11 Quaternary shelf deposits and drainage patterns off the French and Belgian coasts

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ABSTRACT

High-resolution reflection seismic data recorded in the Southern Bight of the North Sea have allowed to draw a first general reconstruction of the topography of the base of the Quaternary deposits. The morphological aspects of this erosion surface have been confronted with the knowledge of the Quaternary history of the Belgian coastal plain, yielding a hypothesis about the origin of the palaeolandforms and of the present-day offshore morphology. The evolution of this erosion surface is also related to the present-day knowledge of the river terraces in the coastal backland.

INTRODUCTION

The erosional surface at the base of the Neogene and Quaternary deposits has been analysed in a limited area of the Southern Bight of the North Sea, encompassing the Belgian coastal plain, the Belgian continental shelf, the French continental shelf in the Strait of Dover and the southernmost offshore area of the Netherlands. Most data have been derived from reflection seismic profiles, calibrated in terms of seismic velocities with a few borehole data. The results are presented as an isohypse map of the complex post-Palaeogene erosion surface (figure 1) and an isopach map of the post-Palaeogene cover sediments (figure 2).They are based on the seismic data-base, available in 1985. Meanwhile, the Renard Centre of Marine Geology (Gent University) has continued its exploration efforts in the Southern Bight, which will in the future lead to a more detailed model of the Quaternary evolution of the coastal plain and its offshore extension.

In the major part of this region, the surface which truncates the regular sequence of Palaeogene strata coincides with the base of the Quaternary deposits. In the Strait of Dover, this erosional surface also truncates Mesozoic deposits. In the extreme northeastern part of the considered area, the surface truncating the Palaeogene sequences however does not correspond with the base of the Quaternary. In this region, the Palaeogene strata have a larger dip of 2-3°NE and are covered by a thick sequence of Neogene and Quaternary deposits. As in this area the base of the Quaternary cannot be recognized from the seismic data alone, without borehole control, the northeastern part of the map (figure 1) displays the erosional surface at the top of the Palaeogene sequences.

The maps shown have also been implemented with morphological data of the base of the Quaternary deposits and of their thickness in the Belgian coastal plain, as compiled from boring data and literature (BAETEMAN, 1981 ; DE BREUCK and DE MOOR, 1974 ; DE PRET, 1983 ; DEVOS, 1984 ; HENRIET *et al.*, 1981 ; MOSTAERT, 1985 ; SOMME, 1979).

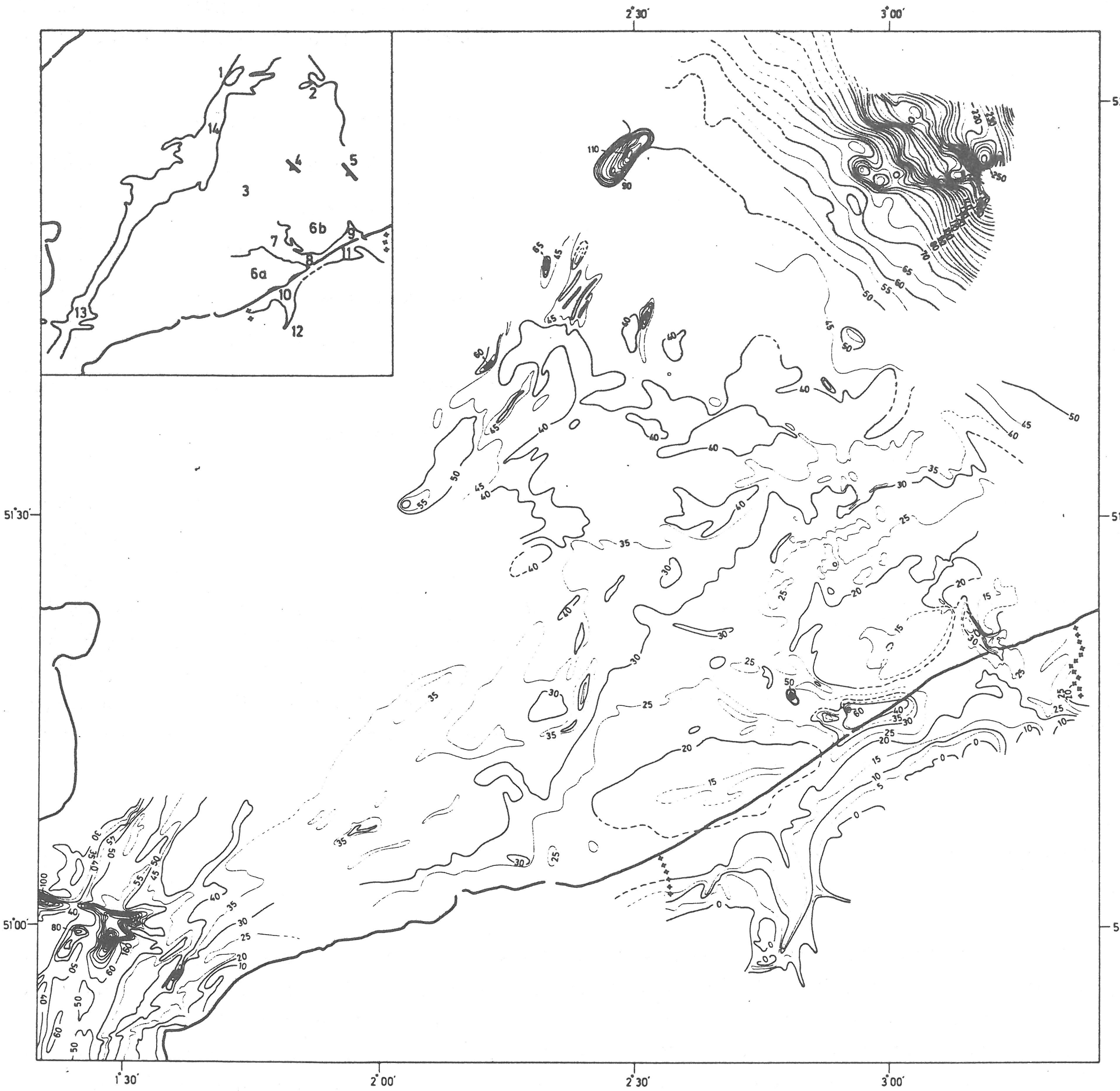

Figure 1 Topography of the erosional surface at the base of Neogene or Quaternary sediments in the Southern Bight of the North sea.
Morphological units : 1. Murray pit with Pliocene fill. 2. Buried valleys (Late Oligocene ?). 3. Abrasion slope. 4. Bartonian cuesta. 5. Rupelian cuesta. 6. Marginal platform. 7. Ostend valley. 8. Sepia pits in Ostend valley. 9. Zeebrugge pit and Bartonian cliff. 10. Western coastal palaeovalley. 11. Eastern coastal palaeovalley. 12. Yzer valley. 13. Dover Strait scour hollows. 14. Axial channel (see also BRIDGLAND and D'OLIER, this volume).

GENERAL FEATURES OF THE EROSION SURFACE

The description of the erosional surface truncating the Mesozoic and Palaeogene sediments will in this paper be limited to that area, where it effectively forms the base of the Quaternary and recentmost deposits. For a description of the morphology of this erosion surface below the Neogene cover on the Dutch continental shelf, we refer to VANNESTE' s thesis (1987).

The origin of the erosion surface at the base of the Quaternary deposits is polygenetic. The erosion took place under variable climatic conditions and in marine as well as fluvial circumstances.

In the present-day offshore area, the morphology of the erosion surface clearly shows a central, regular abrasion slope, bound to the northwest by a northeast-trending axial channel. This axial channel can be morphographically linked to the complex Strait of Dover channel system. The Belgian nearshore zone and coastal plain show a seaward dipping marginal slope, interrupted by the Yzer valley system and by a coastal valley floor, further referred to respectively as the eastern and western coastal palaeovalleys. A marginal platform limits the palaeovalleys to the north except for the central part of the Belgian coastal area, where it is transected by the so-called Ostend valley, with an east-west orientation.

THE CENTRAL ABRASION SURFACE

The slightly seaward dipping open marine abrasion surface is found at a depth of -15 m close to the present coastline and at depths of -35 to -40 m further seaward. It is characterized by a specific microrelief, sometimes reflecting structural aspects of the Tertiary substratum. The general trend of the surface seems to be independent of the strike and dip of the Tertiary layers and of the existing tectonic deformations.

The largest part of this surface, situated to the west of the Ostend valley, is modeled in Ieper Clay (London Clay). There the platform is quite regular, the main anomalies being rock-head depressions of low amplitude, some of which are filled up by Quaternary deposits (KIRBY and OELE, 1975). A detailed study of the seaward dipping slope allowed to detect continuous changes of dip probably indicating erosion in separate phases.

To the east of the Ostend valley the Tertiary substratum consists of alternating sand, clay and sandstone layers (HENRIET *et al.*, this volume). This lithological diversity is reflected in some morphological features on the erosion surface, such as remnants of cuestalike ridges. Scattered depressions occur as well. The asymmetric cuesta ridges have probably not been pre-modeled by subsequent rivers but should be regarded as the product of preferential scouring of the erodable sands in tidal channels, a phenomenon frequently accompanied by local overdeepening features. Locally the Asse Clay (Eocene - Bartonian) and the Boom Clay (Oligocene - Rupelian) are clearly exposed. In most cases, these ridges are covered by Quaternary deposits (sand waves and sand banks) and are consequently not reflected in the present-day sea floor morphology.

Systematic seismic profiling on the Zeeland Ridges (Thornton, Akkaert and Goote Bank) has revealed bedrock elevations generally located at their southwestern end. The Akkaert Bank and especially the Goote Bank are largely located on Tertiary bedrock swells and are characterized by relatively minor Quaternary accumulations.

These phenomena, together with the location of some sand banks along slope breaks on the abrasion surface suggests a wide-spread bedrock morphological control on sand bank setting and geometry in the Southern Bight of the North Sea. However, the active present-day erosion processes observed in channels lying between the sand ridges may also suggest that the bedrock swells are relict highs, partly modeled after the emplacement of the sand bank and protected from erosion by the thick sand cover. The overall orientation pattern of the sand ridges seems anyhow to be essentially controlled by tidal processes, and that since the opening of Dover Strait about 8,000 years BP.

Another characteristic feature of the erosional surface is the presence of remnants of palaeovalleys. The gully systems and their fills, which are of fluvial origin, existed before the final (Holocene) open marine scouring took place. Due to this erosion, only scarce remnants are left which makes it difficult to reconstruct the areal distribution pattern of these palaeoriver systems. The most typical palaeovalley is found under the Thornton Bank and has a northwestward trend. Based on the fact that fluvial incision in the Belgian coastal area did not reach relatable depths until the Saalian times, an older age of these palaeovalley remnants and their fills may be excluded. Except for the Ostend palaeovalley, correlation of these remnants with equivalents on land has not yet been possible.

THE NORTHEASTERN SLOPE

The regular norhteastward dip of the base of the Quaternary in the northeastern part of the study area (not represented on figure 1) corresponds with an Early Quaternary erosion surface. Marine Icenian deposits and Tegelen Clays covering this surface may be expected, as is the case in the laterally equivalent land position in Walcheren (VAN RUMMELEN, 1965). One of the internal Quaternary reflectors of the seismic profiles follows the dip of the central abrasion slope, which is of more recent age (Late Quaternary).

The present-day sea floor morphology does not reflect the northeastern slope at all. In this area the Quaternary sequences reach considerable thicknesses. It must be kept in mind that the erosion surface of the northeastern part of the study area, drawn on figure 1, corresponds with a post-Oligocene denudation related to an important sea level lowering (VANNESTE, 1987). It shows valleylike incisions which underline a continental fluvial impact.

THE AXIAL CHANNEL

The mid-Southern Bight drainage channel is characterized by a weakly pronounced southern margin. The channel has an average depth of 50 m. The transition to the abrasion platform is gradual. Several drift-filled hollows seem to be confined to this major gully system. The most spectacular rock-head depression is the Murray pit. This broad elliptical depression, scoured in Bartonian clays and Eocene sands, has been filled by eastward dipping drift deposits, of which some are of Pliocene age (BALSON, this volume). This implies that the first modeling of a central Southern Bight palaeovalley is at least of Pliocene age. The existence of a connection of the Southern North Sea with the ocean through the Channel in Late Tertiary time seems to be confirmed by marine faunas (FUNNEL, 1972). However it is generally assumed that the connection of the North Sea with the Channel through the Strait of Dover did not come into existence in recent geological times before Late Pleistocene (DESTOMBES *et al.*, 1975 ; KELLAWAY *et al.*, 1975 ; ZAGWIJN, 1979).

Very little information is available about the age and the origin of the thin and scarce infillings of the axial channel. The presence of overdeepened hollows indicates tidal scouring which does however not preclude a fluvial origin. Marine and fluvial erosion and infilling phases have alternated. The channel could have been an important southward orientated river system in glacial periods, when northward drainage was blocked by the glaciers.

THE STRAIT OF DOVER

The Strait of Dover, connecting the Channel with the North Sea, is situated on a structural westnorthwest-eastsoutheast-trending high, the Weald-Artois Horst, which has formed a barrier between the northern Anglo-Belgian basin and the southern Anglo-Paris basin from Middle Eocene up to recent geological times. Deposits which could be correlated with the erosion phases which formed the Strait of Dover are scarce :

some channel fills or remnants of terraces have been described (AUFFRET and ALDUC, 1977). Three drowned terrace levels, which could be correlated with secondary alluvial infillings, have been identified.

The pre-existence of a structural inversion landscape (Boulonnais) and the transversal fracturation of the Boulonnais are considered as important factors in the development of an initial drainage pattern.

The presence of so-called "fosses" (Fosse Dangeard and Fosse de la Bassurelle) indicates that tidal action was a major factor of remodeling of the initial drainage pattern and of the creation of Dover Strait itself. The Fosse Dangeard is located on erodable sands and clays of Aptian-Albian and Wealdian age. A combination of lithological and structural factors has probably controlled the overdeepening processes. According to HAMILTON and SMITH (1972), the "fosses" must be related with tidal scouring during periods of withdrawal or penetration of marine action in pre-existing channels, due to sea level changes. Moreover, it may be expected that tidal currents are amplified in the narrow strait when communication is achieved between the Channel and the Southern Bight, because of the decalation of the tidal waves in the separate basins.

THE COASTAL PALAEOVALLEYS AND THE OSTEND VALLEY

The seaward dipping topography of the Tertiary substratum on the southeastern margin of the coastal plain is steeper than the general slope of the offshore abrasion platform. This marginal slope shows little structural influences (MOSTAERT and DE MOOR, this volume) and runs 10 km landward of the present-day coastline except along the Yzer valley, where this slope retreats further landward. The Yzer valley joins the palaeovalley which runs parallel with and underneath the present-day coastline. Smaller tributaries as the Waardamme river join the eastern branch of the coastal valley.

These coastal palaeovalleys show a striking asymmetric cross profile. The northern flank is little exposed and not higher than -10 m. The southern flank corresponds with the steeper and higher coastal margin reaching at some places levels of +20 m. The asymmetry is a result of marine erosion, as will be developed further. The average depth of the valley floor is about 25 to 30 m.

The northwest trending Ostend valley was probably related to the so-called Flemish valley via the eastern branch of the coastal palaeovalley. In offshore direction the valley morphology is obliterated by the general northward dipping abrasion surface. The longitudinal profile of the coastal valleys and of the Ostend valley is fairly irregular. The Sepia pits off Ostend, scoured to -62 m in the Ieper Clay, and the depression under the outer harbour of Zeebrugge, flanked by a steep Bartonian cliff, probably are tidal scouring structures created in ancient estuarine environments.

The Quaternary history of the eastern part of the Belgian coastal plain is quite different from that of the western part. In the western coastal plain, marine deposits of Middle Pleistocene age have been found (the Herzeele Formation). These deposits have been laid down in a sea which may have penetrated from the southwest through an open Strait of Dover (SOMME, 1979 ; PAEPE and BAETEMAN, 1979) into a precursor of the Yzer valley. Due to later sea level changes, renewed fluvial erosion took place in the Yzer valley. These erosive processes have apparently not been able to remove all older marine deposits, hence leaving a fringe of tidal flat sediments.

Such Middle Pleistocene marine deposits are totally lacking in the eastern coastal plain. The eastern coastal valley and the Ostend branch got not shaped before the Saale glacial period (MOSTAERT and DE MOOR, this volume).The maximal deepening took place during the Eemian period, when the sea breached into the valley. Tidal scour hollows have been formed, comparable with those found in the present-day Western Scheldt estuary. Both in the eastern and in the western coastal plain, the Eemian open marine environment penetrated further landward than during the Holocene. As a consequence the northern flank of the coastal valleys got fairly but not entirely flattened by open marine erosion.

It is not fully clear yet whether the Yzer valley ever joined the Ostend valley along the western coastal valley, or kept a totally independent evolution with drainage to the northwest via the western outlet of the valley, as was the case during earlier marine inundations.

On base of these palaeogeographic considerations, the age of the modeling of the northward dipping abrasion surface can be brought back to Eemian times. This may as well be the age of the deepest scouring of the Ostend valley and of the Sepia pits. The study of the Quaternary infillings of the Sepia pits, which is now in progress, may shed some new light on this problem. Anyhow, thick Eemian deposits are preserved in the eastern coastal plain. The present-day nearshore ridges also contain Eemian sediments.

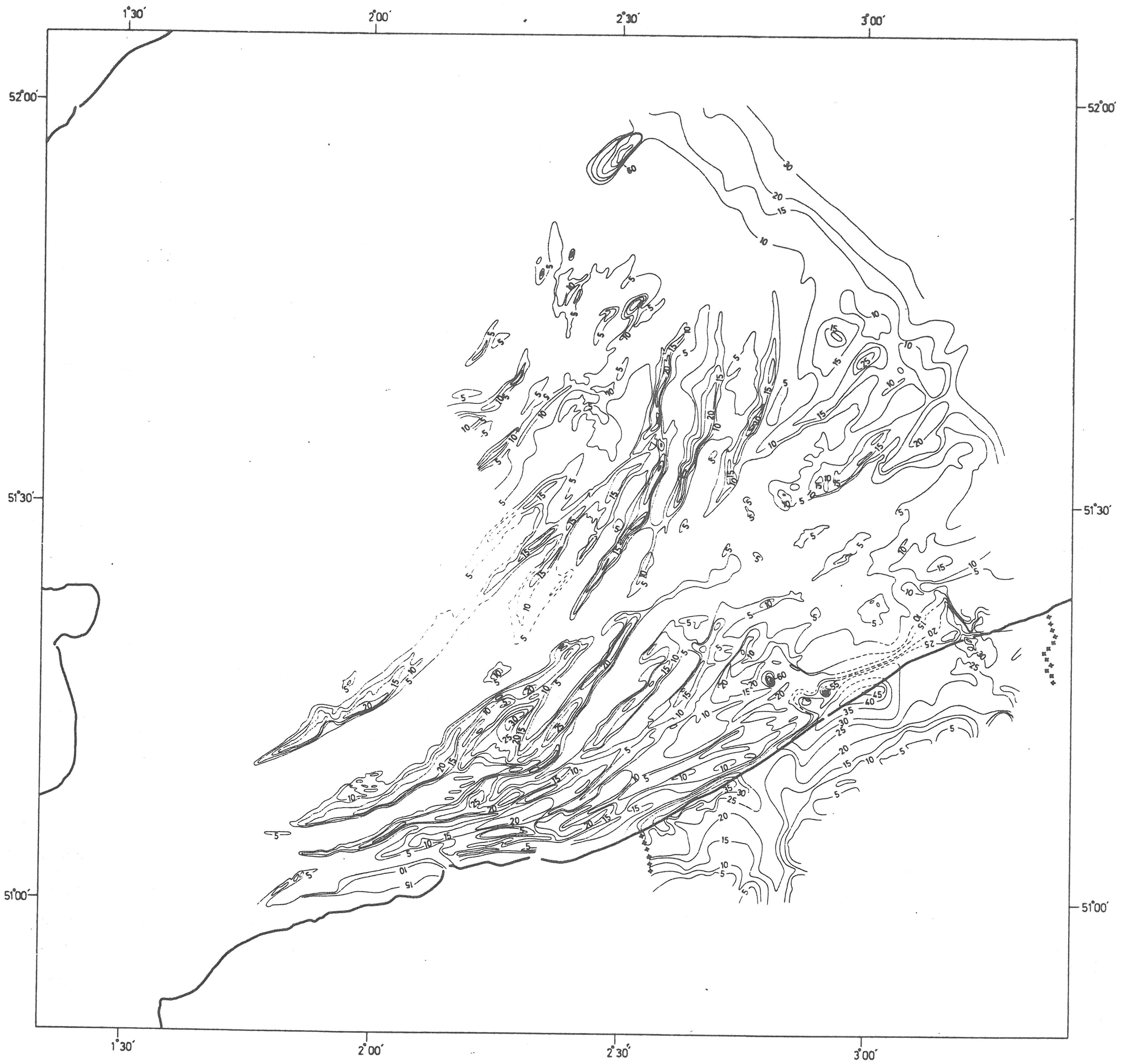

Figure 2 Thickness of Quaternary deposits or Quaternary plus Neogene deposits (NE edge of the study area)

The Weichselian drainage pattern, which seems to be directed to the central Southern Bight deeps, has locally eroded the Eemian abrasion platform. Also Holocene erosion influenced by sea level rise partly uncovered the Eemian abrasion platform. The re-opening of the Strait of Dover caused a spectacular and complex redistribution of the sediments available in the basin and created new sand supplies. These changes in the sedimentary environment, accompanied by differential erosion and deposition form the context which lead to the development of a rather flat basal plain covered with sand banks and sand wave fields. The modeling of the Tertiary substratum is still taking place for instance in the erosive gullies between the sand banks. There the Tertiary strata are exposed or lay beneath a thin gravel veneer. The map showing the thickness of the Quaternary deposits (figure 2) clearly shows that a substantial part of the offshore area is characterized by little or no Quaternary cover. This map also clearly reflects the distribution pattern of the Holocene sand banks. It is only in the northeastern part of the study area, in the present-day coastal plain and in the nearshore zone that the pre-Holocene Quaternary deposits get a sizable importance.

CONCLUSION

Seismic high-resolution surveys in the Southern Bight of the North Sea have allowed to study the present-day morphology of specific stratigraphical boundaries and may lead to palaeoenvironmental and palaeomorphological reconstructions. The palaeomorphological surface which has been investigated here is a result of fluvial and dominantly open marine scouring under varying sea level conditions since the end of the Tertiary, a process which has been achieved in a rather short period of time. The morphological features which have been described and if possible explained may contribute to the interpretation of older, more important erosion plains, reflecting major long-term sea level changes.

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