THE TERTIARY AND QUATERNARY SUBBOTTOM OF THE SCHELDE ESTUARY NEAR ANTWERPEN (BELGIUM)[1]

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ABSTRACT

Wartel, S. 1980 The Tertiary and Quaternary subbottom of the Schelde estuary near Antwerpen (Belgium) – Geol. Mijnbouw 59: 233-240.

The subbottom stratigraphy of the Schelde estuary near Antwerpen was studied using an O.R.E. subbottom profiler. The estuary valley is incised in Tertiary and Quaternary deposits, still eroded at several places. In the Boom Clay (Oligocene) uparching and diapirs occur. They result from an unloading of the clay after one or more erosion periods. The top of the Boom Clay consists of an undulating erosion surface, dipping roughly NNE and covered unconformably by Miocene (Edegem Sands) and Pliocene (Kattendijk Sands) deposits. The contact between Miocene and Pliocene has not been observed. The lowermost Quaternary deposit consists of a gravel and shell layer irregular in thickness and unconformable with the older deposits. The recent sediment cover, where present, is less than 1 m thick.

INTRODUCTION

It is the aim of this paper to discuss the Tertiary and Quaternary subbottom stratigraphy of the Schelde estuary near Antwerpen (Fig. 1). Special attention is paid to (1) the thickness of the recent sediment layer and (2) structural deformations in the top layer of the Boom Clay (Oligocene).

Erosion of Tertiary sediments in the neighbourhood of Antwerpen has been postulated previously (WARTEL, 1972). This assumption was based on the presence of some characteristic foraminifera in the recent sediment layer. Therefore a study of the stratigraphy below the Schelde bottom is important for a better understanding of the origin of the recent sediment layer.

METHODS

The study was performed with an O.R.E. subbottom profiler, composed of a 10 kw transceiver, mod. 140, and 4 transducers with a variable frequency (3.5 to 7 kHz). The echoes were graphically recorded on a Gifft 4000 recorder. Information up to 25 m below the bottom was obtained in the river channel. Penetration was smaller in the shallower parts of the river. Recent sediment layers thicker than 30 cm were distinguishable. Sediment thicknesses were calculated on the basis of 1,500 m/s sound velocity. This value closely approximates to the velocity in clayey sediments (SMITH & LI, 1966). The water depth was measured with an Atlas Deso 10 echo sounder (accuracy 10 cm). Positions were determined using a sextant (accuracy 5 m) between Burcht and Oosterweel and with a Motorola Miniranger III (accuracy 3 m) in the Oosterweel area.

The depth scale in figures 2 to 7 is given in metres below the Belgian ordnance level. In this study one track along the axis of the river and two transverse profiles, recorded in May 1978, are discussed (Fig. 1).

The main reflecting horizons (further called horizons) are numbered, starting from the lowest observed layer, and briefly described in table I.

The geological interpretation of the subbottom profiles is based on studies of the Tertiary in the Antwerpen area (LAGA, 1972; DE MEUTER, 1974), a sedimentological study of the Boom Clay (VANDENBERGHE, 1978) and the files of the Geological Survey of Belgium (Map 28, Antwerpen-Borgerhout).

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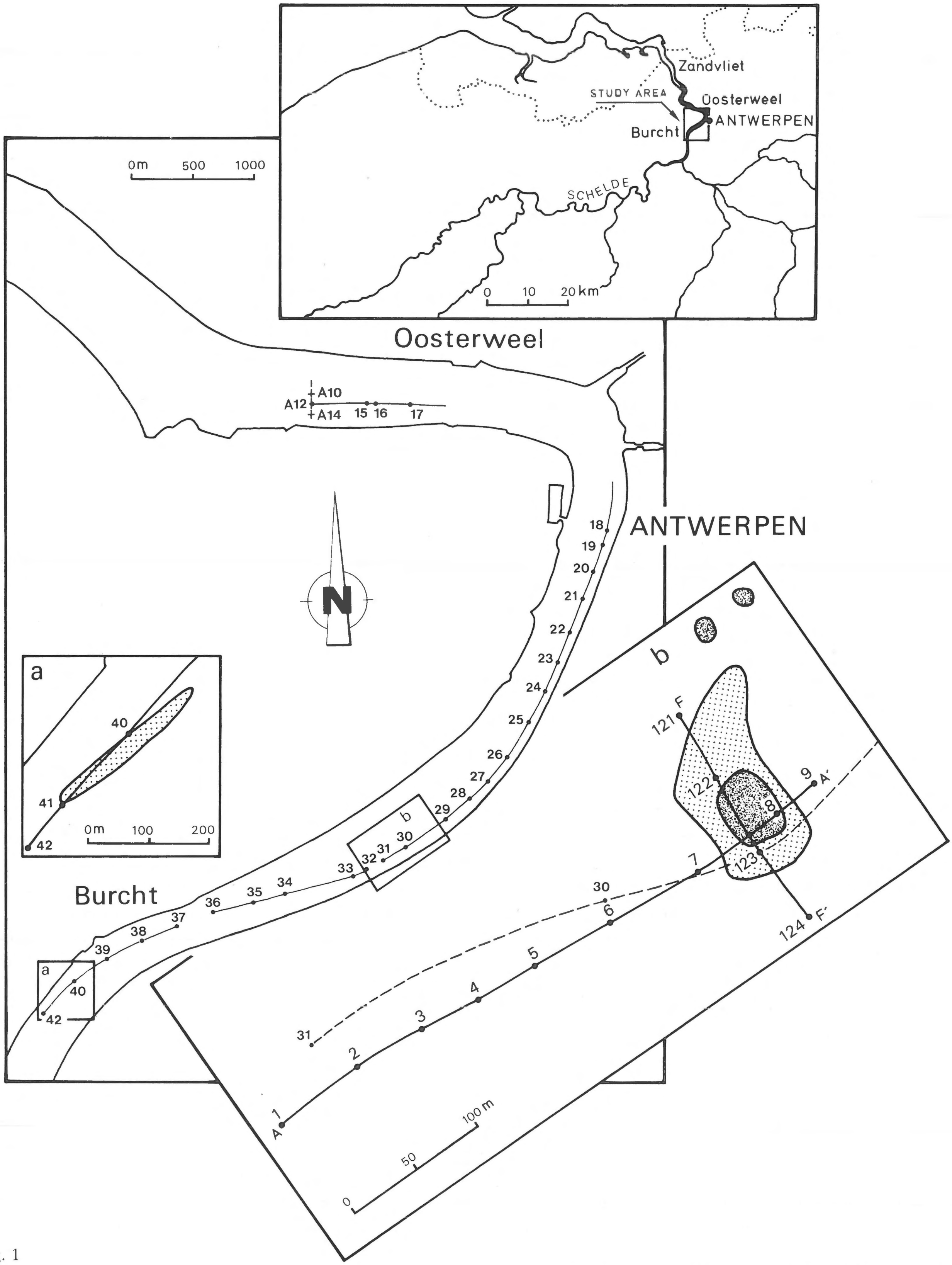

Fig. 1
Locality map showing the navigated tracks and location of two main diapirs. For the sake of clearness some intermediate positions, represented in the longitudinal subbottom profiles (Figs. 2 and following) are omitted. The dotted areas in inserts a and b show the extension of the diapirs based on several subbottom observations. The grey shaded area indicates where diapirs reach the Schelde bottom.

THE BOOM CLAY

The top of the Boom Clay clearly appeared in the cone penetration tests (ANTWERPSE ZEEDIENSTEN, 1978) as a result of the marked difference in resistance to penetration between the clay and the overlying sands. It matches horizon 11 (Fig. 2). Likewise a boring near position 19 (HALET, 1931) and another 200 m eastward of position 27 (Fig. 1) (Geological Survey Belgium, Map 28, Antwerpen-Borgerhout) showed horizon 11 as the top of the Boom Clay. It corresponds to an undulating erosion surface, unconformable with the subjacent strata (e.g. Fig. 2), and can be followed from position 12 upstream to position 30 (Fig. 1). Farther southward the Boom Clay is very close to the Schelde bottom and is eroded between position 32 and position 42 (Fig. 1).

The Boom Clay is characterised by septaria layers (loaf-shaped calcareous concretions, differing from one layer to another in their form and number) (VANDENBERGHE, 1978). In the excavation of Kruibeke (about 1.500 m SW of position 42, Fig. 1) a septaria layer (S5, Vandenberghe's annotation) occurs in a silty bed at -7m, dipping 10′ NNE (VANDENBERGHE, 1978). One can calculate that horizon 3, occurring at -11,5 m at position 42, lies in the projected prolongation of this layer. Horizon 3 was used for correlating horizons 1a to 6c with Boom Clay strata shown in table I. Hard nodules (septaria?) were observed at depths corresponding to horizons 7b and 10 in the cone penetration tests (ANTWERPSE ZEEDIENSTEN, 1978). No interpretation can be given for horizons 7a and 8. The observed strata of the Boom Clay dip conformably NNE. Structural deformations occur at several places. They range from (1) diapirs (one near Burcht, Fig. 6 position 40-42), others south of Antwerpen (Figs. 1b, 7 and 8) protruding through overlying strata and eroded by the Schelde to (2) several degrees of uparching (e.g. Fig. 9). The Burcht diapir, more than 200 m long and 50 m wide, (Figs. 1a and 6) has its long axis oriented parallel to the river channel (NE-SW). The deformation rapidly diminishes downward. It is asymmetric in a vertical plane: folding and faulting are more pronounced at the SW side (near position 42, Fig. 1). The Antwerpen diapir, roughly oval-shaped in horizontal section, is also asymmetric in vertical section: slight downward foding and faulting occur at the NW side (Fig. 7, profile FF′ and Fig. 8). It is surrounded by uparched Boom Clay strata (Fig. 4 between position 30 and 29). The location of position 30 with respect to profiles AA′ and FF′ (Fig. 7) is shown in figure 1b. Northward of this diapir two smaller ones, 15 m in cross section, occur (Fig. 1b). Uparching can be seen in figure 5, near position 34 and 35, and on the left of figure 9 (this profile occurs parallel to the one

Table I
Characteristics and interpretation of observed horizons.

Horizon	Reflection		
	intensity	nature	Interpretation (after Vandenberghe, 1978)
1a	w	c,h	Septaria layer (S4): large septaria; numerous; occurs in a clayey bed.
1b	w	c,h	Silty bed (31) beneath a very dark bituminous bed and separated from it by a pyrite horizon.
2a	s	c	Very coarse silty sandy bed (39), thicker than bed (41).
2b	w	c,i	Very coarse silty sandy bed (41), separated from 2a by a clay layer.
3	vs	c,h	Reference horizon for correlation; septaria layer (S5); numerous very typical flattened septaria; occurs in a silty bed.
4a	vw	c	Silty bed (53) beneath a very dark bituminous bed.
4b	vw	i,h	Septaria layer (S6), numerous more spherical shaped septaria.
5	s	c	Septaria layer (S7); only a few septaria were observed in the Kruibeke excavation.
6a	s	i,h	Very silty sandy layer (64) beneath a clay bed.
6b	w	c,i	Very silty sandy layer (66) beneath a bituminous bed.
6c	s	i,h	Septaria layer (S8); stratigraphically the uppermost septaria layer observed by Vandenberghe (1978).
7a	w	i,h	No interpretation.
7b	vw	i,h	Possibly a septaria layer.
8	vw	c	No interpretation.
9	vs	c,h	Possibly a septaria layer.
10	vs	c,h	Possibly a septaria layer.
11	vw	c,i	Reference horizon for correlation; top of Boom Clay.
12	w	c	Gravel and shell layer.
13	w	c	Gravel and shell layer.
14	vs	b	Thick gravel and shell layer; base of Quaternary.
15	s	b	Thick gravel and shell layer; possibly to be correlated with horizon 14.
16	w	i	Gully-like structure, indistinct layered sediments.

w: weak; vw: very weak; s: strong; vs: very strong.
c: continuous horizon; h: separate hyperbolic reflections present; i: frequently interrupted horizon.
( ): numbers between brackets refer to annotations in Vandenberghe (1978).

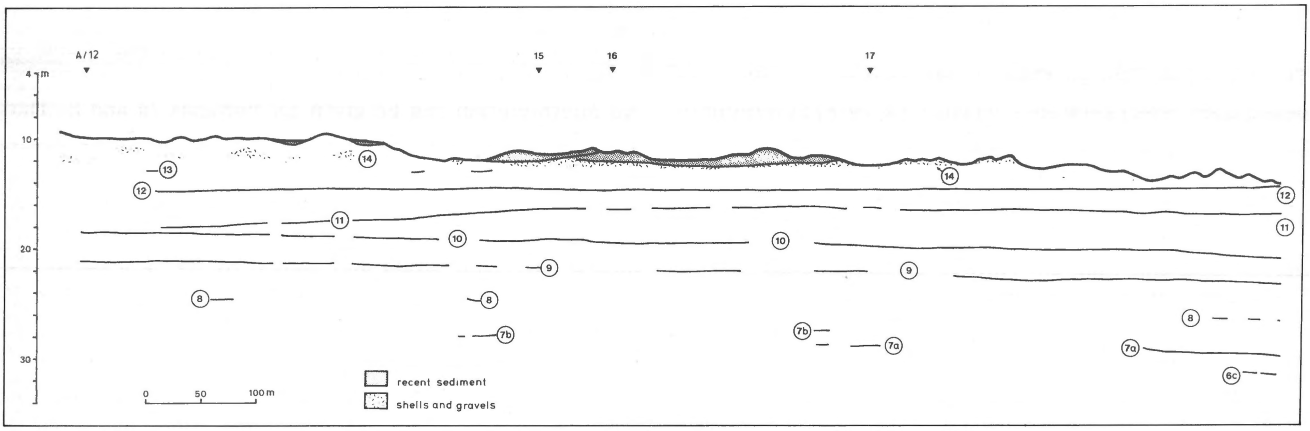

Fig. 2
Longitudinal subbottom profile. The depth scale is given in metres below the Belgian ordnance level. Positions refer to Fig. 1. Circled numbers refer to horizons described in table I.

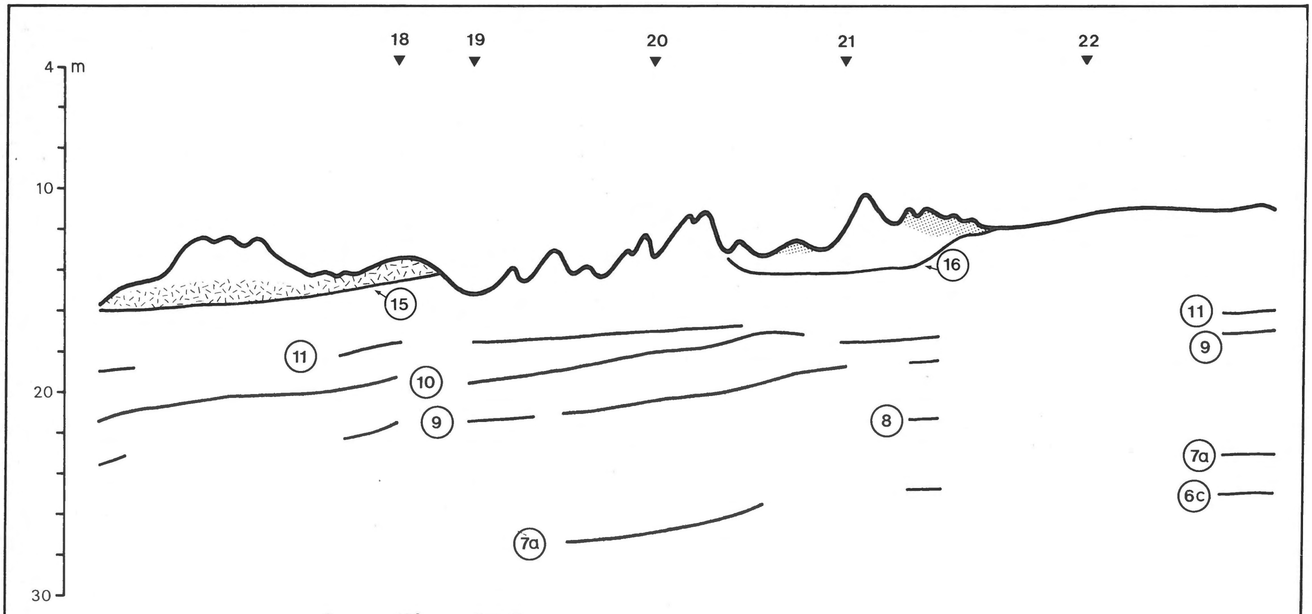

Fig. 3
Longitudinal subbottom profile. Legend see Fig. 2.

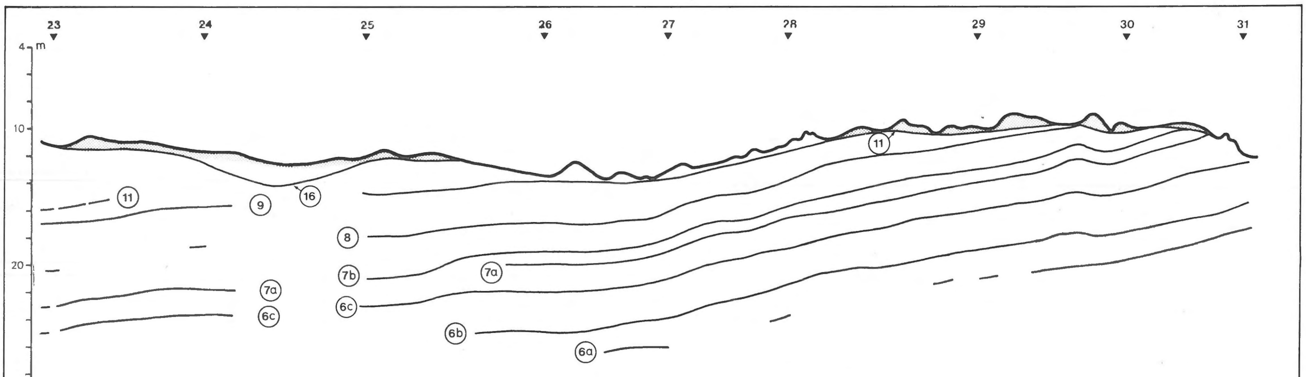

Fig. 4
Longitudinal subbottom profile. Legend see Fig. 2.

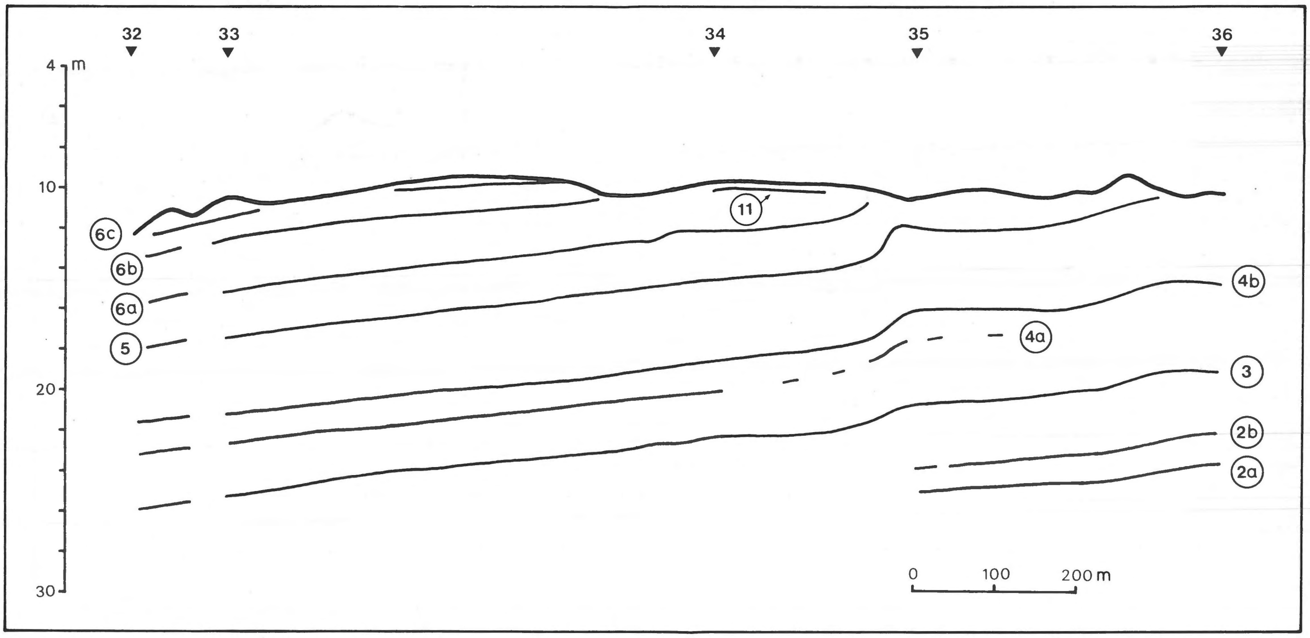

Fig. 5
Longitudinal subbottom profile. Legend see Fig. 2.

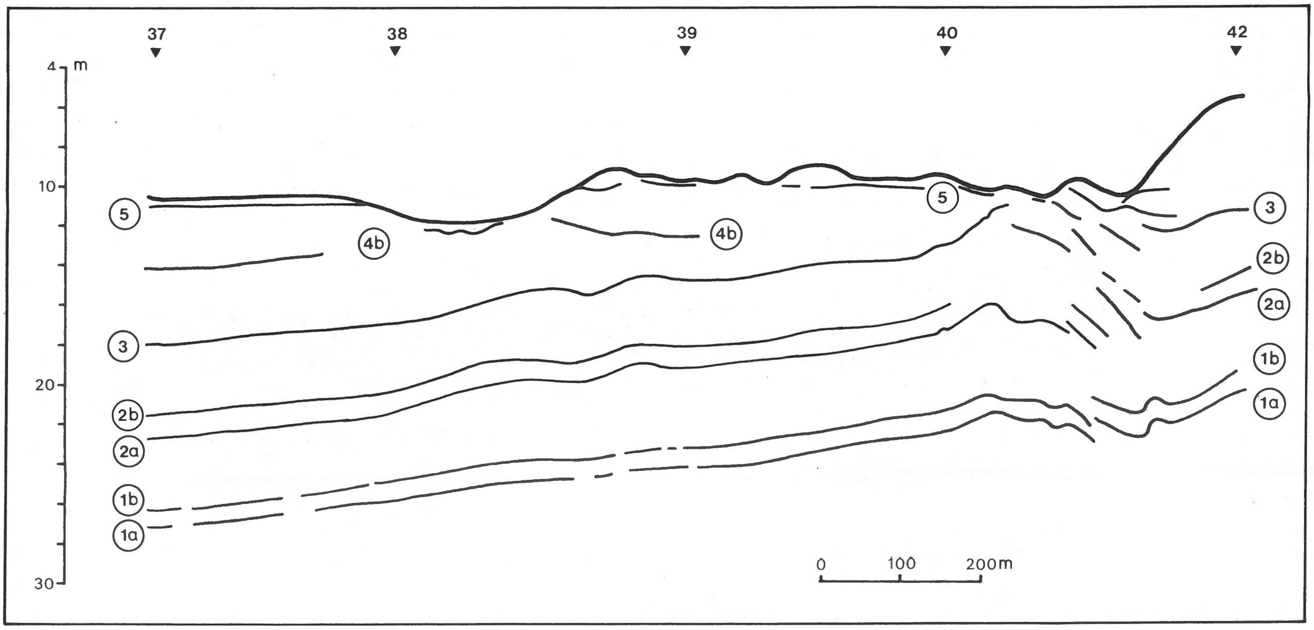

Fig. 6
Longitudinal subbottom profile. Legend see Fig. 2.

shown in figure 5; it is not represented in Fig. 1). The cross sections shown range from 50-100 m (Figs. 4 and 5) to 200-250 m (Fig. 6). A much larger one, more than 800 m long and approximately 250 m wide, occurs near Oosterweel (WARTEL, 1978). The uparching diminishes rapidly with depth and is limited to the top layer (upper 12 to 15 m) of the Boom Clay. Both types of deformation probably have the same origin.

The diapirs can be considered as a later stage of the uparching. Two forces can explain their formation. A normal force, oriented perpendicularly to the surface of the clay and with downward decreasing strength, can be attributed to unloading of the clay (e.g. after an erosion period) followed

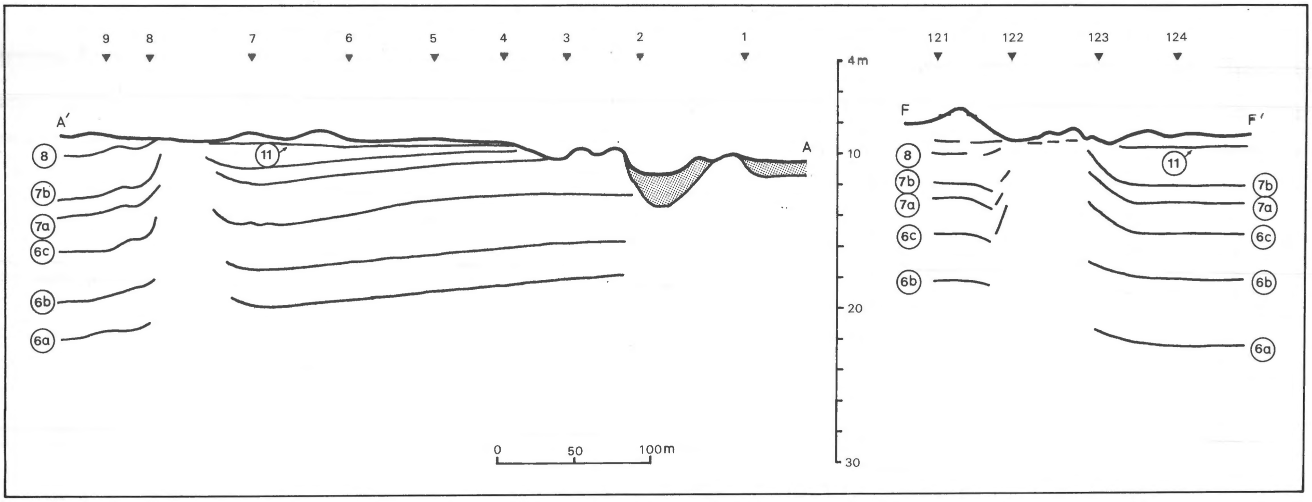

Fig. 7
Longitudinal and transverse subbottom profile showing the Antwerp diapir. Positions refer to Fig. 1b. Legend see Fig. 2.

by relaxation and swelling of the uppermost layers. A tangential force, oriented parallel to the dip, may have caused downward sliding of the clay after relaxation, and explains a more pronounced deformation of the layers at the upward pointing side (when viewed in the direction of dip) of the diapirs. LAGA (1966) and DE MEUTER (1974) described a small diapir (20 to 30 m wide) and very small uparchings (a few metres wide), both injected in the Edegem Sands (Miocene), 200 m north-eastward of position 30 (Fig. 1). The diapir was eroded and overlain with Quaternary gravels. The foraminifera assemblages at both sides of the diapir proved that the Edegem Sands were not displaced during the clay injection (DE MEUTER, 1974). This indicates that these structural deformations are younger than the Edegem Sands and were already active before the Quaternary. Furthermore cone penetration tests in the Antwerpen area show a relaxation of the clay under the Schelde channel (L. Meyvis, Antwerpse Zeediensten, pers. comm., 1979). Thus river erosion also may have influenced the relaxation process of the Boom Clay. If so, the question arises of whether this process is still active or not.

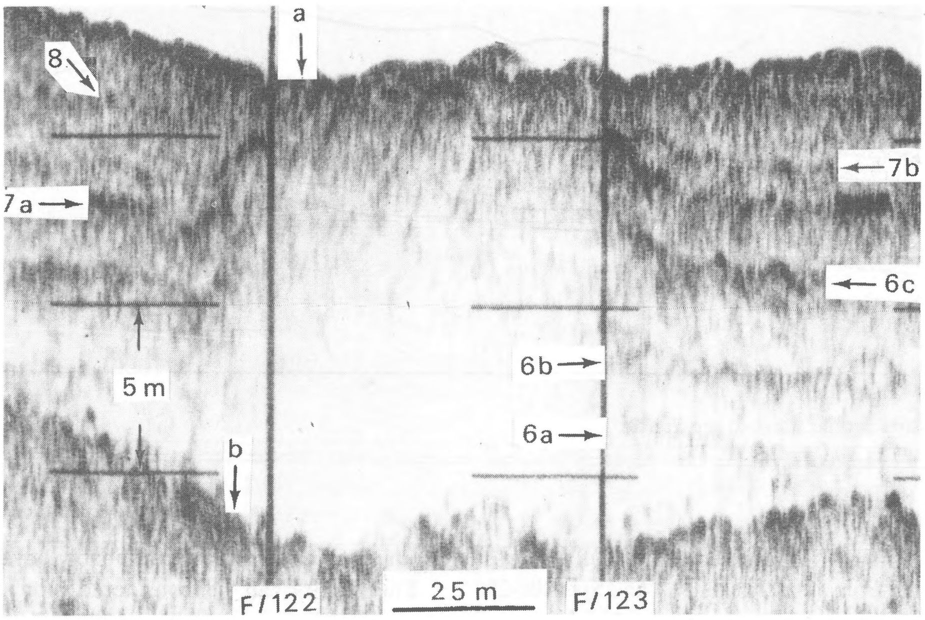

Fig. 8
Subbottom record of the Antwerp diapir (Figs. 1b and 7). The numbered vertical lines are position marks. The horizons are numbered according to table I. a = Schelde bottom; b = first multiple echo of the Schelde bottom. Left of position F/122 one can observe a depression of the septaria layers 6c, 7a and 7b.

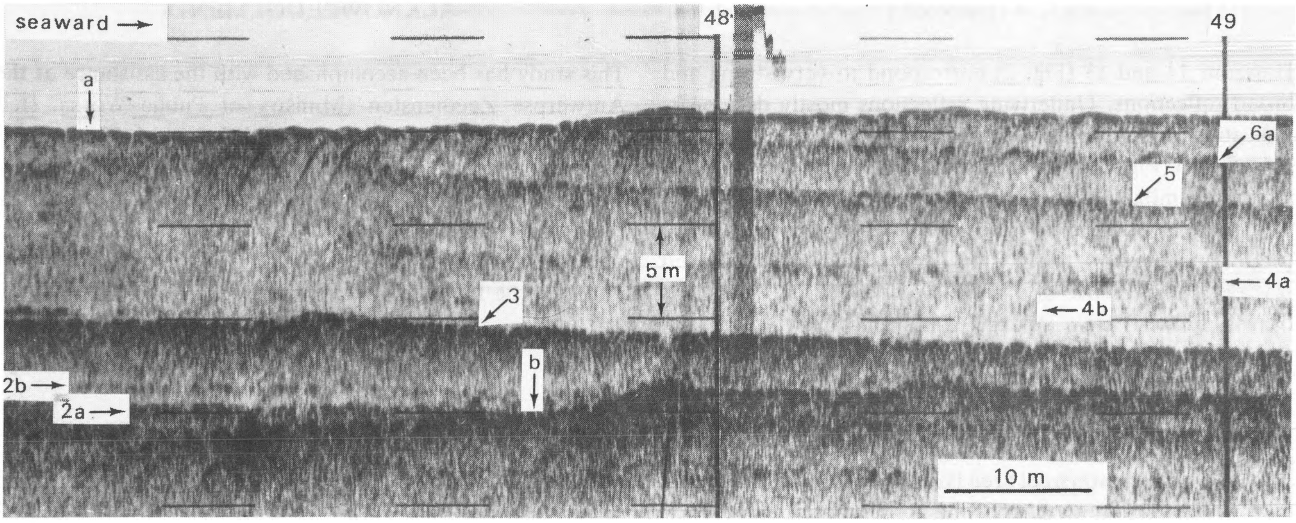

Fig. 9
Subbottom record parallel to the one shown in Fig. 5. Legend see Fig. 8.

MIOCENE AND PLIOCENE

The interpretation of horizons 12 to 16 is only a tentative one. The geology in the Antwerpen area is complicated and lateral correlations between the left and right bank of the Schelde can not always be made with certainty.

(1) Northward of position 26 (Figs. 3 and 4) a 3 to 5 m thick layer discordantly covers the Boom Clay. It correlates with the fine green sands (Edegem Sands: LAGA, 1972) described by HALET (1931) in a boring near position 19 and also observed in a boring 200 m eastward of position 19 (boring 355, Geological Survey of Belgium). It is eroded by sediment-filled gullies (horizons 15 and 16) or by the Schelde (e.g. near position 26 and between position 20 and 13). At other places a recent sediment cover occurs (between position 25 and 23, near position 21).

(2) In the Oosterweel area (Fig. 2) the Miocene deposits are absent and the Boom Clay is covered with Pliocene sands (Kattendijk sands: LAGA, 1972). Horizon 12, and probably also horizon 13, correlate with a gravel and shell layer in the Kattendijk sands (WARTEL, 1978). These sands are eroded by the Schelde (Fig. 2), or are overlain by Quaternary deposits.

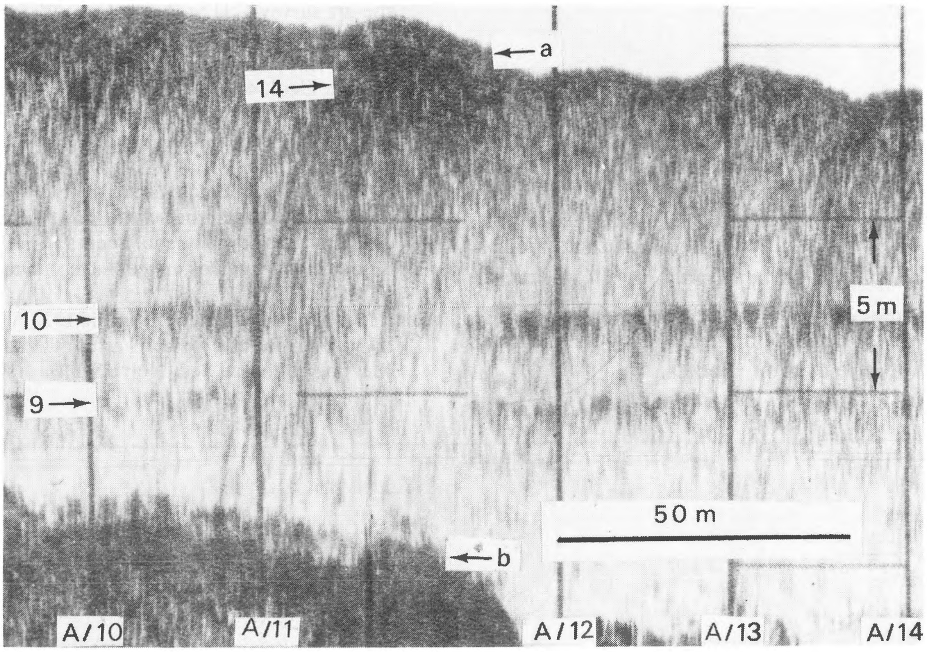

Fig. 10
Subbottom record from the Oosterweel area (Fig. 1) showing a gravel and shell layer (base of Quaternary) (horizon 14) and possibly two septaria layers (Boom Clay) (horizon 9 and 10). Legend see Fig. 8.

QUATERNARY

Horizons 14 and 15 (Fig. 2) correspond to very strong and broad reflections. Underlying reflections mostly disappear, indicating an important absorption of acoustic energy in horizons 14 (Fig. 10) and 15. SAUCIER (1970) and HAYES (1977) attribute similar phenomena to the presence of a relatively thick shell layer. Recently, bottom samples near position 17 (Fig. 2), where horizon 14 is eroded by the Schelde, indeed revealed the presence of a gravel and shell layer. The shells (mostly broken) are a mixture of Pliocene and younger species, typical for the lowermost Quaternary deposit in the Antwerpen area (K. Wouters pers. comm., 1978).

A Quaternary gravel and shell layer is known at a depth of -10 to -12 m from several borings at the right bank of the Schelde in the Oosterweel area (Geological Survey Belgium, map Antwerpen 28 West) and field observations (LAGA, 1972). Horizon 14 can be correlated with this layer. Horizon 15, occurring at almost the same depth, can be considered as the prolongation of horizon 14, although evidence for this is lacking at present. No data for interpreting horizon 16 (Figs. 3 and 4) are available. This horizon probably correlates with horizon 14, although the acoustic reflection character, indicating the presence of irregularly layered sediments, is different. A recent sediment layer, generally less than 1 m thick, is observed in most places, but at some others it is lacking and the Schelde erodes the Quaternary or Tertiary subbottom. This has been corroborated by the analysis of gravels and foraminifera (WARTEL ET AL., 1979). Erosion of the Boom Clay is seen south of Antwerpen. This is illustrated in figure 9: septaria (represented by small hyperbolae) derived from horizon 6a form a lag deposit at the river bottom left of position 48.

CONCLUSIONS

Two conclusions can be drawn from the subbottom survey of the Schelde estuary: (1) the subjacent Tertiary and Quaternary layers are an important source of sediments supplied to the estuary; (2) the top layer of the Boom Clay shows several diapirs and uparching structures related to post-Miocene relaxation of the clay. The scouring action of the Schelde possibly influences this relaxation process.

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