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ACOUSTIC TELEDETECTION OF SEA-BOTTOM STRUCTURES IN THE SOUTHERN BIGHT

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ABSTRACT - The sea-bottom relief in the area of the Flemish Banks has been studied with the help of a side-scan sonar. A description of all detected bedforms is given and an isometric map of the recorded features is presented. Finally a residual sedimentdynamic analysis is made based on the geometric characteristics of the sea-bottom structures.

RESUME - Le relief sous-marin des Bancs de Flandre a été étudié à l'aide d'un sonar à balayage latéral. Une description morphologique des structures détectées est donnée et une carte isométrique des formes enregistrées est présentée. Une analyse de la dynamique sédimentaire résiduelle est faite basée sur les caractéristiques géométriques des structures sous-marines.

SAMENVATTING - Het zeebodemreliëf van de Vlaamse Banken werd bestudeerd met behulp van een side scan sonar. Een beschrijving van alle gedetecteerde reliëfsvormen wordt gegeven en een isometrische kaart van de geregistreerde strukturen wordt voorgesteld. Een residuele sediment dynamische analyse wordt gemaakt steunende op de geometrische karakteristieken van de zeebodemstrukturen.

KEY-WORDS - Flemish Banks, North Sea, side-scan sonar, sedimentdynamics, marine geomorphology.

MOTS-CLES - Bancs de Flandre, Mer du Nord, sonar à balayage latéral, dynamique des sédiments, géomorphologie marine.

SLEUTELWOORDEN - Vlaamse Banken, Noordzee, side scan sonar, sedimentdynamiek, mariene geomorfologie.

1. INTRODUCTION

The Flemish Banks (fig. 1,2) are a complex of large off-shore sand banks, reaching lengths of tens of kilometres, widths up to a few kilometres and relative elevations up to 20 m. They have a general SW-NE orientation and present a elongated plan form with several gentle or well pronounced longitudinal articulations. They are subject to strong rotating tidal currents.

The banks consist of Holocene marine sands covering cores of older deposits (DE MOOR, 1984). The sands are generally coarser on the banks than in the swales. The highest concentrations of silt and gravel occur in the central parts of the swales. The bank surface does not present uniform grain-size characteristics. On the ridges the sediments coarsen towards the north-east extremity and the western slopes show coarser sand than the eastern ones (LANCKNEUS, 1988).

The purpose of this research is to evaluate the path of the residual sand transport in the area of the Flemish Banks. The sedimentdynamic interpretation of this study is based on the analysis of bedforms and more specifically on the determination of the asymmetry of megaripples. Few data are available on these smaller-scale bedforms of the sea-bottom in this area. The mapping of bedforms by side-scan sonar techniques give excellent results and they are far better and more detailed than those obtained by continuous echo-sounding recording (DE MOOR, 1984).

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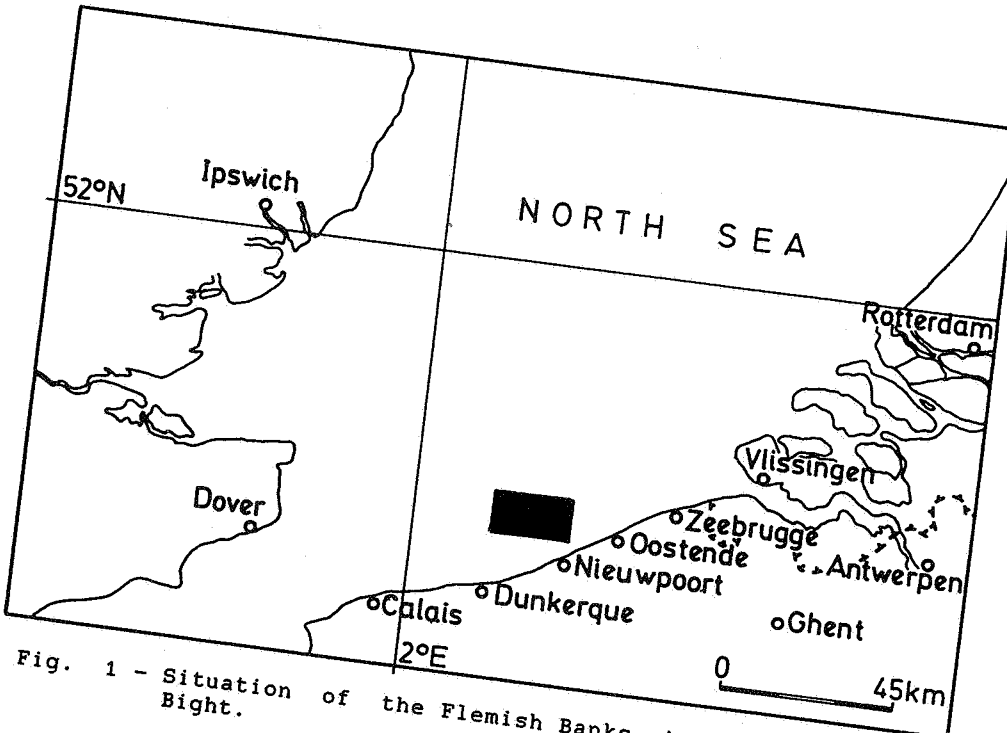

Fig. 1 - Situation of the Flemish Banks in the Southern Bight.

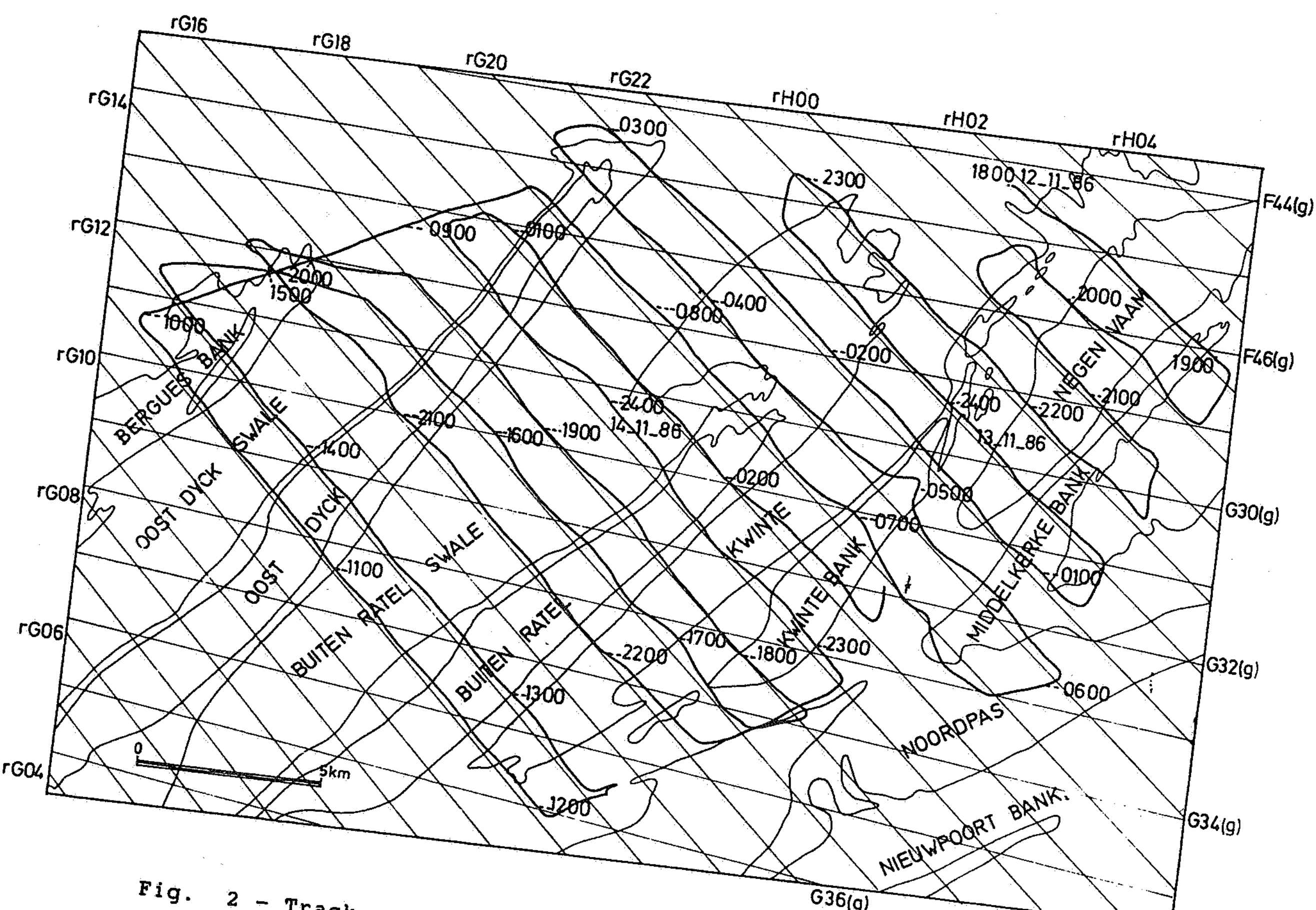

Fig. 2 - Tracks navigated along red (r) Decca-lines on the Flemish Banks between the 12 and 14 november 1986. Navigation is based on Navstar, positioning on Toran.

2. PRINCIPLE OF THE SIDE-SCAN SONAR

The side-scan sonar technique (LEENHARDT, 1974) can be considered as an acoustic analog to aerial photography although there are marked differences in information content. The side-scan sonar registration allows to develop a plan view of the relief of the sea-floor and to detect its texture (BELDERSON et al., 1972).

Basically the side-scan sonar system consists of three units : a transducer which forms the underwater unit (the tow-fish),a steel wire reinforced cable acting as transmission and tow cable and a dual channel recorder.

The tow-fish consists of a streamlined body about 1.20 meter long containing two sets of transducers that scan the sea-bed on either sides (fig. 3). The used tow-fish has a horizontal beamwidth reduced to 1°and a vertical beamwidth pointing 10° downwards. The ultrasonic beams cover the whole distance from a point vertically below the fish to the limit of the maximum chosen slant range. The transducers emit short pulses of sound of 0.1 ms duration at regular intervals and receive the resulting echoes which are displayed on the recorder.

The recorder contains most of the transmission and amplification electronics as well as the graphic recording mechanism. The returning signals are amplified in the recorder and fed as variable currents to the helix electrodes which sweep out from the center of the recording drum. The current passes through the recording paper to the printer blade-electrode and produces marks of varying intensity which are proportional to the strength of the incoming signals, thus reflecting the nature of the sea-bed (fig.3) (FLEMMING, 1976).

The intensity of the received echo (E) is given by the sonar equation (FLEMMING, 1981).

$$E = H + D + T + I - 2A$$

where H is the sensitivity index of the receiving transducer in decibels, D is the directivity index of the transducer in decibles, T is the target strength in decibels, I is the intensity of the transmitted signal in decibels and A is the one-way transmission loss of the out-going signal in decibel. This weakening of the acoustic signal can be approximated by (FLEMMING, 1981)

$$2A = 40 \log R + 2aR$$

where R is the slant range and a the ab-

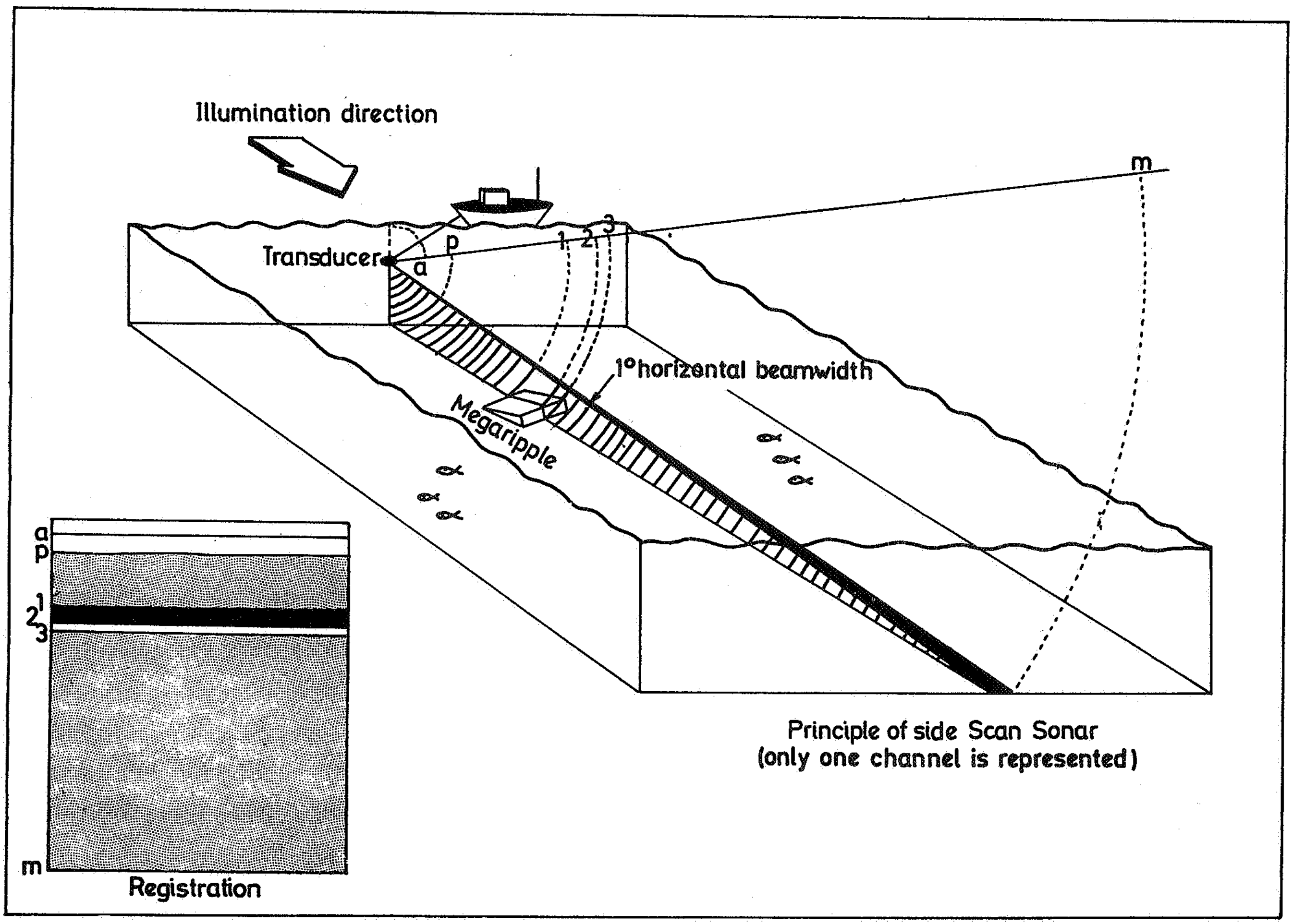

Fig. 3 - Principle of side-scan sonar registration.

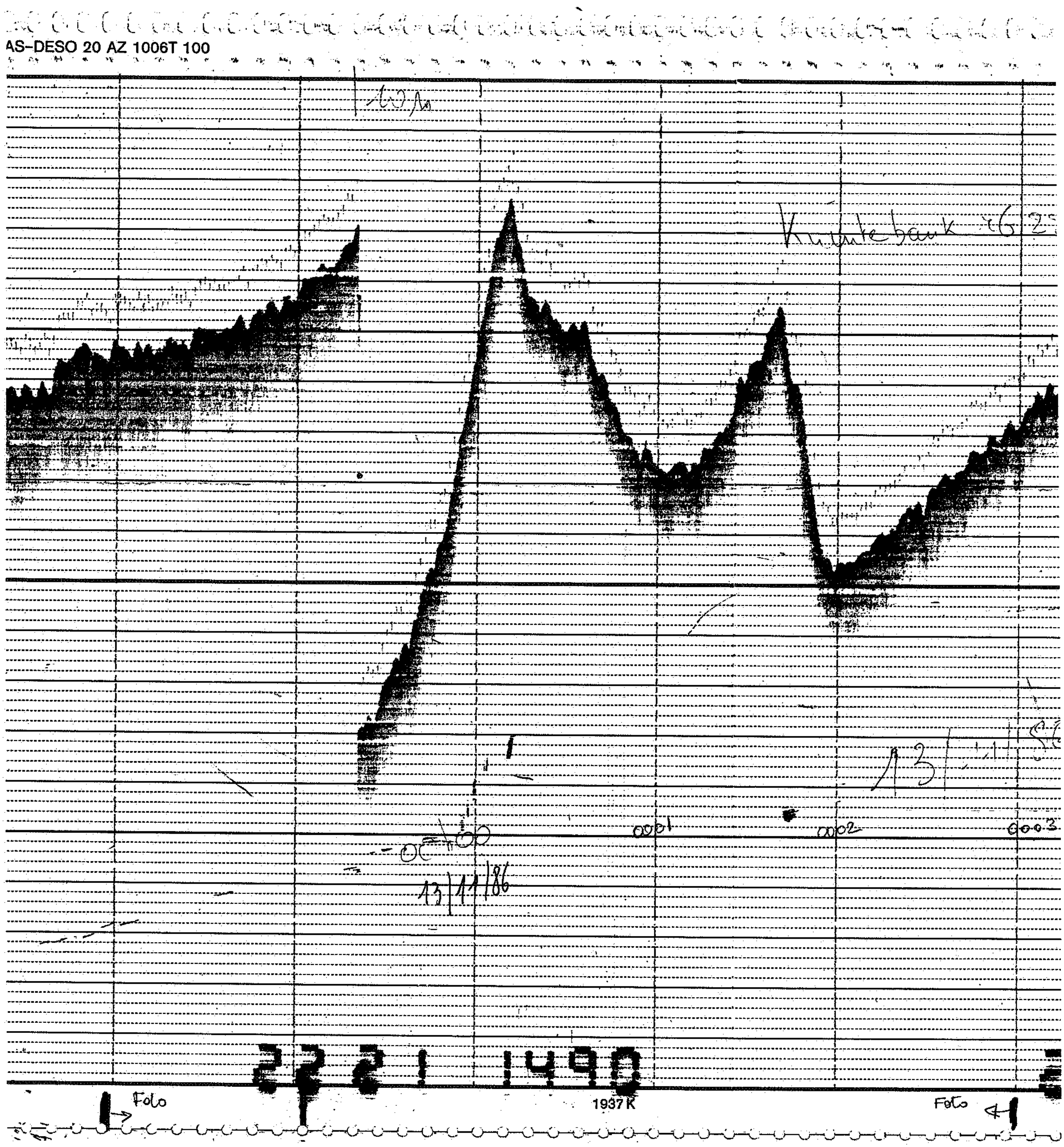

Fig. 4 - Example of a bathymetric profile (event marks spaced one minute away).

sorption coefficient. The attenuation of sound is defined as transmission loss due to scattering (reflection by suspended particles and air bubbles) and absorption (function of several factors such as temperature and salinity of the sea-water). Normally the attenuation of sound by scattering is very small.

The parameters H, D and I are predefined transducer characteristics and they remain the same during side-scan sonar operations. Furthermore the returning signals are amplified in function of their arrival times in order to compensate for decrease of intensity of the outer range signals (Time Varying Gain). Finally the absorption does not change much in a particular environment. So we see that the only remaining factor which influences the intensity of the returning signal is the target strength. This factor is function of the material properties as well as the topography (dimension, position and geometry of the reflector on the sea-floor). Sand for example is a better reflector than mud and will therefore record darker. Slopes facing the transducer reflect sound waves better than surfaces lying oblique to the sound beam and will consequently plot darker. Steep slopes mark darker than slight slopes.

The resulting sonograph does not represent an isometric map of the sea-bed and various distorting factors have to be accounted for when reproducing sonograph mosaics in map form (FLEMMING, 1982). A distortion will occur in the travel direction due to variable ship speeds, resulting in a compression of the sonograph in this direction and a distortion of all linear displays. Furthermore due to the obliquity of the sonar beam, equal true-distance intervalls will not follow a linear scale on the sonograph. The short-range intervals are compressed and the far-range intervals slightly stretched.

3. SIDE-SCAN SONAR OPERATIONS

The sonographs of the Flemish Banks here presented were obtained during a survey in november 1986 with the oceanographic vessel Belgica. The superficial sea-bottom structures were recorded with the help of a KLEIN two-channel side-scan recorder (model 521 T) connected with a 100 kHz transducer. During the operations a slant range of 100 m was continuously used. Event marks were spaced 1 minute away. The fish was towed on starboard and was lowered 5 meters under the water-surface. A ship speed of 4.5 knots was continuously maintained.

During the side-scan sonar operations a bathymetric profile of the sea-bottom was recorded with a Deso XX echosounder (fig. 4).

The position of the ship, together with other navigation parameters such as absolute ship speed above the bottom and bearing were recorded every 30 seconds by computer and stored in a datafile. The hyperbolic electronic positioning systems Decca (5B chain) and Toran (Belgian chain) (DE CEURT & VAN CAUWENBERGE, 1982) were simultaneously used during the survey.

Decca was used for the navigation together with the help of a real time video track plotter. The survey tracks correspond with loxodromes each defined by 2 reference points fixed along a red Decca-line (fig. 2). An accurate navigation along reference tracks with a shipspeed as low as 4.5 knots is difficult to perform due to the strong currents in the area and to the variable errors of the Decca system whose effects are visible because of positioning by Toran. Therefore some navigated sections do not coincide exactly with the reference tracks (fig. 2). Nevertheless this fact does not interfere with the scientific value of the side-scan sonar survey as

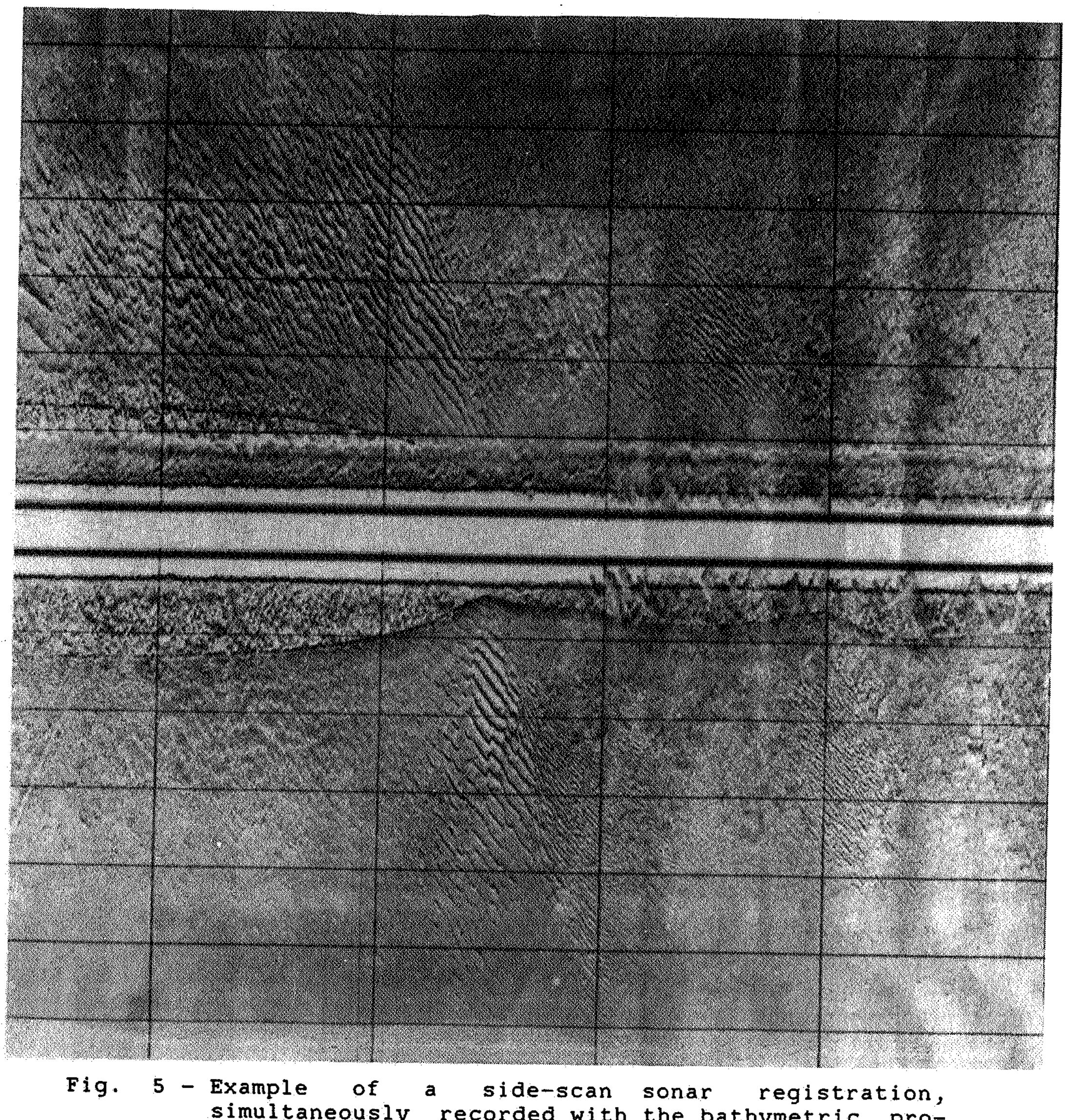

Fig. 5 - Example of a side-scan sonar registration, simultaneously recorded with the bathymetric profile shown in figure 4 (event marks spaced 1 minute away). The registration shows 2 asymmetric sandwaves with superimposed megaripples . Note the different types of megaripples on both flanks of the sandwave.

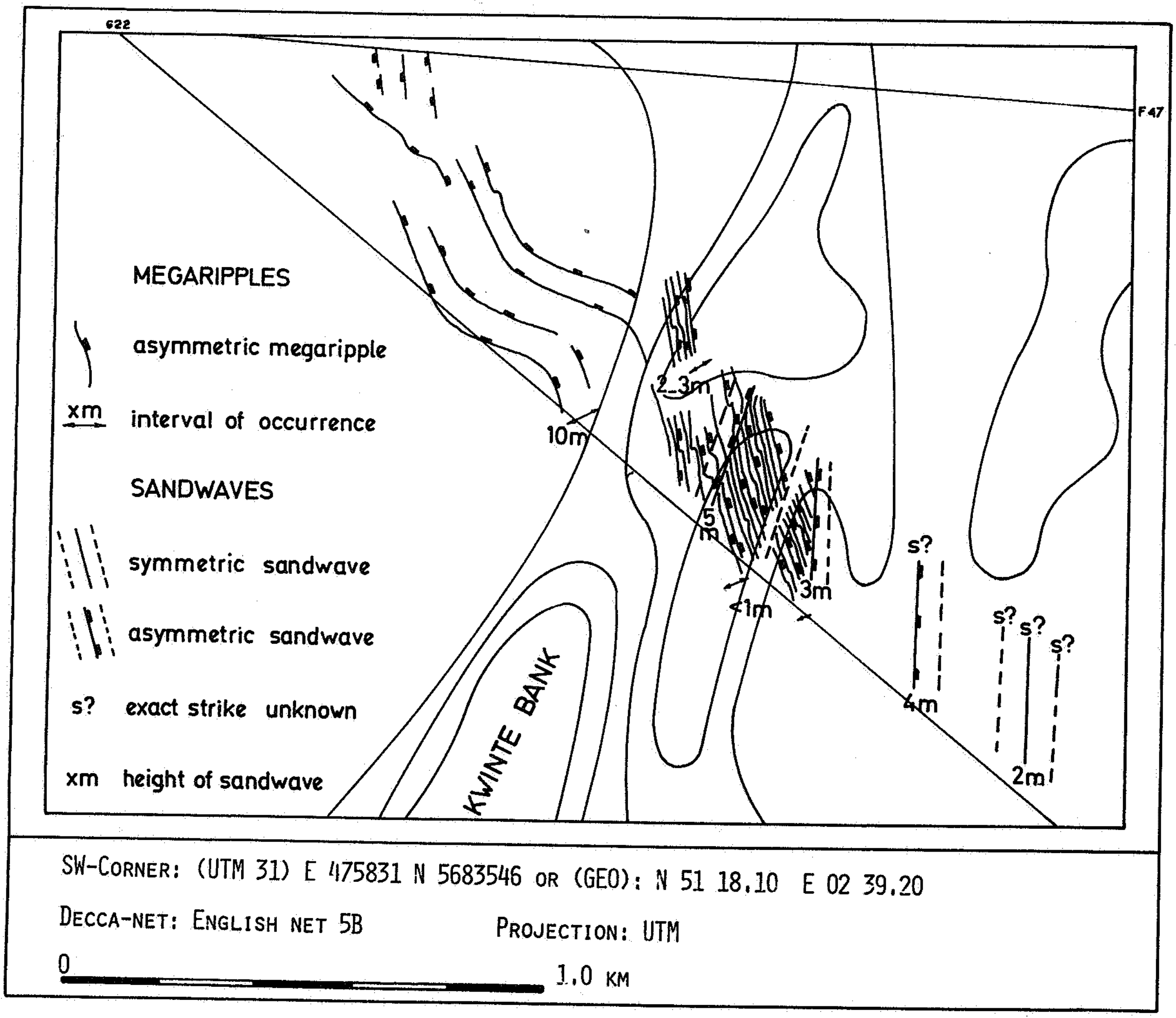

Fig. 6 - Example of a detailed processing of the side-scan sonar registration shown in figure 5.

long as an accurate and high-frequent positioning is obtained.

4. PROCESSING OF THE SONOGRAPHS

As already mentioned the sonograph does not represent an isometric map and all visible structures are compressed and distorted. Those distortions must be corrected as the true strike of the sea-bottom structures is of capital importance. For this reason any feature or group of features visible on the sonograph (fig. 5) was re-drawn with true strike on maps on a scale 1/10 000 (fig. 6). A special attention was paid to the determination of the asymmetry (or symmetry) of the structures and their steep slope. Furthermore the height of the sandwaves was deduced from detailed bathymetric profiles. The interval of occurrence of megaripples was also determined and used as a classification criterion. A distinction was made between megaripples with continuous crests (longer than 10 m) and megaripples with discontinuous crests. All those parameters gave rise to the classification of bedforms as used in figure 7. The symbols used for the different bedform types (fig. 8) made it possible to digitize the bedforms in a synthetic way which gives the essence of information and to store them in a data file. Cartography of the bedforms to any scale can than be obtained by computer plotting (fig. 7). Figure 9 fives a synthesized map of the bedform characteristics on the whole of the Flemish Banks.

Fig. 7 - Fig. 8 - Fig. 9

5. MORPHOGRAPHIC FEATURES ON THE FLEMISH BANKS (Fig. 9)

Two important types of bedforms can be distinguished on the sea-floor : sandwaves and megaripples. We will first consider the sandwaves.

a. SANDWAVES

Sandwaves are the biggest bedforms occuring on the banks and in the swales. They have a length of several hundreds

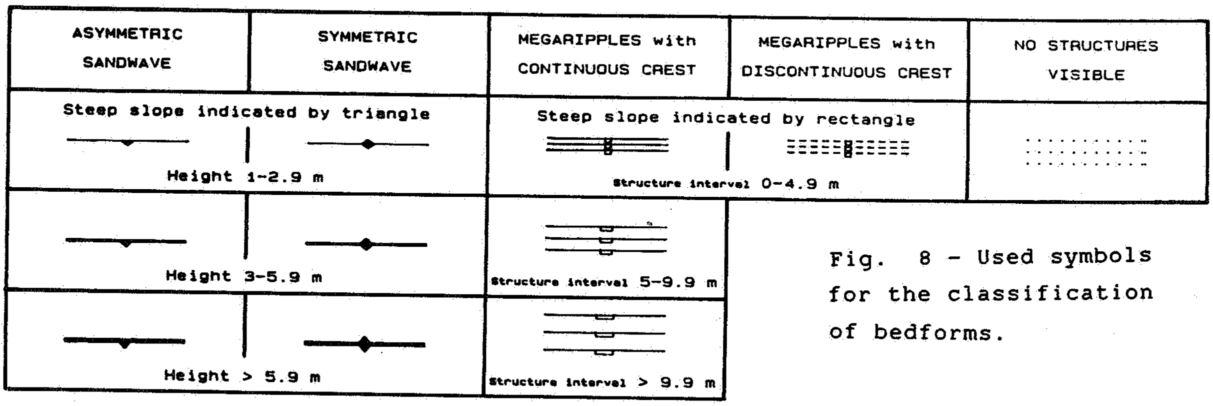

Fig. 8 - Used symbols for the classification of bedforms.

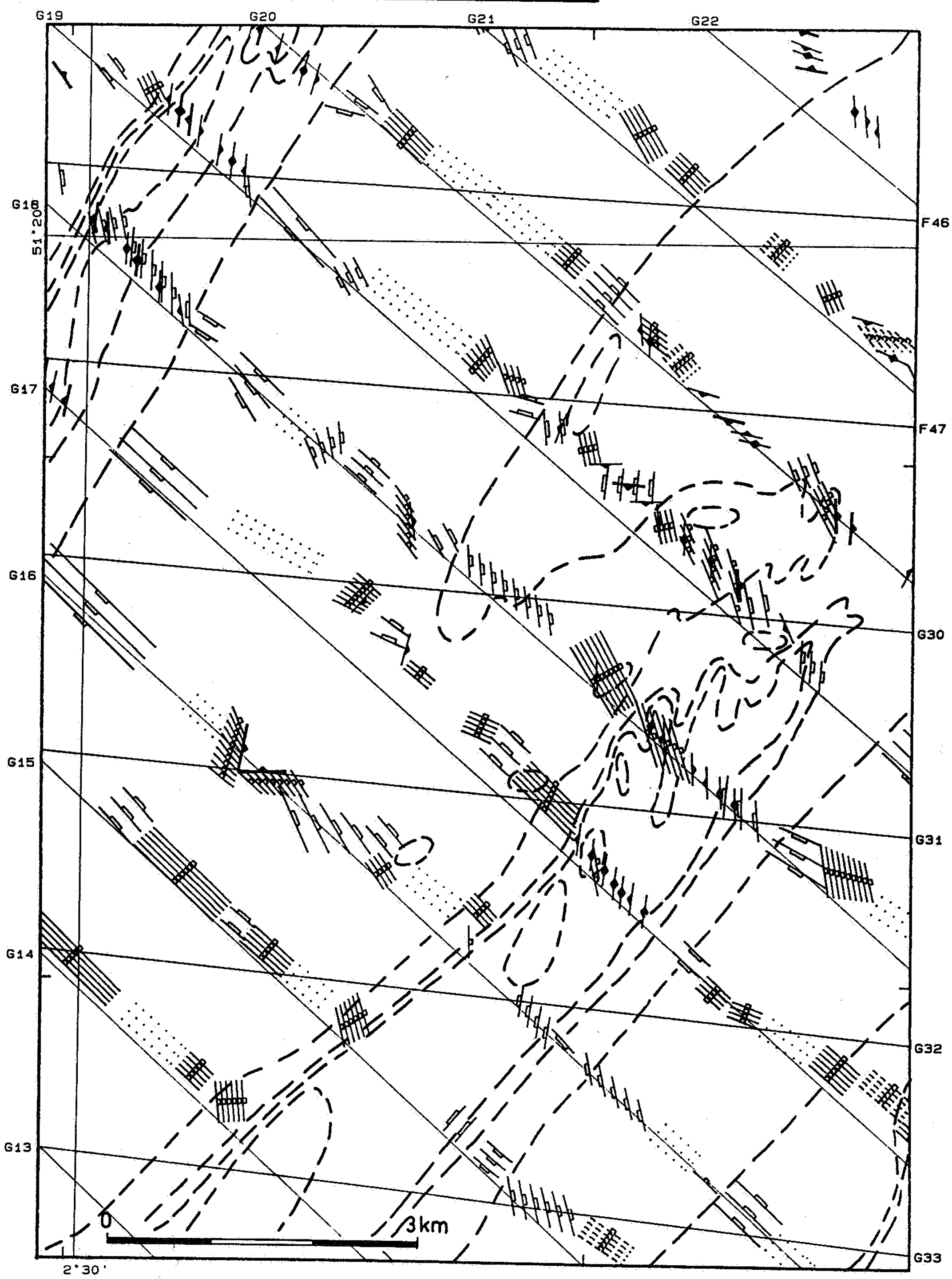

Fig. 7 - Example of detailed cartography by computer plotting on the north side of the Buiten Ratel Bank and the Buiten Ratel Swale.

of meters, a width of several tens of meters and a height varying here between 1 and 8 meters.

In the area of the Flemish Banks they are mainly restricted to the banks. The northern extremity of the Kwinte and the northern part of the Buiten Ratel swale contain however a few small sandwaves. A big barchan-type sandwave occurs also in the Buiten Ratel swale (fig. 10).

On the north-west edge of the whole of the Flemish Banks a field of important sandwaves occurs. There all sandwaves are asymmetric, having their steep slope dipping to the southwest and a height between 2 and 5 meters. The strike of their crests presents an uniform NW-SE direction.

On the Flemish Banks the height of the sandwaves becomes more important towards the northern extremities. The

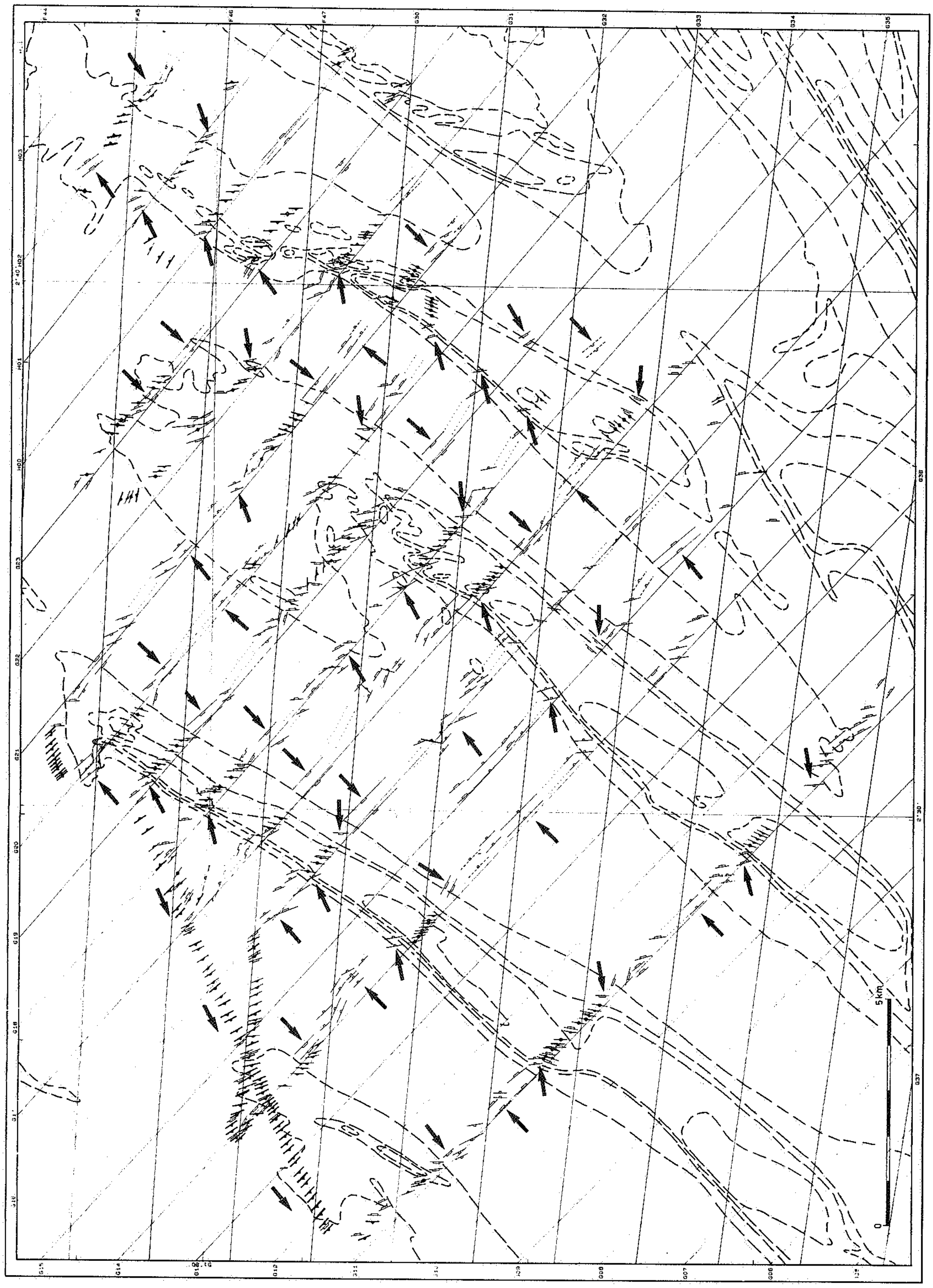

Fig. 9 - Synthesized cartography by computer plotting. The arrows indicate the directions of residual sand transport around the Oostdijk (W), Buiten Ratel (Central) and Kwintebank (E).

sandwaves on southern and central parts of the banks show a general height of 1 to 3 meters. Towards the north this height increases to values of 4 and 5 meters with even a few exceptional values of 5,7 and 8 meters, indicating a distinct correlation with the water-depth : the deeper the water, the bigger the sandwave may be.

The strike of the sandwaves on the banks is generally more or less parallel to the crest of the bank; that is a NNE-SSW direction. Towards the northern parts of the Kwintebank and Buiten Ratel the strike even turns slightly to the NNW-SSE. On the northern extremity of the Buiten Ratel the situation is more complex due to the interference of 2 systems of sandwaves with different orientations. On the eastern and northern edge of the Buiten Ratel the strike is the normal NNE-SSW direction. However in its central part the sandwaves present an approximate E-W orientation. On the Middelkerke Bank a few sandwaves have been detected with the same orientation as those of the large field on the north-west edge of the Flemish Banks.

Symmetric sandwaves occur dominantly in the shallowest parts of the banks. In deeper water they are mainly asymmetric. The situation of november 1986 does not show a distinct relationship between the direction in which the steep slope is dipping and any other morphographic or bathymetric parameter.

b. MEGARIPPLES

Megaripples and fields of megaripples occur as well on the banks as in the swales of the Flemish Banks. Our classification of megaripples is based on the interval between the structures as the height of those smaller bedforms could not accurately be estimated neither from the bathymetric profile because of wave interference nor from the sonographs. A distinction was also made between megaripples characterized by a continuous straight to sinuous crest extending over a distance of more than 10 metres (fig. 11, 12) and megaripples with discontinuous crest (lunate type) (REINECK & SINGH, 1980) which on the sonographs often produce sicle-shaped lobes.

The strike of the megaripples in the swales is dominantly NW-SE. The steep slope of the ripples is dipping in opposite directions on both sides of each bank. In the eastern parts of the swales megaripples dip to the north-east while in their western parts the megaripples dip to the south-west. Megaripples with seawards dipping steep slope are generally smaller (fig. 11) than those with landwards dipping slopes. However the ribbons with smaller ones are mostly larger than the fields of megaripples with landwards dipping steep slope.

On both flanks of the banks the ripples turn off to climb the bank almost parallel to its axis. On the top of the banks the megaripples have a strike genrally corresponding to the length axis of the sandwaves (NNW-SSE).

The megaripples with discontinuous crests are restricted to some areas in the swales and to the lowest parts of the banks such as the northern part of the Buiten Ratel. They do not occur on the highest portions of the sand banks.

During the processing of the sonographs some areas without visible structures were detected. They are limited to the central parts of the Kwinte and Buiten Ratel swale. They also occur near the western flank of the central part of the Buiten Ratel. The lack of megariples and sandwaves in those areas is probably due to the heigher bottom shear stresses, locally enhanced by insufficient sand supply resulting in small patches of tertiary clay substatum outcropping in the swales (DE MOOR, 1984).

6. RESIDUAL SEDIMENT DYNAMICS

The geometric characteristics of the bedforms give a valuable insight into the residual sediment dynamics in this area, because of their relationship with the residual current directions. Our following analysis of the residual sand transport is mainly based on the asymmetry of the megaripples.

In each swale two opposite directions of residual sand transport can be distinguished. In the eastern part of the swale it is directed seawards, in the western part landwards and restricted to a more narrow ribbon.

Each bank receives sand from both adjacent channels in opposite directions. Along both flanks of the banks the residual sand transport becomes perpendicular to the bank axis, provoking a sand uppiling towards their central parts. Along the western flank of each bank the residual sand transport is commanded by residual south-western flood currents while on the eastern sides the residual transport is conditioned by residual north-eastern eb currents.

7. CONCLUSIONS

The sediment dynamic model, advanced by DE MOOR (1984) for the Kwintebank, is of application for the whole of the Flemish Banks.

Probably the sand uppiling is balanced by wave and storm action and by some oblique transport.

The mechanism of sand transport here described is one of the main factors responsable for the maintenance of the sand banks (DE MOOR, 1986).

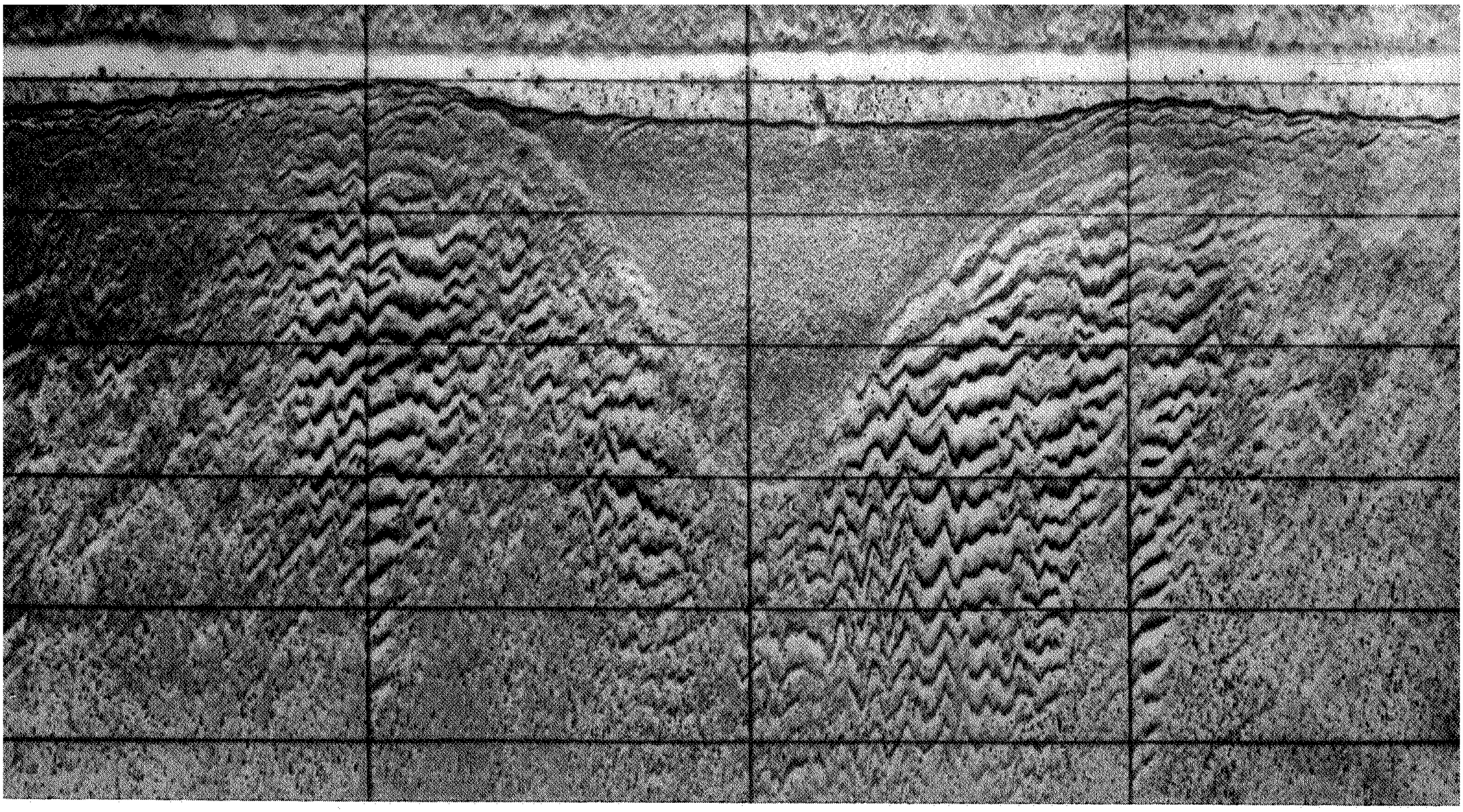

Fig. 10 – Side-scan sonar registration of a barchan-type sandwave with superimposed megaripples (event marks spaced 1 minute away).

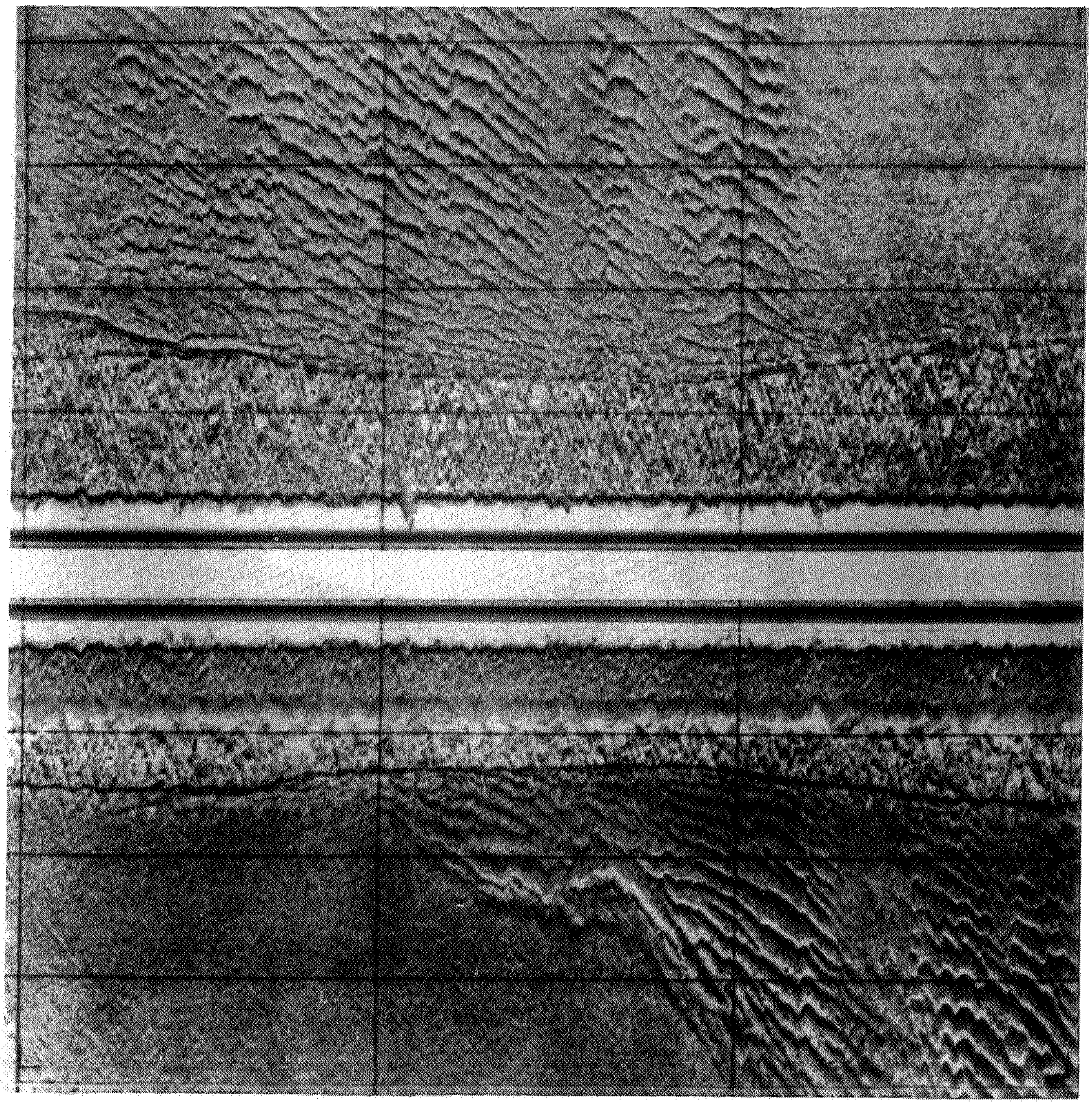

Fig. 11 – Side-scan sonar registration of small megaripples with continuous crests (event marks spaced 1 minute away).

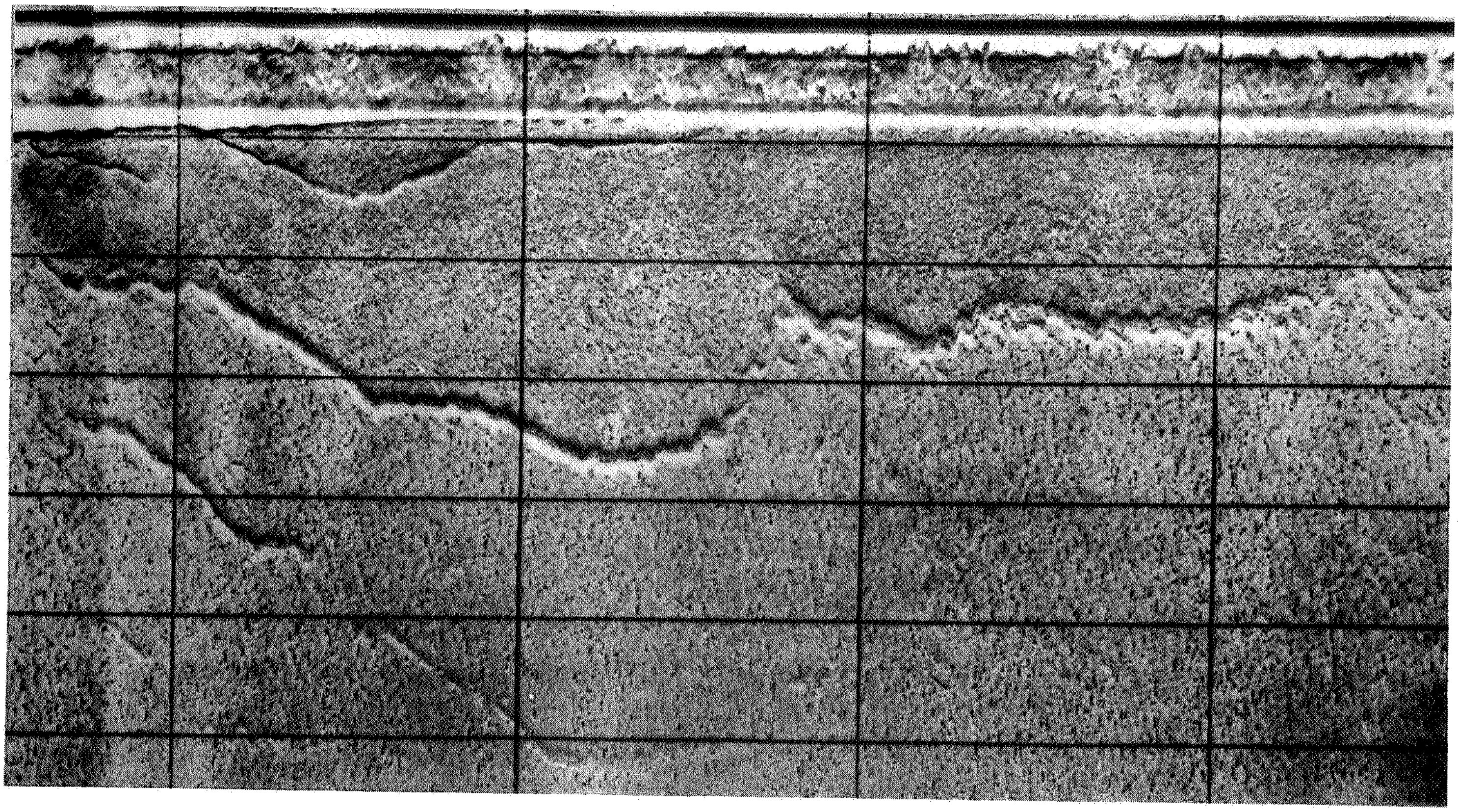

Fig. 12 - Side-scan sonar registration of large megaripples with continuous crests (event marks spaced 1 minute away).

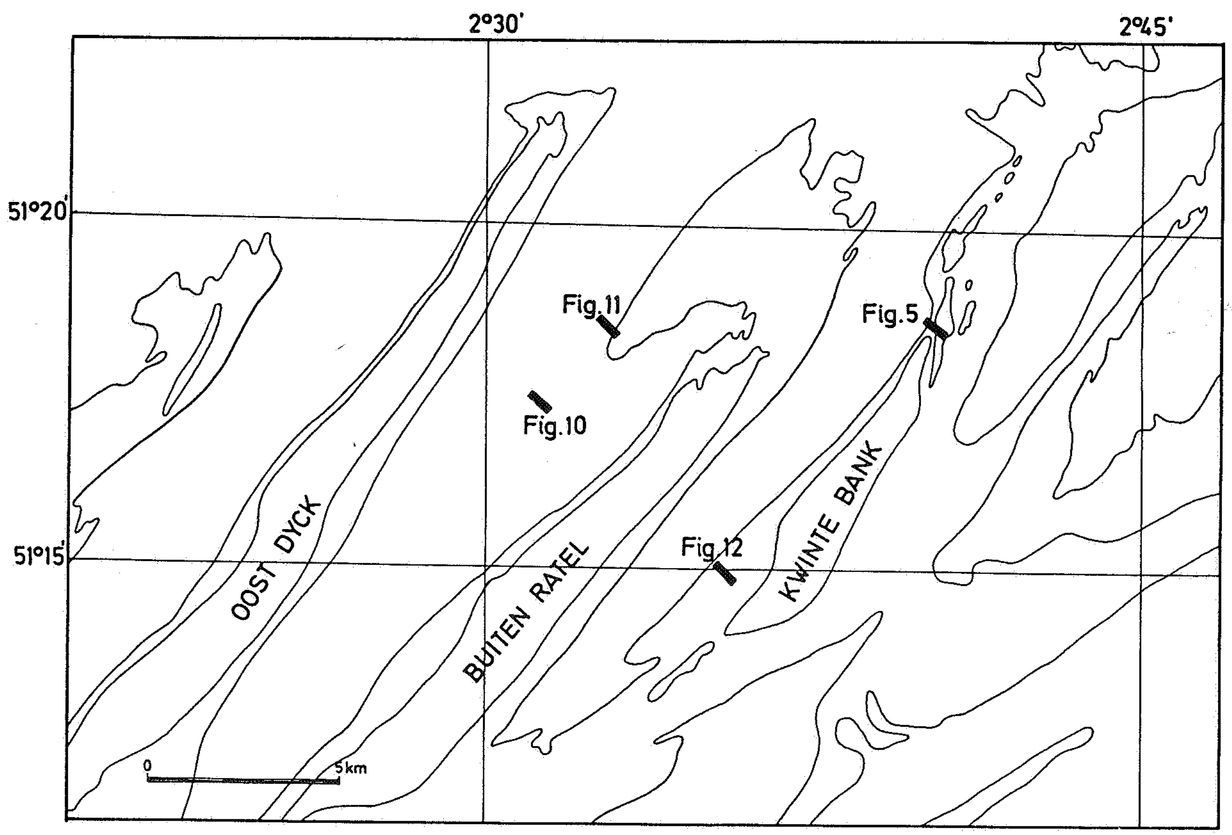

Fig. 13 - Situation of the side-scan sonar registrations shown on fig. 5, 10, 11 and 12.

This cartographic synthesis of sand transport paths suggest that two higher level sand transport mechanisms are involved : a sand supply and reworking mechanism bound to each of the banks and a more regional sand transport mechanism processing sands arround the field of the Flemish Banks itself.

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