Present-day evolution of sand waves on a sandy shelf bank

Sediment dynamics
Sand waves
Seabed cartography
Side scan
Continental platform

Dynamique sédimentaire
Vagues sableuses
Cartographie marine
Sonar latéral

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ABSTRACT

A sand wave field on the northern extremity of the Kwintebank (Belgian continental platform) was mapped three times over a period of one year with the help of side-scan sonar and echosounder. The geometric characteristics of the sand waves are described in detail. Shifting of the sand waves occurred in the directions of both their gentle and steep slopes. The net movement over one year is, however, minimal.

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RÉSUMÉ

Évolution actuelle des vagues de sable sur un banc sableux du plateau continental

Un système de vagues de sable se trouvant sur l'extrémité septentrionale du Kwintebank (plate-forme continentale belge) a été cartographié trois fois durant la période d'un an à l'aide d'un sonar latéral et d'un sondeur bathymétrique. Les caractéristiques géométriques des vagues de sable sont décrites en détail. Des déplacements des vagues de sable ont été détectés, aussi bien dans la direction de leurs flancs raides que de leurs flancs à pente douce. Le résultat net de ces déplacements après un an est néanmoins minime.

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INTRODUCTION

The term sand wave is used to refer to bedforms which are sufficiently large to have megaripples superimposed on them (Dalrymple, 1984). Sand waves are common bedforms in shallow-water tidal environments and many attempts have been made to study sand wave migration (Berné *et al.*, 1988 ; Langhorne, 1982 ; Ludwick, 1972 ; Mc Cave, 1971 ; Terwindt, 1971). During the early years of research on this topic, chrono-sequential measurement of bedforms was considered a difficult task as positioning and navigation relied on inaccurate systems. In recent years the development of high-frequency positioning systems with an accuracy of a few metres has made it possible to overcome these difficulties.

The purpose of this paper is to provide a detailed description of a sand wave field on the extremity of a tidal sandbank and to discuss the behaviour of these large bedforms through time with the help of several sets of observations recorded over a period of one year. In these preliminary results, emphasis is laid on the detection and measurement of sand wave movements. Discussion of the processes causing the movements is beyond the scope of this presentation.

LOCATION

An area of sand waves on the northern Kwintebank was selected for this study. The Kwintebank, one of the Flemish

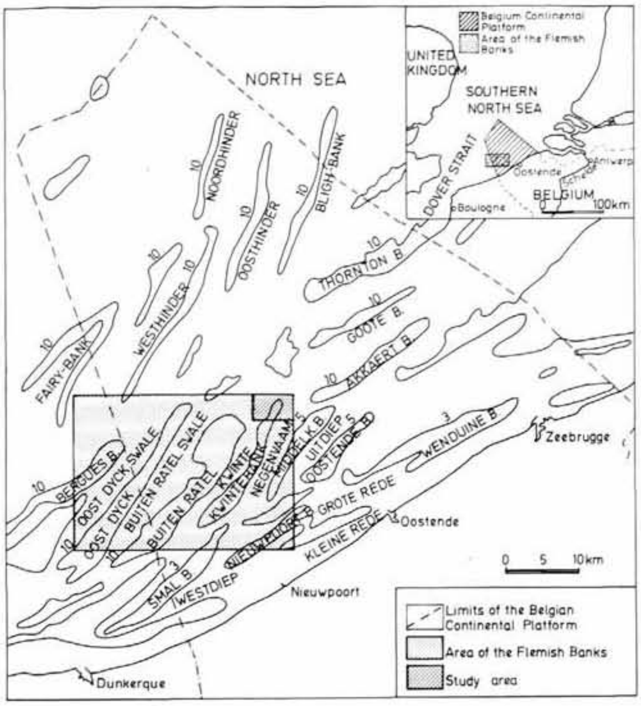

Figure 1

The Flemish Banks and the Belgian continental platform (depths in fathoms).

Les Bancs de Flandre et la plate-forme continentale belge (profondeurs en brasses).

Banks, is situated adjacent to the Belgian coast (Fig. 1). It has a SW-NE orientation, a length of 20 km, a width of 2 km and a height relative to the seabed of some 10 to 20 m. Like many tidal sandbanks, the Kwintebank has a general morphology dominated by a transverse asymmetry (de Moor, 1986; de Moor and Lanckneus, 1989).

Previous studies on the Kwintebank (De Moor, 1985; De Moor and Lanckneus, 1988; Lanckneus *et al.*, 1989) made it possible to develop a sediment-dynamic model based on the net bottom load transport directions. Analysis of the sediment transport paths can be made using sand waves (Caston, 1972) or megaripples (McCave and Langhorne, 1982). When we examine sand waves and superimposed megaripples on the Kwintebank we see that the latter are usually oriented at an oblique angle to the former with a divergence varying between 10° and 20°. If we compare the orientations of the two types of bedforms with the directions of peak tidal currents (N 74° E for the flood peak near the southern edge of the Kwintebank) it is clear that megaripples with a mean strike of N 18° W are almost perpendicular to the directions of the peak tidal current. Sonographs recorded during several periods of the tidal cycle clearly show that on the Kwintebank, megaripples can maintain their identity over long periods. As we assume that megaripples are a product of the peak currents and that they can maintain their identity over a long period we will base our following analysis on megaripples rather than on sand waves.

Sand is transported on to the bank from both the adjacent channels, but from opposite directions. Peak flood currents give rise to a net north-easterly movement of sand on the western flank, while peak ebb currents towards the south-west move sand on the eastern flank. This causes an accumulation of sand on the bank summit, which is the principal mechanism maintaining the bank in its presently stable configuration.

METHOD

Three detailed surveys (February 1989, June 1989 and November 1989) were carried out on the northern Kwintebank using echosounder and side-scan sonar equipment. Each survey was accomplished in approximately 15 hours. A Deso XX echosounder was used for the bathymetric recordings and the sonographs were obtained with a Klein two-channel side-scan recorder coupled to a 500 kHz transducer.

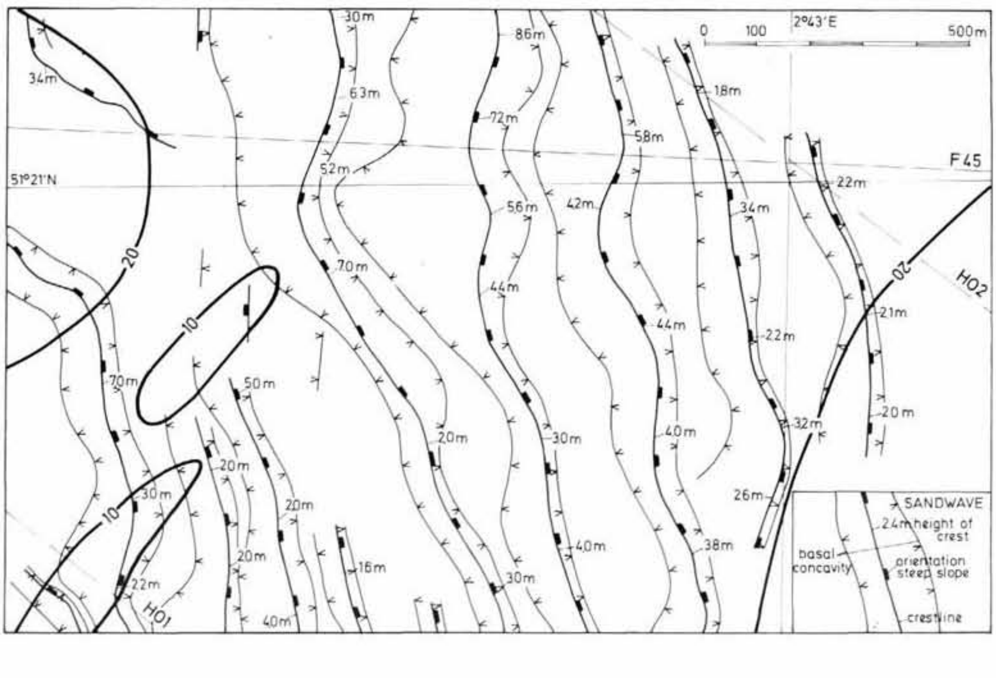

Figure 2

Example of a sand wave map deduced from the sonographs recorded in June 1989 (depths in metres).

Exemple d'une carte de vagues de sable, déduite des sonogrammes enregistrés en juin 1989 (profondeurs en mètres).

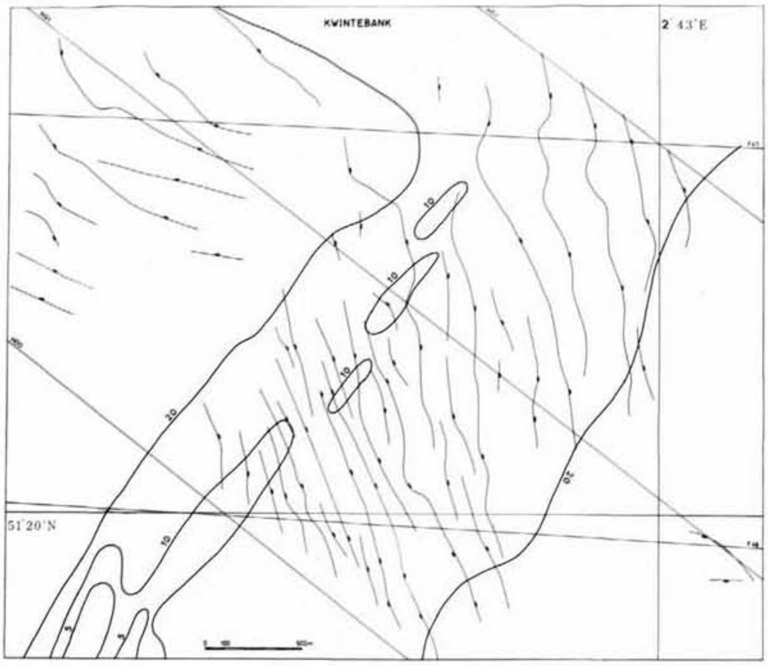

Figure 3

Sand waves on and around the northern Kwintebank (situation in June 1989). Only the sand wave crestlines and the orientation of their steep slopes (see legend Fig. 2) are shown (depth in metres).

Vagues de sable sur et autour de la partie septentrionale du Kwintebank (situation en juin 1989). Seules les crêtes des vagues de sable et leur asymétrie sont représentées (légende: *voir* fig. 2 ; profondeurs en mètres).

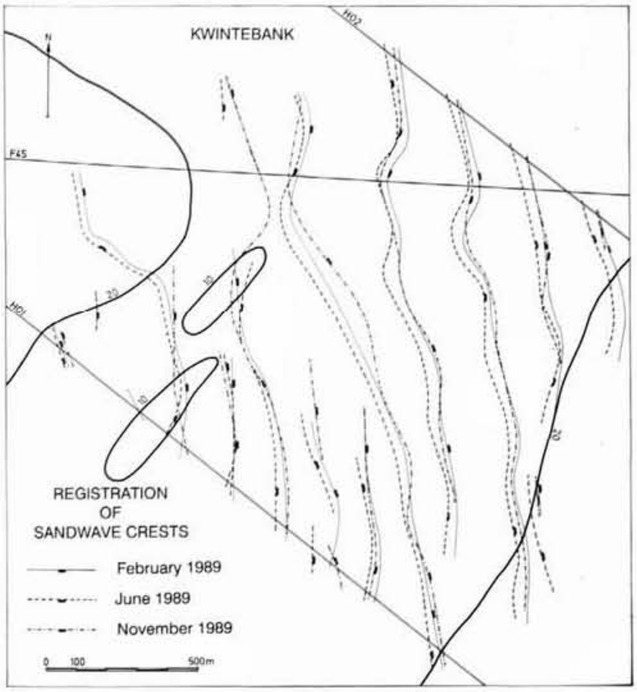

Figure 4

Shifting of the sand wave crests (see legend Fig. 2) during the three periods of observations (depth in metres).

Déplacement des crêtes des vagues de sable (légende: *voir* fig. 2) durant les trois périodes d'observation (profondeurs en mètres).

During the three survey periods, navigation and positioning were performed by Syledis with a positional accuracy of 3 m.

The surveys were run along lines 141 m apart. Recordings made in mosaic form allowed complete sonograph coverage of an area 4 000 m in length by 1 500 m in width. The location of the crestlines and of the basal concavities were deduced from the sonographs and the bathymetric recordings. The height of the crestline and the orientation of the steep slope were deduced from the echosounder recordings (Fig. 2).

Comparison between the three sets of measurements has been limited to the area of the Kwintebank between the red Decca lines H02 and H01 (*see* Fig. 3).

RESULTS

Characteristics of the sand waves (Fig. 3)

The strike of the sand waves is remarkably uniform and constant and varies on the bank between N 15° W and N-S. Most sand wave crestlines are nearly straight but some pronounced sinuous forms occur especially in the northern parts. The sand waves display a good lateral continuity and their crestlines are traceable for up to 2.5 km. The smallest feature has a length of 200 m. In the northern, deeper part of the study area, wavelength and height average 210 m and 3.6 m respectively. The highest observed sand wave has a height of 8.6 m. In the shallower waters of the southern part, sand waves decrease in size (*e.g.* the average height remains about 1.6 m) and denser trains of sand waves occur as their wavelength is reduced to an average value of 90 m. The height of an individual sand wave can vary considerably along its crest and variations were observed between 1.8 and 8.6 m. The spacing between adjacent crests remains more or less constant along their length. However a sand wave was observed for which the width of its gentle slope varied between 75 and 300 m. Branching of crestlines was never observed. All sand waves were asymmetrical in cross-section. All sand waves on the slopes and summit of the bank had their steep slopes always facing the north-east, which is the direction of the peak flood currents.

Notable is the discrepancy in asymmetry pattern between sand waves and megaripples. On the western slope of the bank both types of bedforms have their steep slope dipping towards the north-east while on the eastern slope sand waves and megaripples dip in opposite directions.

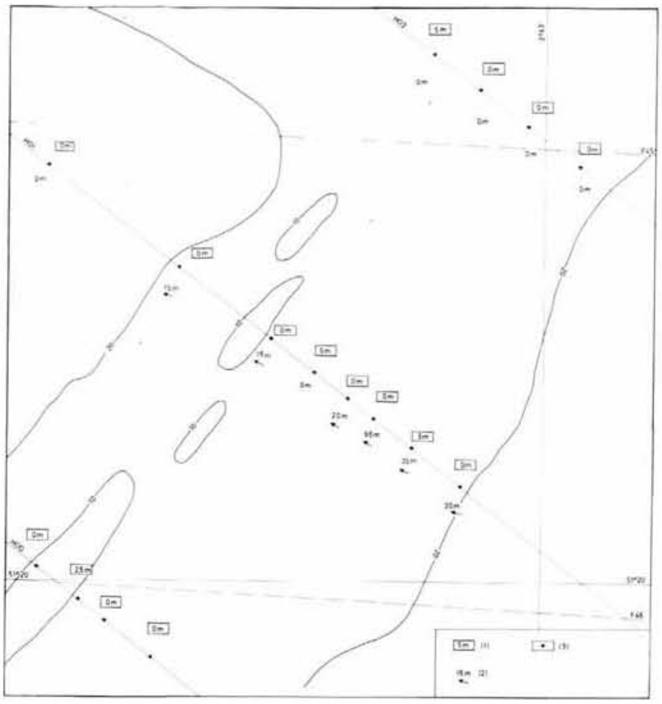

Figure 5

Position of sand wave crests in July 1990 (depths in metres). 1) movement of sand wave crests in metres between 17 and 20 July 1990; 2) movement (direction and value in metres) of sand wave crests between February 1989 and July 1990; 3) position of sand wave crests on July 17 1990 deduced from echosounder recordings.

Position des crêtes des vagues de sable en juillet 1990 (profondeurs en mètres). 1) déplacement des crêtes en mètres entre le 17 et le 20 juillet 1990 ; 2) déplacement (direction et valeur en mètres) des crêtes entre février 1989 et juillet 1990 ; 3) position des crêtes le 17 juillet 1990 déduite des enregistrements bathymétriques.

Few sand waves were found in the eastern adjacent channel, the Negenvaam. In the western channel, the Kwinte, several important sand waves occur. These display a NW-SE to almost W-E orientation, which differentiates them from the bedforms on the flanks and the summit of the bank. Such a NW-SE structure can extend beyond the channel on the flank of the bank. The transition between channel and bank is accompanied by a change of strike of the sand wave.

Evolution of the sand waves (Fig. 4)

The general characteristics of the sand waves, such as strike, asymmetry, height and general pattern, remained unchanged during the three periods of observations.

The position of the sand waves, however, was subject to changes. Comparison between the recordings of February with those of June shows a net movement of the crest positions over an average horizontal distance of 28 m towards the W. This movement is similar for all sand waves. Small variations in the amplitude of the crestal movement occur along the length of the individual bedforms. Notable is that the movement of the sand waves occurred in the direction of their gentle slopes. The length of some structures can decrease or increase by 100 to 200 m.

The recordings of November showed again a sand wave movement but now towards the east. This movement, in an opposite direction to that which was previously observed, has an average value of 29 m and caused the crests to return to roughly the same position that they had eleven months previously.

Accuracy of the positioning data on sea is an intricate problem. As Syledis was the most accurate system available on board of the research vessel, it seemed incongruous to control the recorded movements with the help of a less reliable system. Instead the following control operations were carried out. Echosounder recordings were obtained of the Kwintebank along the same reference tracks H02, H01 and H00 on 17 and 20 July 1990. The recordings were made in the same phase of the tidal cycle to reduce as much as possible the effect of minor crest oscillations (Langhorne, 1982). The assumption was made that a three-day period would not affect the position of the sand wave crests in a substantial way. The results are presented on Figure 5.

The crest movements of 16 sand waves were analysed. No shifting was detected for twelve sand waves, three had an observed movement of 5 m and one of 2.5 m. The values of 5 and 2.5 m fall in the positional error range of the Syledis. We conclude from these figures that the detected values of 28 and 29 m correspond to actual movements. Figure 5 also displays the movement of the sand wave crests between February 1989 and July 1990. No sand wave movement was recorded on the H02 track. However values of 35 and even 65 m were detected on the H01 track.

CONCLUSIONS

The sand waves of the northern Kwintebank appear to be stable features which can move in the directions of both their steep and gentle slopes. Sand wave oscillation occurs but the net movement over one year can be considered negligible. In a three-day period no significant movement could be detected.

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