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Incised Pleistocene valleys in the Western Belgium coastal plain: Age, origins and implications for the evolution of the Southern North Sea Basin

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ABSTRACT

The Belgian coastal plain occupies a key position as it is located at the transition between the Southern North Sea Basin and the Strait of Dover. It is characterized by thick sequences (>20 m) of Pleistocene terrestrial and littoral sediments. Yet the wider stratigraphical and palaeo-environmental significance of these sediments received little attention. In this paper we draw on the results of a recent sedimentological study based on >100 drillings that spans the Pleistocene sequence, and present new biostratigraphical (pollen, foraminifera, ostracods) data, all revealing a complex history of deposition. The record includes evidence of the development of incised-valley systems that were initiated in the late Middle and Late Pleistocene. Five phases of fluvial incision can be identified. The majority of the infills are deposited in an estuarine environment that passes into a fluvial environment land inward, except the Weichselian infill which has a predominant fluvial origin. The greatest part of the most seaward located zone of the western coastal plain was free of valley incisions, there, shallow marine sediments built up the record. Local biostratigraphical investigations provide a timeframe. The result is placed in a regional context.

1. Introduction

The western coastal plain of Belgium (Fig. 1) is characterized by a thick (>20 m) accumulation of Pleistocene sediments, which extend about 20 km inland. The deposits have never been studied in the context of the Pleistocene evolution of the Southern North Sea Basin. The few existing studies concern local investigations (e.g. Denys et al., 1983; Tavernier and de Heinzelin, 1962; Vanhoorne, 1962, 2003). That the Pleistocene deposits along the whole Belgian coast consist of littoral deposits, locally covered with Weichselian fluvial and/or aeolian deposits, is widely accepted. It is believed that the littoral deposits only extend back to the Eemian Stage and linked to one transgressive phase (Baeteman, 1993; Denys et al., 1983; Mostaert and De Moor, 1984; Mostaert et al., 1989 and Paepe, 1971), with the exception of the deposits in the area nearby the city of Lo to which a Holsteinian/Cromerian age is given (Vanhoorne, 1962, 2003). The idea that the Quaternary geological history of the western coastal plain, and even the entire Belgian coastal plain, is so simple and as young as the Eemian contradicts evidence from neighbouring countries of the Southern North Sea Basin where older littoral deposits of Middle Pleistocene age have also been described (e.g. Balescu and Lamothe, 1993; Bates et al., 2003; 1999; Roe et al. 2009; Roe and Preece, 2011; Sarnthein et al., 1986; Sommé et al., 2004). One hundred and five undisturbed mechanically drilled cores covering the whole Quaternary sediment succession provided the opportunity to make a cohesive and comprehensive sedimentological and morphological study that has led to new insights on both local and regional scale. A multidisciplinary approach is used whereby the sedimentological interpretations are supported by foraminiferal, ostracod and pollen analyses. A pollen record from a borehole at Woumen, near Diksmuide in the west of the area is described, and foraminiferal and ostracod analyses are presented from six cores from the northern, central and southern parts of the region (Fig. 1). The new morphological, litho- and biostratigraphical findings show the presence of a complex incised-valley system in the western coastal plain as a result of a series of erosional and depositional phases, controlled by terrestrial and marine processes. Those processes span the late Middle and Late Pleistocene. As the western coastal plain occupies a transitional position between the largely depositional area of the Southern North Sea and the predominantly erosional Strait of Dover region (cf. Gibbard, 1988, 1995,

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2007; Gupta et al., 2007; Hijma et al., 2012) the findings also provide additional insights into the late Middle and Late Pleistocene development of the wider Southern North Sea Basin.

2. Geographical and geological setting

2.1. Study area

The western coastal plain (WCP) lies on the margin of the southern North Sea in the northwest of Belgium, extending from the border with France to Oostende in the north, and from Diksmuide to Lo-Reninge and Merkem in the south (Fig. 1). The coastal area is drained by the River IJzer, which rises in France, and its tributaries the Kemmelbeek and Sint Jansbeek, both having their source in Belgium (Fig. 1). A significant dune system extends along much of the coastal region. This has been locally downgraded by development and aggregate extraction. Because of embankments, the coastal plain today forms a low-lying, flat artificial landscape with sluices, ditches and canals. Its land surface ranges from + 1 m and + 5 m TAW, (TAW ordnance datum and refers to mean lowest low-water spring at Oostende, i.e. ca. 2 m below mean sea level – Agency for Maritime Services and Coast-Division – COAST) which is below high water level. The plain is protected from flooding by the remaining dunes and locally by seawalls. The present-day landscape results from a continuous infill process controlled by sea-level rise during the Holocene (Baeteman, 1999, 2013). The modern topography thus masks the Pleistocene coastal and continental deposits that underlie the Holocene infill. The Pleistocene sediments in turn overlie Paleogene deposits of Eocene age. The Pleistocene sedimentary record is predominantly composed of shore-shelf, tidal and fluvial deposits, each depositional unit showing a variety of lithofacies and architectural elements (Bogemans, 2014; Bogemans and Baeteman, 2014). The textural composition ranges from coarse to fine sediments (gravel to clay). The gravel component is mainly composed of shell remains, with subsidiary siliciclastic particles. The rest of the deposits is mainly siliciclastic.

2.2. Research history

Previous studies have mainly described the fossiliferous Pleistocene sediments of the WCP. Tavernier and de Heinzelin (1962) and Vanhoorne (1962, 2003), for example, describe palaeontological investigations that were undertaken on deposits from the western margin of the WCP near Lo and from the Vinkem–Izenberge area, the latter known as the Izenberge Plateau, and bordering the coastal plain (Fig. 1). At both localities Tavernier and de Heinzelin (1962) observed shell-bearing sediments between + 1.45 m to + 12.2 m TAW. The associated molluscan assemblages were dominated by small-sized *Cardium edule*, now known as *Cerastoderma edule* (Linnaeus, 1758), along with *Macoma baltica* (Linnaeus, 1758), *Hydrobia stagnalis* (Baster, 1765) and *Theodoxus fluviatilis* (Müller). The authors noted the similarity between these faunas and those found today along the Belgian coast and estuaries and ascribed them to an interglacial or interstadial phase. Furthermore, they concluded that the stratigraphical position and elevation points to a Middle Pleistocene age. Similarly, Vanhoorne (1962, 2003) investigated the palynology and the chronostratigraphy of a peat unit that occurs in Lo beneath the shell-bearing layer observed by Tavernier and de Heinzelin (1962). In the so called "shell-bearing layer" in Lo the molluscan remains are often broken and form part of a predominantly siliciclastic sand deposit (Tavernier and de Heinzelin, 1962). Vanhoorne (1962), initially concluded that the peat accumulated during the Holsteinian Stage, although he could not rule out an interglacial within the Cromerian Complex. However, in 2003 he reassigned the peat bed to the Cromerian IV Substage, and attributed the overlying shell-bearing layer to the Holsteinian (Table 1). Also in 2003, Vanhoorne observed a distinct faunal succession within the shell-rich stratum in the vicinity of Lo (+ 1.65– + 2.55 m TAW). Freshwater molluscs and ostracods were observed at the base of the studied unit, whilst brackish and marine species were present at the top, dominated by the mollusc *Cerastoderma glaucum* (Poiret, 1789) and by the foraminiferal species *Ammonia beccarii* (Linnaeus, 1858), *Nonion depressulum* (Walker & Jacob, 1798), *Elphidium exvavatum* s.l. Terquem, 1875, *Elphidium selseyenese* (Heron-Allen & Earland, 1919) and *Elphidium margaritaceum* (Cushman, 1930).

The multidisciplinary palaeontological study of Denys et al. (1983) was based on drillings from near De Panne at the present coast (Fig. 1) and carried out as part of a hydrogeological survey of the Pleistocene deposits. Diatom analyses confirmed that the species composition was similar to that found today in the littoral section of the southern North Sea. However, some diatoms were associated with both warmer and colder environments (Denys et al., 1983). In addition, the samples yielded abundant marine molluscs, although terrestrial and freshwater species were also present. The appearance of Chenopodiaceae pollen in all samples, re-affirmed according to Denys et al. (1983) the littoral origin of the sediments. The sequence was assigned to the late Eemian Stage notwithstanding the predominantly sandy nature of the sediments, which yielded only poorly preserved pollen that did not permit firm biostratigraphical correlations, and the stratigraphical uncertainties associated with twenty-one stratigraphically undiagnostic molluscan species (Spaink and Sliggers in Denys et al., 1983) (Table 1).

Lithostratigraphically the marine sediments are named in Belgium the Oostende Formation and defined as tidal and subtidal sand deposits, tidal mudflats and storm beach deposits (Gullentops et al., 2001) (Table 1). The marine deposits underlying the northern French coastal plain near the Belgium border are ascribed by Sommé et al. (2004) and Sommé (2013) to the Loon Formation and correlated with the Oostende Formation on the basis of the similar character of the sediments and their stratigraphic position. An Eemian age is also given (Table 1).

Furthermore in northern France, at Herzeele (Fig. 1), exposures of interglacial coastal and shallow marine sediments have been studied intensively. Sommé et al. (1978) proposed a stratigraphic correlation of the deposits in Herzeele with the shell-bearing deposits described by Tavernier and de Heinzelin (1962) in Lo and Vinkem-Izenberge. However Baeteman (Sommé et al., 1978) and later Paepe et al. (1981) expressed doubts regarding the chronostratigraphic precision of the correlation between these deposits. Baeteman carried out about 100 hand drillings in a north–south corridor from Bulskamp to Roesbrugge-Haringe (Fig. 1) in order to identify the extension of the Herzeele Formation in Belgium. In particular, she paid attention to the distribution of *C. edule* in the sediments as this species are described as being dominant in both Herzeele and Lo/Vinkem-Izenberge (Sommé et al., 1978; Tavernier and de Heinzelin, 1962). In the said corridor, only fragments of bivalves and no articulated specimens like those at Herzeele were observed. The occurrence of *C. edule* was also limited, especially in the deposits present beyond the border of the Izenberge Plateau. All the other molluscan taxa recovered were also fragmented, except freshwater molluscs. The shell fragments were concentrated in several rather thin strata between + 13 and − 1 m TAW (Baeteman in Sommé et al., 1978).

Pollen analysis of the peat beds underlying the shell-bearing bed at Herzeele by Vanhoorne (Sommé et al., 1978) prompted a biostratigraphic correlation with both the shell-bearing bed and the peat beds near Lo. In Vanhoorne and Denys (1987) the shell-bearing bed retains that correlative Holsteinian age as stated in 1978 by Vanhoorne whilst the underlying deposits including the peat beds are supposed to be older; most probably Cromerian.

Absolute dating of the shell-bearing bed of the Herzeele Formation at its type locality in Herzeele yielded a different age depending the dating techniques. The thermoluminescence determination gave an age of 228 ± 30 ka or preliminary corrected 271 ± 36 ka (Balescu and Lamothe, 1993) whereas the Th/U and ESR analyses gave an age between 300 and 350 ka (Sommé et al., 1999).