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2.3 Can the period of Dolmens construction be seen in the pollen record? Pollen analytical investigations of Holocene settlement and vegetation history in the Westensee area, Schleswig-Holstein, Germany

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Abstract
This study focuses on the high-resolution reconstruction of land use and forest history and the changes of vegetation connected to the erection and use of megalithic graves at Krähenberg in Schleswig-Holstein, Northern Germany. Pollen analysis of a peat core from a small mire directly neighbouring the graves was performed in connection with the analysis of archaeological data. A chronological framework is provided by \textsuperscript{14}C AMS radiocarbon dating. Analysis of known archaeological records using GIS-technique provides information of the intensity and time periods of human activities in the study area. The megaliths in close vicinity of the investigated mire present a clearly visible evidence of anthropogenic use during the middle Neolithic. The pollen diagram shows the vegetation development of the study site from the end of the Atlantic, Subboreal and early Subatlantic period. A small forest opening is suggested around 3500 BC, possibly in connection with the construction of the megaliths, but there is no strong evidence of considerable woodland clearances. The archaeological data indicate that human impact in the area took place during the Neolithic, the Bronze Age and Iron Age, which is corroborated by the pollen record, suggesting that human impact in the study area occurred periodically from the end of the Atlantic period, with an increasing intensity during the Bronze Age.
KEY WORDS

Pollen analysis, Neolithic, megalithic graves, human impact, Schleswig-Holstein

INTRODUCTION

In the prehistory of northern Europe megalithic graves belong to the most remarkable and mysterious structures. The time of their construction, as well as their function and role in the development of human culture are intensely discussed topics not only in archaeology, but also in the natural sciences, dealing with the impacts of human activities on the landscape. The boulders pertaining to the megalithic structures in the study area potentially yield information on their geological age and origin, but they do not provide evidence of when or by whom the structures were erected nor their possible function. In archaeology, the question of dating megalithic structures to a particular Neolithic cultural period can be done by characteristic finds (Müller 1997), which are potentially related to different cultures.

Difficulties of such dating are mainly caused by the phenomenon of reusing the megaliths and its surrounding area during thousands of years. Even if the megaliths possessed a particular primary function, this could have been changed several times during the Neolithic and Bronze Age periods (Steinmann 2009). At present, using archaeological and radiocarbon dating methods (Klassen 2001; Persson & Sjögren 1995), the construction time of northern German and Scandinavian megalithic graves is estimated between the late Early Neolithic period until the early Middle Neolithic period. These monuments were probably erected during a very short time period (Schuldt 1976). Forests in the surroundings have been opened possibly in connection with the construction of the megaliths (Andersen 1992). After their construction the monuments were used as graves by people associated with the TRB culture (Hoika 1990). The megaliths become a part of the landscape as objects and indicators of human influences on the landscape.

Pollen analysis has shown that small mires represent valuable archives for the reconstruction of vegetation changes in the immediate surrounding area (Behre & Kučan 1986; Kühl 1998; Prentice 1985; Rickert 2001) and are thus particularly suitable to track small-scale human impact on the landscape. Changes of vegetation resulting from human impact, including the erection of megalithic graves, are often reflected in the pollen records by the occurrence of pollen grains of anthropogenic indicators. In this study, we investigate whether the erection and use of megalithic graves is reflected in the pollen diagram. By combining the pollen record with archaeological data, we are attempting to identify whether and when local woodland clearance took place as a possible result of the construction and use of the megalithic graves.

MATERIALS AND METHODS

Study area
The research site ‘Krähenberg’ (Crows Hill) is located in northern Germany within the municipality of Westensee, Schleswig-Holstein, south-west of the city of Kiel. The area belongs to the Westensee and mo-
raine region (Meynen & Schmithüsen 1962). The landscape was formed by the Weichselian glaciation spreading from the Baltic Sea almost to the middle of Schleswig-Holstein. The climate can be classified as temperate humid, the mean annual precipitation ranges from 750 to 850 mm and the mean annual temperature is 8.5 °C. The dominating soils in the area are cambisols on sand and clay or luvisols on boulder clay (Kielmann 1996). Today, woodlands are dominated by beech (*Fagus sylvatica*) or planted conifers. Historically old woodland is found in the investigation area. The wooded area is separated from agricultural fields by hedge rows. Small land depressions (kettle holes) are numerous due to Late Glacial dead ice relics. They developed into lakes and were later transformed into small mires (Dierssen 2005). Due to the usually continuous deposition of sediments, these old, small (1-8 ha) mires are especially valuable for a high-resolution pollen analytical reconstruction of local vegetation and landscape history (Rickert 2006).

The Krähenberg mire (Crows Hill mire) is located in the Westensee region about 2 km south from the Lake Westensee (54°15’40.15” N, 9°54’10.05” E). The mire surface covers an area of 3.45 ha and was separated in the past by the hedge bank. At a distance of approximately 100 m of the mire, five megalithic graves exist. The graves 164-168 (Sprockhoff 1966) are arranged in a more or less straight line and nowadays are surrounded by arable fields (fig.1).

**GIS-analyses of the archaeological records and geomagnetic surveys**

In a periphery of 5 km diameter of the study site the known archaeological records of all prehistoric time periods were analysed using GIS-techniques. The morphology of the area adjacent to the graves was investigated using airborne laser altimetry data (Land Survey Office Schleswig-Holstein® 2009). Additionally, geomagnetic surveys at this site have been done.
Peat coring and pollen analysis
A 560 cm long peat core (KRM) was retrieved in July 2009 from the centre of the western part of the Krähenberger mire using the high-precision rod-operated Usinger piston corer (Mingram et al. 2007). The extracted undisturbed 1m-long cores are 80mm in diameter. Stratigraphic features were recorded in the field. Cores were cut longitudinally, thus two halves are available in half plastic tubes for sampling.

The uppermost 2.24m of the core was sampled in 2cm intervals. Samples were processed following standard laboratory techniques (Fægri & Iversen 1989; Moore 1991), and microscopically analysed with 400x and 1000x magnification by using the pollen reference collection of the Palaeoecology research group at the Institute for Ecosystem Research, University of Kiel, as well as the pollen atlas by Beug (2004). Glycerine was used as the embedding medium to prepare slides. A minimum of 500 arboreal pollen grains were counted in each sample. Microcharcoal fragments bigger than 10 µm were counted to reflect fire events (Tinner & Hu 2003). The pollen diagram was constructed using the program TGView© Version 2.1 (Grimm 1994). Percentage calculations of pollen taxa and types are based on the terrestrial pollen sum. Additionally, the AP/NAP ratio was calculated. For that, pollen grains of Corylus (hazel) were excluded from the AP and calculated as NAP (Overbeck 1975). Pollen grains of wetland plants, Cyperaceae and aquatic plants are excluded from the terrestrial pollen sum, as well as spores of cryptogams. The pollen diagram is composed as follows, from left to right: tree taxa indicating long distant pollen transport (Pinus), trees and shrubs of the local and regional vegetation, plants of the heath family (Ericales), upland herbs, cereals, anthropogenic indicators, cryptogams, wetland and aquatic plants, non-pollen palynomorphs and microcharcoal fragments (> 10 µm).

14C AMS dating and radiocarbon calibration
Five 14C measurements with the accelerator mass spectrometry system AMS were provided by the Leibniz-Laboratory for Radiometric Dating and Stable Isotope Research, University of Kiel (Grootes et al. 2004). Sediment samples were checked under the microscope and an appropriate amount of material was selected for dating. Selected material was then extracted with 1% HCl, 1% NaOH at 60°C and again 1% HCl alkali residue. The combustion to CO2 was performed in a closed quartz tube together with CuO and silver wool at 900 °C. The sample CO2 was reduced at 600 °C with H2 over about 2 mg of Fe powder as catalyst, and the resulting carbon/iron mixture was pressed into a pellet in the target holder. Conventional 14C ages were calculated according to Stuiver & Polach (1977) with a δ13C correction for isotopic fractionation based on the 13C/12C ratio measured by the AMS-system simultaneously with the 13C/12C ratio. ‘Calibrated’ or calendar ages were calculated using OxCal v4.1.6 (Bronk Ramsey 2009), data set IntCal09 (Reimer et al. 2009).

RESULTS AND DISCUSSION

Archaeological evidence for prehistoric landscape use
In a periphery of 5 km of the study site there are about 250 located places of discovery from all archaeological periods. Archaeological records from the Palaeolithic and Mesolithic are represented by three records of stone tools including a tranchet axe. In the area of Krähenberg several megalithic structures and Neolithic findings are recorded: 17 megalithic graves, 9 earth graves, 34 findings of silex-axe, silex-chisel, four records of silex-knifes and seven stone axes. Altogether 58 archaeological records in the surround-
The graves at Krähenberg have been described by Sprockhoff as three extended dolmens and two passage graves (Sprockhoff 1966, 164-168), but have not been investigated in detail or dated radiometrically. Dating of similar structures in Schleswig-Holstein and in Northern Germany (Fansa 2000; Baldia 1995/2009; Midgley 1992) yielded dates of early to middle Neolithic age. Based on the types of the found artifacts, especially the silex-axes (fig. 3), the assumed human impact in the study area can be put mainly in the time of Middle Neolithic (3500-3300/3200 BC). Therefore, it is suggested that the graves at Krähenberg might date back to the same period in Northern Germany, i.e. the Funnel Beaker (TBK) culture (4100/4000-2800/2700 BC).

Figure 2. Archaeological records from the Neolithic (4100-1800/1700 BC) around the study site: megalithic graves (dark gray), earth graves (light gray), and findings (black).

Figure 3. Silex-axe (TBK-culture) from the study site.
Studies of the early Bronze Age (Aner et al. 2005) show in contrast to the archaeological recordings of the Archaeological State agency of Schleswig-Holstein (only 15 records) continuous and intensive human activities in the area, especially in the surroundings of the study site. The Bronze-age finds are usually devices and decoration made of bronze or also made of amber. The Iron Age however is particularly represented by ceramic findings and the remains of urn grave fields.

The megaliths at Krähenberg represent the first, clearly visible evidence of the landscape use by people during the Middle Neolithic. The magnetogram shows unknown anomalies and remains of the mound fill and of the stone kerbs surrounding the graves (fig. 4). The two rows are 11m apart from each other, run over a distance of ca.100m along the graves. The accurate parallelism of the rows within an otherwise rather unimpaired range south of the graves are clearly of anthropogenic origin. They can be interpreted as prehistoric construction structures (Sadovnik et al. 2010). However, clarity can only be brought by an excavation.

**Pollen analysis and radiocarbon calibration**

The pollen record (fig. 5) shows that the upper peat layer of the mire was removed by historical peat cutting in the 18th century (Hedemann-Heespen 1906). The pollen of Beech (Fagus) as a dominant tree species in natural woodland communities since the migration period in Northern Germany (Schmitz 1951; Aletsee1959; Wiethold 1998; Wiethold & Lütjens 2001) is not sufficiently present in the upper part of the core. However, the periods since the Neolithic to Bronze Age are fully presented in the pollen record, without any indication for a hiatus, thus providing a high resolution record of the Neolithic and Bronze Age. This is supported by the five $^{14}$C AMS datings.

Nine local pollen assemblages zones (LPAZ) were identified according to the pollen assemblages (Birks 1986; Hedberg 1972a, b) KRM-1 to KRM-9 (table 1). Ages of the zone boundaries and samples age were modelled with OxCal v4.1.6 (Bronk Ramsey 2009), based on the five $^{14}$C AMS samples from peat (table 2). AMS measurements covered a period from about 4000 cal BC until 361-204 cal BC.
2.3 Can the period of dolmens construction be seen in the pollen record?

The lowermost zone KRM-1, from 4045 BC to 3841 BC, represents the transition from the Atlantic to the Subboreal period. At the beginning of this period the study area was covered by deciduous forests, dominated by oak (*Quercus*) with high amounts of lime (*Tilia*) and elm (*Ulmus*). Decrease in *Ulmus* and *Tilia* pollen around 3841 cal BC, at the depth of 2.08m, is interpreted as the ‘elm decline’. The chronology of these phenomena is not yet fixed to an absolute date, but a number of conventional and AMS datings assemble it around 3800 cal BC in Schleswig-Holstein (Nelle & Dörfler 2008). The change in the pollen spectra of arboreal pollen and increase in pollen of *Corylus* indicate some human impact on the landscape. At this time, the change from the Mesolithic culture of hunters and gatherers to Neolithic economic systems with agriculture and permanent settlements occurred in Northern Germany (Behre 2008). Change of burial rites also took place at this time with the beginning of the period of megalithic graves.

Further evidence of an anthropogenic effect on the vegetation composition is seen in the pollen record from 3841 to 3542 BC, in zone KRM-2. At the depth from 1.90m to 1.94m (3646-3525 cal BC) the diagram shows a succession of the occurrence of grasses, Ericales and a marked peak of *Corylus*. A decrease of oak and lime in the pollen diagram and an increase of wetland and aquatic plants can be interpreted as a short but significant, moderate opening of the landscape, which might have been related to the con-
struction of megaliths at Krähenberg. A – probably short – opening of the forest might have resulted in an increase of surface runoff and spring activity, which promoted the wetness of the mire. The peak of Corylus is especially remarkable. At the moment, it is not yet possible to tell whether small anthropogenic gaps in the forest were already present before the construction of megaliths, or whether this peak might be related to some canopy opening during and after the construction. Corylus produces especially high numbers of pollen after disturbance (cutting) and has a relatively high light demand for its growing. This peak will be checked for reproducibility with a second core in the future. The increase of long-distance

<table>
<thead>
<tr>
<th>LPAZ/AGE</th>
<th>ZONE</th>
<th>Depth (m)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>KRM-9 from 1773 BC</td>
<td>Alnus-Corylus-Poaceae Zone</td>
<td>0.63 – 0.30</td>
<td>Increase of grasses, cereals and anthropogenic indicators, decrease of Tilia (0.30 cm end of core)</td>
</tr>
<tr>
<td>KRM-8 (2036-1773 BC)</td>
<td>Alnus-Corylus Zone</td>
<td>0.79 – 0.63</td>
<td>Decrease of arboreal pollen, increase of anthropogenic indicators and charcoal</td>
</tr>
<tr>
<td>KRM-7 (2320-2036 BC)</td>
<td>Betula-Quercus-Tilia Zone (forest regeneration)</td>
<td>0.91 – 0.79</td>
<td>Decrease of Alnus, Corylus and Ericales, increase of Betula and Tilia</td>
</tr>
<tr>
<td>KRM-6 (2642-2320 BC)</td>
<td>Alnus-Corylus Zone</td>
<td>1.09 – 0.91</td>
<td>Increase of grasses and Plantago lanceolata-type, increase of Corylus and charcoal particles</td>
</tr>
<tr>
<td>KRM-5 (2940-2642 BC)</td>
<td>Betula-Corylus Zone</td>
<td>1.33 – 1.09</td>
<td>Decrease of Alnus, increase of Betula and Corylus, increase of Tilia, small peak of grasses</td>
</tr>
<tr>
<td>KRM-4 (3131-2940 BC)</td>
<td>Alnus-Calluna Zone</td>
<td>1.49 – 1.33</td>
<td>Increase of Alnus and Calluna, increase of charcoal particles, slight decrease of Corylus, decrease of Tilia</td>
</tr>
<tr>
<td>KRM-3 (3542-3131 BC)</td>
<td>Betula-Quercus-Tilia Zone (forest regeneration)</td>
<td>1.83 – 1.49</td>
<td>Increase of Tilia, and increase Quercus in lower part of zone, increase of grasses, very low charcoal value</td>
</tr>
<tr>
<td>KRM-2 (3841-3542 BC)</td>
<td>Alnus-Betula-Corylus Zone</td>
<td>2.09 – 1.83</td>
<td>Increase of Pinus-pollen, Corylus-peak, slight increase of grasses, decrease of Tilia, decrease of Quercus in upper part of zone</td>
</tr>
<tr>
<td>KRM-1 (4045-3841 BC)</td>
<td>Tilia-Ulmus-Quercus Zone</td>
<td>2.24 - 2.09</td>
<td>Decrease of Tilia, elm-decline, transition from the Atlantic to the Subboreal 3841 BC</td>
</tr>
</tbody>
</table>
transported pollen of *Pinus* is also a sign of a temporal opening of the woodlands around the mire, during a comparatively short period of time.

For the Zone KRM-3 from 3542 to 3131 cal BC the increase of grass pollen as well as a slight increase of other anthropogenic indicators like *Plantago*-Type and *Rumex*-Type can be recorded. At this time the increase of lime and oak pollen percentages indicates a regeneration of forest ecosystems. However, this phenomenon can be interpreted as a sign for using the tree leaves to provide fodder (Andersen 1990). Pollarded trees tend to produce more flowers (and pollen) in the upper parts of the crown. Rickert (2006) discusses this use of Neolithic forests to exist locally and for a short period, not longer than 500 years. The landscape in the surrounding of the megaliths at that time might have been a semi open pasture. The openings in the forested landscape must have been small and local. The microcharcoal amounts are low. Very few pollen grains of the *Cerealia*-Type were found in the pollen record during this period. Thus, we do not assume arable fields to be present close to the mire.

For the zone KRM-4, from 3131 to 2940 cal BC, a rise of *Alnus* (alder, growing on wet sites) up to 70% was observed. The curves of *Quercus*, *Tilia* and *Betula* (birch) show very low values. *Corylus* decreases, while *Calluna* (heath) increases. Charred particles increase during this pollen zone, which indicates more fire activity, which is most likely connected to human activities.

Pollen zone KRM-5, from 2940 to 2642 cal BC, is characterised by elevated frequencies of grasses,

<table>
<thead>
<tr>
<th>Lab. ID</th>
<th>Sample</th>
<th>Depth (m)</th>
<th>Fraction</th>
<th>Corrected pMC†</th>
<th>δ13C(‰)‡</th>
<th>Conventional Age (14C yr BP) (probability 95.4%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kia40648</td>
<td>KRM-52</td>
<td>0.52</td>
<td>Peat, alkali residue, 4,3 mg C</td>
<td>75.87 ± 0.20</td>
<td>-29.60 ± 0.16</td>
<td>2219 ± 21 (378 – 341, 17.2%) (326 – 204, 78.2%)</td>
</tr>
<tr>
<td>Kia40649</td>
<td>KRM-72</td>
<td>0.72</td>
<td>Peat, alkali residue, 4,7 mg C</td>
<td>64.95 ± 0.22</td>
<td>-27.21 ± 0.37</td>
<td>3466 ± 27 (1882 – 1735, 89.7%) (1714 – 1694, 5.7%)</td>
</tr>
<tr>
<td>Kia40631</td>
<td>KRM-100</td>
<td>1.00</td>
<td>Peat, alkali residue, 5,2 mg C</td>
<td>60.62 ± 0.22</td>
<td>-27.86 ± 0.26</td>
<td>4020 ± 30 (2619 – 2607, 2.9%) (2599 – 2593, 1.0%) (2586 – 2471, 91.6%) (2770 – 2763, 1.0%)</td>
</tr>
<tr>
<td>Kia40632</td>
<td>KRM-160</td>
<td>1.60</td>
<td>Peat, alkali residue, 3,1 mg C</td>
<td>57.71 ± 0.19</td>
<td>-27.96 ± 0.28</td>
<td>4416 ± 25 (3264 – 3241, 4.8%) (3105 – 2921, 90.6%)</td>
</tr>
<tr>
<td>Kia40633</td>
<td>KRM-200</td>
<td>2.00</td>
<td>Peat, alkali residue, 4,2 mg C</td>
<td>53.45 ± 0.20</td>
<td>-25.41 ± 0.25</td>
<td>5032 ± 31 (3946 – 3760, 90.6%) (3741 – 3728, 1.9%) (3726 – 3714, 2.9%)</td>
</tr>
</tbody>
</table>
Corylus and ruderal plants. While Alnus pollen decreases, Betula increases. A regeneration of the forest in the older part of the zone is reflected by a slight increase of Tilia and Quercus. This zone corresponds to the end of the TBK cultural period in Northern Germany (2800/2700 BC) and the beginning of the Single Grave period.

In zone KRM-6, from 2642 to 2320 cal BC, the pollen record shows again an increase of Alnus and Poaceae (wild grass) pollen as well as elevated frequencies of charred particles. This is paralleled by high values of Corylus and an increase of anthropogenic indicators, but there is no indication of cereal cultivation. A moderate intensity of human impact can be assumed for this period. During the following zone 7 (2320 to 2036 cal BC) the regeneration of forests (increase of Tilia) together with the reduction of pollen of the anthropogenic indicators, Poaceae and Calluna can be observed in the diagram. From 2036 to 1773 cal BC (KRM-8), arboreal pollen decrease, while grass pollen grains increase, as well as microcharcoal and anthropogenic indicators. At the end of the late Neolithic period (c. 1800 cal BC) the stratigraphic boundary at the depth of 0.78m is indicated with a change of the peat composition of the mire from sedge peat with Bryopsida to sedge peat with Eriophorum. Sequence calibration of AMS-data of the core KRM shows that in this period the peat growth of the mire decreased dramatically. The age for this period was modelled from 1898 to 1773 cal BC and corresponds to the beginning of the Early Bronze Age in Northern Germany. Clear evidences of land use with arable fields and cereal farming could be detected only for the Bronze Age (pollen zone KRM-9) with an increase of cereal pollen grains.

CONCLUSIONS

Though there is no clear signal of woodland clearance, the forest was opened slightly in a period between 3560–3512 BC (by modelled age using OxCal v4.1.6) in the immediate surroundings of the megaliths. We assume that the forest was opened in connection with the construction of the megaliths c. 3500 BC. After this short, moderate opening, the surrounding landscape was used as a semi-open pasture, but with no grain cultivation. Forest regeneration took place thereafter over a period of c. 500 years.

A further forest regeneration around the megaliths after their construction permits conclusions over the role of megalithic graves in the landscape of Middle Neolithic in Schleswig-Holstein. As is the case for current investigations of the megaliths of Altmark (Demnick et al. 2008), the graves at Krähenberg lie at the crow mountain in an isolated manner from settlement and arable fields areas in the time of the TBK-culture. After the construction of the megalithic graves the site probably might have been used as a cult and ritual place, but the graves were present in a wooded landscape. Clear evidence of land use with arable fields and cereal cultivation was recorded only for the Bronze Age.

Forest composition changed with a succession from Quercus to Betula to Alnus periodically. The reasons and processes of this phenomenon are yet to be understood.

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