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Hunter-gatherer responses to the changing environment of the Moervaart palaeolake (Nw Belgium) during the Late Glacial and Early Holocene

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A R T I C L E I N F O

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A B S T R A C T

This paper presents new geo-archaeological perspectives on the Late Glacial and Early Holocene human occupation around a large palaeolake, the Moervaart palaeolake ($\sim$25 km^2). Intensive fieldwork, using invasive and non-invasive survey techniques, combined with modelling of the palaeotopography and palaeogroundwater and multi-proxy palaeoecological analyses have resulted in a detailed reconstruction of the landscape during the Final Palaeolithic and Early Mesolithic occupation of the area. A major shift in the occupation from the *Federmesser* Culture to the Early Mesolithic was contemporaneous with a sudden and drastic change in the palaeohydrology of the area between ca. 13,300 and 13,000 cal BP (end of Allerød), which coincided with a short but abrupt cooling event known as the Intra Allerød Cold Period (IACP) GI 1b. It is assumed that this event triggered the sudden drying up of the Moervaart palaeolake and surrounding ponds, which until then had provided *Federmesser* hunter-gatherers with extensive and fertile grounds for hunting, gathering and drinking water. The population decline which followed this hydrological event was reinforced by the prevailing cold and harsh conditions of the Younger Dryas and probably lasted until the Pre-boreal. Hunter-gatherers returned to the area in the Boreal, now settling along the proximal floodplain regions of a meandering channel which was connected with the southern Scheldt River.

1. Introduction

1.1. Background

Since the 1980s, the lowland area of Sandy Flanders (NW Belgium) has been the focus of extensive archaeological survey by means of different techniques, including fieldwalking, manual drillings, aerial photography, and trenching. As a result, very detailed maps showing the distribution of archaeological sites are now available, allowing the diachronic investigation of the settlement system from the earliest human presence during the Middle Palaeolithic until Medieval times.

One such study (Crombé et al., 2011) focused on prehistoric hunter-gatherers from the Late Glacial (Final Palaeolithic) until the Early Holocene (Mesolithic) and highlighted a much denser occupation in the central part of Sandy Flanders, where at that time a large lake existed, now called the Moervaart palaeolake. The site density is at least 5 times higher compared to other areas within Sandy Flanders; the distance between sites often is so small that sites form almost continuous clusters in a kind of site-complexes stretching over 10–15 km. The same study also revealed major shifts in settlement locations, in particular at the transition from the Final Palaeolithic (*Federmesser* Culture) to the Early Mesolithic. These changes are characterised by changes in the focus of occupations from lake edges to riverbanks.

In order to explain these prehistoric occupation patterns in this particular area, intensive archaeological and palaeoenvironmental

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research has been carried out in the framework of an interdisciplinary research project. This project conducted detailed investigations of the palaeotopography, palaeohydrology and palaeovegetation, combined with extensive radiocarbon and OSL dating. In the present paper an overview of this research, mainly focusing on the geomorphological and palaeohydrology development of the area, is presented in an attempt to understand the observed prehistoric site distribution patterns. Detailed reports on the multi-proxy palaeoecological investigations will be published in separate papers (Demiddele et al., in press; Gelorini et al., in press a,b; Van Damme et al., in press). Particular attention in this study is given to possible climate induced environmental changes which might have impacted the hunter-gatherer occupancy of this former lake area at the transition from the Pleistocene to the Holocene.

1.2. Regional setting

The Moervaart study area is situated in the centre of the coversand lowlands of NW Belgium, known as Sandy Flanders (*Zandig Vlaanderen*) (Fig. 1). This area, covering ~3300 km^2 and situated at ~2 to 10 m TAW (Second Belgian Ordnance Sea Level), is delimited roughly by the North Sea coastal plain to the west, the Lower Scheldt river to the (south-)east, and the Belgian–Dutch border to the north. The Moervaart study area developed on top of a deep (−30 m) and broad (~50 km) Pleistocene valley called the Flemish Valley (*Vlaamse Vallei*). This palaeovalley developed through the incision of Palaeogene strata of the North Sea Basin, which locally outcrop or are situated at shallow depths in the cuesta landscapes of Central West Flanders to the west, and in the Waasland to the east (Tavernier, 1946; De Moor, 1963; Tavernier and De Moor, 1974; Mathys, 2009; Hijma et al., 2012) (Fig. 1c). The genesis of the Flemish Valley spans several periods of periglacial fluvial incision and infilling, caused by extreme climatic fluctuations and corresponding sea level changes in the Middle and Late Pleistocene. The final incision-and-infilling period was during the Last Glacial, the Weichselian (115–11.5 ka) (De Moor and Heyse, 1978), which resulted in a thick accumulation of mainly sandy sediments, reaching ~25 m in the thickest parts. In the Late Pleniglacial and Late Glacial (ca. 27–11.5 ka) alternating drier and wetter climatic conditions increased aeolian and fluvial activity and promoted the development of three main landscape features (Fig. 1d), i.e. in chronological order: the massive coversand ridge, named the Great Sand Ridge of Maldegem-Stekene (De Moor and Heyse, 1978; Verbruggen et al., 1996); the large Moervaart palaeolake directly south of the Great Sand Ridge (Heyse, 1979, 1983); and the local river named Kale (upper course) or Durme (lower course), which currently runs through the palaeolake area from west to southeast where it joins the River Scheldt.

In the Moervaart study-area numerous sandy ridges occur that are believed to have been formed during the final Pleniglacial and Late Glacial by aeolian sedimentation (Heyse, 1983). The massive sand ridge known as the Great Sand Ridge of Maldegem-Stekene is undoubtedly the most important of these sand ridges (Fig. 1d). Starting at the present-day North Sea coastal plain, it extends west to east over a distance of ~80 km. Its width varies locally between 1 and 3 km and its height is generally >5 m above the surrounding topography. According to earlier studies (Heyse, 1979, 1983), this feature was created by dominant northern winds providing the ridge with a gentle northern slope and with a steep southern slope. This massive coversand ridge contrasts sharply with other sand ridges in the study-area both in dimensions and orientation. Smaller sand ridges have a clear SW–NE orientation, sometimes ranging to N–S, with some clearly parallel to the Kale/Durme river.

The Moervaart depression comprises the remains of one of many hundreds of shallow freshwater palaeolakes in Sandy Flanders dating from the Late Glacial. These palaeolakes are all situated along the southern steep slope of the Great Sand Ridge of Maldegem-Stekene (Fig. 1d), which suggests that the latter is partially responsible for their formation. It is currently believed that these freshwater palaeolakes came into existence while the Great Sand Ridge was forming and blocking the previously open northern exit route for surface waters (De Moor and Heyse, 1978; Verbruggen et al., 1996). The palaeolakes formed as surface water and groundwater accumulated in local closed depressions. Initially such local lakes would be a few hundreds of meters in diameter, some of them evolving into larger palaeolakes covering several km^2. The Moervaart palaeolake was by far the largest within NW Belgium, covering a maximum surface of ~25 km^2. It developed within an asymmetric depression with a steep northern slope and gently sloping southern edge, the deepest part being situated in the centre along the northern lakeside.

So far limited research has aimed at understanding the formation of the Kale/Durme river. The few studies have focused on the palaeoecology of the infilling of deep palaeochannels, which have been detected to the west and east of the study area at Vinderhoute and Waasmunster respectively (Verbruggen et al., 1996). According to these studies, the incision of the Kale/Durme dates to at least the Allerød, but little is currently known about its exact course and its relation with the Moervaart palaeolake.

1.3. Research aims

Although the general genesis and evolution of the three main landscape features within the selected study area is already known from earlier studies, a more detailed knowledge is needed regarding human–environment relationships during the Late Glacial and Early Holocene. To understand the dynamics of hunter-gatherer groups occupying and exploiting the area, it is of uttermost importance that the contemporaneous landscape and its development is reconstructed as accurately as possible. Important questions in this context are, amongst others: how and when did the Moervaart lake appear and disappear, how did the Moervaart lake and the Kale/Durme river relate to each other, what was the ecological value of the area in terms of wild resources, such as wild game, fish, plants and drinking water. These questions can only be approached through a more in-depth and multi-disciplinary study of the different landscape components.

2. Materials and methods

This project consisted of two main lines of research: detailed mapping and modelling of the sedimentary facies, palaeohydrology and palaeotopography of the Moervaart area, and detailed reconstruction of its palaeoecology.

The first line of research was attained by means of intensive fieldwork (Bats et al., 2009, 2010, 2011) and subsequent modelling of various aspects of the palaeolandscape. The fieldwork strategy was based on a newly constructed filtered digital elevation model (DEM), representative of the pristine topography prior to the 19th century (Werbrouck et al., 2011). This filtered DEM (resolution 2 m × 2 m), which excluded the main present-day anthropogenic features, was composed using high precision airborne LiDAR (Light Detector and Ranging) data taken between 2001 and 2003 (AGIV 2003) and ancillary information such as topographical vector data, thematic maps (e.g. soil maps), and historical maps (e.g. from 1576, 1775 and 1910) (Werbrouck et al., 2011).

The filtered DEM locally revealed a microtopography of sandy elevations and palaeochannels, which was further investigated in the field by means of a combination of invasive and non-invasive survey techniques (Fig. 2). Manual and mechanical coring was conducted throughout the study area. More than 1000 manual

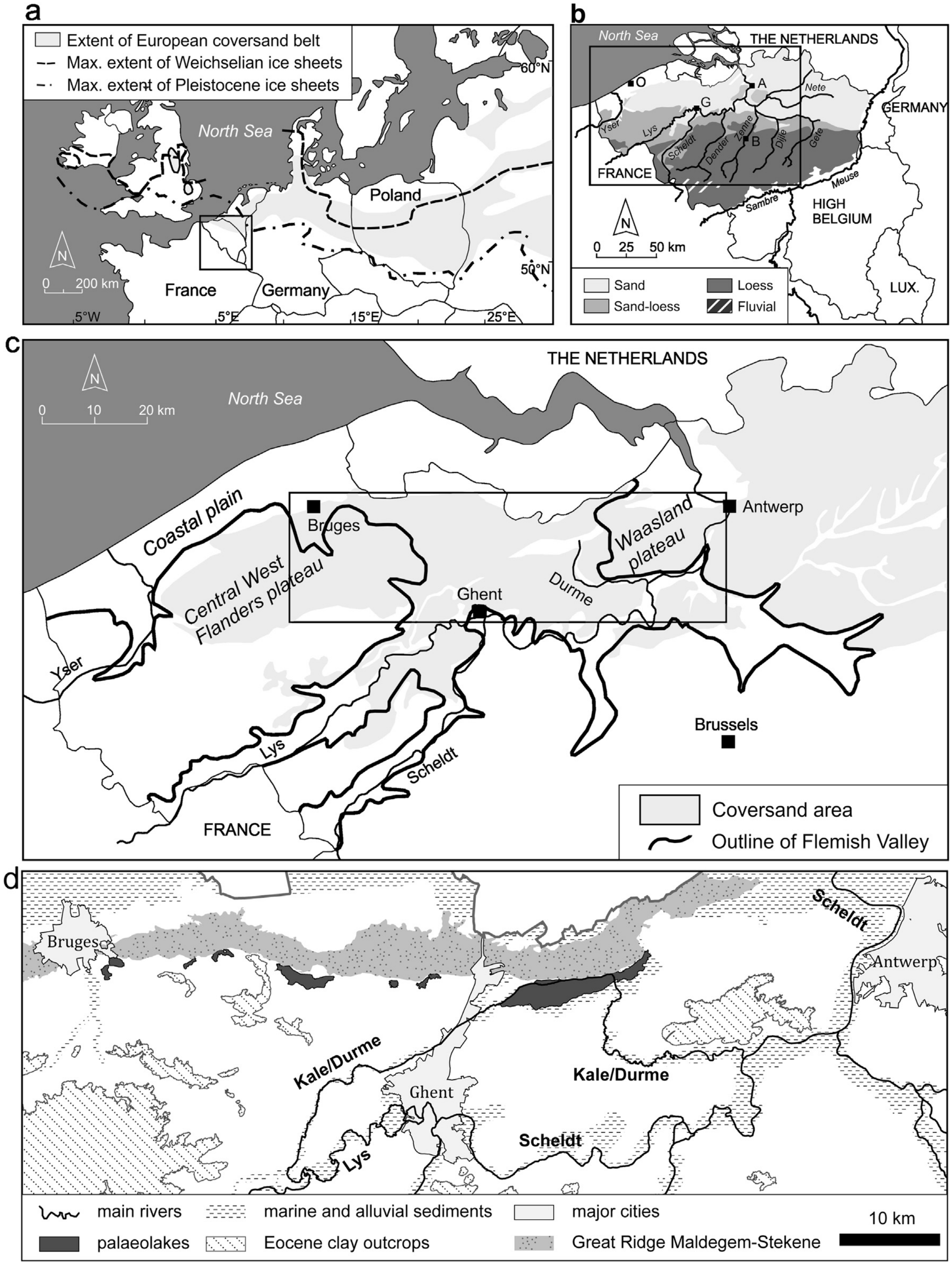

Fig. 1. (a) Extent of the European coversand belt. The location of Belgium is indicated with an open square. (b) Schematic map of Belgium, showing some of the major rivers and the Pleistocene sedimentation areas in N Belgium. (c) Extent of the coversand area and major geomorphological units in NW Belgium. The study area of Sandy Flanders is indicated with an open square. (d) Simplified geomorphological map of Sandy Flanders (after Derese et al., 2010; Crombé et al., 2011).

augerings were performed with a 7-cm Edelman and 3-cm gouge auger at a mean interval of 25 m along six north–south transects in the central and eastern parts of the Moervaart depression (shown on Fig. 2). The western section was drilled in a separate project by the *Agentschap Onroerend Erfgoed* by means of ~140 corings (Meylemans et al., 2011). In addition, smaller transects and isolated corings (not indicated on Fig. 2) were set at specific locations in order to verify particular landscape features (e.g. channels, depressions) detected on the DEM and/or by EMI (cf below). The obtained coring data, including sediment colour, texture, mineral

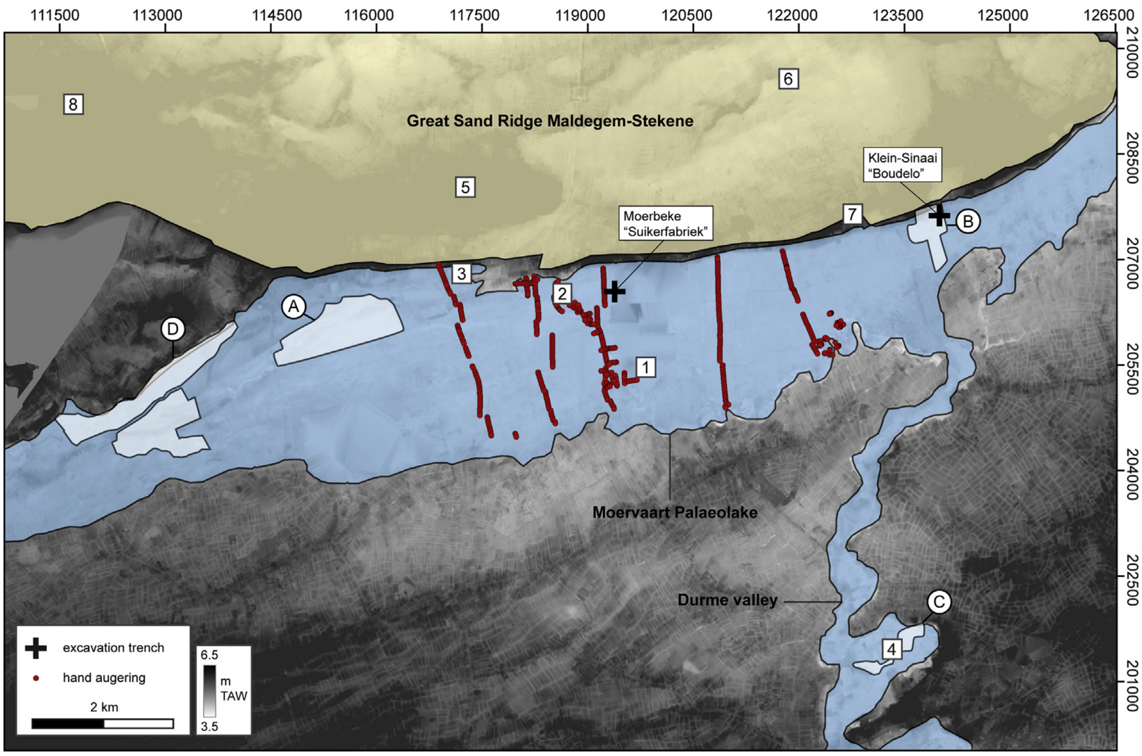

Fig. 2. Elevation of the Moervaart study-area (Lidar, AGIV 2001–2004) with schematic indication of the Moervaart depression and the Great Sand Ridge. The different areas where detailed EMI-surveys were conducted are shown (A–D) along with the locations of the mechanical coring campaigns (1–7) and test-pitting (8). In the central part of the palaeolake, manual auger transects are shown along with the location of the two trenches (Moerbeke "Suikerfabriek" and Klein-Sinaai "Boudelo").

and organic inclusions, sedimentary structures, and $CaCO_3$ amount, were subsequently interpreted in terms of lithofacies and used to make general lithostratigraphical cross sections through the Moervaart depression. These severed as tools for selecting interesting locations for further, more in-depth research into the lithostratigraphy and palaeoenvironment. From the cross-sections seven locations with long and complex sedimentary sequences were sampled by means of 15 mechanical drillings using Begemann and Nordmeyer HBS-RKR drills (sampling locations 1–7 on Fig. 2). In addition to these corings, ~4000 core logs obtained in the study area mainly during the 1980s and 1990s in the context of soil and geomorphological mapping and hydrogeological projects were integrated into the study, mainly for modelling purposes (cf below).

Following the coring, mobile geophysical surveys were performed in selected areas (areas A–D on Fig. 2), collecting spatial data concerning subsoil variability (De Smedt et al., 2012). This survey was mainly done in areas in which the augerings indicated the presence of complex networks of palaeochannels that were difficult to map by coring. In these areas we used a mobile multi-receiver electromagnetic induction instrument for mapping the soil apparent electrical conductivity (ECa). The use of a mobile survey setup enabled gathering spatially continuous data at an efficient sampling rate. At a 2.0 m × 0.25 m measurement sampling resolution, 1 ha could be mapped per hour (De Smedt et al., 2011). The resulting high-resolution datalayers allowed for the discrimination of minute palaeotopographical variations, surpassing the lateral resolution of the auger survey. The use of a multi-receiver EMI sensor, the Dualem-21S (Simpson et al., 2009), enabled mapping the ECa of four soil volumes simultaneously, representative for measurement depths down to 0.5 m, 1.0 m, 1.5 m and 3.2 m below the soil surface. By combining these different measurements into a modelling procedure, the palaeotopography of EMI surveyed areas was reconstructed (De Smedt et al., 2011; De Smedt et al., 2012).

The various field-data combined with the DEM resulted in a high-resolution reconstruction of the palaeorelief and palaeohydrological system, both in horizontal and vertical sense, within the Moervaart study-area, which could be used subsequently for studying the distribution of prehistoric sites.

More or less synchronously with this fieldwork, excavations and deep mechanical test pitting were undertaken in order to obtain further insights into the lithostratigraphy of the area and to facilitate palaeoenvironmental sampling. Two research trenches were excavated in the Moervaart palaeolake; one ~70 m long trench in the deepest part of the palaeolake (Moerbeke "Suikerfabriek", Fig. 2), and a second 35 m long trench near the eastern extremity of the palaeolake (Klein-Sinaai "Boudelo", Fig. 2), adjacent to the Great Sand Ridge. These long trenches provided continuous cross-sections, which were recorded in detail both in drawings (scale 1:10) and photos. These cross-sections offered a detailed view on the lithostratigraphy and its lateral variability, and served as reference for the lithofacies deduced from the coring. Also the cross-sections were sampled intensively for various palaeoenvironmental analyses. For safety reasons, mechanically dug test pits were used on the Great Sand Ridge instead of long trenches. At Rieme-Noord (Hoorne et al., 2009; Bos et al., 2013) (8 on Fig. 2), a total of 189 test pits that ranged from 1 to 4 m deep were excavated, which resulted in a very detailed mapping of the coversand stratigraphy over a surface of ~57 ha.

Modelling of past conditions of phreatic groundwater was performed (Zwertvaegher et al., 2013), using the model MODFLOW-96 (Harbaugh and McDonald, 1996) to calculate mean water table depths for a study period starting near the middle of the Younger Dryas and covering the entire Holocene (12,716 cal BP–1953 AD). Mean water table depths are used for land evaluation and carrying capacity assessments in (post-)Neolithic agriculture and to assess occupation and housing conditions over the entire simulation period. Based on present-day climate data and time series of temperature and precipitation anomalies from Davis et al. (2003) and Davis (pers. com., 2008), time series of local temperature, precipitation, and potential evapotranspiration were constructed. The temporal resolution of the model was set at 30 years, and the spatial resolution at 100 m × 100 m, for a model area of 584 km^2, encompassing the Moervaart study-area. Default hydraulic properties of the substrate were taken from the Flemish hydraulic database (VMM, 2008). Values of these properties for the upper model layers were calibrated for the year, represented by the drainage class map surveyed in the 1950s, by minimizing the differences between mean water tables from the drainage class map and simulated MWT. Subsequently, the calibration was extended to the period starting 12,716 cal BP by adjusting the hydraulic conductance of the upper 20 cm. Simulated water tables were compared to the recorded presence of archaeological sites and podzol locations (bottom of Bh-horizon) recorded in the Aardewerk database (Van Orshoven et al., 1988).

For palaeoenvironmental reconstruction, a multi-proxy study was executed, documenting physical parameters (bulk sediment composition, magnetic susceptibility, micromorphology) and biotic remains (palynomorphs, plant macroremains, diatoms, freshwater molluscs, ostracods and chironomids) from high-quality lacustrine and fluvial sediment records. Altogether four complete sedimentary sequences – in the Moervaart palaeolake, on the Great Sand Ridge, in the meandering, and anastomosing palaeochannels – were analysed in full detail (sampling interval 1–2 cm), while another five sequences were investigated in low resolution (sampling interval 5–10 cm). Cluster analysis applied independently on the different biotic proxies identified well-defined main biozones that were commonly related to the Late Glacial and Early Holocene climatic events. For independent age control, we performed extensive radiocarbon AMS dating ($n = 55$), mainly of terrestrial macroremains, and optically stimulated luminescence OSL ($n = 11$) dating of aeolian sediments (Derese et al., 2010; Crombé et al., 2012b).

3. Results

3.1. Great Sand Ridge of Maldegem-Stekene

In the framework of the project, research focused more on the Great Sand Ridge and less on the smaller sand elevations. At Rieme "Noord" (8 on Fig. 2) (Hoorne et al., 2009), Wachtebeke "Heidebos" (5 on Fig. 2) (Derese et al., 2010) and Moerbeke "Driehoek" (7 on Fig. 2), sequences were observed which consist of thick coversand deposits alternating with thin (from a few cm to 0.25–0.30 m) organic to peaty layers (Figs. 3 and 4). The former indicate phases of major aeolian deposition, the latter corresponding to stability phases partly resulting from increased vegetation and groundwater rise due to permafrost melting (Bos et al., 2013). By combining ^{14}C and OSL dates with pollen and micromorphology data, it was possible to link these stability phases with shallow slacks and ponds dating mainly to the Bølling and/or early Allerød (Crombé et al., 2012b; Bos et al., 2013). The pollen record of these organic horizons (Fig. 4) points to a similar environmental evolution as in the adjacent Moervaart palaeolake. Initially (Bølling) most depressions were no more than swamps or shallow pools, the edges of which were dominated by grasses (80–60%) and some dwarf-birch; during the Allerød they rapidly turned from shallow (<1 m, e.g. Rieme 126, Wachtebeke) to slightly deeper ponds (3–6 m, e.g. Rieme 143), although periodic fluctuations of the water level must have occurred (Bos et al., 2013). Simultaneously, vegetation became more closed with birch and willow as dominant trees and shrubs, although grasses/sedges remained largely present along the banks.

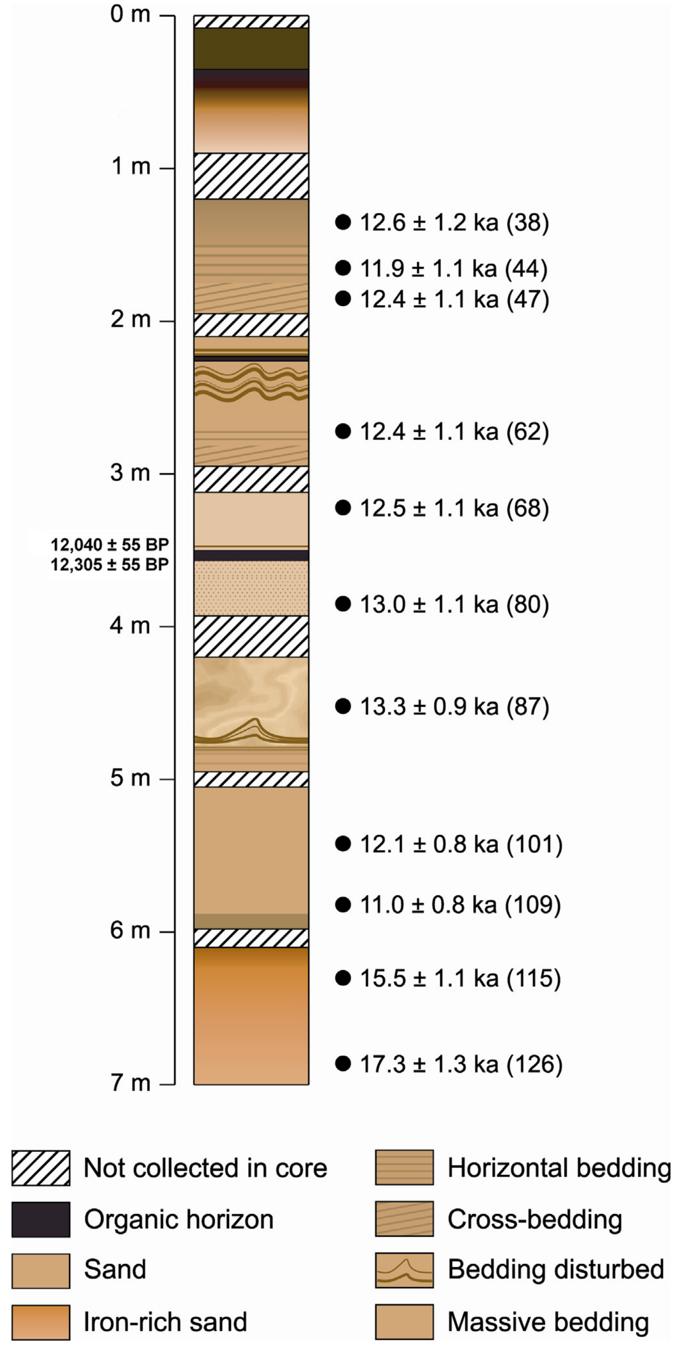

Fig. 3. Schematic log of the investigated sequence of coversands and intercalated humiferous soil horizons at the locality of Wachtebeke "Heidebos" situated on the Great Sand Ridge, showing the results of the radiocarbon (left) and OSL dating (right) (modified from Derese et al., 2010).

Locally important episodes of aeolian deflation and sedimentation occurred during the Older and Younger Dryas, with the deposition of 1 m–3 m of coversands during each event. The upper 6 m of these coversands seem to be decarbonised, which is still ongoing. Based on thin sections of the deeper non-decarbonated sand layers of the ridge, the carbonate content of these sediments is visually estimated to be originally around 10%. In the eastern section of the Great Sand Ridge deflation during the Older Dryas resulted in a southwards displacement of the sand ridge, covering part of the lacustrine Moervaart deposits with 1.5 m–2 m of aeolian sands. In addition, evidence of limited aeolian activity during the

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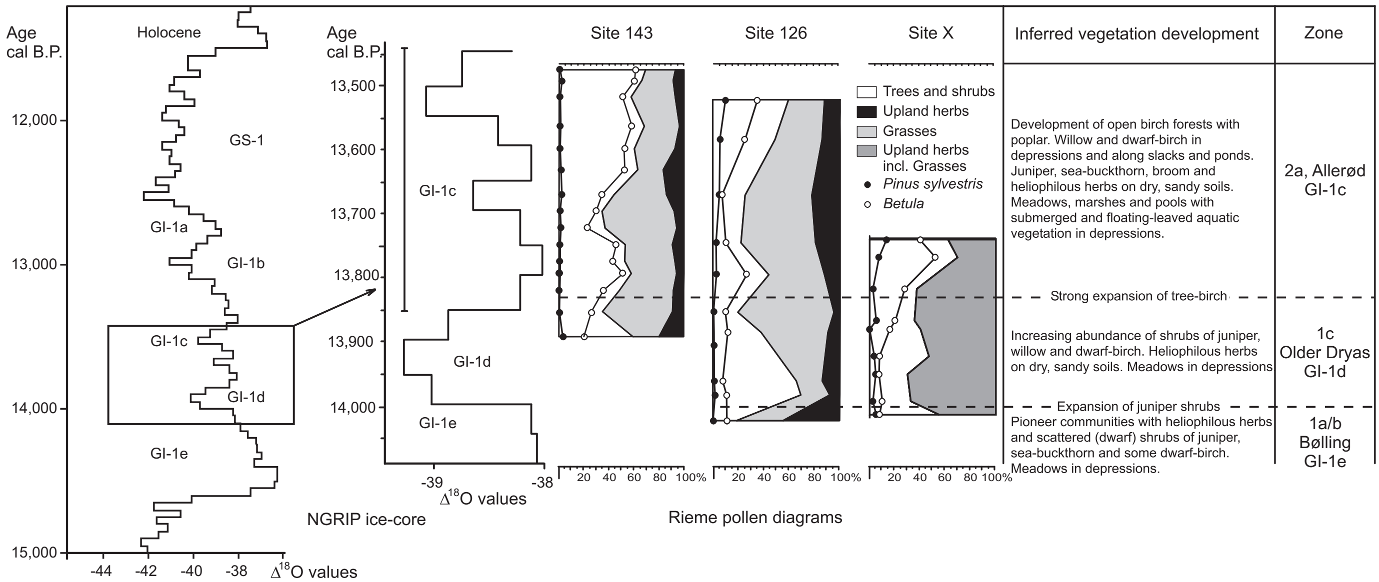

Fig. 4. Correlation of the summary pollen diagrams of the three sequences at Rieme, situated on the Great Sand Ridge, with the calibrated time-scale in years cal BP on the vertical axis. Ages were obtained from radiocarbon dates performed on samples of selected macroremains ($n = 6$; Bos et al., 2012) and tentatively correlated to the δ^{18}O data of NGRIP ice core record (given in 50-year time intervals, NGRIP members 2004). Age is in years BP (BP = 2000). Furthermore, the inferred regional vegetation development in the Rieme area is given (Bos et al., 2012).

early Allerød was also observed at Rieme (Crombé et al., 2012b; Bos et al., 2013) due to the presence of thin sandy sediments mixed with or interstratified within the organic slack horizons. These might indicate that during the early Allerød climate was not that stable and/or vegetation was not always very dense. Deflation was possibly also stimulated by fires in the woodlands and reed-swamps, as indicated by the presence of charcoal fragments and/or powder and charred epidermis fragments of grasses and ascospores of *Gelasinopora* (e.g. Rieme 143) (Bos et al., 2013).

Apparently after ca. 13,300 cal BP, i.e. before pine could immigrate, all ponds dried up. It is not yet clear whether this was caused by a sudden drop of the groundwater table and/or the influx of drifted sand. However, increased aeolian deflation could also be attested in the eastern part of the adjacent palaeolake. Within the excavated sequence at Klein-Sinaai "Boudelo" the lacustrine sediments, which were deposited from ca. 13,550–13,250 cal BP (11,540 ± 60 ^{14}C BP) onwards, have much higher mineral contents compared to the central part of the Moervaart (trench Moerbeke), possibly indicating that aeolian deflation during the late Allerød was much more important in the east of the Moervaart area.

3.2. Moervaart palaeolake

The stratigraphy of the lake sediments in the deepest part of the palaeolake at Moerbeke "Suikerfabriek" (Fig. 5) is at maximum ~2 m thick. It comprises alternations of calcareous gyttja (lake marl) and more humic/peaty sediments. The amount of $CaCO_3$ in the marl reaches to ~45%. According to macro- and micromorphological analyses of the lake marl, the $CaCO_3$ most likely originates from the strong leaching of carbonates from the adjacent coversands of the Great Sand Ridge through lateral groundwater-flow. The high amount of carbonate deposited on the palaeolake bottom is indicative of a climate with at least some periods with significant rainy seasons (recharge on the upland) and summer periods with considerable evapotranspiration and discharge at the level of the palaeolake (Arndt and Richardson, 1989). Winter periods with high snow precipitation producing in short time high amounts of cold water upon melting, followed by summers with relatively high temperature (continental conditions), favour this dynamics in the soilscape. Such climatic conditions did not occur throughout the whole time span of the lake existence, as evidenced by the stratigraphy of the lake bottom soil profile.

The lithological sequence (Fig. 5) described in this paper represents the longest and most well-preserved part of the trench profile at Moerbeke. It starts at the base with a ~0.25 m thick stratified layer (C) of humic calcareous gyttja with intercalated thin organic to peaty lenses. This layer is followed by two deposits of laminated lake marl (D and F), separated by a thin humic to peaty horizon (E). These lower lake marls are covered by two layers of (very) organic calcareous gyttja (G and I); between these, a layer of white sands is present (layer H), which increases in thickness towards the eastern part of the palaeolake. Micromorphological analyses suggest an aeolian origin for these sands, which were most likely blown into the palaeolake from the adjacent Great Sand Ridge by northern winds. The roundness, size and mineralogy (dominance of quartz and some calcium carbonate) of the sand grains are very similar to the deeper, non-decalcified sand layers of the ridge. Most likely these sediments were deposited as lake infill beds on the lake surface during episodes of freezing.

The gyttja layer I is followed by a second horizon of lake marl deposits (J–L), varying from organic (J) over clayey (K) to finely laminated with traces of oxidation (L). At the top of the sequence the lake sediments are covered by ~0.5 m of peat (M). The latter is relatively thin and discontinuously preserved at the sampled site. Further east in the palaeolake, however, it is much thicker and better preserved, thanks to the deposition of overlying sediments dating back to the Medieval period (13th–14th century). Elsewhere in the Moervaart depression the upper peat has disappeared almost entirely due to extraction and subsequent ploughing (Jongepier et al., 2011).

A series of 16 radiocarbon dates from terrestrial macroremains, obtained from the excavated sequence as well as from a nearby drilled sequence recovered in 2001 (Van Strydonck, 2005), demonstrates that the Moervaart palaeolake existed almost throughout the entire Late Glacial, from ca. 14,890 until ca. 13,255 cal BP (95% probability range), excluding the Younger Dryas (Fig. 6). During this

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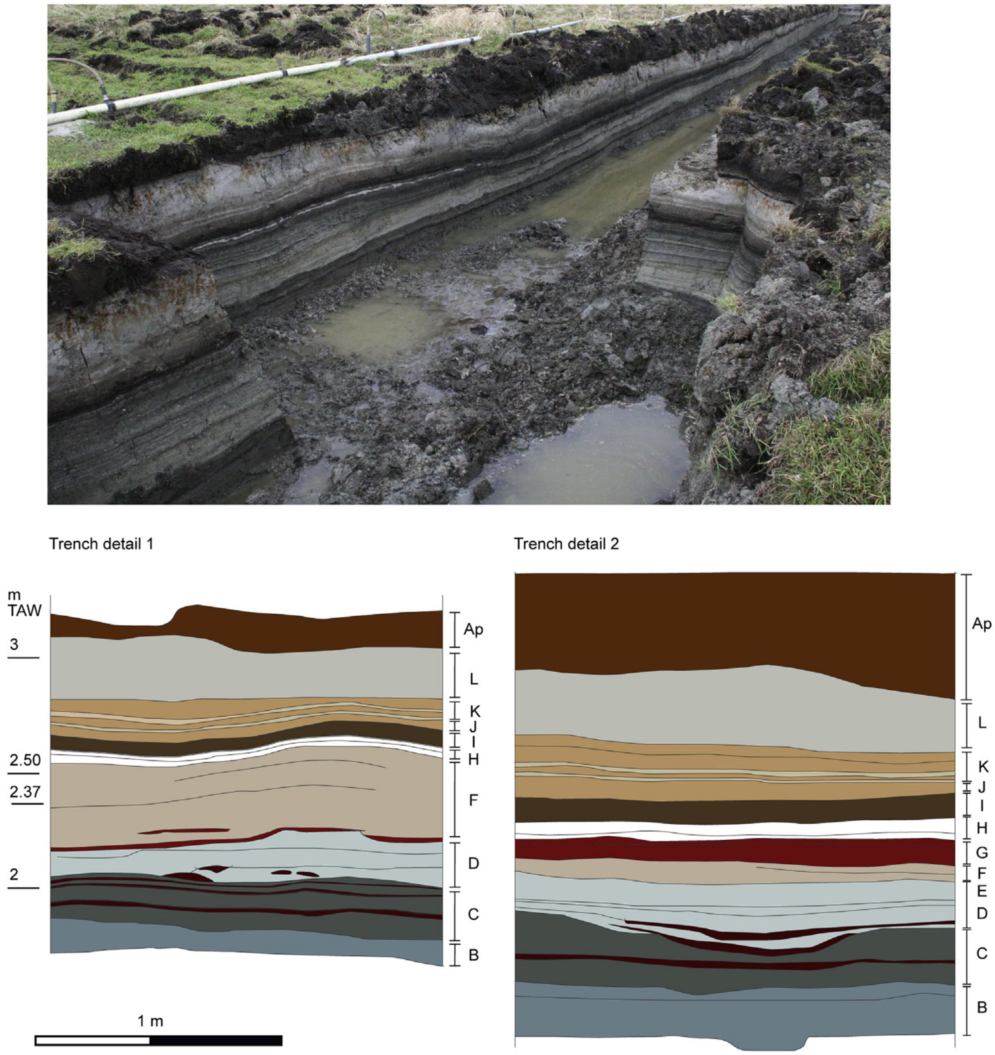

Fig. 5. Top: photograph of the trench through the palaeolake sediments at Moerbeke "Suikerfabriek" (photo UGent, 2009). Trench details 1 and 2: Lithostratigraphy of the Moervaart palaeolake sequence at two locations in the trench. Ap: plough layer; L–J upper lake marl; I–G: middle organic layer; F–D: lower lake marl; C: lower organic layer; B: Pleniglacial sand.

long period the lake hydrology and vegetation constantly changed, most likely in response to climate fluctuations. According to the pollen record (Fig. 7), the infill of the palaeolake started in the Bølling interstadial (14,692–14,075 cal BP; Blockley et al., 2012) (layer C) as an extensive but shallow swamp with horsetail (*Equisetum*) and submerged plants and an open vegetation of mainly birch (*Betula*), grasses (Poaceae), willow (*Salix*) and juniper (*Juniperus*). This milder phase, however, was interrupted abruptly by a short cold phase, the Older Dryas (14,075–13,954 cal BP), in which open grassy tundra conditions prevailed (layers D-F). After this short period of (periodic) desiccation, climatic amelioration during the subsequent Allerød interstadial (13,954–12,896 cal BP) caused major water-level changes, resulting in a lacustrine environment with shallow, open water (layers G–L). Based on the increased presence of aquatics, such as waterlily (*Nymphaea*), Eurasian watermilfoil (*Myriophyllum*) and buckbean (*Menyanthes trifoliata*) and other aquatic proxies, such as macrophytes, chironomids and diatoms, the maximum water depth can be estimated at ~3–4 m. Coeval with the climatic amelioration during the Allerød, *Bithynia tentaculata*, a warm-sensitive gastropod species, also abruptly appeared in the environment (Van Damme et al., in press). Initially (layers G-K), a more dense birch forest was continuously present in the surroundings of this large, shallow palaeolake, whereas, in the second half of the Allerød (layer L), Scots pine (*Pinus sylvestris* type) became the dominant tree species. In the top part of layer L an increase in cold-resistant diatom species, such as *Cymbella affinis*, is observed which indicates the start of a colder period (Demiddele et al., in press). This is also corroborated by the massive abundance of *Synedra* and *Ulnaria* diatoms, two species which peak (bloom) under the ice.

The youngest date of the upper marl of 13,410–13,150 cal BP (11,420 ^{14}C BP) (Van Strydonck, 2005) (situated at −70/75 cm in layer L), contemporaneous with the start of the pine increase, as well as the absence of indications of the Younger Dryas in the pollen record, indicate that the final phase of the palaeolake sequence most likely situates around the end of the Allerød. This is also strongly implied by the presence of numerous frost cracks which clearly intersect the upper lake marl. Whether peat began accumulating immediately after lake desiccation or later is not fully clear from the currently available data. However, peaty deposits dated around 13,150–12,750 cal BP have been found in one of the channels from the anastomosing system (cf 4.3), which would have supported Late Glacial peat formation in the Moervaart depression nearby. Furthermore, in a comparable but smaller palaeolake situated adjacent to the Moervaart at Snellegem (Denys et al., 1990) ^{14}C-dating of peat covering lake marl sediments also yielded a

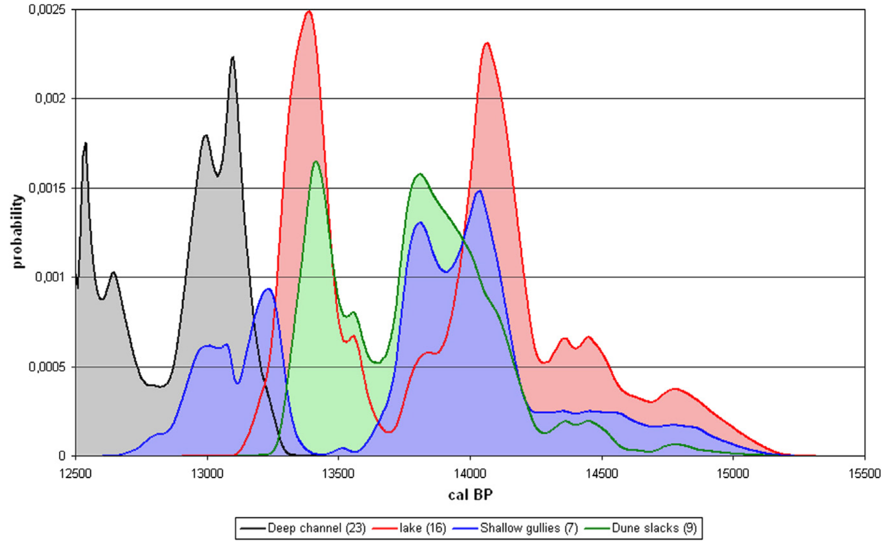

Fig. 6. Sum probability range of the radiocarbon dates obtained within the Moervaart study-area. Graphite for AMS radiocarbon dates was prepared at the Royal Institute for Cultural Heritage in Brussels (Belgium) (Van Strydonck and van der Borg, 1990-1991) and measured at the Leibniz Labo für Altersbestimmung und Isotopenforschung in Kiel (Germany) (Nadeau et al., 1998). Calibration according to Reimer et al. (2009).

result of 10,940 ± 60 ^{14}C BP, i.e. 12,980–12,630 cal BP at its base. This shows that during the Late Glacial palaeolakes across Sandy Flanders experienced a substantial lowering of their lake levels and groundwater tables at the transition from the Allerød to the Younger Dryas. This promoted the formation of peat through lateral encroaching of lake rim vegetation over more central parts of the shallow lakes while they were falling dry, with hydrological feedback from the low permeability of the accumulated lake marls below. Shallow mean water table levels during the Younger Dryas (~2.5 m below surface in the coversand area and 0.5 m below surface in the Moervaart palaeolake) were also found in a recent simulation of the groundwater tables in the area (Zwertvaegher et al., 2013). Mean water level tables started to rise again towards the very end of the Younger Dryas and during the Preboreal.

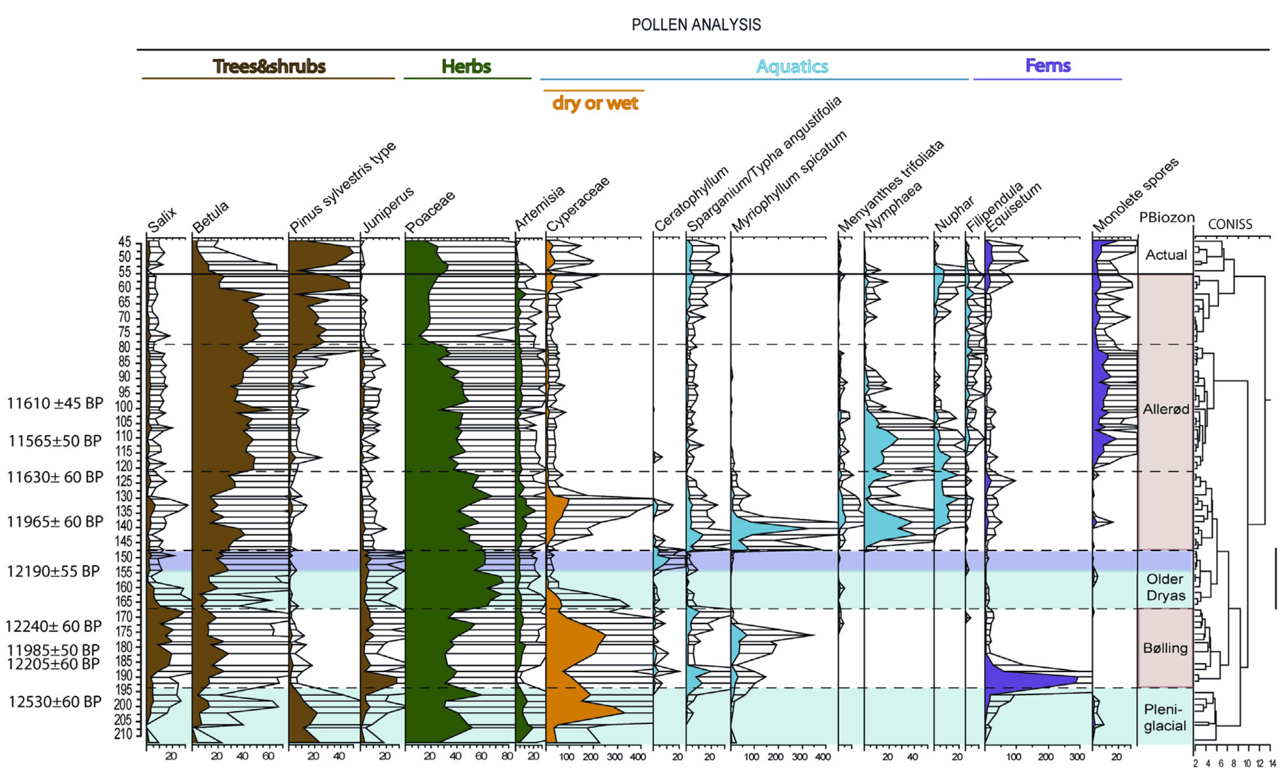

Fig. 7. Pollen diagram of the Moervaart palaeolake (excavation site Moerbeke "Suikerfabriek").

3.3. Anastomosing gullies

In the western part of the Moervaart depression, a complex network of narrow (~15–20 m wide) and shallow (on average ~1.5–2.5 m deep) gullies was detected (Figs. 8 and 9). Although there is no absolute certainty that the channels were contemporaneously active, given the organic-rich nature of the channels and the low-angle slope feeding into the Moervaart lake, it is likely that these minor gullies co-existed as a small anastomosing network. The anastomosing gullies appear to have been flowing from the west and recharging the freshwater lake in the east. There is no evidence that they formed a major drainage element, and the negligible slope on which the gullies were active suggests that the flow may have been very slow or even stagnant as they drained into the receding lake (De Smedt et al., 2012). There is no sedimentological or geomorphological evidence for the gullies having the capacity to transport large amounts of sediment.

Several of these gullies were sampled at 3 locations: Mendonk (D on Fig. 2) (Meylemans et al., 2011), Wachtebeke "Potdam" (A on Fig. 2) (De Smedt et al., 2012), and Moerbeke "Wulfsdonk" (2 on Fig. 2). Apart from one record (Moerbeke "Wulfsdonk") that has been analysed using pollen, plant macroremains and NPP's (Gelorini et al., in press a), only radiocarbon evidence is available. Based on close similarities in the organic-rich sediment, the pollen spectra and ^{14}C record, these gullies existed and were aggradationally infilled in broad synchronicity with the Moervaart palaeolake. Seven radiocarbon dates of terrestrial macro-remains indicate that the infilling of these shallow gullies started from ca. 14,890 BP onwards (Fig. 6). During the Bølling and Allerød, they were gradually infilled with calcareous gyttja and intercalated thin organic layers. Their infilling ends with an upper peat layer, dated at Wachtebeke "Potdam" (A on Fig. 2) between ca. 13,150 and 12,750 cal BP. This date indicates that these shallow gullies most likely became inactive before the end of the Allerød, simultaneous with the drying out of the Moervaart palaeolake.

3.4. Meandering palaeochannel

Fieldwork also revealed that the northernmost part of the gully complex consists of a single, much larger meandering channel (Figs. 8 and 9). The channel measures between 30 and 50 m wide and reaches to a depth of 4–6 m. Within the research project, this deep channel has been sampled at 6 locations along its entire course, resulting in a total of 23 radiocarbon dates covering the entire infilling. In addition, we performed high-resolution palaeolake analyses on one location, Moerbeke "Peerdemeers" (site 1 in Fig. 2; Gelorini et al., in press b), which is situated in the central part of the Moervaart depression.

The infilling of this deep channel consists of fine to broadly laminated brown to grey-coloured sediment units, with a high range of grain sizes (from sand to clay), organic matter (plant remains) and calcareous material (bivalves). This meandering deeper channel could be mapped from west to east, first running parallel with the northern palaeolake edge and then halfway across the Moervaart palaeolake changing its direction towards the south-southeast, inducing localised deep erosion of the lake sediments. Further east the palaeochannel connects to the actual Durme valley (Fig. 2) and joins the River Scheldt near Temse. The palaeochannel is thought to be the former course of the actual Kale/Durme that was connected with the palaeochannels discovered earlier to the west and east of the Moervaart depression, e.g. at Vinderhoute and Waasmunster (cf. 1.2).

The radiocarbon dates from the channel base demonstrate that the infilling of this deep channel started in the west (Mendonk) near the end of the Allerød, roughly between ca. 13,250 and ca. 12,750 cal BP (Fig. 6). The close temporal correlation with the abandonment of the anastomosing gullies to the south of the deep meandering channel suggests that these two different elements may record the partly autocyclic reorganization of the local drainage system in response to the recession and ultimate cessation of lacustrine conditions in the Moervaart depression (De Smedt et al., 2012). Fig. 10 shows a simplified conceptual model whereby the anastomosing gullies responded to the falling lake water table by migrating in conjunction with the eastwards-retreating palaeoshoreline. As the lake proceeded to dry up, local water flow is interpreted to have re-organized and coalesced into the northern single channel system, leading to the abandonment of the small gullies as drainage elements. This would have been a direct response to the disappearance of the former lake. After the palaeolake had ceased to occupy the Moervaart depression, the

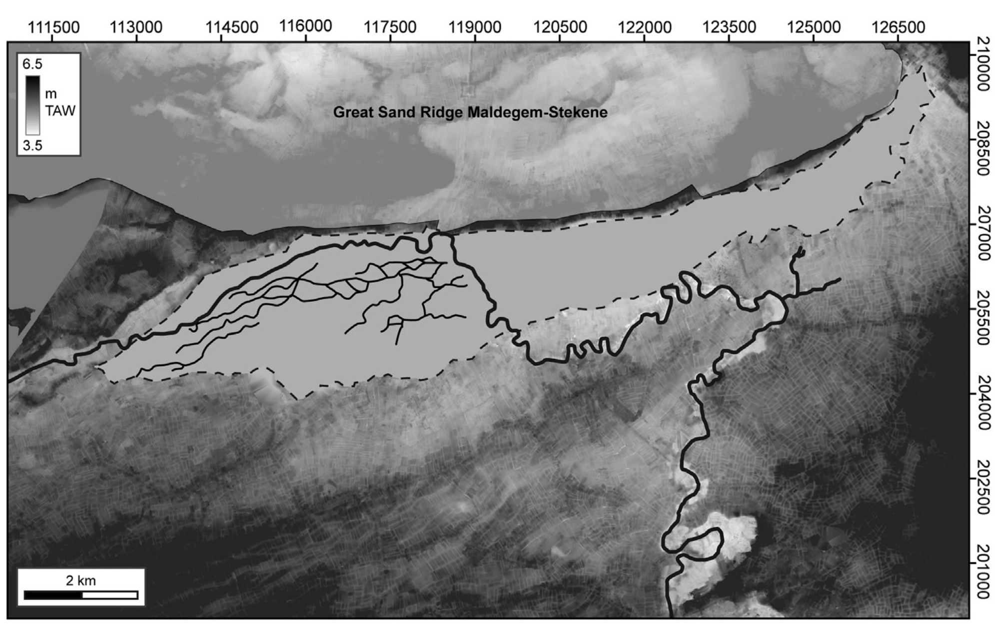

Fig. 8. Reconstructed course of the anastomosing and meandering palaeochannels in the Moervaart depression, based on data from corings, EMI and DEM (Lidar, AGIV 2001–2004).

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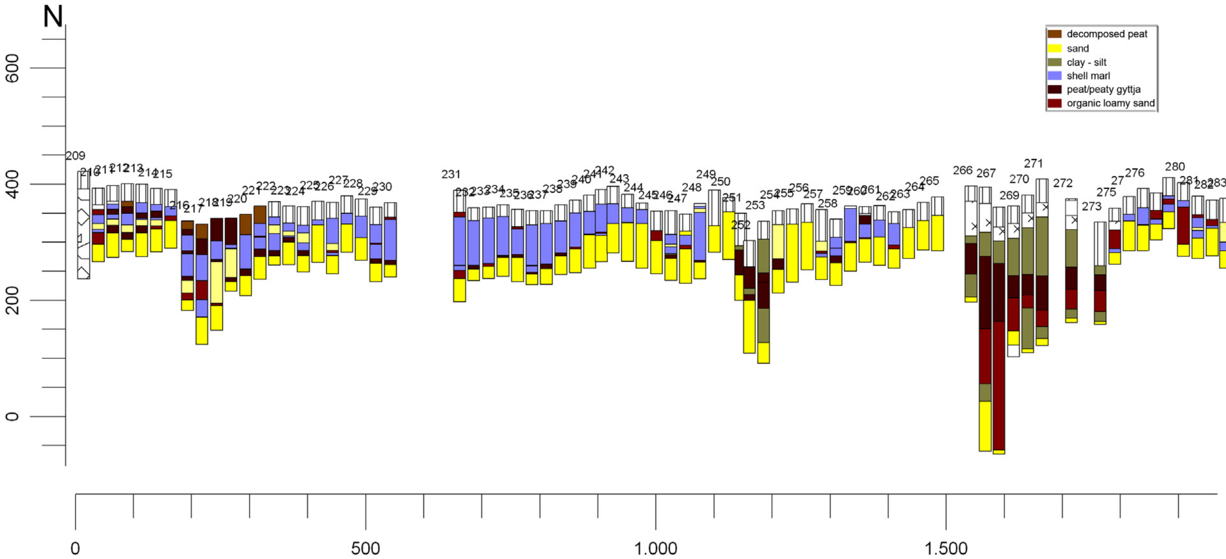

Fig. 9. Schematic transect from north to south through the Moervaart depression based on data from manual coring. The transect reveals the presence of several palaeochannels belonging to either an anastomosing (north) or a meandering river system (middle and south), the latter locally eroding the lacustrine sediments of the Moervaart palaeolake.

Kale/Durme headwaters entering the area from the west would no longer have been debouching into the Moervaart lacustrine system at the level of the shoreline, but would have sought hydrological connectivity with other elements of the regional-scale drainage basin. The slight topographic variation in the now-dry lake bed in the Moervaart depression and its outlet to the southeast forced an autocyclic response from the drainage system. The drop of water level reorganized water and sediment transport through the incision of a single-channel of greater width, depth, and carrying capacity than the former multiple small channels. This channel system exhibits a marked southwards diversion, broadly corresponding to the strike of the former palaeoshoreline as inferred from the termination of the anastomosing system. This course would thus have been favoured by the pre-existing topography that remained following lake drainage.

Uncertainty persists regarding conditions and hydrological connections to the east of the Moervaart palaeolake. After the lake was fully drained, the channel systems must have maintained connectivity with the regional drainage system: the River Scheldt. However, soon after its formation the flow within the meandering river became more tranquil, indicated by ostracod assemblages (Gelorini et al., in press a). The major ecological changeover during the analysed interval is a shift from *Candona* towards *Cyclocypris ovum*-dominated assemblages. Although the broad ecological tolerances of the retrieved species does not support detailed habitat inference, the overall trend is in accordance with a gradually shallowing, warming, and more vegetated aquatic environment.

According to the pollen and ^{14}C evidence, the infill of the meandering channel continued during the entire Younger Dryas (sandy gyttja) and Early Preboreal (more organic to peaty sediments). Because in most sequences the upper 1.5 m of sediments are disturbed by peat-extraction, it remains unknown how long it took this meandering channel system to be completely colmated. Fortunately at sample location “Zuidlede” an almost continuous sedimentary sequence was discovered, from which the ^{14}C dates suggest that peat growth continued at least until the end of the Boreal, ca. 9000/8800 cal BP (8025 ± 40 uncal $_{14}$C BP).

The pollen record of the meandering channel mainly consists of herbaceous taxa, such as grasses (Poaceae), and to a lesser degree, wormwood (*Artemisia*) and cinquefoil (*Potentilla* type). Woody species such as willow (*Salix*), birch (*Betula*), and Scots pine (*Pinus sylvestris* type) are also present. However, the percentages of the arboreal pollen are much lower (~35–45% on average) than those of the non-arboreal pollen (~55–65% on average) including the predominant grasses. The pollen assemblages indicate a dry forest-steppe vegetation trend with a more open, patchy covering of trees, shrubs and herbs, resulting from abrupt cooling of the climate during the Younger Dryas. The pollen signal of the relatively warm Preboreal is less apparent, and mainly characterized by the same plant species that occurred during the Younger Dryas. Here, the abrupt presence of birch and Scots pine was interrupted abruptly by a high increase of grasses, suggesting a sudden succession of open grasslands. This climatic event may correlate to a weak intra-Preboreal climatic setback (possibly the Rammelbeek phase, see also Bos et al., 2007).

4. Discussion

4.1. Geomorphological changes and climatic forcing

Based on the currently available data, the environmental evolution of the Moervaart study-area can be described as follows:

- During part of the Weichselian Pleniglacial (MIS 2), when the Flemish Valley had nearly completely filled with aeolian-fluvial sandy sediments, the braided river system was running north or northwest following an inherited valley path. At the transition from the Pleniglacial to the Bølling the east–west running Great Sand Ridge of Maldegem-Stekene started to develop and began to block the northwards run-off of the surface water (De Moor and Heyse, 1978; Heyse, 1983);
- During the Bølling, this blocking together with the melting of the permafrost, resulted in a higher groundwater table, turning the extensive Moervaart depression (~25 km^2) and numerous smaller slacks to the north into swamps with a grass dominated vegetation. The groundwater flow from the adjacent higher coversand deposits supplied the Moervaart depression with calcium carbonate that precipitated by the combined effect of biological activity and an evapotranspiration that exceeded the precipitation in summer period; this led to the formation of calcareous sediments (gyttja formation) at the base of the Moervaart depression;

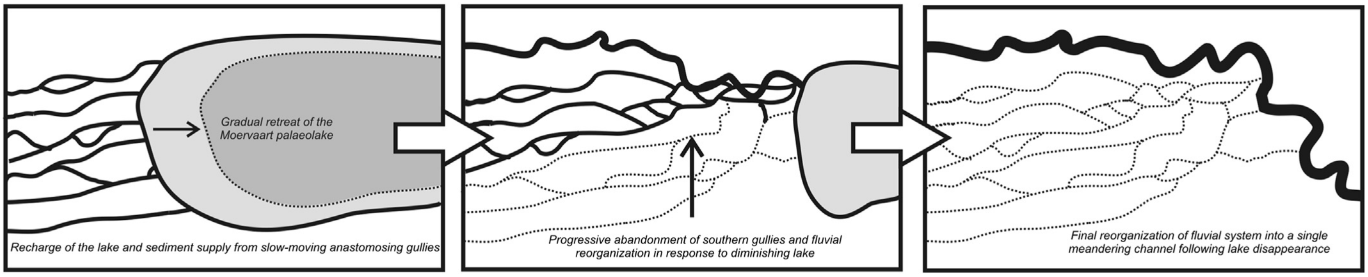

Fig. 10. Conceptual model of changing discharge system in the Moervaart depression between ca. 13,300 and 13,000 cal BP.

- During the short Older Dryas, a general lowering of the groundwater table occurred which stimulated wind erosion. This locally led to the deposition of important coversands, culminating in a massive and thick ridge north of the Moervaart depression;
- During the early Allerød, the groundwater level rapidly rose again, now creating a landscape with numerous shallow lakes and ponds bordered by grasses and an increasing number of trees, e.g. birch and willow. The largest lake, Moervaart lake, was connected to the west with a network of small and shallow channels which, combined with further groundwater flow, fed the lake. Further decalcification of the higher grounds of the Great Sand Ridge brought more carbonate into the lake system, sustaining the deposition of a second important layer of gyttja;
- Near the end of the Allerød, this hydrological system abruptly collapsed. A general drop in the groundwater level led to a considerable lowering of the water levels in lakes and ponds, probably turning them again into swamps. This lake drainage event resulted in the development of a meandering palaeochannel connected with the southern River Scheldt.

This last phase of drainage of the lake occurred well before the start of the Younger Dryas. It occurred in the time-span of roughly ca. 13,300 to 13,100 cal BP (Fig. 6), which coincides with a short but abrupt cooling event, known as the Intra Allerød Cold Period (IACP) (Donnelly et al., 2005), as reflected in the oxygen isotope record of the Greenland ice-cores (GI 1b; Björck et al., 1998; Lowe et al., 2008; Blockley et al., 2012) and the Gerzensee lake record in Switzerland (van Raden et al., 2013). Whether there is really a causal link between both events needs to be further investigated, but its contemporaneity is clearly established. This is also supported by the diatom evidence which testifies an increase of cold resistant diatom species in the top part of the Moervaart lake sequence, clearly indicating the onset of a colder period (Demiddele et al., in press). Similar temporal lowering of lake levels, often leading to facies transitions, if not hiatuses, have been observed in adjacent areas such as northern France (Deschodt et al., 2009) and the southern Netherlands (Hoek and Bohncke, 2002). For example, at the French site of Dourges the Allerød lake marls are also covered by a thin peat layer, the basis of which has been dated to 11,030 ± 70 uncal. $_{14}$C BP.

4.2. Hunter-gatherer presence and responses to landscape change

The general distribution of sites in the Moervaart area demonstrates a clear change in settlement location from the Final Palaeolithic towards the Early Mesolithic, i.e. from a focused occupation along the Moervaart lake edges towards the Kale/Durme riverbanks. The initial question was whether this shift was conditioned by climatic and/or environmental factors which changed throughout the Late Glacial and Early Holocene or instead was a human (cultural) choice independent of the environment. Thanks to the detailed palaeoenvironmental reconstruction obtained from the research project presented in this paper, this question can now be addressed.

For the Bølling and Older Dryas there is thus far no evidence of human presence neither within the Moervaart area nor in the remaining parts of NW Belgium (Crombé and Verbruggen, 2002). No finds are reported belonging to the Magdalenian, Hamburgian or Cresswellian Culture, generally dated in NW Europe to this time-span (Terberger et al., 2009). Although the possibility of undiscovered sites preserved beneath thick aeolian layers cannot be fully ruled out, there are more reasons to believe that humans were not yet attracted to the Moervaart area in these early stages of the Late Glacial. First, there was a lack of suitable settlement locations, as the coversand ridges had only just started to be created and were mainly formed during the Older and Younger Dryas. Furthermore, during the Bølling and Older Dryas there was probably not yet a permanent source of open drinking water for both humans and animals. Hence, it is also questionable as to whether wild game (reindeer, horse, etc.) would have been present in the area. Moreover the conditions around the Moervaart depression do not quite correspond to the environmental setting of hunter-gatherer groups from the Bølling-Older Dryas, which mainly focused on margins of upland areas (Terberger et al., 2009). Another negative factor of the Moervaart area (and the whole of NW Belgium) for human settlement is the complete absence of good-quality flint and voluminous nodules, which were necessary for knapping long straight blades. Late Magdalenian sites in Belgium and the southern Netherlands mainly occur in the vicinity of flint rich areas along the Meuse valley (Deeben, 1988; Miller and Noiret, 2009). All flint available in NW Belgium is of mediocre to bad quality due to very small volumes and severe frost damage, making them unsuited for knapping long blades. Better quality flint might have been available in the dry southern North Sea basin situated at hardly 50 km to the (north) west of the Moervaart area (Hijma et al., 2012). Long-distance transport of good quality flint over distances of up to 100 km, either by direct procurement or exchange, is well-known for Magdalenian hunter-gatherers occupying areas lacking outcrops of large nodules, such as the central Rhineland (Street et al., 2006).

At present, it thus seems that hunter-gatherers belonging to the *Federmesser* or Arch-Backed-Piece techno-complex were the first settlers of the Moervaart area. Altogether at least 13 camp-sites are known (Fig. 11 top), all except one (Klein-Sinaai "Boudelo") found at the present-day surface. During the Allerød the Moervaart study area had changed from an extensive swamp into a large but shallow lake with increased vegetation along its banks and bordered to the north by a massive and dry coversand ridge. These changes most likely turned the area into a much more attractive environment for prehistoric hunter-gatherers, explaining the much higher density of *Federmesser* sites compared to the remaining parts of NW Belgium (Crombé et al., 2011). Similar dense concentrations of

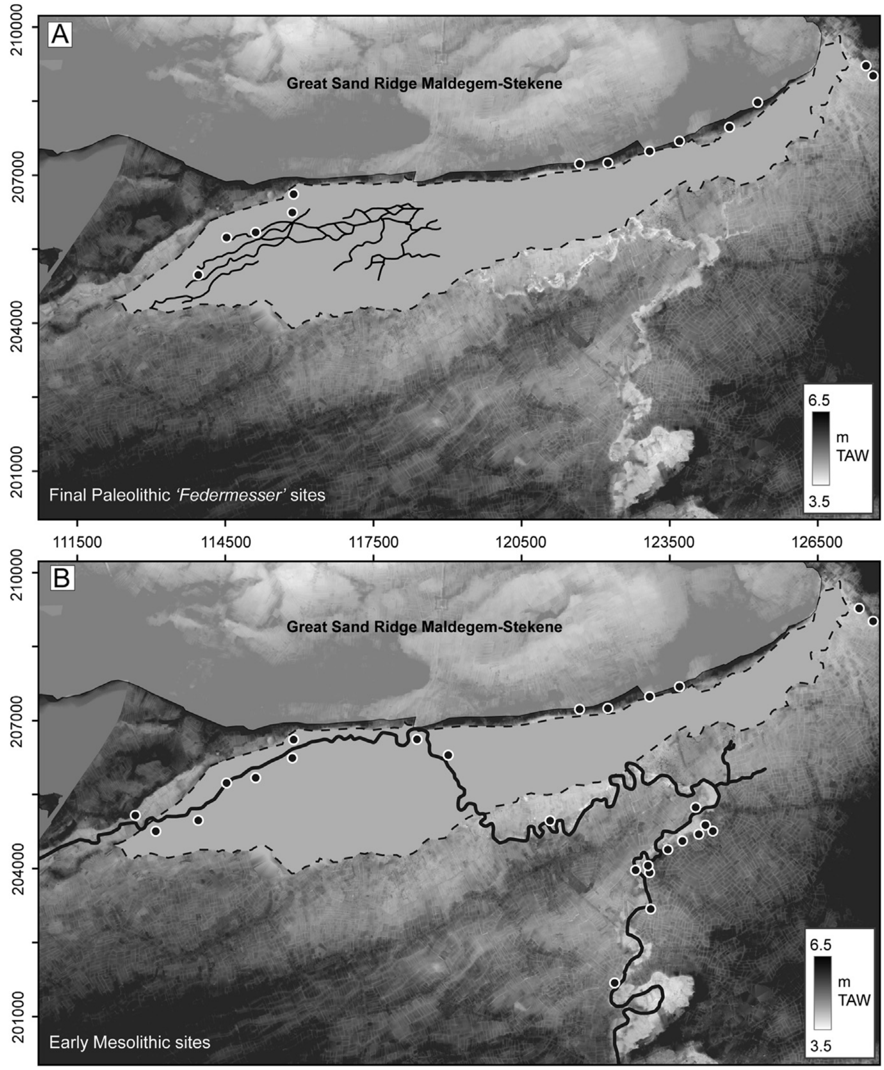

Fig. 11. Top: Plot of the maximum extent of the Moervaart depression (area within dashed line) and the distribution of *Federmesser* sites (dots) along the southern edge of the Great Sand Ridge of Maldegem-Stekene (shaded area) on top of the elevation model (Lidar, AGIV 2001–2004). Bottom: Plot of the maximum extent of the Moervaart depression (area within dashed line) and the distribution of Early Mesolithic sites (dots) along the course of the meandering channel (black line) and the southern edge of the Great Sand Ridge of Maldegem-Stekene (shaded area) on top of the elevation model (Lidar, AGIV 2001–2004).

Federmesser sites, often leading to site-complexes covering many hectares, have been observed along numerous, mostly smaller palaeolakes and fens in other parts of the NW European coversand region, e.g. in the Belgian (De Bie and Van Gils, 2006) and Dutch Campine (Deeben, 1988).

From this, it is clear that shallow lakes had a special attraction to *Federmesser* hunter-gatherers, probably due to their higher ecological value in addition to the availability of drinking water. Although no faunal remains have been found in the Moervaart study-area, the frequent occurrence in pollen samples of animal dung (coprophilous) fungi (*Bombardioidea* type, *Sporormiella* type, *Podospora* type, *Sordaria* type and other Sordariaceae) (Bos et al., 2013) as well as high phosphate ratios (Louwagie and Langohr, 2005, p. 103) indirectly demonstrate the presence of numerous large herbivorous mammals, especially during the Older Dryas and Allerød. Some ascomycete fungi of *Bombardioidea* type can be associated with specific game, such as European elk (*Alces alces*) (Bos et al., 2013). It thus seems that the Moervaart area with its open forested areas and forest edges (boreal forests), alternated by lakes and marshes and probably covered in winter by snow, must have been very suitable for large herbivores such as elk. From adjacent study-areas in NW Europe (Terberger et al., 2009, pp. 192–193) it is known that elk was an important prey, especially during the Allerød, hunted for its meat and hide.

Federmesser hunter-gatherers preferentially settled along the northern bank of the Moervaart lake, either along a small strip on the steep southern edge of the Great Sand Ridge (eastern section) or on small sandy elevations along the shallow anastomosing gullies (western section); these positions would have been ecologically very valuable at least during certain seasons as they are situated at the transition between two different ecotones; a dry and forested one suited for hunting wild game and settlement, and a wet one (lake or shallow gullies) suited for exploiting lacustrine resources such as water plants, waterfowl, and most importantly direct access to permanent drinking water. Fishing, however, most likely did not form a regular part of *Federmesser* subsistence around the Moervaart lake, as there is so far no direct evidence of the presence of fish in the lake, nor in the smaller ponds on the Great Sand Ridge. This is supported by indirect evidence such as the presence of water-fleas, among which *Daphnia* that are usually eaten by fish (Bos et al., 2013) and the absence of large edible freshwater molluscs such as unionids, which in their larval stage are obligatory ectoparasites on fish (Van Damme et al., in press). However, as indicated by the discovery of fish remains (pike, salmonids, carp), fishing definitely was part of *Federmesser* subsistence within NW Europe, but apparently only on camp-sites situated along river valleys, such as the Oude IJssel and the Regge in the Netherlands (Lauwerier and Deeben, 2011) and the Rhine (Street et al., 2006). Limited seasonal evidence points to spring and/or summer occupations of some of these valley sites. Whether this implies that sites along inland freshwater lakes, such as those around the Moervaart lake, were occupied in other (fall/winter) seasons is far too speculative at the moment. It is hoped that future research in the Moervaart will yield faunal remains, which will shed new light on the *Federmesser* subsistence and seasonal mobility. The recent discovery of an isolated bone tool at Klein-Sinaai (Crombé et al., 2012a), although not yet dated, already indicates the potential of the area for organic remains, in particular within the calcareous lake sediments.

As a result of their advanced perturbation, it is impossible to date the *Federmesser* sites of the Moervaart area accurately. However, based on techno-typological similarities with well-dated lithic assemblages in other study-areas (Bodu and Valentin, 1997; Coudret and Fagnart, 2006; Street et al., 2006), it may be reasonably assumed that the main *Federmesser* occupation took place during the Allerød. This is also confirmed by the total lack of *Federmesser* camp-sites along the lower course of the meandering palaeochannel, which was only formed towards the end of the Allerød. There is not even a single find of a *Federmesser* armature in the Durme valley, implying that these hunter-gatherers had left the Moervaart area already before the end of the Allerød or at the start of the Younger Dryas at the latest. Possibly the IACP event, coincident with the draining of all shallow lakes and ponds in the Moervaart area, was responsible for their retreat, as it turned the area into a much less attractive environment for human (and animal) occupation due to the major loss of open water.

Lacking high-resolution palaeoenvironmental evidence from adjacent areas within NW Belgium, it is at present difficult to determine the geographical extent of the *Federmesser* retreat. Was this strictly local limited to the Moervaart, or did it have more regional impact and if it did was that synchronous or diachronic? Although the limited evidence so far available (Denys et al., 1990) indicates a general lowering of water levels near the end of the Allerød within several smaller palaeolakes, it remains unclear whether this also implied the definite disappearance of all lakes and ponds present within Sandy Flanders. If future research confirms this hypothesis, the impact on the contemporaneous hunter-gatherers must have been even greater, making the entire coversand area of NW Belgium unattractive for settlement due to a lack of open water. In the adjacent coversand area of the southern Netherlands a lowering of the lake water level around the IACP event has also been observed at many locations (Hoek and Bohncke, 2002; Bos et al., 2006). Contrary to the Moervaart area this, however, did not result in a definite disappearance of the lakes; soon after, at the start of the Younger Dryas, a renewed major rise of the lake water level followed. In these areas with permanent open water *Federmesser* hunter-gatherers may have survived longer than in the Moervaart area, i.e. till after the IACP event, but this remains difficult to prove due to the overall poor chronological resolution of *Federmesser* sites (De Bie and Vermeersch, 1998; Barton et al., 2009; Lauwerier and Deeben, 2011). Possibly *Federmesser* hunter-gatherers from the Moervaart area during and after the abrupt cold event IACP shifted to the nearby Scheldt valley in order to settle along the many large meanders which were active during almost the entire Late Glacial (Bogemans et al., 2012). Recent archaeological surveys in and along the floodplains of the Lower Scheldt, immediately south of the Moervaart area, have revealed the presence of *Federmesser* sites, which unfortunately are not (yet) dated accurately (L. Van Vlaenderen, pers. communication). *Federmesser* hunter-gatherers could also have migrated in north-northwestern direction towards the Rhine-Thames valley in the still not inundated southern North Sea basin (Hijma et al., 2012). Although so far no typical *Federmesser* artefacts have been reported from the North Sea floor, the frequent discovery of Early Mesolithic finds, including some human mandibles, show the presence of prehistoric humans just before the drowning of this deep and broad valley (Glimmerveen et al., 2006).

No hard evidence for human occupation during the succeeding colder Younger Dryas and early Pre-boreal are known in the Moervaart study-area. Clear Ahrensburgian sites, characterised by the occurrence of small tanged points, are totally lacking. However there is one site, Wachtebeke "Potdam", situated along the meandering channel in the west, which yielded numerous burins, some backed blades and early microlith types (obliquely truncated points) but no microburins. This might indicate the presence of an Epi-Ahrensburgian site, but this tradition still remains poorly dated in Belgium and the southern Netherlands around the transition from the Younger Dryas to the early Preboreal (Crombé et al., 2013). This attribution is strengthened by the presence of numerous artefacts in black fine-grained flint, typical of Final Palaeolithic industries in the sandy lowlands of Belgium and the southern Netherlands. Its use stopped at the start of the Mesolithic (Crombé et al., 2013). It is reasonable to assume that more sites comparable with Wachtebeke "Potdam" existed, but can no longer be distinguished due to their intermixing with *Federmesser* artefacts in the surface assemblages. Indeed, on numerous *Federmesser* sites also early microlith types have been recorded, some of which might belong to this transitional stage, but this remains highly speculative.

Furthermore, a few finds of so-called Malaurie points, typical of the Epi-Laborian Culture that was contemporaneous with the Ahrensburgian in France (Bodu, 2000; Valentin, 2006), were found within *Federmesser* surface assemblages and may testify to continued human presence during the Younger Dryas/Preboreal. Such armatures have been found within four *Federmesser* surface-assemblages, two situated along the actual Molenbeek brook at the eastern limit of the Moervaart depression and two along the meandering channel in the west. No such finds, however, are reported along the northern dry bank of the Moervaart depression, formerly occupied by *Federmesser* groups.

In conclusion, there is meagre evidence pointing to the presence of human groups in the Moervaart area during (parts of) the Younger Dryas/Preboreal. This is not exceptional, since similar occupational decreases or even hiatuses have been reported in many other parts of the Belgian and Dutch coversand region, except for the area in between Eindhoven and Maastricht (Crombé et al., 2013). Clearly, if occupation occurred in the Moervaart area, it was much less intense and dense compared to the preceding Allerød. Most likely the environmental conditions were no longer suited for long-term presence of human groups. The temperatures had decreased considerably, stimulating renewed aeolian activity and reducing vegetation. Furthermore the sudden disappearance of the extensive Moervaart lake near the end of the Allerød must have reduced the ecological value of the area as supplier of extensive grounds for hunting, gathering, and drinking water. In addition the meandering Kale/Durme river during the Younger Dryas/Preboreal was no more than a tranquil flowing to stagnant shallow channel prone to winter freezing.

Human activity increased again near the end of the Preboreal and the start of the Boreal. From ca. 10,650 cal BP Mesolithic hunter-gatherers resettled the area, now focusing on the dry banks of the

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meandering Kale/Durme river (Fig. 11 bottom). For the first time, camp-sites were also erected along the lower course of the meandering Kale/Durme palaeoriver close to its connection with the River Scheldt. At least 25 camp-sites have been located, sometimes forming extensive site-complexes running over several kilometres. Occupation shows the same density as during the Allerød, demonstrating that although the Moervaart lake had already vanished long before, the area regained its ecological importance. It seems that the meandering river and its floodplain offered the same conditions as the former lake, perhaps due to the formation of extensive peatlands. This is also suggested by a recent groundwater modelling (Zwertvaegher et al., 2013) which points at a relatively rapid rising of the phreatic levels of 1 m on average during the Preboreal and Boreal, after a period of very low water levels during the Younger Dryas.

Future multi-proxy analyses of the upper peat, both within the palaeolake (layer M) and meandering gully, will provide important evidence with respect to the Early Holocene environment and will allow us to extend our human-environment study to the middle and later stages of the Mesolithic as well as the Neolithic. During these stages a shift towards a reduced mobility, an increasing focus on prolonged riverside settlement, and a more rigid organization of residential sites has been observed (Crombé et al., 2011). To what extent these cultural changes were influenced by environmental changes needs to be investigated.

5. Conclusions

Extensive geo-archaeological research along a large palaeolake from the Late Glacial in northwestern Belgium has provided valuable new palaeoenvironmental evidence, permitting a better understanding of the occupation dynamics of the area during the Final Palaeolithic and Early Mesolithic. The previously observed occupational contrast between the *Federmesser* Culture of the Allerød and the Early Mesolithic of the Boreal is clearly due to a major environmental change in the palaeohydrology of the area. This change occurred as a sudden event dated to around 13,300/13,100 cal BP, coincident with and possibly triggered by the Intra Allerød Cold Period (IACP) GI 1b, causing the Moervaart palaeolake and smaller ponds to disappear. This event was responsible for a drastic decline of human occupation in the area, which most likely persisted until the Preboreal. Due to this event at the end of the Allerød, *Federmesser* hunter-gatherers living in seasonally concentrated sites along the northern lakeside were confronted with a sudden reduction of drinking water and probably also wild resources such as game and water plants. New cultures of hunter-gatherers regained interest in the area only from the start of the Boreal, now situating their camp-sites preferably along the dry banks of a meandering small river which cuts through the former Moervaart lake.

Extending our geo-archaeological study to the entire coversand area of NW Belgium in the future will tell whether or not all palaeolakes underwent a similar environmental evolution as the Moervaart, which will be important for further understanding the Late Glacial–Early Holocene human occupation of an area situated at the limits of a gradually inundating North Sea valley. The latter event certainly must have affected hunter-gatherers living on both sides of this basin. Similarly it would be interesting to invest further research effort in validating the many prehistoric sites recently detected by coring in the adjacent Scheldt valley (Perdaen et al., 2011), given its proximity relative to the Moervaart study-area.

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