THE VLIERZELE SANDS (EOCENE, BELGIUM): A TIDAL RIDGE SYSTEM

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ABSTRACT. It is suggested that the Vlierzele Sands (late Lower Eocene) represent a longitudinal tidal sand ridge deposit. They consist of regular, cm- to dm-scale, cross-bedded sands originating from mobile, 20 cm - 50 cm high, two-dimensional megaripples. In the lower ranges of this facies, the intact megaripple forms have been preserved under a cover of vaguely horizontally laminated sands. The latter could be the result of rapid storm deposition on the lower flank of the sand ridge.

INTRODUCTION

The Lower Eocene of western and northern Belgium consists of a thick (100 m and more) marine clay (Ieper Clay). Some sandy deposits occur near the top. The uppermost, and most sandy, interval is the Vlierzele Sand (Fig. 1) (Kaasschieter, 1961), a 10 m - 20 m thick deposit which is included in the Paniselian 1d on the Geological Map of Belgium.

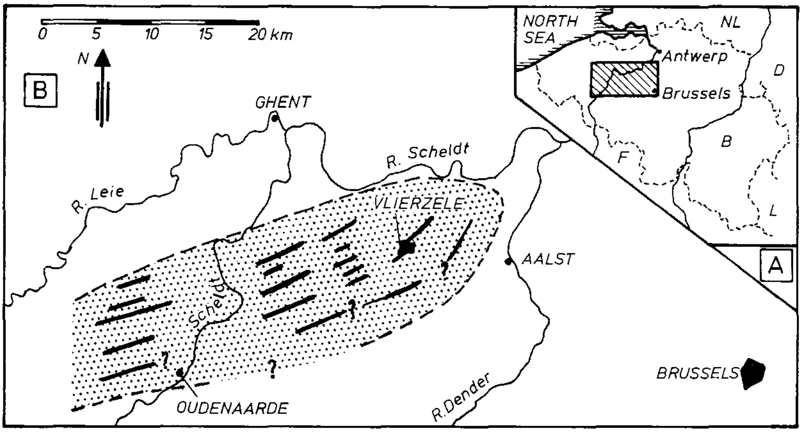

Figure 1. A. Location map.
B. Type area of the Vlierzele Sands. Full lines represent hill crests at the places and level where Vlierzele Sands outcrop.

P. L. de Boer et al. (eds.), Tide-Influenced Sedimentary Environments and Facies, 139–152.

The Vlierzele Sands consist of fine (100 - 200 microns), glauconiferous quartz sand with thin, intercalated clay layers. The sand shows cross-stratification and numerous 'herringbone structures' (Fig. 2).

In some locations however, the deposit contains apparently homogeneous horizontal layers. Some zones are intensively burrowed. Fossils are rare but there is evidence of a shallow marine environment, with water depths of less than 50 m (Kaasschieter, 1961). The Vlierzele Sands were formed during a strong regression following the Ypresian transgression into the Paris, London and Brussels Basins.

Gulinck (1952) interpreted the Vlierzele Sands as intertidal (wadden) deposits. Nolf (1972) referred to shoreline conditions. De Moor & Geets (1974) suggested a system of weakly developed sand banks in a 20 m - 50 m deep epicontinental sea were responsible for the parallel zones of equal grain size in the Vlierzele Sands southeast of Ghent.

Some new sand pits have recently provided good exposures. We describe the sedimentary structures exposed in one new Vlierzele Sand's pit (50°56'54" N, 3°53'52" E). The exposure was visited during Excursion A of the Symposium in 1985. Special attention is paid to morphological features and internal structures of meso-scale bedforms, which have been exceptionally well preserved.

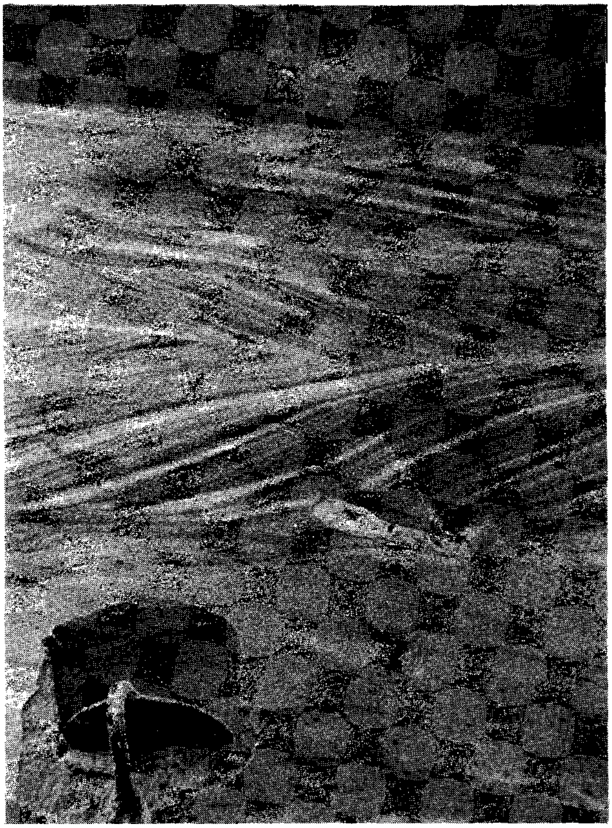

Figure 2.

Transverse section of the cross-laminated Vlierzele Sands, showing herringbone cross-lamination.

Note mud pebble at base of cross-laminations

The spade is 12 cm wide.

GENERAL DESCRIPTION OF THE SANDS AT VLIERZELE

Present geomorphology

The outcrop of the Vlierzele Sands is characterized by a series of parallel, low, elongated hills. The long axes lie SW - NE (Fig. 1B). The cores of these hills consist of the 'Sand' which, because of its high permeability, gives relatively good protection against runoff erosion. On the crests of the hills the base of younger, marine Tertiary layers is exposed. Following earlier studies of Belgian Tertiary deposits (Gullentops, 1957; Houthuys & Gullentops, 1985), we suggest that this topography reflects the original deposits of the Vlierzele Sands as long, parallel sand bodies. These were brought into relief during the Quaternary by differential erosion which removed the overlying and lateral deposits.

The sand pit at Vlierzele; Local stratigraphy

The sand pit is located in the northern flank of one of the hills. The Vlierzele Sands are here about 12 m thick (Figs. 3, 4). They overlie the easily recognizable Merelbeke Clay (data from local boreholes). The upper contact with the Middle Eocene Lede Sand shows an erosional gravel lag.

The base of the sand pit (A in Fig. 5) comprises very fine, slightly clayey and intensively burrowed sand. Remains of primary lamination show the original alternation of sand layers with a few, very thin mud laminae. Some vertical burrows are mud-clad. The upper part (B to G in figure 5) represents the Vlierzele Sands proper. The lower contact is erosional. The boundary surface dips 1°, NW. The profile shows a regular succession of cross-bedded (C, E, G) and poorly structured zones (B, D, F). The bounding planes between these subhorizontal zones dip about 2°, NNE. The local tectonic dip is 0.4°, also NNE.

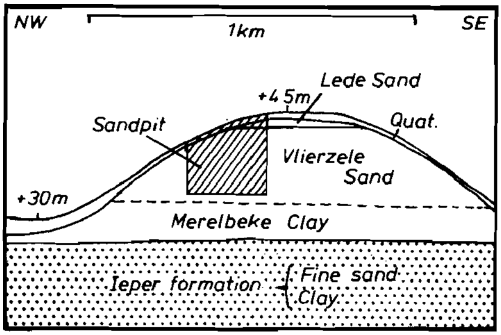

Figure 3.

Schematic position of the sand pit at Vlierzele.

CROSS-BEDDED ZONES

Morphology of the bedforms

The top plane of the cross-bedded zones C and E (Fig. 5) is an undulatory, non-erosive surface formed by megaripples (sensu Reineck & Singh, 1973), which were preserved as form sets (Fig. 6).

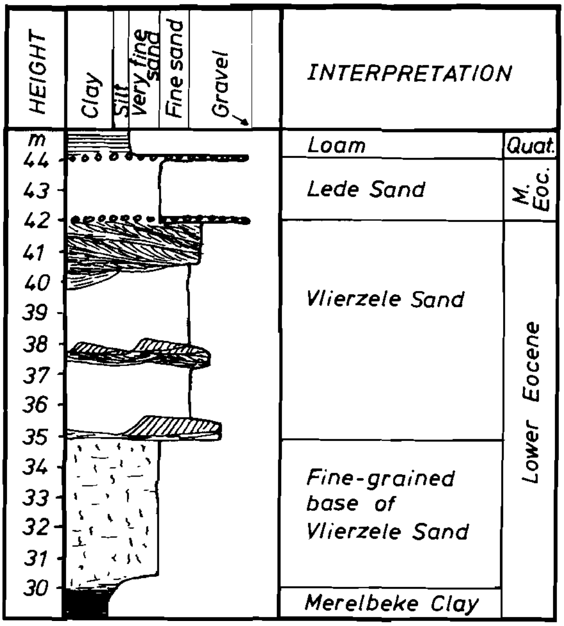

Figure 4.

Field log of the Vlierzele sand pit.

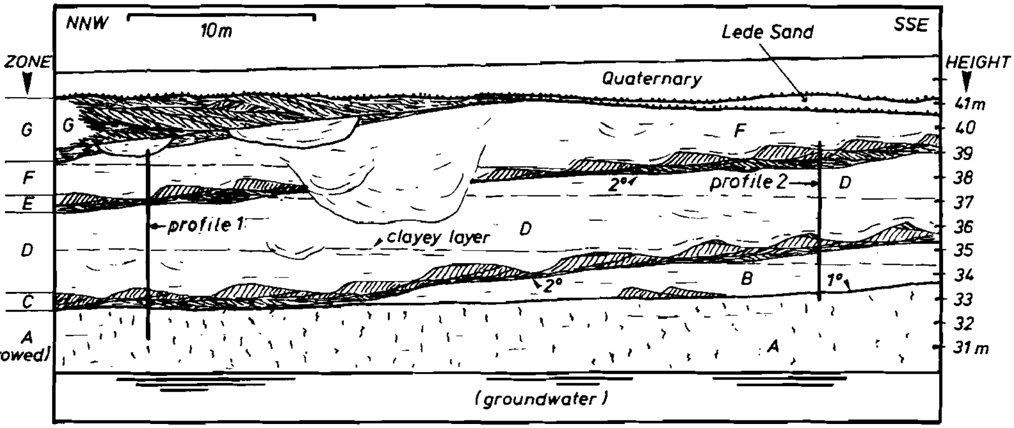

Figure 5. Sketch of the facies, exposed at Vlierzele.
A: Intensively burrowed, fine sand.
B, D, F: Poorly structured, fine to medium sand.
C, E, G: Megaripple, cross-bedded, fine to medium sand.
Position of the profiles of figure 15 is indicated. Note that orientation of exposure is not perpendicular to the megaripple strike.

Most of the megaripples of the Vlierzele exposure have been preserved without modification of form. Figure 7 shows that even the brinkpoint of the bedform is preserved. The cover of fine, clayey sand is described later. Because of the good preservation, the morphology of the megaripples could be studied closely. The walls of the sand pit were described and measured, following the continuing excavations, so that a good three-dimensional picture was obtained.

The top plane of zone E represents a field of 18 megaripples that are very similar in shape. This field dips 2°, NNE (N22°E). The bedforms are straightcrested (Allen, 1968); their lee sides face WNW at a dip angle of 20° - 25°; the WNW direction of the ripple migration is thus perpendicular to the dip of the surface which they cover.

The external shape of the zone E bedforms is that of unidirectional mega-current ripples (Fig. 8). The ripple heights range from 0.2 m - 0.5 m and the wavelengths from 4.5 m - 6.5 m. The form asymmetry is well developed. The stoss side (5° to 10°) is often covered with small current ripples; also small megaripples (5 cm - 10 cm high) are sometimes superimposed on the larger megaripples. There is usually a sharp brinkpoint.

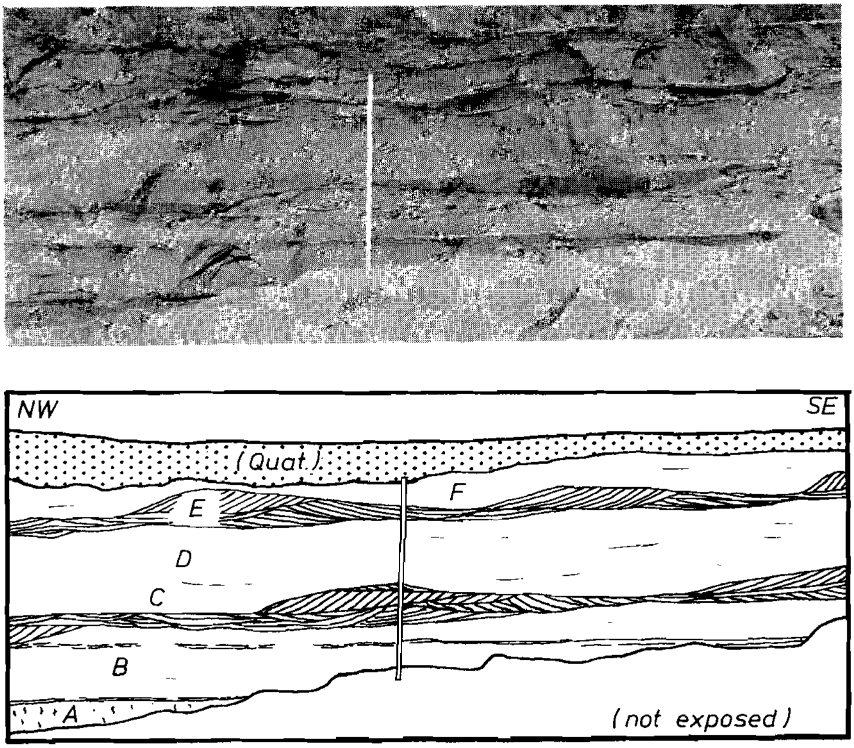

Figure 6. Part of the exposure at Vlierzele, situated in the right half of figure 5. Measuring stick is 4 m long. Layers that contain some clay are darker and protrude from the wall. Two megaripple forms of the upper level and one complete, opposite-current capped, lower megaripple can be seen.

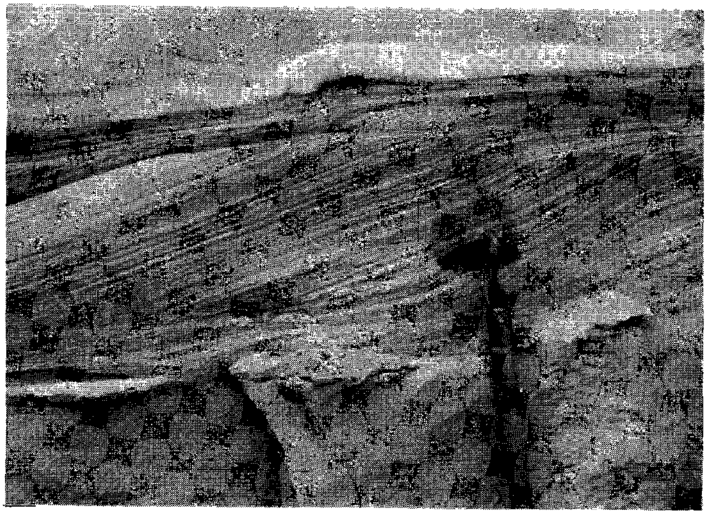

Figure 7. Part near the brinkpoint of a megaripple at Vlierzele. Most of the oblique lamination belongs to one bundle. A small, superimposed megaripple has started to create a convex upward reactivation surface. The dark, 5 - 10 cm thick deposit on top of the megaripple contains sub-horizontal clayey layers and wave ripple lamination. Spade 40 cm long.

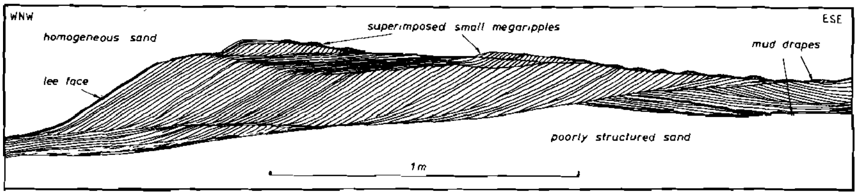

Figure 8. Internal structures of a zone E megaripple. Drawn from lacquer peels.

The top plane of zone C is part of a megaripple field, in which also 18 megaripples were observed. This field dips 2°, N (N6°E). The lee sides of the straight bedforms face WNW so that their direction of migration makes an angle of 75° with the dip direction of the surface over which they migrated. The megaripples of zone C resemble those in zone E. The main lee side (facing WNW) however, has a smaller angle and a sharp brinkpoint is absent (Fig. 9).

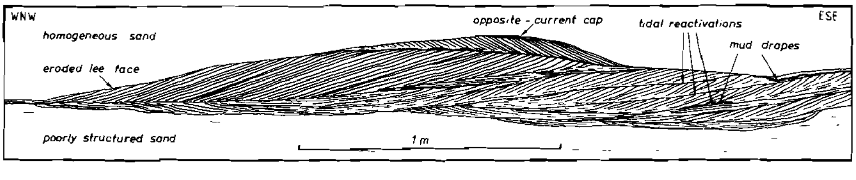

Figure 9. Internal structures of a zone C megaripple. Drawn from lacquer peels.

On top of the truncated bedform, a small megaripple-like cap of opposite orientation is found, showing a well-defined brinkpoint and a short, steep lee side. It resembles the ebb-caps on intertidal megaripples described by Boersma & Terwindt (1981). Not every megaripple of zone C has this opposite-current cap. The easternmost megaripples in the pit have the largest caps (up to 10 cm high).

Internal structures of the form sets

Lacquer peels were made of some megaripple form sets from zones E and C (Figs. 8, 9). Each megaripple consists of oblique laminae, dipping 20° - 26°, WNW. The lower bounding surface of this bed dips 5° - 10°, WNW. This is sometimes mud-draped and, locally, fragments of a mud drape couplet can be found. The mud couplet forms the upper and lower boundary of a thin sand deposit with ESE-oriented ripple lamination. This is good evidence for a subtidal origin (Visser, 1980; Allen, 1981; de Mowbray & Visser, 1984; Allen & Homewood, 1984). The large cross-bedded sets could thus be a tidal bundle sequence (Boersma, 1969), and the lower boundary surface a reactivation or pause plane (Boersma & Terwindt, 1981). The mud drape is the slackwater deposit and the thin sand layer within the mud drape couplet is the subordinate tidal current deposit.

The strike measurements of the laminae of the form set bundles coincide with the strike of the megaripple sequences found by the 3-D mapping of the sand pit.

Other bundle sequences are preserved. Some groups (sets) of bundles have laminae oriented WNW, others ESE. The latter appear to be predominant. In places where small megaripple form sets are superimposed on larger ones, the contact is an erosional surface, lacking any mud drape (Fig. 7). This surface is often convex-upwards. It is obviously a unidirectional reactivation surface (de Mowbray & Visser, 1984). The opposite-current cap is separated from the underlying sequence by a (sometimes mud draped) reactivation plane (Fig. 9).

Internal structure of the cross-bedded zones

Most of the observations of internal structures in the form sets, apply to the complete Vlierzele Sands cross-bedded zones. A considerable part (about 50%) of the exposed area is represented by groups of bottomsets (see e.g., bottom part of cross-beds in Fig. 9). Truncations and reactivation planes are abundant. Cross-beds are mostly preserved in shallow troughs, especially when seen in longitudinal sections. Also flow-transverse sections show slightly scooped bed boundaries. Lateral bundle sequences (Visser, 1980; Boersma & Terwindt, 1981) are therefore rare; only locally were parts of such lateral sequences preserved, showing cyclic changes in bundle thickness over some 20 bundles. In spite of the incomplete character of these sequences, they suggest that a fortnightly semidiurnal spring tide system was active. The largest of the preserved bundles are 20 cm - 30 cm thick and over 1 m long. In these bundles, topsets are often preserved.

The sand contains some small mud clasts, probably derived from the thin mud drapes, and small fragments of wood. The lamination is very distinct; the laminae are normally graded and cover the complete lee side. The organization of laminae within a bundle is shown in figure 10. The coarser laminae contain less glauconite.

In cross-bedded zone G (Fig. 5), bundles of laminae dipping ESE are definitely predominant and most reactivation surfaces dip in the same direction (Fig. 11). Thin mud layers draping the tidal reactivation planes are relatively frequent here.

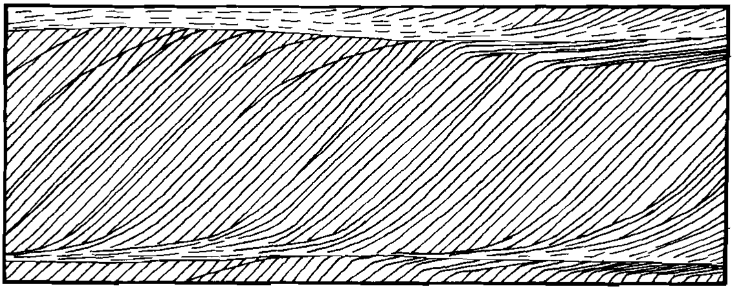

Figure 10.

Organization of laminae within a bundle.
Laminae slope is exaggerated.
Bundle thickness about 30 cm.

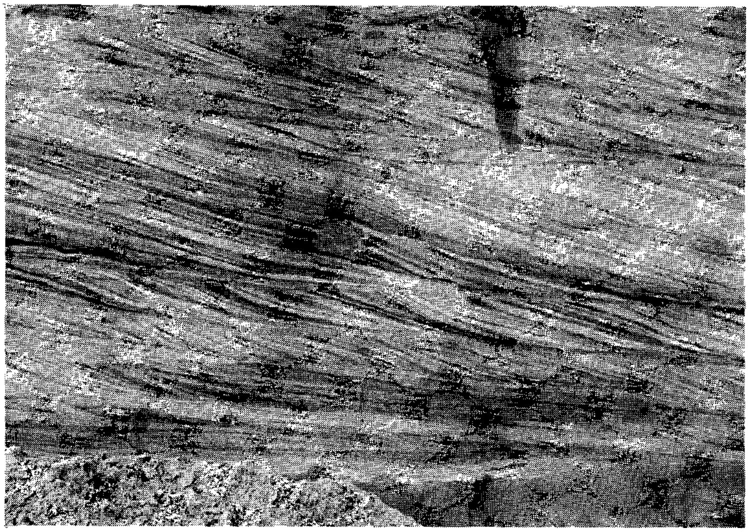

Figure 11. Cross-bedding of zone G. Note small ripples on the tidal reactivation surfaces. The groove in upper part is ±40 cm long. ESE is to the right.

The poorly structured zones

The poorly structured zones (B, D and F in Fig. 5) are some decimetres to 2 m thick (in other sand pits they attain a thickness of 4 m). Many tiny clay clasts and carbonized wood fragments speckle the exposure.
Three kinds of lower contact are observed:

(1) A homogeneous mass of sand covers the megaripple below directly and the sharp outline of the megaripple is undisturbed (Fig. 12).

(2) A thin mud drape covers the unaffected megaripple. The drape is covered by a deposit of slightly clayey, very fine sand. This layer is thicker in the troughs (maximal thickness of 0.3 m) and so reduces the relief of the sedimentary surface (Fig. 13). It contains fine parallel laminae and, especially at its base, lacquer peels revealed fine wave-ripple lamination. No bioturbation was found. This deposit is covered by poorly structured sand.

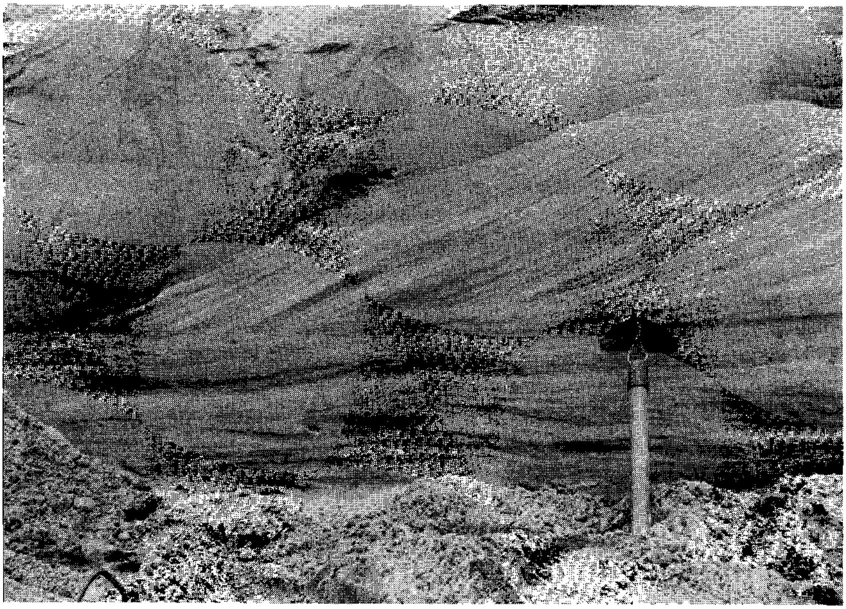

Figure 12. Lee side of an intact megaripple at Vlierzele, preserved without cover of horizontally-layered clayey sand. The spade is 40 cm long.

(3) A sharp, strongly erosional contact (see e.g., deep cut of zone F into zones E and D in left half of figure 5; figure 14 shows a small-scale example). These cuts are filled in with sand showing a vague, concordant or subhorizontal lamination. The adjacent, eroded, cross-bedded sand is sometimes plastically deformed: i.e., the regular oblique laminae are folded (disturbance on cm-scale) as if they consisted of plastic material.

The main feature of zones B, D and F is their apparent lack of structures. Only close observation reveals the subhorizontal, even lamination of most parts. Many internal cuts occur, like those of (3). Another striking characteristic is the dense packing, causing this loose sand sometimes to behave like solid rock. No bioturbation was found. Two or three clayey horizons are intercalated in the poorly structured zones. They are only 1 cm - 2 cm thick and consist of slightly clayey, very fine sand. They resemble the clayey layer of (2). As a result of their horizontal position, they merge laterally into the clayey layer of (2) or are truncated by an erosional cut (Fig. 5). The clayey horizons often show small deformations, resembling loading structures.

GRAIN SIZE

Two profiles were closely sampled. The proportion of grains smaller than 32 and 62 micron was measured by wet sieving. The sand fraction was dry sieved and recalculated to 100%. Median and graphic standard deviation (Inman, 1952) were determined on the sand fraction. All the data are represented in the vertical logs of figure 15; measurements are in Ø units.

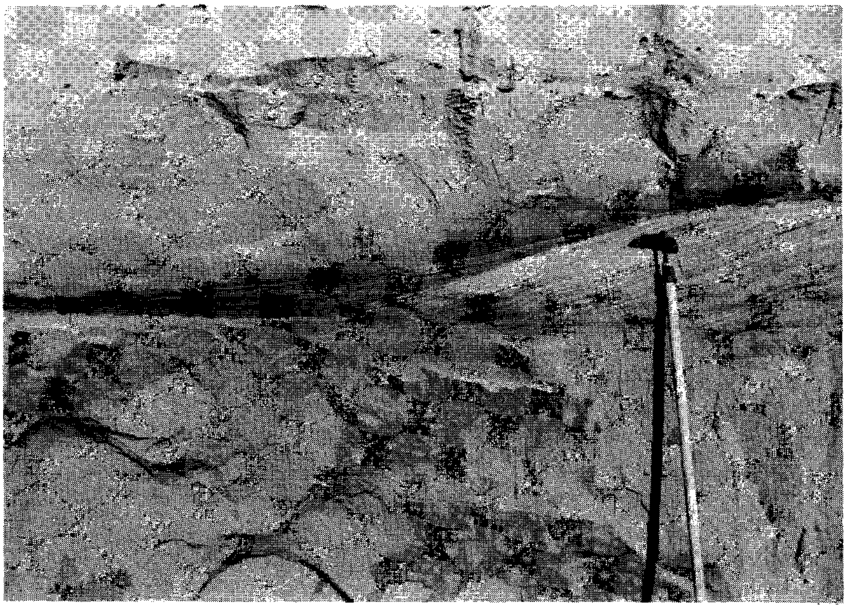

Figure 13. Trough in front of a megaripple at Vlierzele. The trough floor is current-rippled. The subsequent cover of clayey sand concordantly fills in the trough. At the base and top of photo is poorly structured sand. The stick is ±1.20 m long.

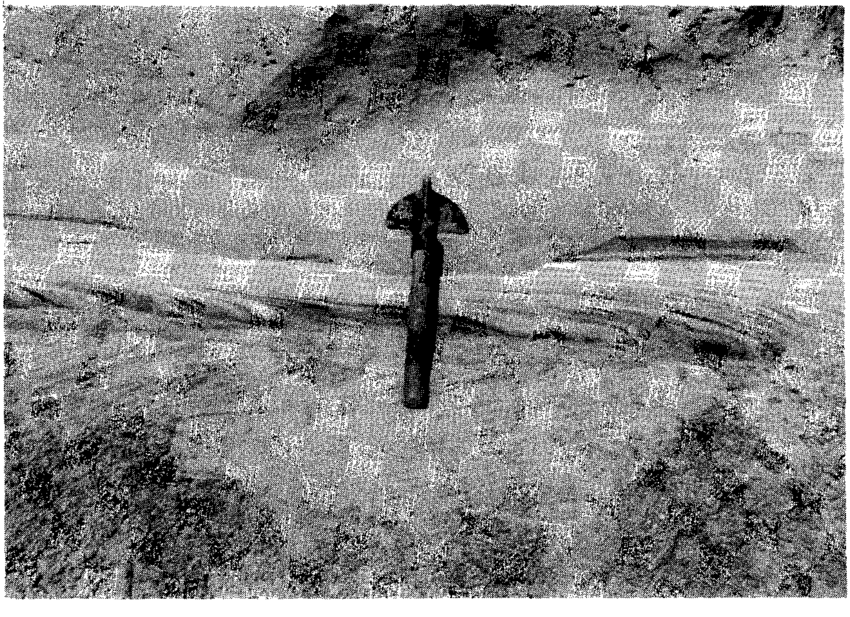

Figure 14. Erosional contact between a zone of megaripple lamination and a zone of poorly structured sand. Lower half of the picture shows an indistinct complex of bottomsets.

Profile 1 (Figure 15A)

The base consists of layer A, a slightly clayey, very fine sand that is vertically very uniform. The sand fraction has a median of 2.96 Ø - 2.98 Ø and very good sorting of 0.25 - 0.28 Ø. In the lower part a fine tail corresponds to the admixture of 5% - 8% of extremely fine sand. Together with the 4% - 6% of silt and clay, this represents a fair amount of suspension trapping. The coarse end is straight and perfectly lognormal. In the two upper samples a coarse tail shows the admixture of 2% of a coarser population; the sand mode coarsens to 2.90 Ø and the trapped suspension diminishes.

The next horizon, the cross-bedded zone C, coarsens upwards (median of 2.25Ø - 2.06Ø - 1.91 Ø). The sorting is moderate (0.42Ø - 0.44 Ø), with faint symmetrical tails but without a suspended fraction.

Zones D and F are made of fine sand with thin intercalations of very fine clayey sand, defining three units. The two lower units consist of a remarkably stable sand population with a median of 2.60 Ø and sorting of 0.33Ø - 0.35 Ø. The upper unit is coarser, up to 2.50 Ø and less well sorted: 0.35Ø - 0.42 Ø. The coarsening is best seen in the slight bulge of the 2 Ø line. The sand lacks a suspended fraction.

The three intercalations consist of very fine sand (3.15 Ø), comparable to the sand of unit A, but less well sorted (0.35 Ø - 0.45 Ø) and incorporating up to 12% clay and silt. The coarser (2.38 Ø) point in the middle is a single sample from cross-bedded set E.

Three types of sediments can thus be distinguished based on grain size parameters (see figure 15): <u>ms</u>: medium-sized sand, moderately sorted and completely devoid of suspended material; <u>fs</u>: fine sand, with good sorting and equally winnowed; <u>vfs</u>: very fine sand with very good sorting and incorporating an appreciable amount of suspended material.

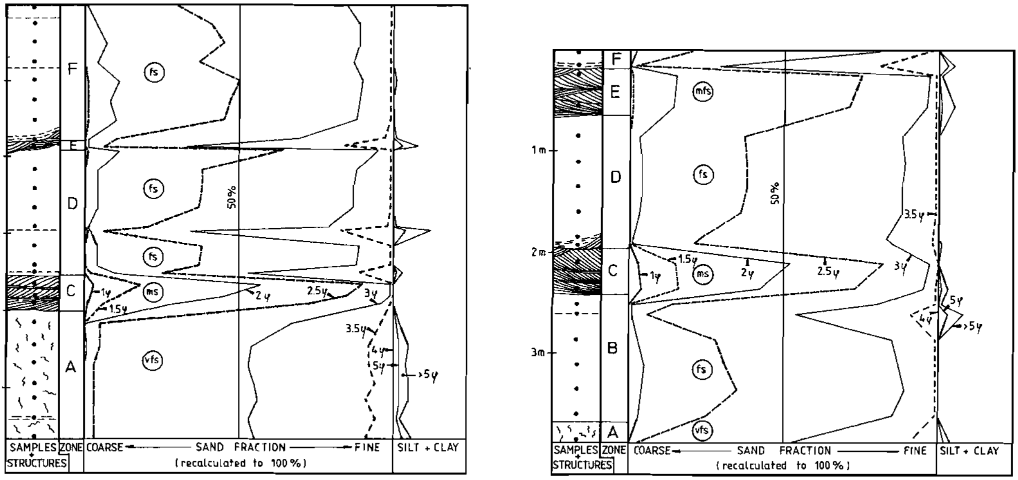

Figure 15. Granulometry. A: profile 1. B: profile 2. Encircled letters, ms, mfs, fs, vfs, indicate grain-size facies. Vertical scale of profile 1 does not have the same zero reference as the scale of profile B.
For position see figure 5.

Profile 2 (Figure 15B)

In this shorter section the same sediments are easily recognized. The bulk is made up of type fs. Three thin intercalations of type vfs are present, the base being the top of layer A. At the top of the lower half a layer of type ms is present, corresponding to cross-bedded zone C. Between 25 cm and 55 cm a moderately fine sand (2.30 Ø) appears (mfs), very well sorted (0.29Ø - 0.30 Ø), with a slight fine tail together with some clay-silt, totalling ±5% of suspended material.

DISCUSSION

The Vlierzele Sand shows entire megaripples preserved. The top plane of the cross-bedded zones C and E (Fig. 5) dips 2°, NNE. It is therefore suggested that the megaripple fields developed on the northern flank of a sand body. These megaripples were 20 cm - 50 cm high, parallel-crested, straight to slightly sinuous and had a wavelength of 4.5 m - 6.5 m. Their direction of movement was parallel, or slightly oblique, to the strike of the migration surface. The internal structures suggest that the megaripples were governed by a tidal current regime. The preserved form sets were almost entirely built up by the dominant tidal current. However, the resultant movement of the megaripples was small. The subsequent opposite-current reversed the orientation of the megaripples almost completely. Thus the tidal system must have been nearly symmetrical (cf. Allen, 1980; de Mowbray & Visser, 1984), and it is hard to say in which direction the sediment was finally transported. Due to the continuously changing bedforms, no infaunal life was possible.

Resultant sediment transport during the deposition of zone G was exclusively to the ESE. The bundle boundaries in figure 11 dip 12°, ESE, the set boundaries 5°, ESE. The sets are tabular and descending. So the megaripples that caused the deposition of these sets were migrating down a 5° slope. It is inferred that this slope belonged to a large, flow-transverse sand wave (sensu Allen, 1980), at least 1 m high.

The poorly structured sand deposits coincide with grain size facies fs. They are thought to have resulted from the fallout of dense storm wave suspensions. They are deposited (or 'dumped') in a short time: no bioturbation, no chance to even modify the underlying megaripples. The water must have been turbulent: large amounts of sand were probably transported giving rise to deep erosional cuts. There is no sorting into distinct laminae. Mud layers of 1 cm thick were eroded and fragments of them were transported. The even lamination and dense packing suggest upper flow regime conditions, which may also have been due to storm waves. The clayey layers were deposited during quiet intervals within the stormy periods. The horizontal position shows that after a phase of storm deposition the original topography of the sea bed was flattened. However, the upper limit of a poorly structured zone has an inclined (2°) surface, shaped by megaripple erosion. Indeed, the megaripple zones, especially the C-megaripples, consist of relatively coarse sand; the fine particles were winnowed out. Zone C, related to the C-megaripples, is very thin (0 m - 0.5 m). It is inferred that, during migration, these megaripples eroded and reworked the fine sand of the poorly structured zones, reforming the coarse fraction into megaripples, and removing the finer part.

Paleo-environment of deposition

The long, parallel hills of the Vlierzele Sands' outcrop are thought to reflect an original system of longitudinal sand bodies. The internal structures and characteristics show a buildup by storm deposits being constantly reworked by tidal currents. We believe it to represent a specific type of tidal current ridge environment. Tidal current ridges are groups of parallel, longitudinal sand bodies, 10 m and higher, in epicontinental sandy seas. They are aligned parallel to the local tidal flow (Off, 1963) or slightly oblique to it (Belderson et al., 1982). From the presence of flow-transverse sand waves and megaripples on their flanks (Houbolt, 1968; Caston, 1972; Stride et al., 1982; McCave & Langhorne, 1982) their internal structure is inferred to consist of mega- and meso-scale cross-beds, although no direct observations exist from recent environments.

The Vlierzele system incorporates a high proportion of preserved storm deposits. The sand ridge at Vlierzele progressed by offlap sedimentation over a quiet, intensely burrowed, sandy sea bottom in a regressive marine environment. Storm deposits were dumped on its northern flank. Subsequent fair-weather tidal currents quickly restored the slope of the flank. The occurrence of meso-scale megaripples on this flank, their orientation and internal structures (indicating symmetrical tidal currents) as well as the slope angles and dimensions measured for the Vlierzele Sands' ridges are fairly consistent with data on e.g., the Flemish Banks (Houbolt, 1968; Caston, 1972; Bastin, 1974; Vlaeminck et al., 1985). However, the much smaller grain size of the Vlierzele Sands indicates weaker tidal currents which may be why important parts of the storm deposits have been preserved. We estimate that the visible sequence represents the lateral evolution of only a few years.

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REFERENCES

Allen, J.R.L. (1968) Current ripples; their relation to patterns of water and sediment motion. Holland Publishing Cy. Amsterdam. 433 pp.

Allen, J.R.L. (1980) Sand waves: a model of origin and internal structure. Sedim. Geol. 26, 281 - 328.

Allen, J.R.L. (1981) Lower Cretaceous tides revealed by cross-bedding with mud drapes. Nature 289, 579 - 581.

Allen, P.A. & Homewood, P. (1984) Evolution and mechanics of a Miocene tidal sand wave. Sedimentology 31, 63 - 81.

Bastin, A. (1974) Regionale sedimentologie en morfologie van de Zuidelijke Noordzee en van het Schelde Estuarium. Doct. Thesis, Sci. Fac., Univ. Leuven, Belgium, 91 pp.

Belderson, R.H., Johnson M.A. & Kenyon, N.H. (1982) Bedforms. In: Stride, A.H. (Ed.) Offshore tidal sands, processes and deposits. Chapman and Hall, London, 222 pp.

Boersma, J.R. (1969) Internal structure of some tidal mega-ripples on a shoal in the Westerschelde Estuary, The Netherlands. Report of a preliminary investigation. Geol. Mijnb. 48, 409 - 414.

Boersma, J.R. & Terwindt, J.H.J. (1981) Neap-spring tide sequences of intertidal shoal deposits in a mesotidal estuary. Sedimentology 28, 151 - 170.

Caston, V.N.D. (1972) Linear sand banks in the southern North Sea. Sedimentology 18, 63 - 78.

De Moor, G. & Geets, S. (1974) Sedimentologie en lithostratigrafie van de eocene afzettingen in het zuidoostelijk deel van de Gentse agglomeratie. Natuurwetensch. Tijdschrift 55, 129 - 192.

Gulinck, M (1952) Une coupe dans le Paniselien inférieur en Flandre Orientale. Bull. Soc. Belge Géol. 61, 273 - 277.

Gullentops, F. (1957) L'origine des collines du Hageland. Bull. Soc. Belge Géol. 66, 81 - 85.

Houbolt, J.J.H.C. (1968) Recent sediments in the Southern Bight of the North Sea. Geol. Mijnb. 47, 245 - 273.

Houthuys, R. & Gullentops, F. (1985) Brusseliaan faciëssen en hun invloed op de genese van het reliëf ten zuiden van Brussel. Bull. Soc. Belge Géol. 94, 11 - 18.

Inman, D.L. (1952) Measures for describing the size distribution of sediments. J. Sedim. Petrol. 22, 125 - 145.

Kaasschieter, J. (1961) Foraminifera of the Eocene of Belgium. Royal Belgian Inst. Nat. Sciences, Mem. 147, 271 pp.

McCave, I.N. & Langhorne, D.N. (1982) Sand waves and sediment transport around the end of a tidal sand bank. Sedimentology 29, 95 - 110.

de Mowbray, T. & Visser, M.J. (1984) Reactivation surfaces in subtidal channel deposits, Oosterschelde, SW Netherlands. J. Sedim. Petrol. 54, 811 - 824.

Nolf, D. (1972) Stratigraphie des formations du Panisel et de Den Hoorn (Eocène belge). Bull. Soc. Belge Géol. 81, 75 - 94.

Off, T. (1963) Rhythmic linear sand bodies caused by tidal currents. Bull. A.A.P.G. 47, 324 - 341.

Reineck, H. & Singh, I. (1973) Depositional sedimentary environments. Springer. 439 pp.

Stride, A.H., Belderson, R.H. & Johnson, M.A. (1982) Offshore tidal deposits: sand sheet and sand bank facies. In: Stride, A.H. (Ed.) Offshore tidal sands, processes and deposits. Chapmann and Hall, London, 222 pp.

Visser, M.J. (1980) Neap-spring cycles reflected in Holocene subtidal large scale bedform deposits: A preliminary note. Geology 8, 543 - 546.

Vlaeminck, I., Gullentops, F. & Houthuys, R. (1985) A morphological study of the Buiten Ratel Sandbank. In: Van Grieken, R. & Wollast, R. (Eds.) Proceedings 'Progress in Belgian oceanographic research'. 114 - 124.