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Late Weichselian (fluvio-)aeolian sediments and Holocene drift-sands of the classic type locality in Twente (E Netherlands): a high-resolution dating study using optically stimulated luminescence

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A B S T R A C T

The Late Weichselian and Holocene (fluvio-)aeolian sands of the type locality Lutterzand in the E Netherlands have been the focus of many palaeoclimatic, palaeoenvironmental and geochronological studies. In the present study, an accurate and detailed chronological framework has been established using radiocarbon and optically stimulated luminescence dating. Additionally, the sedimentological characteristics of the fluvio-aeolian and aeolian sequences have been reinvestigated.

Four main phases of (fluvio)aeolian sedimentation have been differentiated in the Lutterzand sections, consistent with the Late Pleniglacial, the pre-Allerød Lateglacial, the Late Dryas, and the Late Holocene. From at least 25.2 ± 1.9 ka up to 19.9 ± 1.6 ka, the area was marked by a transition from fluvial to aeolian deposition under continuous permafrost conditions (Older Coversand I). The Beuningen Gravel Bed is considered as the lithostratigraphic marker for permafrost degradation, shallow channelling and aeolian deflation associated with the formation of a desert pavement. Localised fluvial sedimentation in shallow channels took place in two phases, a first from ~20 ka to ~23 ka, and a second at around 16 ka; the desert pavement formed in between ~16 ka and ~14 ka, but probably shortly after 16 ka. The aeolian sediments overlying the Beuningen Gravel Bed were deposited as sand sheets and low dunes, and yielded ages between 15.8 ± 1.4 ka and 12.2 ± 0.9 ka. Although the OSL ages seem to point to fairly continuous coversand sedimentation during the Lateglacial, the intercalated Usselo Soil allows distinguishing a pre-Allerød phase (resulting in the Older Coversand II and the Younger Coversand I between 15.8 ± 1.4 ka and 12.3 ± 1.0 ka) from a post-Allerød phase (with deposition of the Younger Coversand II between 13.6 ± 1.1 ka and 12.2 ± 0.9 ka). During the major part of the Holocene, (podzol) soil formation occurred in the top of the aeolian sediments. Probably due to human activities, local erosion of the upper part of the Lateglacial sequences and redeposition took place. These drift-sands were dated between 0.40 ± 0.04 ka and 0.20 ± 0.02 ka.

1. Introduction

The classical stratigraphic subdivision of the Late Weichselian fluvio-aeolian and aeolian sediments in the NW European lowlands (Belgium and The Netherlands) was first described in the Lutterzand area (Twente, E Netherlands; Van der Hammen, 1951; Van der Hammen and Wijmstra, 1971) and comprises the following succession: Older Coversand I, Beuningen Gravel Bed, Older Coversand II, Lower Loamy Bed, Younger Coversand I, Usselo Soil and Younger Coversand II (Fig. 1). The alternation of coversand units, a major unconformity and soil horizons were thought to reflect the rapid climatic and environmental changes during the Late Weichselian and the Weichselian–Holocene transition. Since then, the stratigraphic units have been recognised and correlated in large parts of NW and Central Europe (Koster, 1982, 2005; Kasse et al., 2007, and references therein), mainly on the basis of their stratigraphic position, sedimentological characteristics, pollen analysis and radiocarbon ages of organic horizons intercalated between the coversands. Establishing a chronological framework for the fluvio-aeolian and aeolian deposits in the NW European lowlands was long hampered by some of the limitations inherent to the radiocarbon dating technique. Radiocarbon dating can only be applied to organic material, while the sediments in Belgium and The

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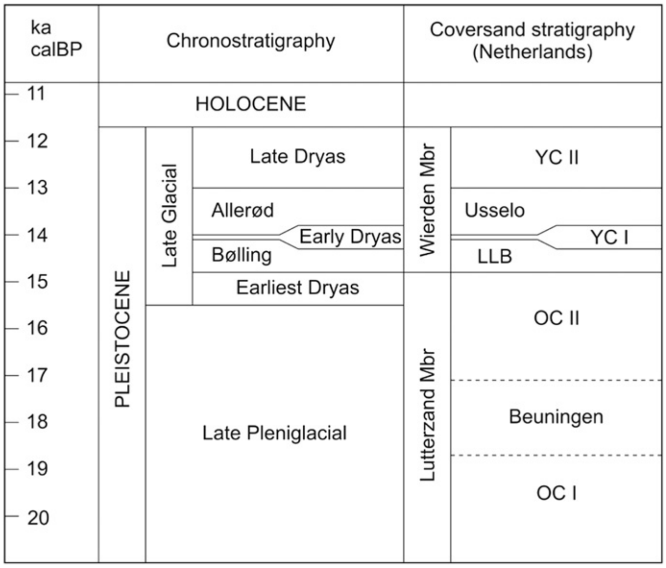

Fig. 1. Chronostratigraphy and coversand stratigraphy of the Late Weichselian fluvio-aeolian and aeolian sediments in the Netherlands (based on Van der Hammen, 1951; Van der Hammen and Wijmstra, 1971; Van Huissteden, 1990; Hoek, 2001; Van Huissteden et al., 2001; Derese et al., 2010a,b). OC: Older Coversands; YC: Younger Coversands; LLB: Lower Loamy Bed.

Netherlands are usually sterile, i.e. they do not contain sufficient organic material for radiocarbon dating. Direct age information can only be obtained for intercalated soils and peats, while the timing of sand deposition cannot be determined in a direct way. It follows that, using radiocarbon dating, information about sedimentation rates or the occurrence of sedimentary hiatuses cannot be obtained. Luminescence dating, on the other hand, does allow directly dating the time of deposition of the sediments. Feldspar thermoluminescence (TL) dates for Late Weichselian coversand deposits from the Lutterzand area underestimated the age expected from radiocarbon chronologies (Dijkmans et al., 1988; Dijkmans and Wintle, 1991). Optically stimulated luminescence dating of quartz yielded more reliable ages (Stokes, 1991; Bateman and Van Huissteden, 1999), but these studies were limited to the dating of only a sample or two per sedimentary unit. These observations led us to reinvestigate the sequences at Lutterzand using a high-resolution sampling strategy and with the use of a luminescence dating method that is more modern and more precise i.e. the single-aliquot regenerative-dose or SAR protocol (Murray and Wintle, 2000).

SAR dating using the fast component of the quartz OSL signal is considered as a reliable chronological tool in a range of geomorphological settings (see e.g. Murray and Olley, 2002; Wintle and Murray, 2006; Wintle, 2008, and references therein; Madsen and Murray, 2009). The approach has already been successfully applied at several Late Weichselian fluvio-aeolian and aeolian sand sequences deposited during oxygen isotope stages (OIS) 1 and 2 in the NW European lowlands (e.g. Vandenberghe et al., 2004, 2009; Kasse et al., 2007; Wallinga et al., 2007; Buylaert et al., 2009; Derese et al., 2009, 2010a,b, 2011, 2012; van Mourik et al., 2010; Bogemans and Vandenberghe, 2011). The main aims of the present study are to establish a detailed and accurate chronological framework for the fluvio-aeolian and aeolian sediments at the type locality Lutterzand in the E Netherlands, and to reconstruct the depositional history and changes in the sedimentary environment during the Late Weichselian and Holocene. The age information was provided by quartz SAR-OSL dating of 57 samples taken from four natural exposures along the Dinkel river at Lutterzand, complemented with radiocarbon dating. Additionally, all sedimentary units were sampled for grain size analysis.

2. Geological setting

Weichselian fluvio-aeolian and aeolian sands occur in an area extending from Great Britain, over the NW European lowlands, N Germany, Denmark and Poland to Russia (see Kasse, 2002, and references therein). Often, this area is referred to as 'the European coversand belt' (Fig. 2a). The sediments of Weichselian Pleniglacial age are considered to originate mainly from the present North Sea region, of which large parts were exposed during the Last Glacial Maximum as a result of lower sea levels (Koster, 1982; Schwan, 1986; Bateman, 1995). To a lesser degree, the large delta plains of the Rhine and Meuse rivers and the (pro)glacial areas along the Pleistocene glacial limits also contributed (Kasse, 2002). The different conditions during the Weichselian Lateglacial, resulting from recession of the ice sheet margin, gradual re-inundation of the North Sea basin, changes in the atmospheric pressure system and increasing density of the vegetation cover, rather promoted transport from nearer sources. The aeolian deposits from this period are thought to be derived from pre-existing aeolian formations and from temporarily dry river beds (Schwan, 1986). During the Holocene, the coversands were locally remobilized and blown into driftsand dunes.

The Weichselian (and Holocene) fluvio-aeolian and aeolian sediments form a substantial part of the surficial deposits in The Netherlands (Koster, 1982). However, sedimentary sequences thought to give an overall picture of the changes in the sedimentary environments from the Weichselian Pleniglacial up to the Holocene are rare.

One of the relatively complete Late Weichselian records from The Netherlands is situated in the Lutterzand area (Twente, E Netherlands) according to Van der Hammen and Wijmstra (1971), where natural exposures with a combined height of several metres, can be found over a distance of ~2 km along the Dinkel river (Fig. 2b and c). Its completeness is probably related to the geomorphological evolution of the region, which has been discussed by Van der Hammen and Wijmstra (1971), Van Huissteden (1990) and Van Huissteden et al. (2001). The presence of glaciers, extending from the N European continental ice sheet during the Saalian, resulted in the development of north–south oriented ice-pushed ridges and intermediate glacial basins. During the Weichselian, the Saalian topographically elevated landforms in E Netherlands were affected by periglacial erosion, while sedimentation processes occurred in the adjacent depressions, resulting in valley and basin fills of more than 25 m thickness. During the Lateglacial, the present-day valley of the Dinkel river was shaped by a phase of fluvial incision (Van Huissteden, 1990). At present, the valley is bordered to the east by outcrops of Early Cretaceous shales and sandstones, and to the west by the ice-pushed ridges of Oldenzaal and Ootmarsum, dating from the Saalian. The northern part of the valley consists of a glacial basin, the so-called Nordhorn Basin (W Germany), in which Eemian and Weichselian fluvial and aeolian sediments reach thicknesses of more than 25 m (Van Huissteden et al., 2001; Fig. 2b).

3. Sedimentary succession and sedimentological characteristics

The stratigraphy of the Late Quaternary sediments in the Lutterzand area was studied in detail by Van der Hammen and Wijmstra (1971), mainly in natural exposures along the Dinkel river and in excavations for the Dinkel regulation canal. The stratigraphic subdivision of the sedimentary succession made by these authors, was primarily based on the presence of intercalated soil horizons and periglacial phenomena, on the pollen content and to a certain extent on the sedimentological characteristics. In the