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Proceedings "Progress in Belgian Oceanographic Research"
Brussels, March 1985

PRESENT DAY MORPHODYNAMICS ON THE KWINTEBANK AND THEIR MEANING FOR THE EVOLUTION OF THE FLEMISH BANKS.

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ABSTRACT

Present day short term morphodynamics of the Kwintebank, one of the Flemish Banks, have been analysed by means of a chronosequence of 13 successive bathymetric profiles recorded over the period 1982-1983 along 8 fixed reference lines and with constant sailing speeds. After tide reductions and scale uniformisation, residual changes in position, depth and form of the bank are evaluated by means of visual comparison of successive recordings and the volume evolution is monitored using the unitlength volumes computed above reference levels for the different successive reference transversals. The results point toward a complex maintenance mechanism with some exterior input providing a local and at least temporal dynamic stability and even recovery from a limited sand dredging.

The maintenance mechanism itself has been analysed using bed load transport indications provided by bedform characteristics, by specific erosional features and by a pseudo-tridimensional bedform cartography by means of sequential side scan sonar recordings.

Medium term elements in the evolution have been approached by comparative study of depth data, resulting from 120 years of sounding campaigns by the Hydrographic Service.

Long term elements in the genesis of the banks are considered on the base of internal structure as recorded on acoustic subbottom profiles.

A model of bank development is put forward, taking into account the maintenance mechanism.

1. INTRODUCTION

The banks off the Belgian coast present all the classical problems of the off shore bank morphology. They raise numerous questions related to the various mechanisms involved in the different aspects of their genesis, their evolution, their planform, transversal morphology, pattern and alignment, their shape and dimensions, their bedform components, their position, shape and volume stability and their survival and maintenance in a highly energetic environment, commanded by waves and by strong tidal currents, presenting a bidirectional peak current dominancy as indicated by the typical elongated tidal current ellipses, and by sediment characteristics.

It is however clear that, despite the numerous aspects, the global problem presents 4 main topics :

(1) The genesis of the banks during the pre-Atlantic holocene transgression inundating a fluviatile periglacial landscape, and possibly during fluctuations of the holocene high sea level stand.

(2) The evolution of the banks during the holocene high sea level stand.

(3) The present day morphodynamics of the banks and the morphodynamic processes considered in a factorial framework, especially in relation to the sedimentdynamics and the hydrodynamism.

(4) The stability, survival and maintenance of the banks over different terms.

In order to understand processes and features it is essential to distinguish short, medium and long term components as well as local and regional, instantaneous and residual aspects and the multidirectional character of the hydrodynamism.

Many authors studied one or several aspects of the morphogenetic complexity of these banks off the Belgian coast. Moreover the results of investigations of similar problems in the Norfolk banks area the Southern Bight, cannot be overlooked.

The fundamental way to tackle the problem of present day bank stability and evolution consists of following the bank shape and position variations departing from frequent sequential bathymetric recordings, sailed along fixed reference lines crossing the banks and transformed into comparable hypsometric profiles. Moreover the analysis of the morphologic characteristics of the bedforms and of their motions on such well positioned and detailed sequential records allow to handle the problem of the residual bottom load sediment transport and its relationship to morphodynamics.

Until the last decennia however the high technological prerequisites of navigation, positioning and surface and subsurface sounding made this morphodynamical approach unrealistic and inadequate.

The development of very accurate echo sounding bathymetry, of quite accurate and highly frequent electronic positioning, the elaboration of tide reduction techniques and especially the introduction of computerised processing of the numerical and graphical data in storing and elaboration operations, which before were extremely time consuming, inaccurate, if at least possible at all, now make accurate short term morphodynamical analysis possible.

In order to project the present-day short time results back ward in time in relation to the evolution of the banks one needs to express the sedimentdynamics in terms of bedforms and to observe their older counterparts in the internal sedimentary structures of the banks.

The mapping of surface sedimentary structures depends on the development of water or air-borne remote sensing techniques and especially of side scan sonar techniques, while observation of the internal structures waited for the development of adequate high resolution seismic or acoustic prospection techniques.

The use of older maps and sounding data is subject to great care because of possible inaccuracy of positioning and sounding data.

The study of the very origin of the banks itself mainly depends on the evidence of geological data about genesis and age of the bank and channel deposits and about their structure. Here the development of seismic and acoustic prospection methods and of adequate and fast drilling techniques opens the way to obtain such data.

2. PRESENT DAY BANK MAINTENANCE AND STABILITY MONITORING

The analysis of the present day bank maintenance during this research rests upon a systematic and accurate monitoring of the changes in volume, shape and position of the Kwintebank in the period 1981-83, while it was subject to an important sand dredging whose yield was known. The monitoring has been worked out by a sequence of 13 sailings of hypsometric profiles along 8 fixed reference lines coinciding with red Decca lines crossing the Kwintebank transversally and which have been the subject of a numerical-volumetric and of a graphic elaboration after corrections and adaptations of the records allowed comparative analyses. The depth records have been taken with an Atlas Deso 10 echosounder. Sailing was by Decca navigation, positionning by Decca partly controlled by Toran.

The present-day short term residual sediment dynamics and related net bedload transport paths have been studied by analysis of bedform profiles on hypsometric records after evaluation of wave impact, and by analysis and mapping of bedforms using sequential side scan sonar records from the Kwintebank and surrounding area. Side scan sonar records have been taken with a Klein 320 SSS.

The data covering the period of monitoring point toward very little residual changes in volume, shape and position of the Kwintebank despite important sand losses by dredging, estimated at about 400.000 to 600.000 m^3/year over 7 years for an area with a total sandstock of about 25.000.000 m^3 . In fact there was a little but general loss between 1980 and 1982, but an recovery in 1983.

Such stability ensues a maintenance mechanism comprising not only a circulation of locally reworked sands and maintenance by self supply, but the possibility of an exterior sand input as well. It raises the problem of a regional or at least interbank sand supply with its transport paths and that of a corresponding bank oblique, flood commanded residual regional sand transport.

During the maintenance process bedforms which run transversally in the central zone of both adjacent channels lag behind on the slopes of the channels and move upslope both sides of the bank in opposite direction towards the topzone,their crests becoming more and more parallel to the crest of the bank itself. Near the west topconvexity of the Kwintebank they form large sandwaves, running parallel to the crest, having their steep side towards the bank center. There is no doubt that sand moves up the steep western side of the bank as well as the gentle, eastern one, providing a piling up of sand.

The fact that on both sides of the adjacent channels the lagging of the bedforms is similar, weakens the possible impact of the Coriolis effect and strenghtens that of refraction and friction. Nevertheless the steeper western side of the Kwintebank with its mean slope intensity of 5 to 7 %, is an erosional and not a prograding slope. The gentler eastern slope, with a mean slope of about 2.5 to 3 %, shows residual accumulation as indicated by the internal structure. In the deeper Kwintegeul at the foot of the steeper western slope of the Kwintebank, residual movement of the sands is seaward what indicates flood dominancy, while at the eastern side, bedforms indicate a coastward movement and an eb dominated Negenvaam gradually choked by incoming sands and characterised by a gradual refining of the bottom sands in coastward direction. Moreover, a circulatory movement around the northern tail of the bank seems to recycle some sands. This maintenance model presents many differences with the model of HOUBOLT-BASTIN and with that of CASTON.

If that piling up would continue then the bank would emerge and one could as well expect a progradation of the gentle slope of the bank, at least temporarily. Indeed filling up of the ebb dominated channel will provoke its narrowing and shallowing, increase the shear stress,reactivate the residual erosion and lead to a complete inversion of the evolution.

Emersion of bank crests, at least at low water, is known to have occurred and it certainly pleads in favour of the genesis of island barriers damming the coast and defending intertidal flats. Normally however the wavebase and the amplitude and strength of the waves are so that the crests are regularly topped while the stirred sediments are redistributed over the flanks and dropped in the adjacent channels from where they are reintegrated into the maintenance mechanism.

On the other hand the occurrence of symmetrical sandwaves, especially on the gentle slope topconvexity proves overwash of sediments towards that gentle slope. Moreover the occasional occurrence of distinct longitudinal erosional furrows in between the sandwaves, cut into the sweepzone of the sandwaves and megaripples, points towards occasional, fast but vigorous longitudinal sand transport. An other indication for longitudinal transport on the topzone is given by the oblique orientation of fields of megaripples and ripples in between and on the gentle backs of sandwaves.

3. MEDIUMTERM BANK OSCILLATION

The data of a chronosequence of 7 sounding campaigns by the Hydrographic Service (1866-1981) show that over a period of about 120 years, starting in 1866, at least some of the Flemish banks and of the coast banks knew cyclic to and fro movements over a few hundreds of metres and over periods of a few decades mainly around their longitudinal axis. These shiftings are not translational movements nor continuous migrations of the bank but oscillation movements. They arise from inversions in a preferential residual sand deposition on one side of the bank. Conditions commanding the inversion have been described herefore. In any case, the shifting occurs similtaneously with periods of topping of the crests and sediment stocking in the channels, alternating with periods of residual aggradation on the banks and scouring of the channels.

There are sufficient morphodynamic, sedimentdynamic and structural arguments to advance that the tails of the banks are oscillating as well.

4. BANK STRUCTURE AND LONG TERM EVOLUTION

A model of the internal structure of the bank has been grounded on the results, elaboration and interpretation of hundreds of kilometres of high resolution subbottom profiling (0,5 to 1 m vertical resolution) recorded with a 3,5 kHz pinger working at a 8, 16 or 32 Hz pulse frequency and 0,2 to 0,5 msec pulse length (G. DE MOOR, 1984). The results have been matched and completed with data obtained from a few tens of shallow vibrocorer drillings (G. DE MOOR, 1984), from one 24 m. deep drilling on the central part of the Kwintebank (A. CARPENTIER, 1980) and from data obtained by reflection seismics (A. BASTIN, 1974; J.-P. HENRIET e.a., 1978, 1983, 1984).

The whole area is underlain by a polygenetic and polychronic erosion surface developed in a tertiary substratum. Locally this surface is scoured by burdened relict channels running across the active off shore channels. They present some adaptation to the litho-structural characteristics of the substratum.

In the area of the Kwintebank the holocene channels have been scoured at a lower level in the substratum than underneath the banks. Moreover their marine holocene overburden is less thick than on the banks, the tertiary substratum even outcropping locally.

There are strong indications that many of the banks comprise a thick accumulation of holocene off-shore tidal sands (up to 20 m). At some places in the channels (e.g. in the southern Ratelgeul) surface sediments are gravelly and probably to be considered as lag deposits, in other places (e.g. in the Negenvaam) they consist of fine sands.

The quaternary overburden of the Kwintebank (and many others) show following synthetic profile.

A lower lithostratigraphic unit consists of a complex of planar layers, more or less horizontally stratified and mainly sandy. They are separated by distinct reflectors, possibly horizons with some gravels. The whole belongs to a large sheet of pre-holocene quaternary deposits and pre marine-holocene sediments dissected by the scouring of the large offshore channels.

A second unit consists of sands as well but with some fine intercalations and with marine shells. Its stratification shows a succession of planar layers with internal trough, progradational or horizontally layered structures.These sediments could not be older than mid-holocene, the neo-holocene sea level standing too low for off-shore marine action in this zone till the Late Boreal (S. JELGERSMA, 1979).

Both these units from the erosional core of the bank, whose formation in this area does not seem to have begun earlier than in early mid-holocene time.

A third unit consists of sand with shells. Its stratification shows large subhorizontal planar units dominated by well marked internal diagonally or tangentially progradational reflections and rare trough structures. Giant herringbone patterns have been detected, indicating a bidirectional medium term bed-load transport. The interfaces of the planar units form poorly reflecting horizons. They probably correspond to major sweep surfaces topping the upper parts of giant sand waves. Their directions prove the existence of medium term inversions of the direction of the net sand movement. Sometimes the interfaces show distinct burden megaripple or sandwave like surfaces.

The higher and steeper western side distinctly shows a shallow erosional subsurface cutting the internal subhorizontal planar structures thinly covered by megaripples.

On the gentler eastern side of the Kwintebank, the internal planar structures have been topped as well, but there the subsurface erosional slope is burdened by thicker deposits.

This third unit forms the overburden of the eroded core, brought in by the subrecent and recent maintenance mechanism and complicated by an alternating preferential deposition and preferential erosion on opposite sides. At the present residual deposition dominates the eastern side of the Kwintebank and erosion the westward one so that the residual effect is a week eastward move of the slight eastern slope and a residual erosional steeper western slope.

A fourth unit consists of the present day sandwaves and mega-ripples moving across the bank over a sweepline which is locally out-cropping or even scoured.

5. CONCLUSION

On grounds of the maintenance mechanism the oscillation phenomenon, and the internal bank structure data, following genetic model can be advanced.

During the holocene sea level rise the river valleys existing on the continental flat gradually got a perimarine character and estuarine and prelittoral tidal flats developed. Later on the trans-gression gradually flooded these valley bottoms and the low inter-fluvia which became tidal flats. Tidal currents in the inundated areas adapted to the direction of the former thalwegs of the inundated fluvial topography, which evolved into tidal channels. They initiated the scouring of the former valley bottoms and started the maintenance mechanism by which the eroded sediments were washed from their fines and the sands piled up on the former lower interfluvia. These became the cores of embryonnair banks. Since that early phase fines gradually became more and more available, easying the tidal flat sedimentation behind protective barriers and in estuaries.

During the sea level rise the banks gradually became more flooded and each time the water depth became critical, uppiling of sands by the maintenance mechanism could start again. The sediments required for the nourishment were supplied by new phases of scouring and especially the widening of the channels whose present-day volume exceeds that of the banks, and by possible repercussions upon the morphodynamic and sedimentologic situation along the coast and in the near shore zone. During periods of stabilized sea level the maintenance mechanism especially activated the bank oscillation process.

In this model the banks present a relative positional stability. During the sea level rise they have grown by the maintenance mechanism. Since the maximum was reached, they survive and oscillate around the old cores thanks to the maintenance mechanism which under certain stress conditions calls for exterior inputs or exchanges of sediments.

6. REFERENCES AND BIBLIOGRAPHY

Extensive references and bibliography are provided in :

DE MOOR, G. (1985). - "Shelf bank morphology off the Belgian Coast. Recent methodological and scientific developments", Brussel, V.U.B., Liber Amicorum Peeters (in press).

ACKNOWLEDGEMENTS

The author thanks the Administration of Mines, the Management Unit Mathematical Model North Sea, The Hydrographical Service at Ostend, the Belgian Navy, the Belgian Royal Institute for Natural Sciences at Brussels, and all the people who helped at sea and in the laboratory, especially Cpt BEULEN of the "Spa", Cpt VANDERELST of the "Heyst", Drs. J. LANCKNEUS, Ir. A. VAN CAUWENBERGHE, Ir. H. PICARD, Ir. B. POLLENTIER, Dr. S. WARTEL and Ir. Ph. VAN OVERMEIRE.

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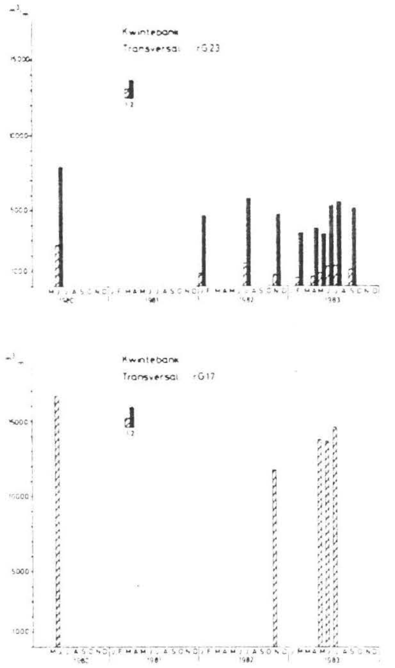

Fig. 1 - Morphodynamics of the Kwintebank (1980-83)
Volumetric comparison of sequential
bathymetric profiling along transversal
reference tracks (local. fig. 5)
(data : G. DE MOOR, 1982-83; M.O.W., 1980)

1 = Volume above level -15 m ÷ H
2 = Volume above level -19 m ÷ H

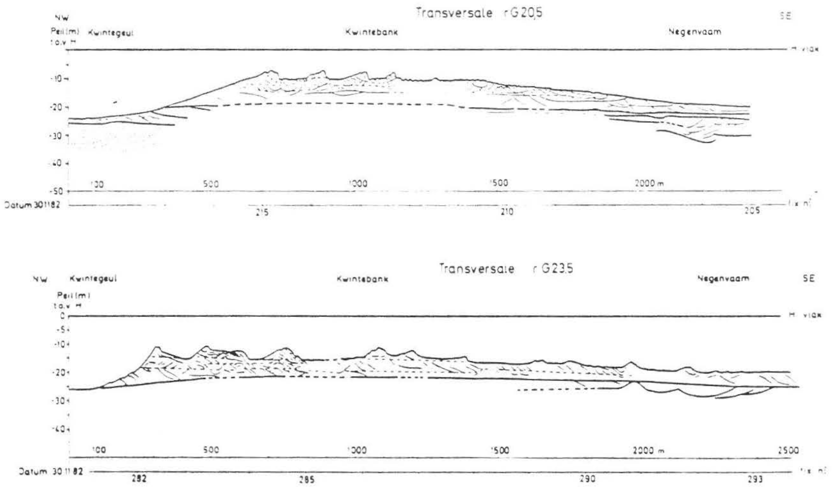

Fig. 2 - Internal sedimentary structures of the Kwintebank, based on transversal ORE
Subbotom profiling records (local. fig. 5)
(data : G. DE MOOR, 1982)

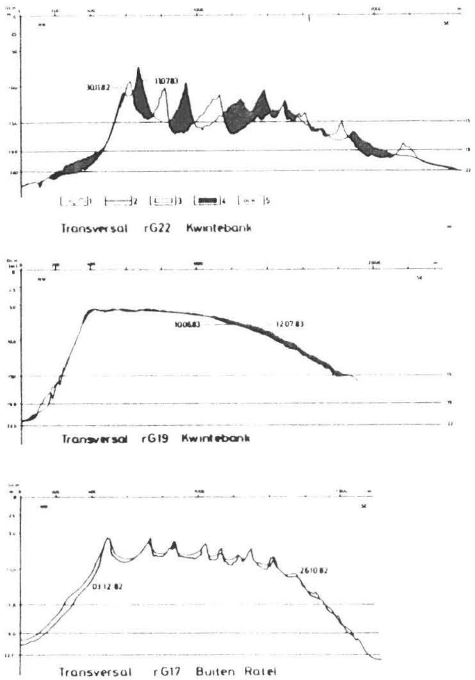

Fig. 3 - Graphic comparison of sequential bathymetric profiles along transversal reference tracks (1982-83). (Continuous Atlas Deso X echo-sounder records) (Data : G. DE MOOR, 1982-83)

1 = Hypsometric profile
2 = Reference levels
3 = Residual loss over the observation period
4 = Residual gain over the observation period
5 = Depth below H-datum (m)

Transversal G17 on the Buiten Ratel shows the typical erosion furrows due to longitudinal currents on top of the bank

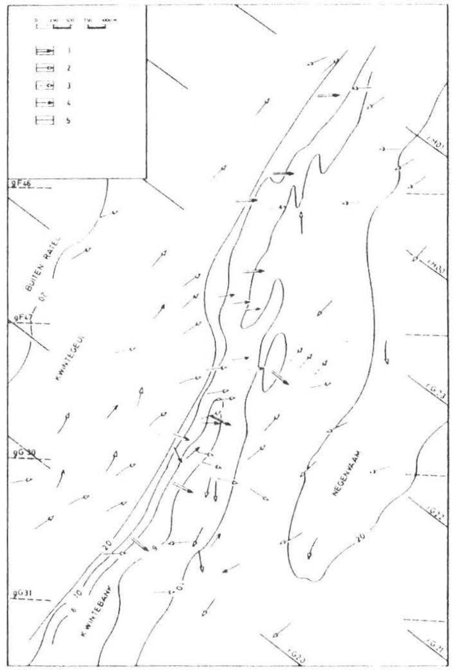

Fig. 4 - Direction and intensity of residual bottom currents around the off shore part of the Kwintebank as indicated by asymmetry and type of bedforms (November 1982) (Data : G. DE MOOR, 1982)

1 = Residual sandmigration by sandwaves
2 = Residual sandmigration by megaripples
3 = Residual sandmigration by lingoïd and parabolic megaripples
4 = Residual migration by megaripples an slight sandwave slopes
5 = Contour lines vrs H-datum

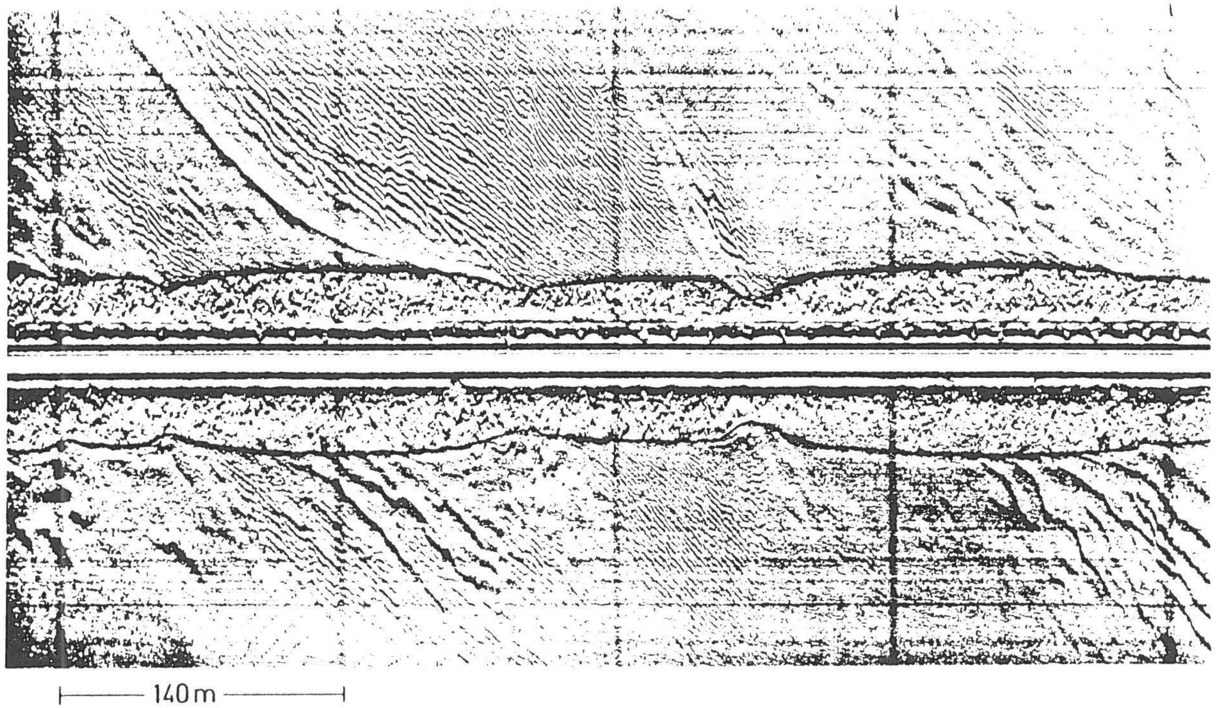

Fig. 5 - Klein Side Scan Sonar record of surficial bed borms at the NW part of the Kwintebank along the transversal reference track Decca red H23 (December 1982)
(Data : G. DE MOOR, 1982)