ABSOLUTE DATING (^{14}C AND OSL) OF THE FORMATION OF COVERSAND RIDGES OCCUPIED BY PREHISTORIC HUNTER-GATHERERS IN NW BELGIUM

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ABSTRACT. Based on radiocarbon and optically stimulated luminescence (OSL) results obtained in the last 5 yr, this paper discusses the absolute chronology of the formation of one of the largest sand dunes within NW Belgium, the Great Ridge of Maldegem-Stekene. Multiproxy analysis of 6 sedimentary sequences points to a complex formation history covering the entire Late Glacial. Dry phases, characterized by eolian deflation and sedimentation, alternated with wet phases in which numerous mostly shallow dune slacks were filled with freshwater. The latter reached their highest water level during the first half of the Allerød, attracting both animals (e.g. European elk) and humans (Federmesser hunter-gatherers). Near the end of the Allerød, all dune slacks finally disappeared as they were filled in with windblown sand ("coversand"), likely forcing prehistoric hunter-gatherers to leave the area.

INTRODUCTION

The northwest of Belgium is situated at the southern margin of the Great NW European Plain covered mainly by coversands (Figure 1). Intensive archaeological research in this area in the past 2 decades has revealed an important prehistoric occupation starting from ~13,900–13,700 cal BP and covering the Final Paleolithic, Mesolithic, and Neolithic (Crombé and Verbruggen 2002; Sergant et al. 2009; Crombé et al. 2011). Most camp sites and settlements from these periods are situated on coversand ridges, which were formed during the Pleniglacial and Late Glacial. However, until recently the absolute chronology of the formation of these sand ridges was poorly understood, mainly due to a lack of reliable dates. In order to understand the dynamics of the prehistoric occupation, it is of uttermost importance to understand the underlying processes of the formation of these sand ridges.

STATE OF THE ART

Extensive eolian activity during the Late Pleniglacial and Late Glacial resulted in the accumulation of a series of east-west running coversand ridges, of which the Maldegem-Stekene coversand ridge (Heyse 1979, 1983), also called the Great Ridge (Crombé and Verbruggen 2002), is the most significant (Figure 1). This extended sand ridge runs over a distance of ~80 km from the North Sea coast in the west to the lower Scheldt Valley in the east, and is locally 1.5 to 3 km wide. Its height varies

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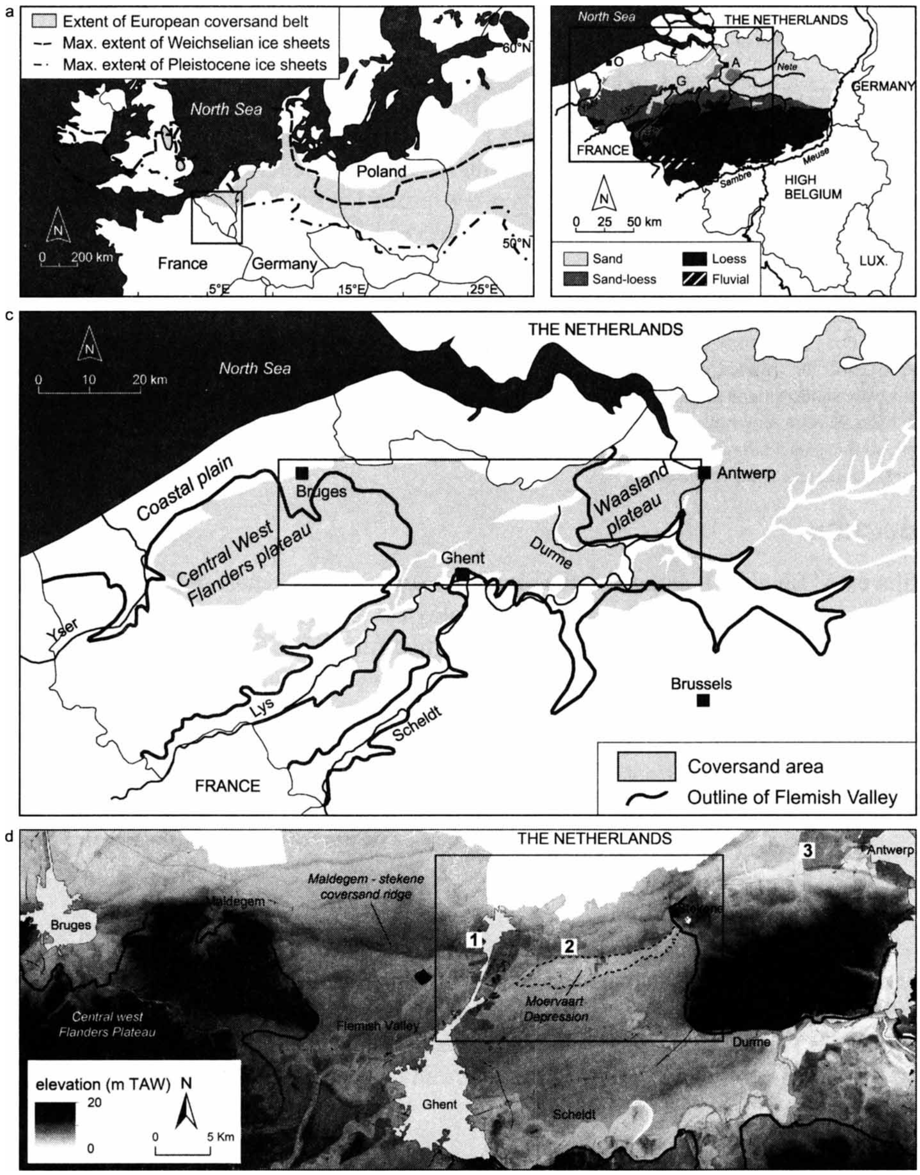

Figure 1 a) Extent of European coversand belt. The location of Belgium is indicated with an open square. (b) Map of Belgium, showing some of the major rivers and the Pleistocene sedimentation areas in N Belgium. (c) Extent of the coversand area and major geomorphological units in NW Belgium. The study area of Sandy Flanders is indicated with an open rectangle. (d) Digital elevation model of Sandy Flanders (Lidar, AGIV), showing the main geomorphological units, e.g. the Great Ridge of Maldegem-Stekene and the Moervaart paleolake. Rectangle = delimitation of Figure 6. Sites discussed in this paper: 1) Rieme; 2) Wachtebeke; 3) Verrebroek (modified from Derese et al. 2010).

between about 5 and 15 m above present sea level, but the relative elevation above its surroundings is only a few meters. Morphologically, the Great Ridge is characterized by a microrelief of smaller ridges and irregularly shaped elongated depressions, indicating a complex genesis. It is characterized by a short and steep southern slope contrasting with a long and gentle northern slope. The prehistoric occupation concentrates along the southern steep edge of this dune complex, while only few sites are known on the northern slope side.

The genesis of the Great Ridge of Maldegem-Stekene, more specifically its westernmost extension near Maldegem, has been discussed in detail by Heyse (1979). The formation of the coversand ridge is thought to have started in the Late Pleniglacial due to the climatic shift towards drier conditions and the subsequent decreasing fluvial and increasing eolian activity in the Flemish Valley. The deflation of the Middle Pleniglacial fluvio-periglacial sands of the Eeklo deposit resulted in the development of a deflation surface, locally known as the Middelburg Gravel. This erosion surface may be equivalent to the Beuningen Gravel Bed (BGB), which is an important marker in the European Late Weichselian coversand stratigraphy (Kasse et al. 2007; Vandenberghe et al. 2009). According to Heyse (1979), the deflated sands were redeposited as low asymmetric coversand ridges under the influence of the dominating northern-northwestern winds; these eolian sands from the lowermost part of the "Maldegem deposit" can hence be interpreted as the time-equivalent deposit of the deflation surface.

At several locations, mainly in the western and central sections of the Great Ridge, Heyse (1979), Kolstrup and Heyse (1980), Verbruggen (1979), and Vanhoorne and Verbruggen (1975) recorded the occurrence of several organic to peaty layers within the "Maldegem deposit" that point to moist phases interrupting the phases of deflation and coversand deposits. In the 1970s, several peat and wood fragments of these organic layers were radiocarbon dated, which resulted in ages between 8,825 ± 50 BP (GrN-6072; 10.1–9.7 cal BP, 95.4% probability) and 12,010 ± 65 BP (GrN-6073; 14.0–13.8 ka cal BP, 95.4% probability). As such, the results of earlier research illustrate that the development of the Great Ridge did not cease at the end of the Late Pleniglacial, but continued during the Late Glacial. However, due to the generally large standard deviations (between 65 and 295 ^{14}C yr) the ^{14}C dates performed in the 1970s and 1980s did not allow to construct a detailed absolute chronology for the genesis of the Great Ridge.

RECENT RESEARCH

Sampling

Thanks to recent improvements in dating techniques, e.g. accelerator mass spectrometry (AMS) ^{14}C dating and optically stimulated luminescence (OSL) dating, new opportunities have been created. In the framework of recent multidisciplinary research projects at Ghent University, renewed research into the chronology of the Great Ridge of Maldegem-Stekene has been carried out, the results of which will be presented below.

At 3 locations (Figure 1d), Rieme "Noord" (sites 63, 126 and 143), Wachtebeke "Heidebos," and Verrebroek "Dok" (sites 1 and 2), long sedimentary sections, up to 3 to 7 m thick, have been sampled for multiproxy analysis, e.g. pollen and plant macroremains (Deforce et al. 2005; Bos and Verbruggen 2011), chironomids (Bos et al., in press), ^{14}C dating (Van Strydonck 2005), OSL dating (Derese et al. 2010), sedimentology and micromorphology (Louwagie and Langohr 2005). Altogether, 6 sequences were analyzed, all showing a complex succession of coversand deposits and intercalated organic and peaty layers of various thickness (Figure 2). The former refer to important episodes of eolian activity while the latter testify to relatively wet and more stable conditions. Based on paleobotanical data (presence of hydrophilous and aquatic plant remains) and pedogenetic data (absence of bioturbation, the abrupt, somewhat wavy lower boundary), these organic layers were formed in (sub)aquatic conditions, i.e. at the bottom of former dune slacks resulting from a blowout, where erosion down to the watertable has occurred.

Figure 2 Photo of a coversand sequence with intercalated peaty layers from the locality of Rieme situated on the Great Ridge (photo courtesy UGent).

At least 3 (maybe 4) important wet phases can be discerned, which can be linked with different regional pollen assemblage zones (Table 1). Depending on their (paleo)topographical position within each sequence, some phases are represented while others are missing. For example, the oldest wet phase is only present at Wachtebeke and Rieme 126, while the youngest one has only been attested at Verrebroek 1 (Table 2).

Table 1 Correlation between the organic layers intercalated within the coversands of the Great Ridge Maldegem-Stekene and different pollen zones. The biostratigraphy (pollen zones) is based on Hoek (1997) and Verbruggen (1979).

Wet phases	Regional pollen assemblage zones	Dominant plant species	Chronozone
Phase 1	1a/b–start of 1c	*Betula – Salix*, *Juniperus*	Bølling – start Older Dryas
Phase 2	End of 1c–2a	*Salix*, *Juniperus – Salix*, *Betula*	End of Older Dryas – Middle of Allerød
Phase 3	2b	*Pinus – Betula*	End of Allerød

Radiocarbon Dating

In order to date these wet phases, the organic layers have been AMS ^{14}C dated on unidentified (Verrebroek) or identified plant remains (Rieme, Wachtebeke), such as birch (*Betula* spp.), sedge (*Carex* spp.), and club-rush remains (*Schoenoplectus lacustris*). The dating project here focused mainly on the base and top of each organic layer, although some levels have not yet been dated (Table 2).

A χ^2 test indicates that the corresponding levels at the different sites can have the same calendar age. Only the date on Verrebroek 1, wet phase 2, bottom, was considered an outlier, as the dated sample originates from the middle and not the bottom of the organic layer. As a consensus value for the base and the top of the organic layer, the average value of the corresponding layers was taken if possible, assuming that the beginning and the end of the wetter conditions were synchronous at the different sites. Table 3 and Figure 3 present the calibrated dates of the consensus results per level. Calibration was done using OxCal v 3.10 (Bronk Ramsey 1995, 2001) and IntCal09 curve (Reimer et al. 2009).

Table 2 Correlation between the organic layers and the ^{14}C dates from 6 investigated locations on the Great Ridge of Maldegem-Stekene. Date NZA-11018 is considered an outlier and hence has not been included in the calculation of the average. The dates indicated with * are unpublished dates; the other dates have been previously published in Van Strydonck (2005).

	Wet phase 1		Wet phase 2		Wet phase 3	
	Bottom	Top	Bottom	Top	Bottom	Top
Rieme 63	—	—	KIA-40799* 11,910 ± 55 BP	KIA-40800* 11,620 ± 60 BP	—	—
Rieme 126	undated	KIA-44312* 12,205 ± 60 BP	KIA-44304* 11,920 ± 60 BP	KIA-44303* 11,625 ± 60 BP	—	—
Rieme 143	—	KIA-44308* 12,110 ± 60 BP	undated	KIA-44323* 11,565 ± 55 BP	—	—
Wacht-ebeke	KIA-43575* 12,305 ± 55 BP	KIA-43568* 12,040 ± 55 BP	undated	undated	—	—
Verre-broek 1	—	—	NZA-11018 11,760 ± 60 BP	NZA-11019 11,690 ± 60 BP	NZA-11521 11,420 ± 65 BP	NZA-11520 10,710 ± 75 BP
Verre-broek 2	—	—	NZA-11013 12,020 ± 60 BP	NZA-11021 11,740 ± 60 BP	—	—
Average	—	12,115 ± 35 BP	11,950 ± 35 BP	11,645 ± 25 BP	—	—

Table 3 Calibrated ^{14}C dates of the average results per wet phase.

Sample	68.2% probability	95.4% probability
Wet phase 1 bottom: 12,305 ± 55 BP	14,500–14,310 cal BP (24.6%) 14,260–14,040 cal BP (43.6%)	14,950–13,950 cal BP (95.4%)
Wet phase 1 top: 12,115 ± 35 BP	14,030–13,890 cal BP (68.2%)	14,120–13,820 cal BP (95.4%)
Wet phase 2 bottom: 11,950 ± 35 BP	13,860–13,750 cal BP (68.2%)	13,930–13,690 cal BP (95.4%)
Wet phase 2 top: 11,645 ± 25 BP	13,580–13,530 cal BP (14.5%) 13,520–13,400 cal BP (53.7%)	13,640–13,360 cal BP (95.4%)
Wet phase 3 bottom: 11,420 ± 65 BP	13,370–13,210 cal BP (68.2%)	13,420–13,140 cal BP (95.4%)
Wet phase 3 top: 10,710 ± 75 BP	12,690–12,560 cal BP (68.2%)	12,800–12,520 cal BP (93.9%) 12,470–12,430 cal BP (1.5%)

This results in the following chronology:

- A first wet phase occurred between about 14,500 and 13,900/13,800 cal BP, which coincides with the Bølling *sensu strictu* (GI-1e) and/or the onset of the Older Dryas (GI-1d);
- A second wet phase started ~13,800 cal BP and ended ~13,400 cal BP, covering the end of the Older Dryas/start of the Allerød until the middle of the Allerød (GI-1c);
- A third wet phase was only attested in the topographical lowest sequence (Verrebroek 1) and coincides with the second half the Allerød (GI-1a/b), dated between ~13,400/13,300 and 12,500 cal BP. In the other sequences, the organic layer(s) of the second wet phase are directly covered by eolian sediments with a thickness varying between 1 and 3.5 m.

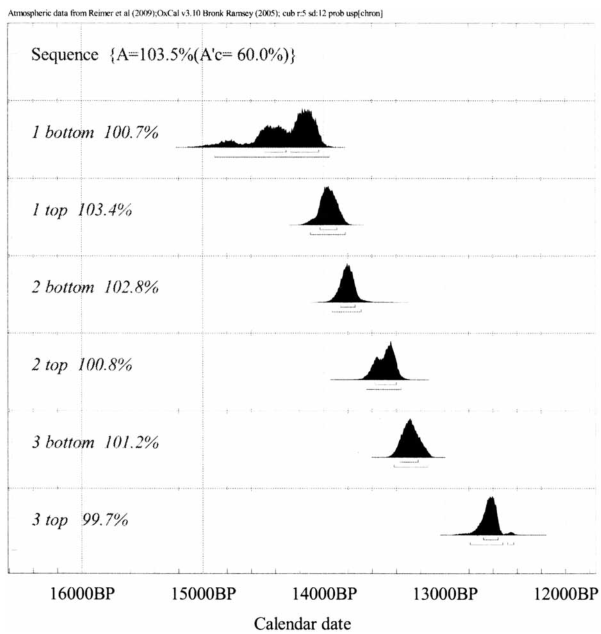

Figure 3 Calibrated ^{14}C dates of the consensus values per wet phase

Optically Stimulated Luminescence (OSL) Dating

In Wachtebeke, the sandy deposits that separate the organic layers have been dated using OSL (Figure 4). The results form an internally consistent data set from about 17.3 ± 0.8 until 12.6 ± 0.6 ka BP, with 2 possibly inconsistent dates between 4.5 and 5.5 m below the surface (Derese et al. 2010). If the latter are omitted, a semicontinuous coversand deposition from the Late Pleniglacial until the Younger Dryas cannot be fully excluded. However, if all OSL results are considered, 2 distinct phases of coversand deposition separated by a marked hiatus ~6 m below surface can be discerned (Derese et al. 2010):

1. A first phase during the Late Pleniglacial (mean 16.3 ± 1.1 ka [n = 2] between 6 and 7 m depth);
2. A second phase during the Allerød and Younger Dryas (mean 12.3 ± 0.9 ka [n = 9] between 1 and 6 m depth).

Within this last phase, 2 organic layers are present. So far, only the lowermost has been ^{14}C dated, linking it to wet phase 1 (~14,500–13,900/13,800 cal BP). The OSL samples below (13.3–13.0 ka, n = 2) and above (12.5–12.4 ka, n = 5) this layer give only minor age differences and suggest that the organic layers represent the Allerød rather than the Bølling.

Comparison ^{14}C and OSL

In Figure 5, the ^{14}C and OSL results of Wachtebeke were put in a Bayesian model. Instead of using the single ^{14}C dates, the consensus values for the start and the end of the wet phases were used. The model does not take into account the actual depth profile but only the sequence of the dates. The agreement is very poor for several samples. The OSL dates generally tend to be younger than the ^{14}C dates. Discrepancies between OSL and ^{14}C results within the same soil sequence are also reported for other locations in the coversand region of Belgium (Derese et al. 2009) and the Netherlands (Kolstrup et al. 2007). Inaccuracies in optical dating can be related to the dose rate—e.g. underesti-

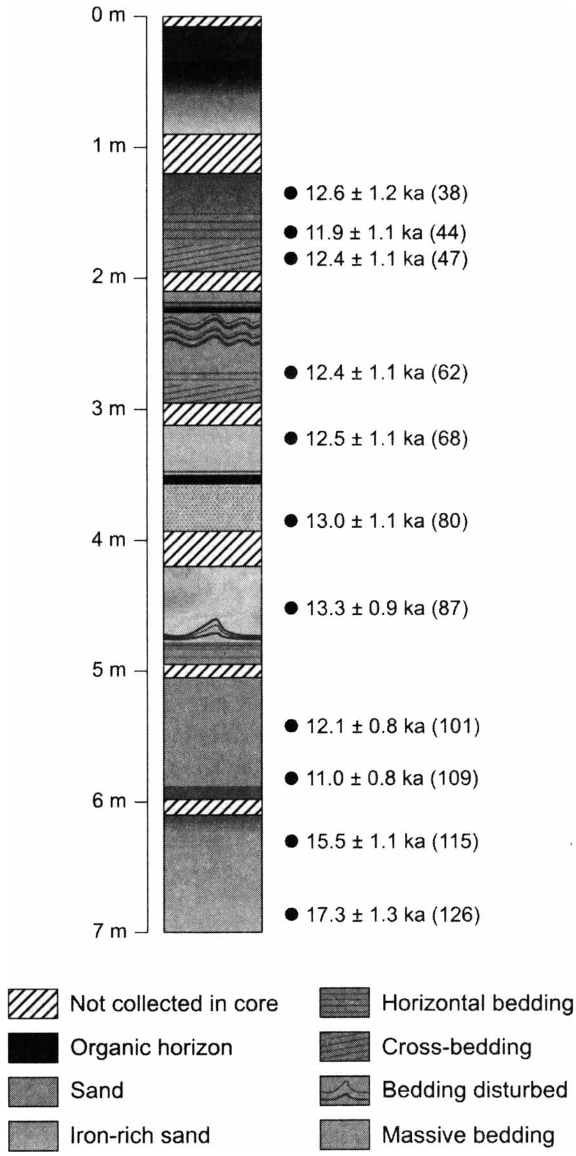

Figure 4 Schematic log of the investigated sequence of coversands and intercalated soil horizons at the locality of Wachtebeke "Heidebos" situated on the Great Ridge, showing the observed sedimentary structures and the results of the OSL dating (Derese et al. 2010).

mation of the true time-averaged water content of the analyzed sediments resulting in an overestimated dose rate; and problems with the determination of the internal radioactivity of quartz grains and postdepositional mixing, although the sediments did not show any direct evidence for such mixing. For ^{14}C dates, the migration of organic material or invasion by younger root systems are common causes for erroneous ages. The use of bulk samples is particularly susceptible to such errors, although the common effect is to lower the age results rather than to raise them. In the present study, nearly all ^{14}C dates have been obtained on AMS-dated samples of carefully selected and determined plant fragments, minimizing the risks for such errors.

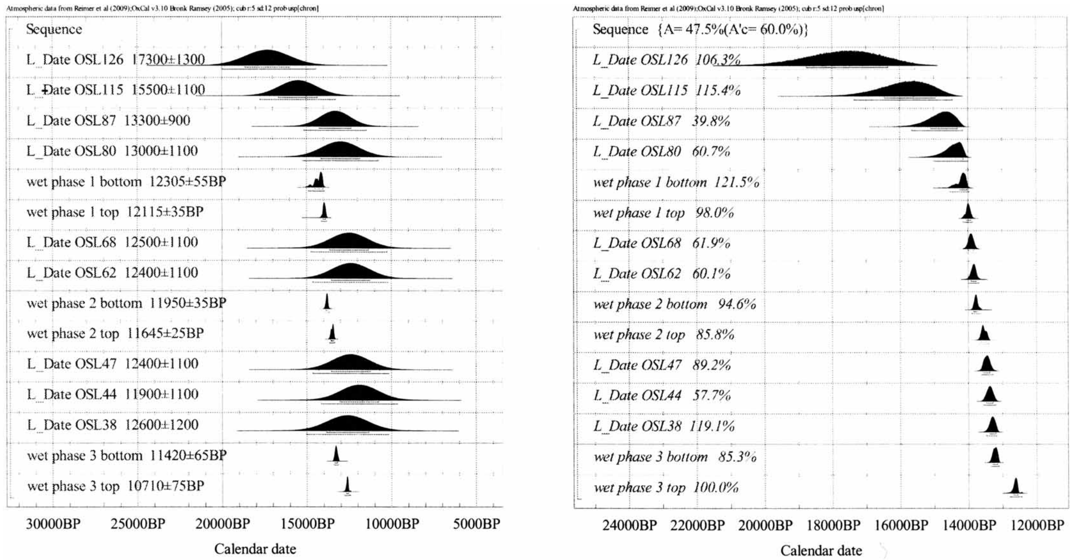

Figure 5 Bayesian modeling of the ^{14}C and OSL dates. Left: original data; right: after modeling. OSL samples 109 and 101 have been omitted because of potential errors. Calibration done using OxCal v 3.10 (Bronk Ramsey 1995, 2001) and IntCal09 calibration data (Reimer et al. 2009).

In the frame of this discussion, it must be noted that the large standard deviation (~1 ka) on the OSL age results does not allow to work out fine chronologies for the Late Glacial with this dating method. The ^{14}C clock, on the other hand, acknowledges a plateau in the calibration curve between 13 and 12 ka BP, which also lowers the precision of the calibrated ages for this time period.

DISCUSSION

Landscape Formation

Using a multiproxy approach, the genesis of the Great Ridge can now be reconstructed in more detail. The following stages in its formation can be discerned:

- Before 14,500 cal BP: dry phase characterized by important eolian deposition above the Pleniglacial sediments; at least 1 m of windblown sand is deposited, probably indicating the onset of the formation of the Great Ridge;
- ~14,500–13,900/13,800 cal BP: during this period the lowest depressions turn into swamps or shallow pools mainly during the summer months, resulting in the formation of organic (sub)aquatic layers. This probably is related to climate amelioration, which induced precipitation and melting of possible relic ground ice. The vegetation cover is still largely dominated by grasses (80–60%) and tree-less, and probably only some dwarf birch occurred;
- ~13,900–13,800 cal BP: short dry phase with little (Rieme, <25 cm) to substantial (Wachtebeke; 120–140 cm) eolian sedimentation, probably consisting of remobilized or redistributed eolian sands within dune system dynamics (Louwagie and Langohr 2005). However, the presence of intercalated thin organic layers (e.g. at Rieme) indicates that deflation was not always continuous and alternated with short periods of local stability. Nevertheless, the Great Ridge was increasing in height and hence became increasingly more attractive for human settling as it provided a dry location for habitation;

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- 13,800–13,400 cal BP: due to increased precipitation and possibly also an increase in local seepage, the groundwater table rose again, resulting now in the formation of shallow (<1 m, e.g. Rieme 126, Verrebroek 1 & 2, Wachtebeke) to slightly deeper dune slacks (3–6 m, e.g. Rieme 143, Bos et al., in press). Most dune slacks remained permanently wet until the middle of the Allerød (GI-1c), though fluctuations of the water level certainly occurred. In most shallow slacks, at least occasional aerobic conditions existed (Louwagie and Langohr 2005). Simultaneously, vegetation was getting more closed with birch and willow as dominant trees and shrubs. However, the immediate surroundings of the dune slacks were still largely open and dominated by sedge marshes. Both the temporal lowering of the water level and the locally rather sparse vegetation induced local deflation, resulting in limited sand influx into the dune slacks. This is confirmed by the generally high mineral content of most organic layers belonging to wet phase 2 (e.g. Verrebroek 1, 2 lower peat) as well as the presence of intermediate small sandy layers (~5 cm) within organic horizons in the deepest slack at Rieme 143 (Bos et al., in press). Deflation was possibly also stimulated by fires in the woodlands and reed swamps, which based on the presence of charcoal fragments and/or powder (e.g. Verrebroek 2) and charred epidermis fragments of grasses and ascospores of *Gelasinopora* (e.g. Rieme 143), must have occurred.
- ~13,400–13,300 cal BP: in all dune slacks the organic accumulation ceased, probably indicating a drastic lowering of the groundwater level around the middle of the Allerød. Although in all sequences the organic wet layer 2 is directly superimposed by coversands (Table 4), it currently remains unclear whether eolian sedimentation started immediately after these dune slacks turned dry. Only at Verrebroek 1 is there proof of limited eolian sand deposition (<10 cm) between about 13,400 and 13,300 cal BP, which might correspond with the short-lived Inner Allerød Cold Period (GI-1c2).

Table 4 Thickness (in cm) of windblown sand deposits in between 2 wet phases/organic layers and on top of the uppermost organic layer; the absolute depth of the latter, with respect to the present sea level (asl), is given in the last column.

	Wet phase 1–2	Wet phase 2–3	Top phase 2	Top phase 3	Top upper peat layer (m asl)
Rieme 63	—	—	250	—	+5.86
Rieme 126	25	—	140	—	+5.18
Rieme 143	8	—	310	—	+4.50
Wachtebeke	120–140	—	220	—	+5.10
Verrebroek 1	—	6–7	—	150	−1.00
Verrebroek 2	—	—	110	—	+1.91

- ~13,300 and 12,500 cal BP: a last weak rise of the water level occurred, which affected only the lowest depressions, e.g. at Verrebroek 1, situated ~1 m below the present sea level. The higher positioned dune slacks (2 to 5 m above actual sea level), on the other hand, remained dry. At present, it is not very well understood whether the eolian sedimentation process ceased or continued in these higher slacks. The lack of mineral material in the peat of wet phase 3 at Verrebroek 1 (in contrast to the sandy peat of wet phase 2 at the same location) suggests a temporary interruption of eolian activity. This is also suggested by the pollen data, indicating an expansion of woodlands mainly consisting of pine, which locally reached a maximum of ~80% in the pollen assemblages.
- ~12,500 cal BP to Early Holocene: new eolian activity, which resulted in the deposition of 1 to 3.5 m of sand and caused the final disappearance of all dune slacks. In this stage, the Great Ridge turned into a massive overall dry coversand dune.

Human Occupation

The combination of a growing massive dune complex, which was gradually becoming drier, and numerous intermediate dune slacks must have created an increasingly attractive environment for prehistoric hunter-gatherers during the Late Glacial. The environment offered opportunities for hunting and gathering a variety of edible and useful plant material. The frequent occurrence of animal dung fungi (*Sordariaceae*), some probably associated with European elk *Alces alces* (Bos et al., in press), as well as high phosphate ratios (Louwagie and Langohr 2005:103), indirectly proves the presence of numerous large mammals, especially during the Older Dryas and Allerød. This is also the time interval in which the dune slacks reached their highest water level, making them attractive for hunting water fowl and mammals, such as beaver, and collecting freshwater snails. It is rather unlikely that these dune slacks were used for fishing as no fish remains were present in the deepest dune slacks, while remains of water fleas, such as *Daphnia*, which are usually eaten by fish, were found (Bos et al., in press).

At present, it seems that the first hunter-gatherers belonging to the Federmesser culture entered the area around 13,900–13,700 cal BP (Crombé and Verbruggen 2002; Van Strydonck and Crombé 2005; Crombé et al. 2011). They mainly settled along the steep southern edge of the Great Ridge, preferably in the proximity of large and deep paleolakes that were formed simultaneously with the dune slacks (Heyse 1983; Crombé and Verbruggen 2002; Bats et al. 2009, 2010). The highest concentration of Federmesser sites occurs in connection with the Moervaart paleolake, which covers a surface of ~25 km^2 and borders the Great Ridge along its southern edge (Crombé et al. 2011) (Figure 6).

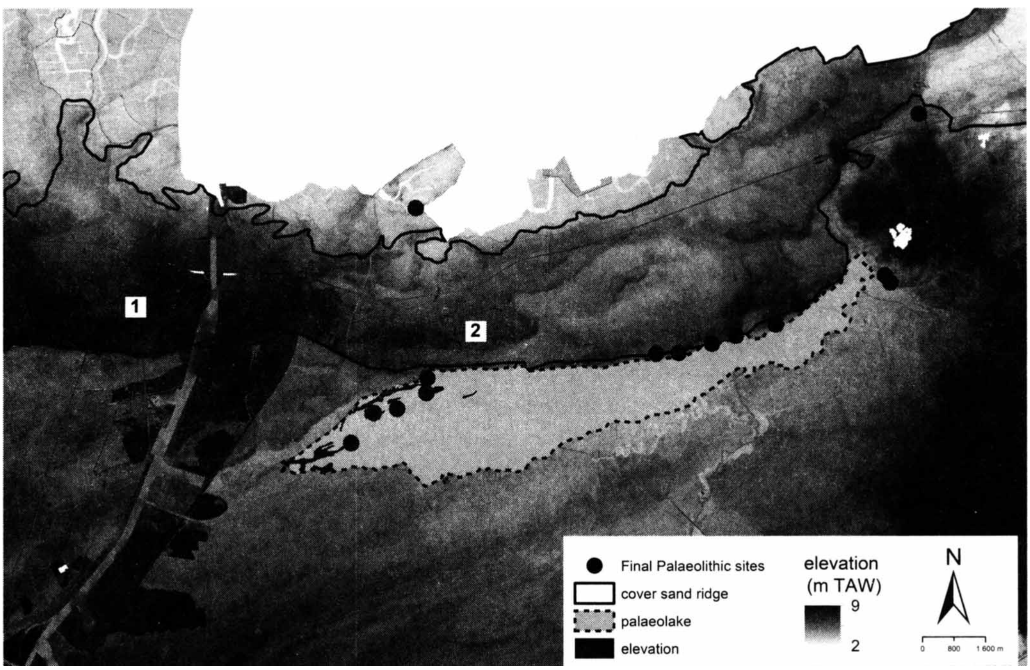

Figure 6 Simplified map showing the maximum extent of the Moervaart paleolake and the distribution of Federmesser sites along the southern edge of the Great Ridge of Maldegem-Stekene. Sampled locations: 1. Rieme; 2. Wachtebeke "Heidebos."

So far, no proof of human presence before the Older Dryas and after the Allerød is available, though this does not necessarily means that the area was unoccupied. Potential Bølling sites, belonging to either the Late Magdalenian or Creswello-Hamburgian, can still be present, buried deeply underneath later coversand deposits. Unfortunately, these sites cannot be detected easily by means of traditional survey methods (field walking, manual coring, etc). Concerning the Younger Dryas, the apparent lack of sites belonging to the (Epi-) Ahrensburgian and/or Epi-Laborian cannot be simply explained using taphonomic arguments (Crombé et al., in press). As most Federmesser sites dating back to the Allerød are found at the present surface, there is no reason to believe that sites from the Younger Dryas or the first half of the Preboreal are buried underneath thick eolian deposits. Possibly the area was too hostile for human occupation during this period due to the intensity of wind erosion and extreme cold conditions. Also, the final disappearance of all open water reservoirs may have had a dramatic impact on human occupation of the area as this source of freshwater was no longer available for drinking water for both humans and animals. The majority of dune slacks dried out by the middle of the Allerød, while the large paleolakes, e.g. the Moervaart lake, disappeared completely in the course of the Younger Dryas (Bats et al. 2009, 2010).

CONCLUSIONS

The Late Glacial recolonization of the NW Belgian coversand region occurred in a constantly changing environment dominated by drifting sand dunes, temporary dune slacks, and large, deep paleolakes. A massive dune complex, called the Great Ridge of Maldegem-Stekene, formed the focus of intense human occupation by Federmesser hunter-gatherers living in the area during the Older Dryas and Allerød. Conditions after the Allerød probably were not suitable enough to attract human groups, as there is so far no evidence of occupation during the Younger Dryas.

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