not only provide food and water but are also means of communication. Rivers can connect communities into smaller regional groups, so-called river-based communities (Jordan 2003). Another such natural connective element is a water catchment area. A water catchment area constitutes the area from which all run-off water comes together in a point or in a stream. A watershed is the boundary between two such areas. Typically, a watershed is a height where the rain falls on two different sides forming two different water catchment areas. This method has been used frequently in studies concerning physical geography and to some extent in the study of prehistoric regions where it has been argued that water catchments have influenced the development of territories and administrative regions (Löwenborg 2007; von Hackwitz 2012; Wijkander 1983).

For these reasons, the Uppland case focuses on the modelling of shoreline dynamics in relation to isostatic land rise. The model used here is based on a shoreline method focused on archaeological sites combined with an isolation method built on analyses to determine when lakes were isolated from the sea. A regression equation is used for making a shoreline reconstruction in order to consider both the isostatic uplift and the eustatic variations. This means that the reconstructions will be more accurately calculated, especially for larger areas, as the uplift is uneven between different land areas. Further, the shoreline can be modelled from any given BP value which means that a site can be put in its specific time context in terms of shoreline displacement as long as there is a valid BP value (Sund 2010). The regression equation used here was originally developed by Risberg *et al*. (2007) and further developed by Sund for the area of Eastern Central Sweden (Sund 2010). The accuracy of Sund's model is comparable with that of Risberg (Risberg *et al*. 2007), but with the advantage of generating a contemporary shoreline over a larger area (Sund 2010, 27). The applied model is generic and well suited to create a model for the Uppland region as a whole. Local deviations might occur as topographic thresholds could later have been eroded, making it difficult to accurately model the shoreline in detail at every point, but overall the model would be fairly accurate and relevant for the analyses proposed here.

Additionally, water catchments can be calculated from a digital elevation model (DEM) using a set of hydrological functions in a GIS (Geographical Information System). Pour points, the points at which water flows out of an area, are determined. Relevant pour points are selected, considering the modelled shoreline, and from the pour points drainage basins can be calculated to identify the upland area that is hydrologically joint at the pour point. The pour point would also act as an important social node in the landscape, connecting everyone using the upstream watercourses, and thus forming a 'natural' region that would be easily recognized. If there is a pronounced isostatic land rise in the

Figure 2 Landscape with royal burial mounds along the lake, at the Iron Age political, religious and economic centre of Old Uppsala (Gamla Uppsala; photo Kim von Hackwitz)

area this will affect both shorelines, thus making different pour points relevant at different periods. In areas with level terrain this might also cause the inland boundaries of the watersheds to shift as the land surface is tilting. It is therefore necessary to use a DEM that has been modified to the relevant time period using a method like the one described above. In the Uppland study area, a high resolution DEM has been produced by the Swedish Cadastral Agency (Lanmäteriet) using LiDAR technology.

Using the shoreline and watershed modelling together with the digital database from the National Heritage Board (Fornsök) the aim is to model the development of social relations through regions and regionalism in the area, in order to better understand the long term land use of the area starting with the early Neolithic (*c*. 4000 BC) and ending with the Viking Age (*c*. 1050 AD).

6.3. Kodavere and Vooremaa, Estonia (figure 3)

Kodavere and Vooremaa are neighbouring regions in the south-eastern Estonian lakeside landscape. The theoretical part of this case study relies on principles that are similar to the Uppland case study. Water bodies in this area form an extensive communication network, which was and still is being used for food procurement, transport, and trade. Occupation and land use focused on the western shore of Lake Peipsi, which is on the one hand a lake, but on the other hand has many similarities with a sea (*i.e*. the Baltic Sea) (Karro 2012). Moreover, the lake is part of a larger lake system including Peipsi and Pskov that has been documented as part of a trade route system that covered an enormous area stretching from Scandinavia to Byzantine (Mägi in press).

The method deployed for analysing landscape changes throughout the Iron Age (500 BC – 1200 AD) correlates geological information about the lakeshore with archaeological data, historical maps and cultural historical information (like historical narratives about particular places). The dynamics of shorelines is reflected in geographical shifts of human settlement as well. Water levels in the lakes went up gradually, but the land still rises faster in the southern part of the study area. This implies that the present-day situation in

Figure 3 Viking Age hillfort at Peatskivi, Vooremaa region, Estonia (photo: Martti Veldi)

the northern part may roughly be indicative of the situation in the past in the southern part. Lake Peipsi has seven visible shoreline terraces dating from different periods since its formation after the last Ice Age, of which the 38 m. shoreline most strongly correlates with historical and present-day settlement patterns. Folklore and historical photographs give some hints about the traditional land cover (19th and the beginning of the 20th century) that was drastically changed during the Soviet period.

For the Vooremaa region a historical GIS is applied. Detailed historical maps are geo-referenced and vectorized into layers based on land use information (*e.g.* arable, pasture, meadow, forest, swamp, fallow) and settlement features (*e.g.* farms, manors, mills, taverns, churches, roads, administrative boundaries). Additionally, a database with relevant attribute data (information about land use) is used. The layers based on historical maps can then be integrated with known archaeological sites, which will result in a series of detailed maps representing pre-industrial landscape changes.

This provides us with a coherent sequence of about 350 years of land-use, indicating land use functions in terms of arable land, pastures and meadows, forests, swamps and bogs. Much of the wetland in Estonia was not drained until the beginning of the 20th century, which is why historical maps and archaeological information are a good source for detecting suitable arable land cultivated before the mechanization of agriculture. The model may also help to understand why some sites developed into centres of power and –subsequently- into important places of local identity 'surrounded' by local narratives and beliefs. Historical land-use data combined with contemporary soil maps and adequate digital elevation models in the historical GIS also provides a good platform for elementary predictive modelling, which could be effectively used in preventive heritage management.

7 Epilogue

In the next two years (2015-2016) the HERCULES WP2 team will study landscape changes in the three regions from a comparative perspective, exploring the conceptual framework and the techniques for linking and analysing archaeological, historical and environmental data outlined above. This exercise will focus on the question to what extent landscape changes either converge or diverge, given different or similar social and environmental conditions. It is important, furthermore, to learn from the effects of 'experiments' that people have conducted in and with landscapes in the past. More often than not these experimental interventions caused unexpected and delayed effects for later generations, who had to 'invent' land use systems anew in order to cope with these consequences. An understanding of such iterative landscape histories can be of value for stakeholders, landowners and planners who face the challenge of environmental decision making today.

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Exploring archaeology's social values for present day society

Monique van den Dries, Krijn Boom and Sjoerd van der Linde

The archaeological sector is going through a challenging period, not only in the Netherlands, but in many European countries. The economic recession in particular has slowed down planning and development activities and, consequently, development-led archaeological research and activity. The result is not only a substantial loss of jobs, but also an increased pressure on the sector to demonstrate its societal relevance. But whilst archaeologists are engaging more than ever with the public, there is still a need to further and better exploit the public benefit of – in particular – development-led archaeology. The authors aim to show that there are various societal values that may help to do so, but which the archaeological sector so far hardly utilizes.

1 Introduction

One would say that the societal value of heritage is clear, as it is often widely acknowledged as a social capital. We can for instance distil from policies of both national and European authorities how they have embraced Europe's cultural heritage as a common wealth, as an 'irreplaceable repository of knowledge and a valuable resource for economic growth, employment and social cohesion', which 'enriches the individual lives of hundreds of millions of people'. In such documents, cultural heritage is seen as 'a source of inspiration for thinkers and artists, and a driver for our cultural and creative industries' (European Commission 2014).

However, such documents usually discuss cultural heritage as concerning preserved city centres with eye-catching historic buildings or restored ancient archaeological monuments in a stunning remote landscape, that clearly serve tourism purposes or other leisure activities. The societal value becomes much less clear when it concerns all those hundreds of archaeological research projects that are being carried out in the context of infrastructural planning and building activities. In particular in the context of the economic downturn, questions are therefore being raised about the costs associated with archaeological research, whether we need all this research and what benefits it yields for society. Stakeholders complain that the cultural sector is introvert, not including the interested audience and often unable to find the right connection with society. This is because the societal relevance of research is usually found in the answers research offers to questions posed by society or in the solutions it finds for the problems society faces, but for the archaeological sector, this is not always so easy. Archaeology generally answers primarily scientific questions, questions it poses itself - it hardly ever asks society what they want to know. Even though Dutch society increasingly influences the choice of time periods that are studied most (Theunissen and Deeben 2011; Van den Dries and Van Vuuren 2012), the sector is still focused on answering questions listed on the national research agenda. Also in the valuation of sites the academic values prevail over those of other stakeholders or society at large – both in the Netherlands (Bazelmans 2013), as well as in Dutch projects abroad (Van der Linde 2012).

The archaeological community itself, in particular the part that is involved in development-led archaeology, is very much aware of the importance of public support. That is not the issue at stake. Those who are conducting development-led archaeology know very well that archaeology can only exist with a public and political interest supporting it, as this interest generates legislation to protect heritage and funding to study and preserve it. Therefore, knowledge dissemination and raising public awareness are seen as intrinsic parts of contemporary archaeology and much effort is made to disseminate research results to the public. The problem is, rather, that these efforts are not always satisfactory to society. Consequently, the archaeological sector is under pressure to justify more than ever its expenditure and to demonstrate its societal relevance, irrespective whether it is being financed by public or private funds. This places the sector for new challenges to enhance and demonstrate its values for society.

A related problem is that the archaeological sector may not fully realize that its efforts for public outreach and support are not yet sufficient and adequate, or that these need to receive more priority. Although a number of contributors to the most recent evaluation of the implementation of the Malta Convention do mention the need to emphasize more explicitly the societal benefits of archaeology for society (Van der Haas and Schut 2014), it can also be observed through studies like the survey on the implementation of the Malta Convention by the European Archaeological Consilium

(EAC) (Olivier and Van Lindt 2014) and the latest reports from the Discovering the Archaeologists of Europe project[1] (DISCO), that the sector and profession as a whole in Europe have not yet embedded society as an intrinsic part of its daily practice (Van den Dries 2015). For instance, the Malta Convention's article 9 on the stimulation of raising public awareness is one of the least implemented and embedded articles in national policies and legislation. Moreover, only a few of the member states who implemented the convention claim to have accomplished significant achievements in the domain of public awareness raising after they implemented the convention (Olivier and Van Lindt 2014, 168). The DISCO-reports show for example how relatively little time is spent on visitor services and other outreach activities (Van den Dries 2015).

The signals from society are clear and we cannot continue to ignore them and carry on work as usual, because there is too much at stake. While the main challenge in the 1960's was unauthorized excavations and in the 1980's the massive construction works, at present the main risk for archaeology is a diminishing political and societal support. Politicians still acknowledge the societal value of archaeology, but they will increasingly expect a societal return on their investments in archaeology. The authors therefore aim with this article to highlight some values and benefits for society that so far have largely been left unexplored and unutilized, but which could make a difference in the near future. As there are some other developments in society going on which may require archaeologists to put more emphasis in particular on the social benefits of their activities, we will focus on the social values heritage projects and excavations potentially may bring along. After a brief introduction of these developments, we will discuss the societal values we experienced in two recent projects of the chair group of archaeological heritage management of the Faculty of Archaeology (Leiden University), which may match those developments in society. The first project concerns the Tell Balata Archaeological Park-project in Palestine (West-Bank), where we were invited by the archaeological department of the Ministry of Tourism and Antiquities (MOTA-DACH) to work together with them and the local UNESCO representative office, on the preservation of a neglected Middle Bronze age fortified settlement and to turn it into a site park. The second project was situated in the southern part of the Netherlands, in Oss (Province of Brabant), where we joined forces with the local municipal archaeologist to experiment with a 'dig-along day'.

2 Developments in society

The main motivation why we should intensify our efforts to look for societal benefits of archaeological projects, are some recent developments in society which can be expected to have a strong influence on the practice of archaeological heritage management. A first development is the Council of Europe's 2005 Framework Convention on the Value of Cultural Heritage for Society (Faro Convention)[2], which came into force in 2011. It aims to involve everyone in society (who so wishes) in the process of defining and managing cultural heritage. It considers cultural heritage a resource for personal and communal development and access to such an asset a right for everyone. Like most Western European countries, the Netherlands has not signed the Faro Convention yet and many practitioners of archaeological projects are not yet familiar with it, but we can expect the convention's principles to influence politics, policies and the public itself, in due time (see also Van den Dries 2014).

Another relevant development is the introduction of the concept of social return on investment (SROI) in local social policies. Our national government decided in 2011 to add a SROI-requirement as of July of that year for tender procedures on projects of 250,000 euro and more.[3] It implies that if a company gets a contract from the authorities to provide a service, that there is an obligation to spend five percent of the total sum on a social or societal benefit. This policy requirement has been adopted by regional and local authorities as well. As archaeological research in our country is considered a service and is primarily conducted by the commercial archaeological sector, our profession can expect to be increasingly confronted with a request for societal benefit. As a large part of our research and fieldwork is paid by local authorities, and often exceeds 250,000 euro, archaeologists will sooner or later have to show what the social impact and the SROI of their heritage project will be. This is especially so, because several municipalities have already started to ask for a social return on investment as of projects with a budget of only 50,000 euro.

At present, municipalities and contractors are still struggling with the practical implementation of the concept of SROI. It is often interpreted as an obligation to accommodate five per cent of the workforce to people who have a difficulty to enter the labour market, such as people with a physical disability or a social or mental disorder. But this is often difficult to achieve and may lead to all kinds of problems, especially in the building and construction sector (cf. Nijenhuis 2013). Some private sector organizations have discovered this market and have started to facilitate the recruitment of disabled people with whom companies could fulfil their SROI duties. These organizations even provide coaching and supervision of such SROI-projects. But important here, is that there is not a predefined way to implemented SROI-requirements. Alternative social activities that may strengthen the local social infrastructure are possible and allowed as well, such as in the domain of sports or the participation of elderly people. It is therefore possible that a company is asked to invest five per cent of a tender in other projects with a social dimension in the municipality or province. Interestingly, the province of Limburg has now included in its SROI action-plan funding for cultural projects, like the project 'Social innovation to preserve religious heritage' [translated by the authors], which aims to renovate chapels and religious funerary monuments with the help of participants in sheltered employment programmes, trainees, volunteers, etc. The province also aims to explore other alternative opportunities for SROI-applications in a culture-economic context (Provincie Limburg 2010, 7).

The inclusion of social care in public projects and services in our country is not an isolated development. The United Kingdom, for instance, has recently implemented a Public Services (Social Value) Act for England and Wales in 2012, which requires contracting authorities to think about the wider social value of services and how they can improve social, environmental and economic well-being of the relevant area.[4] It did not set a financial threshold such as in our country, but the aim is similar - to create jobs or apprenticeships and to support social enterprises or disadvantaged neighbourhoods. But there are more, similar trends. One is that corporate social responsibility (CSR) and creating shared value (CSV) are gaining importance as business concepts. With all kinds of companies, in almost all sectors, there is a growing attention to fair business; to find a balance between profit, people and the environment. As a result, more organizations are looking for ways to give something in return to society, to local communities, usually in areas such as arts, education, sports, social welfare, the environment etc. This could result in the sponsorship of events, to help build the skills of local populations, to contribute to sustainable development and the preservation of environmental and cultural resources for future generations. In this sense, it is important to realize that CSV relates closely to the idea of CSR, as the shared value model is based on the idea that corporate success and social welfare are interdependent, that a business needs a happy, healthy, educated workforce to compete effectively.

The impression that such social ethics are gaining importance can be derived from the fact that it is slowly spreading to the educational sector too. Although it took a long time before universities started thinking about their responsibility towards the (local) community (Mehta 2011), they are now getting much more willing to become involved with the social priorities of the wider world. Also in our country some universities have formulated policies with regard to CSR, or *maatschappelijk verantwoord ondernemen* (MVO), as we call it (cf. Tilburg University 2014). This discussion on the social responsibility of institutions of higher education and universities might be influenced by UNESCO, which states on its website that "the university can no longer be seen uniquely as an institution for personal development".[5] UNESCO also propagates at its summits on education that the educational sector has a task in reaching the Millennium Development Goals, that personal intellectual advancement must go hand in hand with broader goals of sustainable development, poverty reduction, peace and human rights.

For us, these developments are all indications that the concepts of social responsibility and social thinking are gaining importance and are becoming an intrinsic element of good governance, a philosophy at all levels of both the private and the public sector. As a consequence, it can be expected that this will also influence archaeology, especially development-led archaeology, which is currently the standard in European heritage management practice. Archaeological contractors, acting as procurers on public services, will also have to show their social return on investments by society or developers. This could be interpreted as a threat, but we consider it an opportunity. We are convinced that archaeology has a huge potential to provide activities that bring along social values and societal benefits, in particular in the context of engaging with local community members, as will be illustrated by the two examples below. As CSR and CSV also concerns developers and building contractors, who need to fulfil SROI-requirements but may also have CSR objectives, it could be worth the effort for archaeologists to explore where the interests of the various parties could meet and to develop a business model that could turn these potential societal values into an economic asset.

3 Community values at Tell Balata

The aim of the Tell Balata Archaeological Park-project, which ran from 2010 till 2014, was to turn the unearthed architectural remains of this ancient city into a visitor-friendly site park. While doing so, the joint Palestinian and Dutch project team of archaeologists and heritage professionals aimed to involve the local public in its plans and activities, as an important stakeholder in a holistic heritage management approach. This approach sought to combine stakeholder analysis and significance assessment with public outreach, and included for instance gathering oral histories about the site from local community members, such as neighbours of the site, land owners, shopkeepers, religious leaders, etc. (Van den Dries and Van der Linde 2012), as well as working with local students and contractors in the design activities of the park and the site-museum (fig. 1).

These collaboration activities turned out to be a perfect opportunity to identify the opinions and values of local community members on the safeguarding and management of the site. Such an approach was also useful to raise awareness and gain support for site preservation and even to mobilize practical assistance to clear the archaeological

Figure 1 Students interviewing a local resident to capture memories and anecdotes relating to Tell Balata, 2011

architectural remains from vegetation. We learned from these activities and dialogues that there was a lot of interest amongst the local community to become involved in the future management of the site, for purposes ranging from socio-economic gain, fostering identity and education. A direct result was that people wanted to help in cleaning the site and to prevent it would become a dump place again, as to support the future developments taking place at the park. The best illustration was that even people from the nearby Balata Refugee Camp (who already settled near to Tell Balata just after the foundation of the State of Israel and the subsequent displacement process of hundreds of thousands of Palestinians,[6] in 1950, but who never got fully integrated in local society), did seem to feel a connection with the archaeological site next to their camp. We once experienced for example that after the team had finished the field campaign for that year and had left again, several inhabitants of the camp took the initiative to continue the cleaning and clearing of the site from garbage and weeds.

The local community centre of Nablus was also very interested in collaborating, especially to bring their summer camp children to the site for educational activities. Interestingly, they had not solely educational motives for collaborating, as they had important other social motives too. One of their primary aims in this respect was to bring local children and teenagers in contact with foreign people (the Dutch archaeologists and students working at the site) and to show these children - who due to the political situation and their isolation hardly ever see other people or foreigners than Israeli soldiers - that non-Arabs are not by definition ‘the enemy’.[7] The people we worked with in Nablus and the organizers of the summer school indicated to us that they wanted young Palestinians to experience through our project that ‘others’ can be friendly, interesting people who have a genuine interest in them and their cultural history and want to work with them to help them study and protect their heritage. Both the archaeologists and the community centre believed such encounters could have a positive effect on the self-esteem of these young people.

Such objectives might seem unimportant or futile to us, western archaeologists, but they can make a huge difference for such a tormented society with its disrupted generations that are not able to travel freely and go abroad and experience other cultures. Countries in Europe that have suffered seriously from the recent global economic recession and which are confronted with a high unemployment rate especially under young people, are already calling these young people a ‘lost generation’ – we can therefore only imagine how lost the young people in areas like the West-Bank and Gaza Strip might feel. These areas are on the World Bank’s list of places with the highest unemployment rates (20 and 35 percent respectively) in the world (World Bank 2011). Multiple ensuing young generations have been suffering from social and economic isolation, while they have no prospect of any structural and lasting change.

During our work in Balata, we discovered that the project had the potential to offer social benefits to other local community members as well. The participants in our oral history project, for instance, who were mostly neighbours of the site, landowners, shop keepers, etc. (Rhebergen and Nogarede 2012), reacted very positive to the fact that we had a genuine interest in them and their stories about the site. They mentioned that it made them feel worthy and, as a side effect, even more proud of their site – especially when we published their portraits and stories in a booklet that all community members received for free. An important result of combining oral history research with value assessments is that we learned that local community members asked for the site park to become a place for social gatherings. The site in its neglected state was already a place where they had family picnics, but they wished to use the newly built visitor centre as a facility for community meetings – these requests have been incorporated in the management plans for the site.

What we learned from this example is that an archaeological heritage project may have a social value and meaning for the local community in a way that we at first had not thought of. It was only through our engagement with the community and other stakeholders that we could identify these societal values. It made us realise that if heritage managers would more specifically look for such social values while carrying out stakeholder and value assessments in combination with oral history research, that it will be possible to distinguish many more of these. We are convinced that any project team can generate local benefits and increase the societal value of their endeavours with relatively little effort, but ideally one

Figure 2 Residents participating in the excavation work in their neighbourhood, Oss 2014

should liaise with organizations which are already active in social activities to learn the local needs and opportunities to contribute and to maximize the result.

4 Social value pilot-research Oss

The second example comes from Oss, a city located in the southern part of the Netherlands (in the province of Brabant). Oss is well-known for its rich archaeological collection with finds ranging from the Early Bronze Age up until the Late Medieval period, showing a long residential history (Jansen and Fokkens 2002; Jansen and Van As 2012). In 2003 the local authorities in Oss decided to develop a new residential area on the northern edge of Oss, called Oss-Horzak Noord. The development of 400 houses in this district, marked for both the social and private sectors, would be realized between the years 2003 and 2014 (Gemeente Oss 2005; 2006). Early on it was decided that the rich cultural history would be used as a source of inspiration for the planning and design of the area (Gemeente Oss 2006). This resulted in the realization of a district full of references to its archaeological history, with street names such as Laan der IJzertijd (Iron Age Lane), Bekerpad (Beaker Alley) and Waterput (Water well) and with the homesteads (consisting of houses of various sizes and quantities) being built on the actual archaeological sites (Gemeente Oss 2005).[8] The district is also full of information panels, often located at small parks or playgrounds, where residents can leisure and read about the history of Horzak.

The Faculty of Archaeology of Leiden University has been conducting archaeological research in Oss since many decades and on several occasions the wider audience was informed about the results. During the excavation campaign of 2013 it was decided, in co-operation with the municipality of Oss, to extend the public outreach activities with a community participation day, called a 'dig-along day' (*buurtarcheologiedag*). This initiative was carried out by two of our Master students as an internship project for their specialisation in heritage management (Wu and Langbroek 2013). The objective of the event was to invite the people who had just moved to this newly developed residential area, this *nieuwbouwwijk*, to inform them on the long-lasting habitation history of their 'new' area and to join the excavation that was running in their neighbourhood. For this purpose the local authorities invited around 250 households to join the excavation for one day (fig. 2). Here too, we endeavoured to make the experience a bit more lasting and personal by including the finds and testimonies of the participants in an exhibition in the town hall that was set up in the autumn of 2013 (See Langbroek *et al*. 2014) and by producing a booklet for the participants with their testimonies on this day.

This community event turned out to be an inspiring experience. We saw that the participants were fascinated by what was going on in their neighbourhood and they seemed to love the experience of collaborating with professional archaeologists and students in a real archaeological research. They mentioned that they learned a lot about the practice of doing archaeological research and about the habitation history of their area (Wu 2014), but we learned a lot as well – for instance that the archaeological remains in this area could help to give the inhabitants of this '*nieuwbouw*' area, who were hardly socially connected with each other – as they said so themselves – a common ground, namely a shared history and a shared experience.

We experienced that it was not at all complicated or expensive to organize such an event. For reasons of safety regulation we did not make it too complex, nor could we work with machines like large excavators – rather, the excavation team made sure a trench with traces was available for people to investigate. In fact, all that was needed was two enthusiastic students to organize things, a free Saturday of the project leader and his team, and the support from the local authorities, who provided communication facilities to promote the event and facilitated the closing drink at the end of the day.

Nevertheless, the most important research aspect for us was to explore what value this participation initiative had for the local authorities and how willing they were to support the initiative. We knew that it matched perfectly with the already existing and applied ideas of using the local cultural history as a source of inspiration for the planning and design of the area, i.e. to provide the neighbourhood with a character or identity, but we wanted to explore if the proposed event could offer an opportunity to further develop social cohesion in the neighbourhood and among the people who participated.

As we realized that these values of (community) archaeology have so far remained largely untapped, we repeated the community dig in 2014. Moreover, we decided to start a pilot study to get a better understanding of the social benefits the participants would experience by designing a short questionnaire for the households in Oss Horzak about the potential social values the project could have for them. We aimed to have as much questionnaires returned as possible, so we choose to meet the respondents in person and to fill the questionnaire ourselves while talking with the inhabitants. Together with two master students we went from door to door (N=184) and found 51 people willing or able to respond to our questions (28% of the total number of households). The questions we posed all related to the social benefits we could think of in relation to the 'dig-along day'.

One of the first questions we asked the inhabitants of the Horzak-neighbourhood was what they thought of the initiative to organize a community dig for them. A very small minority of two per cent was neutral, four per cent reacted negative but the other 94% was positive to even very positive (fig. 3). This high number was more than we had expected – it may have to do with the fact that we filled in the questionnaire while we were talking with the inhabitants, which might have stimulated some socially desirable responding (social desirability bias). We tried not to be associated with the activity, by making clear to the inhabitants that we were researchers from Leiden University and not representatives from the local authorities, from where the municipality invitation came (most of the people we questioned remembered the invitation letter of the municipality from 2013, so probably they did think it was a municipal initiative). The responses may nevertheless have been different if we would have emphasized that the excavation team of Leiden University was organizing the event.

When we asked the respondents whether they would be interested to join the community event, almost 50% of them answered positively (fig. 4). Some had other activities and could not participate, some were not sure yet, whilst 27% were not interested. We intended to organise the community dig on a Saturday to enable as many people as possible to join, but as it was summer, school holidays had already started and quite a number of people indicated they would not be available due to their holidays. As we were aware of this, we also asked whether they would be interested to join if there would be another occasion. Slightly more people said they would (54%) and another 24% said they might (fig. 5).

We conducted our survey during two workdays, a Tuesday and a Wednesday, and encountered more women than men at home on these days; 75% of the survey participants were female, only 25% male. When we look at the interest to participate amongst these two gender groups, it is striking that a larger percentage of males than females is interested (fig. 6).

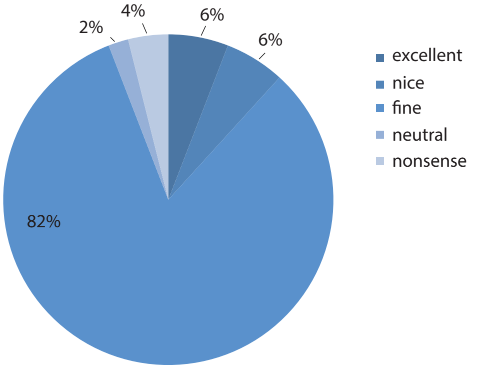

Figure 3 The response of the inhabitants of the neighbourhood to the question what they think of the initiative of the local governing body to organise a community excavation

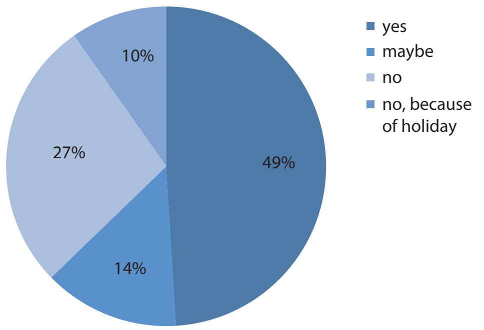

Figure 4 The degree of interest with the survey participants to join the community excavation

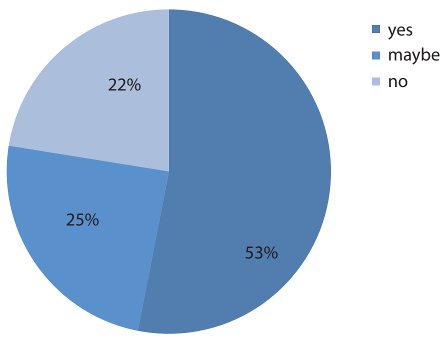

Figure 5 The degree of interest with the survey participants to join a community excavation on another occasion

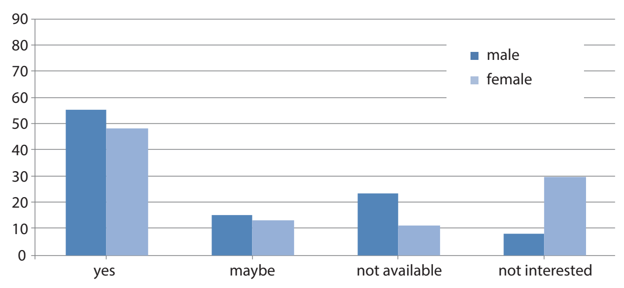

Figure 6 The interest of the two gender groups to join the community excavation (in percentages)

When we asked respondents how they would prefer to participate in the event, most people mentioned they would just like to take a look, visit for instance the 'display centre'. A substantial part also mentioned they would like to learn more about doing an archaeological excavation. Slightly less people mentioned they would be interested to participate by joining the excavation (fig. 7).

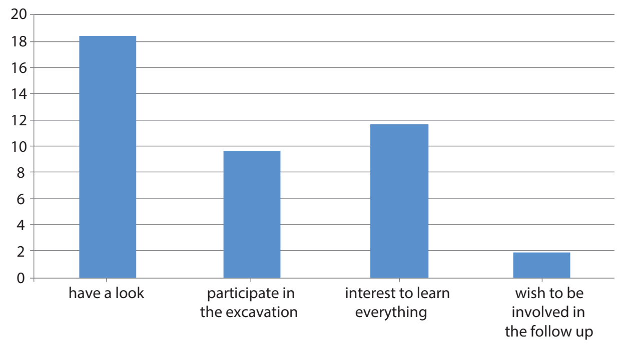

Figure 7 The way the survey participants (35) would like to 'participate' in a community excavation (multiple answers were possible)

We also asked about the motivation people would have to join and it was clear that the majority (68%) would like to join for educational reasons (fig. 8). Nearly one third of the respondents also mentioned social reasons. Health was not a reason people indicated a lot; they apparently did not think that having a relaxed day out in the field as a leisure activity could contribute to their well-being.

The motivations of men and woman turned out to be different. The main motivation for male respondents would be to take a look, while the women indicated to be more interested in participating actively and to learn (fig. 9).

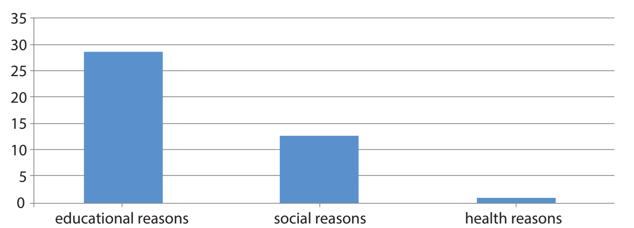

Figure 8 Reasons mentioned by the respondents (35) for joining the excavation (multiple answers were possible).

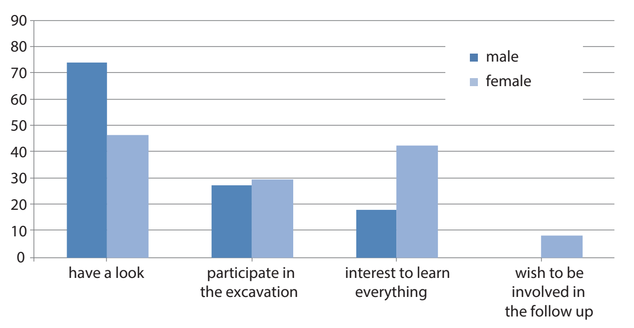

Figure 9 Motivation to participate for women and men (in percentages)

Moreover, only women indicated they would be interested to become involved in the post-excavation activities, such as the analyses and interpretation. It seems worth taking such differences into account when one wishes to organise community activities and aims to attract both groups. It has been observed before that the interest for archaeology is larger with men than woman (Van den Broek *et al*. 2005, 31), but this apparently seems to correlate with the type of activity or level of participation that is offered. With visits to for instance museums and monuments, the situation is the opposite, as this is more popular among woman than men (Van den Broek *et al*. 2009, 28).

As Oss Horzak is a newly built neighbourhood, with mostly young families, nearly three-quarter of the participants belonged to the age category of 21-40 (fig. 10). With all age categories the majority was interested to participate in the excavation, although the group of 41-60 was relatively less interested to join the excavation than the other age groups (fig. 11). Of the ones that responded negative, the largest part belonged to the younger age category. The group of 61 and older was the most hesitant, although they had no other obligations or activities that withheld them from joining the event.

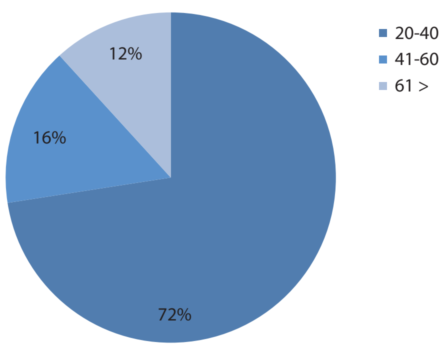

Figure 10 Distribution of the survey participants across the age categories

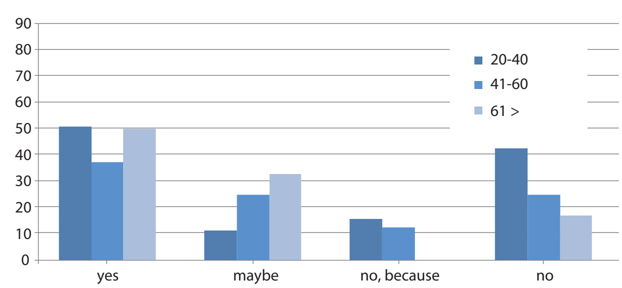

Figure 11 The interest with the age categories to participate in the community excavation (in percentages)

In particular the high interest with younger people, between 20-40 years, is noteworthy. In large scale studies on participation in cultural heritage it was noticed that both young people (under 20) and older people (as of 50) are getting more actively involved in cultural heritage, but not those in between (Van den Broek *et al*. 2009, 122). The latter seem to have less leisure time due to all kinds of duties they are involved in. It is therefore very interesting to see that in our case study there does seems to be a considerable interest in a cultural activity that happens almost literally on their doorstep and for which they do not have to make an effort.

This interest amongst the young residents of Oss-Horzak may have been evoked by the fact that we had strongly communicated our flexibility with regard to their participation. Ideally people would join in the morning to get some instructions, but we also offered the option to come whenever they wanted to, or to just take a look. The excavation team had arranged a '*inloopkeet*', a walk-in portacabine, which functioned as a temporary visitor centre, where people could see some finds and learn about the results of the excavation and the researches that have been going on in Oss for many decades. Children from the age of ten onwards could join the excavation, and we organised supervised activities for the younger ones (as of four years of age), to make it easier for parents to participate.

We also asked the Horzak inhabitants how much they already felt involved in or connected with their new neighbourhood. The largest part (52%) of the survey participants felt already strongly involved, another 38% felt slightly involved, 10% indicated not to have any connection. We then asked whether they thought a project like the community dig could stimulate or enlarge social cohesion in the area (fig. 12), and whether it could have a social value for them personally (fig. 13). A large majority of 76% answered the first question positively, slightly less people (65%) agreed on the second. This suggests the respondents

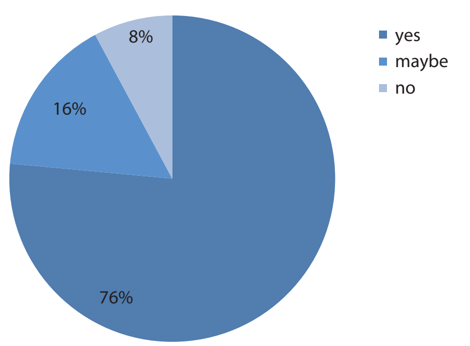

Figure 12 Answer to the question whether a community dig could contribute to the social coherence between the inhabitants of the area

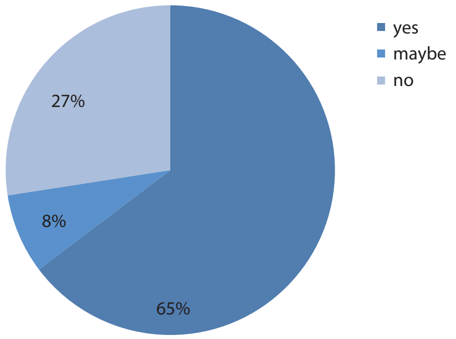

Figure 13 Answer to the question whether a community dig could have a social benefit for the participants themselves

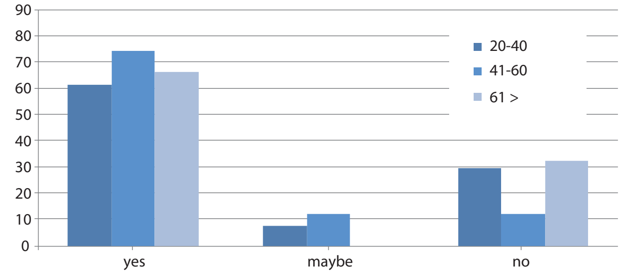

Figure 15 Answers from age categories to the question whether a community dig could have a social benefit for them personally (in percentages)

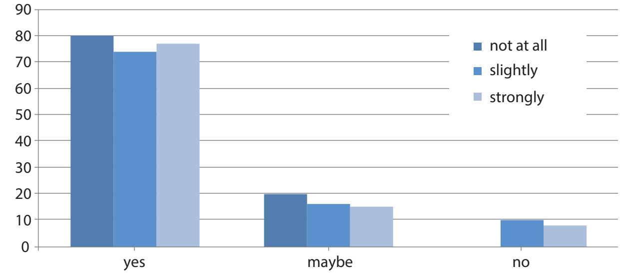

Figure 16 Answer from the people who were not, slightly or strongly involved in the neighbourhood whether a community dig could contribute to the social coherence between the inhabitants of the area (in percentages)

think a social event like a community dig has primarily a benefit for the area, for other people, but less for themselves. It was nonetheless still a large group that did think it could have a social value for them.

We did not find a huge difference between the two gender groups (fig. 14). Only slightly more women than men thought the community dig could have a social value for them personally. Also more women indicated clearly not to see any personal benefit.

There were no huge differences between the age categories either (fig. 15). The most positive responses about the social value and benefit a community dig could bring for them personally, came from people between 41 and 60 years of age. The elder people saw the least benefit for them personally.

It was then analysed whether people who are not at all, slightly or strongly connected with the area, feel differently about the effect a community dig could have on the social cohesion in the neighbourhood (fig. 16). Interestingly, the representatives of all three groups were rather convinced that it actually could contribute. None of the uninvolved people indicated not to believe in the social value of such an event.

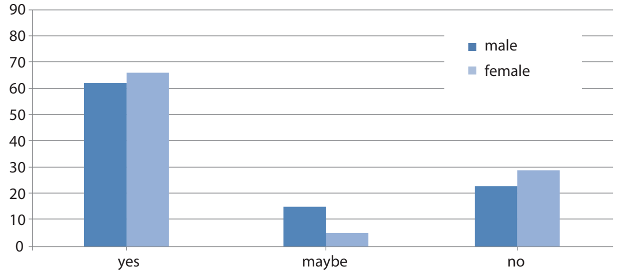

Figure 14 Answers from male and female residents to the question whether a community dig could have a social benefit for them personally (in percentages)

Only a few respondents from the group of people who were already strongly involved, had their doubts that such a project would be needed to improve the social cohesion in the area.

As we were interested to see whether people would answer differently after they had actually experienced a community excavation, we also asked the participants (25) of the community excavation to fill in an evaluation form. In this form we repeated most of the questions of the survey. A total of 15 people participated in this evaluation. However, a considerable part consisted of non-neighbourhood inhabitants, because many other people joined the community dig, like members of the local archaeological/historical volunteer group. Unfortunately not everybody answered all questions and as the evaluation was anonymous, the answers of the non-neighbourhood members could not be separated. So in that sense the sample is contaminated if we want to look for the social value this event had for the Horzak-inhabitants in particular.

But despite the small size of the sample (60% of the total number of participants), the responses do seem to give some indications as to the general social value of such a community event for its participants. It is for instance clear that for most people it had an educational value (table 1).

	yes	no	maybe	total
Did you learn anything?	14	0	1	15
Did you learn new skills?	9	5	0	14
Did you meet new inhabitants of your neighbourhood	4	9	0	13
Did you meet new people?	11	1	0	12
Did you have a good time?	11	1	0	12
Did you feel connected with your neighbourhood?	6	7	0	13
Did you have fun?	12	0	0	12
Did you feel useful?	11	1	0	12
Has it been relaxing?	13	1	0	14
Did you enjoy being out in the field?	12	0	0	12
Do you think it was good for your well-being/health?	11	1	0	12
Did this event strengthen your support for archaeology?	12	0	0	12
Would you like to be involved in the follow-up (in analysis of the results for instance)?	9	1	1	11
Would you participate again?	10	1	0	11

Table 1 Results of the questionnaire that was filled out by 15 participants of the community dig in 2014

There was one individual who was not very positive, but other than this person everybody was positive with regard to all the social values we questioned them on. We overheard participants saying how nice it was they had come to know people that were living in the same street but to whom they had never spoken before. It could even be noticed that people experienced a positive impact on their well-being and health, like they expressed in the evaluation, while as survey respondents they did not yet consider this as a possible impact factor.

These results on the social impact and value of the community dig in Oss-Horzak are still preliminary. We therefore are planning to go back and measure the impact in the longer term to see how sustainable such events are. We also want to explore if people changed opinions after they had participated in the community dig. Moreover, we will have to conduct similar projects and value assessment studies in other living areas to find out whether the potential social values are similar in neighbourhoods with a different social structure. But we can already conclude from this pilot study that even an ordinary development-led excavation does seem to have the potential to bring along societal benefits for the various stakeholders involved if one allows the audience to get involved.

5 Discussion

We have not introduced anything new by advocating for the social value of heritage, as its importance has long been acknowledged. It already played a pivotal role in the The Burra Charter of 1998 (ICOMOS 1998), and it has been the topic of many long-lasting debates, showing the rich variety of meanings and interpretations one can add to the social aspects of heritage. Moreover, authors like Mason have pointed out that the social values of a heritage site ‘might include the use of a site for social gatherings such as celebrations, markets, picnics, or ball games—activities that do not necessarily capitalize directly on the historical values of the site but, rather, on the public-space, shared-space qualities’, as we saw in our first case study, and that these values could relate to all kinds of social groups, ‘from families to neighbourhood groups to ethnic groups to special interest groups’ (Mason 2002, 12). He also referred to ‘the social cohesion, community identity, or other feelings of affiliation that social groups (whether very small and local, or national in scale) derive from the specific heritage and environment characteristics of their “home” territory.’ (Mason 2002, 12), like we witnessed in our second case study.

It was therefore not so much our aim to show that heritage has a social value, it obviously has. Our aim was rather to demonstrate how societal and social values can be found and applied in our daily practice, within the context of an archaeological preservation project or even a typical development-led excavation, which are being conducted annually in large numbers and throughout Europe and many other countries. By showing the social values we experienced, we aimed to illustrate the wider societal relevance that such projects can have, both for the people involved and the authorities, but which are often left unutilized. Although in the Netherlands several studies have been conducted to demonstrate the economic and social value of other cultural heritage domains, such as for instance the historic environment (Klamer 2009) and of museums

(Van der Horst *et al*. 2011), archaeological research and preservation projects have until now not been included in such studies.

We aimed to revisit the social value debate because we believe that the social values of archaeology have the potential to bring three worlds together and to build new partnerships. The first is the world of business, of the construction and planning industry, in which one can observe a growing move for social responsibility and social entrepreneurship. Making profit only is becoming less important for the private sector as it is not sustainable, while the 'soft' values like social or environmental goals are. Yet there is ample room to add shared values to the list. In the public sector, we witness governments recognizing and propagating the importance of social needs, like social return on investment and quality of life. The latter is even part of the Grand Societal Challenges that inspired the Horizon 2020-program. Social participation, involvement and connectedness for example are hugely important issues for society and all options that can help to add to these goals are welcomed. The third party, the archaeological sector, needs to find a better answer to maximise the impact of its public expenditures for society. In our opinion, archaeology could do itself a favour by moulding itself into the ideal partner to contribute to the social goals of local policies and the corporations it is cooperating with. The potential is there; it has the ability to attract participation, as it generally attracts a positive response and a great deal of public support. In fact, there seems to be a real demand for participation with the public, as also the above study has illustrated. Archaeology also has the ability to generate social value, as it can strengthen social relationships and interactions through shared experiences, enhance social inclusion or integration of people into civil society, and add to people's sense of belonging to their place of residence.

As a discipline, we should therefore explore more the social and societal values of archaeology and start developing a vision and a strategy for societal or social marketing. Archaeological contractors might for example utilize and exploit their social value facilities at offer to distinguish themselves from one another during the competition for projects. Moreover, independent platform organisations could think of providing an objective ranking – similar to for instance existing CSR-rankings – of those companies and their social responsibility facilities. Such rankings should however be based on impact measurements with stakeholders such as local authorities, the public, builders and planners hiring archaeological contractors. We therefore ought to keep a close eye on what is happening in other parts of society, such as the developments in the marketing sector, in order to observe how the concept of social entrepreneurship develops and what other innovations could create benefits or opportunities for our sector, such as the tendency in branding to enrich the experience of consumers and the use of storytelling in content marketing (Groot forthcoming 2015). These are all developments archaeology could easily play a role in, as they link up to the very nature of our profession (Holtorf 2007).

The sector should also encourage and carry out more multidisciplinary research in this direction. We could for instance draw upon other (local) research on '*buurthechting*' (cf. Van der Graaf and Duijvendak 2009) to find out what archaeological projects might add to such approaches. We could also look for other untapped social values that archaeological projects may have, because apart from the ones we highlighted in this article, there may be many more. Why should the social value of archaeology only be about participation, inclusion, empowerment and social cohesion, or that the social values of archaeology are confined to well-being and health? Could archaeological engagement projects perhaps also evoke happiness, or reduce the fear of crime in a particular area? The latter for instance was indicated by more than a quarter of the participants of a long-lasting community archaeology project in a problematic district of Manchester, in the United Kingdom, which had the reduction of anti-social behaviour in the district actually as one of its objectives (Russell and Williams 2008). We could also look into archaeological heritage projects as a potentially binding instrument within the context of integration of minority groups. In any case, the sector needs to gather evidence through academic research for any such claims. Some research is being conducted in the context of the NEARCH-project[9], a European research project funded by the European Commission, in which the authors for instance study the cost-effectiveness of outreach and participation activities in terms of impact, stakeholder involvement and economic effects, but many more studies are needed.

Because of the serious positive implications an enhanced societal value of archaeology may have, it is surely worth the effort. If it turns out that archaeology has many other, so far unexploited societal values, and if we learn to define and exploit these social values of our discipline, the sector might be able to turn them into a valuable asset. This might even open-up new partnerships and additional sources of income for archaeological projects, like crowd funding and matchmaking. It may ultimately contribute to the development of a more sustainable economic model for development-led archaeology in Europe, one in which archaeology is no longer primarily considered a burden but as an added value, an asset worth treasuring.

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Notes

1 Www.discovering-archaeologists.eu

2 Http://www.coe.int/t/dg4/cultureheritage/heritage/Identities/default_en.asp

3 Http://www.rijksoverheid.nl/nieuws/2011/04/29/rijksoverheid-zet-social-return-in-bij-aanbestedingen.html

4 Http://www.legislation.gov.uk/ukpga/2012/3/contents/enacted

5 Http://www.unesco.org/en/the-2009-world-conference-on-higher-education/societal-commitment-and-social-responsibility/

6 Balata Refugee Camp was established in 1950 and has become the largest West Bank camp in terms of inhabitants, with over 23,000 registered refugees. See http://www.unrwa.org/newsroom/features/balata-refugee-camp.

7 We experienced that this is an issue when children in occupied East-Jerusalem were throwing sticks at us and yelling we had to leave. As we were clearly not of Arabic origin, they automatically considered us opponents.

8 See: http://www.de-schadewijk.nl/site/content/Publieke_docs/Horzak-Noord%20straatnamen.pdfhttp://www.de-schadewijk.nl/site/content/Publieke_docs/Horzak-Noord%20straatnamen.pdf and http://koenep.home.xs4all.nl/horzak/basis.htm for more examples.

9 Www.nearch.eu

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