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OLIGOCENE DEPOSITS IN THE REGION NORTH OF TONGEREN (BELGIUM), WITH THE DESCRIPTION OF A NEW LITHOSTRATIGRAPHICAL UNIT: THE ATUATUCA FORMATION

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In this third paper on the stratigraphy of mainly Oligocene deposits in the region North of Tongeren (province of Limburg, Belgium) an east-west cross-section with a length of approximately 4 km situated in the municipality of Tongeren is described. The sedimentary history of the deposits is discussed, summarizing the results of the two earlier papers. A new lithostratigraphical unit, the Atuatuca Formation, is introduced. This formation comprises the Henis Clay and the Sands and Marls of Oude Biesen as members. The boundary between these members is redefined. The structural geology of the region is briefly discussed.

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Contents:

SAMENVATTING

Een oost-west verlopend profiel van ongeveer 4 km lengte wordt beschreven. Het profiel doorsnijdt oligocene en kwartaire afzettingen direct ten noorden van Tongeren (provincie Limburg, België). Het omvat (zie fig. 1) de ontsluitingen Galgeberg en groeve Francart. Aangetroffen werden de Zanden van Neerrepen, Klei van Henis, Zanden en Mergels van Oude Biezen, Zanden van Berg en niet nader gedefinieerde kwartaire afzettingen. De afzettingen (fig. 2) hellen in westelijke richting, de helling wordt in het westelijk deel van het profiel eenmaal onderbroken door een breuk.

De Klei van Henis en de Zanden en Mergels van Oude Biezen konden goed bestudeerd worden in de kleigroeve Francart en in een tijdelijke ontsluiting (bouwput) aan de Bilzerbaan te Tongeren (T 1, zie fig. 1). De molluskenfauna uit beide afzettingen wijst op een milieu met sterke schommelingen in het zoutgehalte (euryhalien). In dit milieu zijn beide afzettingen als onderdeel van één sedimentatiecyclus gesedimenteerd. In het onderzochte profiel vinden we (oudste afzetting onder):

- Afwisseling van klei- en zandafzettingen. Mollusken sterk wisselend, met vooral in de zandafzettingen zeer veel schelpen. In de kleilagen veel goed geconserveerde pollen.
- Vette, harde klei, plaatselijk met mollusken, dikte ca. 3 m. Alleen het bovenste gedeelte met goed geconserveerde pollen.
- Zand of kleiig zand, waarin vele geulen, duidend op getijdewerking. Plaatselijk met veel schelpen in de geulen, plaatselijk met kleibrokken. Tussen het zand kunnen kleibanden voorkomen, waarin geen pollen werd aangetroffen. Dikte maximaal 2 m.
- Vette, harde klei, zonder pollen, met plaatselijk pyriet en gips en soms enkele mollusken, dikte tot ca. 5 m. Deze klei is vermoedelijk afgezet in een nagenoeg afgesloten kustmeer of lagune.

De molluskenfauna's zijn steeds individuenrijk, maar soortenarm. Voor deze gehele sedimentatie-cyclus wordt de naam Atuatuca Formatie ingevoerd, waarvan de Klei van Henis en de Zanden en Mergels van Oude Biezen "members" zijn. De grens tussen deze beide afzettingen wordt opnieuw gedefinieerd, waarbij alleen het onderste kleipakket tot de Klei van Henis wordt gerekend. De overige sedimenten behoren tot de Zanden en Mergels van Oude Biezen.

De Atuatuca Formatie wordt van onder begrensd door de Zanden van Neerrepen. De bovengrens wordt gevormd door de Zanden van Berg, die de top van het pakket in wisselende mate geërodeerd hebben.

Een schematisch overzicht (fig. 4a-b) geeft aan, hoe beginnend met de afzetting van de Henisklei de midden-oligocene sedimenten zich in het gebied ten noorden van Tongeren ontwikkeld hebben. Hierin werden tevens gegevens van eerdere publicaties (Van Hinsbergh et al., 1973; Cadée et al., 1976) verwerkt. De opvattingen van deze beide publicaties zijn hier en daar door nieuwe gegevens achterhaald.

"U zal zich allemaal afvragen hoe het zo gekomen is, ..."

(Wim Sonneveld als "Frater Venantius", Grand Gala du Disque, Scheveningen, 12 oktober 1963)

INTRODUCTION

This paper is the third in a series of publications on the stratigraphy of Tertiary (mainly Oligocene) and Quaternary deposits in the northern part of the Tongeren region, province of Limburg, Belgium.

The first paper (van Hinsbergh et al., 1973) described a cross-section of approximately 2 km, situated in an east-west direction in the municipality of Spouwen. The second publication (Cadée et al., 1976) dealt with a cross-section of about 9 km in a north-south direction, situated in the municipalities of Waltwilder, Martenslinde, Spouwen, Elderen and Tongeren. These papers gave descriptions of the sediments and an interpretation of the stratigraphy.

As both papers have been written in Dutch, the present paper will summarize the most important data. Besides, a third cross-section situated in an east-west direction within the municipality of Tongeren will be described here. The progressing investigation revealed so many new facts that we sometimes had to change interpretations of the two earlier papers.

A critical examination of the collected data resulted in the introduction of a new lithostratigraphical unit, the Atuatuca Formation, comprising the Henis Clay and the Sands and Marls of Oude Biesen as members. The boundary between these two members had to be redefined in this paper.

The fieldwork for each of the three papers was done by members of the Werkgroep voor Tertiaire en Kwartaire Geologie (W.T.K.G.), during field camps in the years 1972-1976. It is the intention that the W.T.K.G. will continue this investigation in a more westerly direction.

The hilly landscape of the area provides good opportunities for an investigation of the Cenozoic deposits with the help of such simple instruments as an auger and a spade. On the other hand the data collected in this way can only be evaluated if the altimetric positions are exactly known. Fortunately we could rely on the professional skill of a surveyor.

The Oligocene deposits in the Tongeren area have been known for a long time and many papers are dealing with the description of these sediments and their fossil content. Glibert & de Heinzelin (1954) summarized the knowledge of the so-called "Tongrien" and gave descriptions of the mollusc faunas. For a survey of the older literature we refer to that publication.

Although the general stratigraphy of the Oligocene deposits is fairly well known, detailed sections are hardly available. In our opinion the important palaeontological collections brought together from these deposits justified a detailed investigation, enabling a better interpretation of the depositional circumstances.

ACKNOWLEDGEMENTS

Many members of the W.T.K.G. joined the field-work, among them we want to mention especially Messrs. E. C. Kruissink (Delft), F. Maatman (Geldrop) and L. M. B. Vaessen (Breda).

We are very grateful to Mr A. C. Janse (Brielle) for levelling the various localities. Without his skilful help these papers could not have been written.

We like to thank the governments of the municipalities and the land-owners, who gave permission for the field-work on their properties. Especially Senator F. Vangronsveld, burgomaster of the municipality of Spouwen, was very helpful. We are much obliged to the management of the Francart Brickworks at Tongeren, who allowed our frequent visits to the clay-pit.

The Aardkundige Dienst van België (Geological Survey of Belgium) incorporated our sections in the files of the geological map of Belgium and provided us with the official registration numbers. We thank Dr P. Laga (Brussels) for his co-operation.

The investigation was executed in close co-operation with the Rijksmuseum van Geologie en Mineralogie, Leiden, The Netherlands (RGM). All sedimentary samples and lacker peels are stored in the collection of this museum. Mrs R. P. L. Bremer (RGM) investigated many samples on pollen. Mr J. van der Linden (RGM) assisted in constructing a special device for deep auger borings. A description of this device will be published.

Valuable discussions with Dr Ir P. Buurman (Bennekom) concerning geological features visible in the Francart clay-pit greatly influenced our train of thought and are hereby gratefully acknowledged.

Dr C. F. Winkler Prins and Dr H. J. W. G. Schalke (both RGM) were kind enough to read the manuscript. We are much obliged for their help.

METHODS

An auger has been the most important instrument during the field-work. We used an auger of the Edelman type with a diameter of 7 cm and three different heads for clay, sand/clay and sand. The Edelman auger has lengthening pieces of 1 m that are preferably connected by means of a coarse conical screw-thread. We designed a special device for borings over 8 m depth. In this way borings to a depth of more than 12 m could be carried out. The so-called Dachnowsky sampler prooved to be of little value in heavy clays.

The description of the sediments in the borings was made in the field; so colour descriptions always refer to wet, fresh samples. It could not be avoided that the descriptions are subjective to a certain degree because of the fact that they were made by different persons. This, however, gave no discrepancies in the interpretation of the sediments.

Only a few sections have been completely sampled, otherwise occasional

samples were taken for documentation. Several outcrops and borings have been sampled in detail for palynological investigation. Samples are kept in the collection of the RGM. They are available for palaeontological and sedimentological research.

Several deposits yield rich mollusc faunas. The mollusc-faunas containing large quantities of *Pirenella plicata monilifera* (Deshayes), *Tympanotonos labyrinthus* (Nyst), *Melanoides fasciatus* (Sowerby) and/or *Polymesoda convexa* (Brongniart), should in our opinion be considered as euryhaline. They do not necessarily indicate brackish environments. Terrestrial influences are indicated by the presence of Planorbidae, Lymnaeidae, *Vertigo* and others.

Fossils were collected from sandy sediments in the field, sometimes by sieving. Several large samples from clayey deposits were washed in the laboratory. In some cases the state of preservation of the fossils requires much experience in preparation. The shells were, bit by bit, cleaned from the adhering sediment with needles and small brushes and subsequently treated with a plastic glue (velpon or collal) diluted in acetone. This preparation technique is very successful, although very time-consuming. In this way however, we succeeded in collecting specimens that otherwise could not have been preserved.

For the altimetric measurements the level-marks enumerated in the Tweede Algemene Waterpassing (1962) of Belgium. The heights were measured with an accuracy of approximately 1 cm.

The construction of cross-sections is based on data collected from borings and outcrops (Cadée et al., 1976, Fig. 2; van Hinsbergh et al., 1973, Fig. 2; see also Fig. 2 of the present paper). The approximate surface-line represented in these sections was drawn by measuring the distances between the isohypses from the topographical map 1 : 25 000. In several cases we noticed differences between the surface-line constructed in this way and the real height obtained by levelling. In the cross-sections borings are indicated by straight vertical lines. For several less important borings that penetrated only Quaternary deposits the height was estimated from the topographical maps.

In the text of this paper we use the field numbers of the borings. The official registration-numbers of the Geological Survey of Belgium can be found in Tab. 2.

NOMENCLATURE OF THE LITHOSTRATIGRAPHICAL UNITS

The official denominations of the lithostratigraphical units have been summarized by Glibert & de Heinzelin (1954) and also in the Lexique Stratigraphique International (1957). The originally French denominations have been translated into Dutch and English (see Tab. 1). Usually the Quaternary deposits were not interpreted lithostratigraphically.

Although Glibert & de Heinzelin (1954, p. 310, note 55) reject the indication "argile" for the Glaises de Henis on mineralogical grounds, we use the indications "klei" and "clay" because of the lithological appearance of this sediment. The local name for this deposit is "pot-aarde".

In this paper we introduce the name "Atuatuca Formation". According to

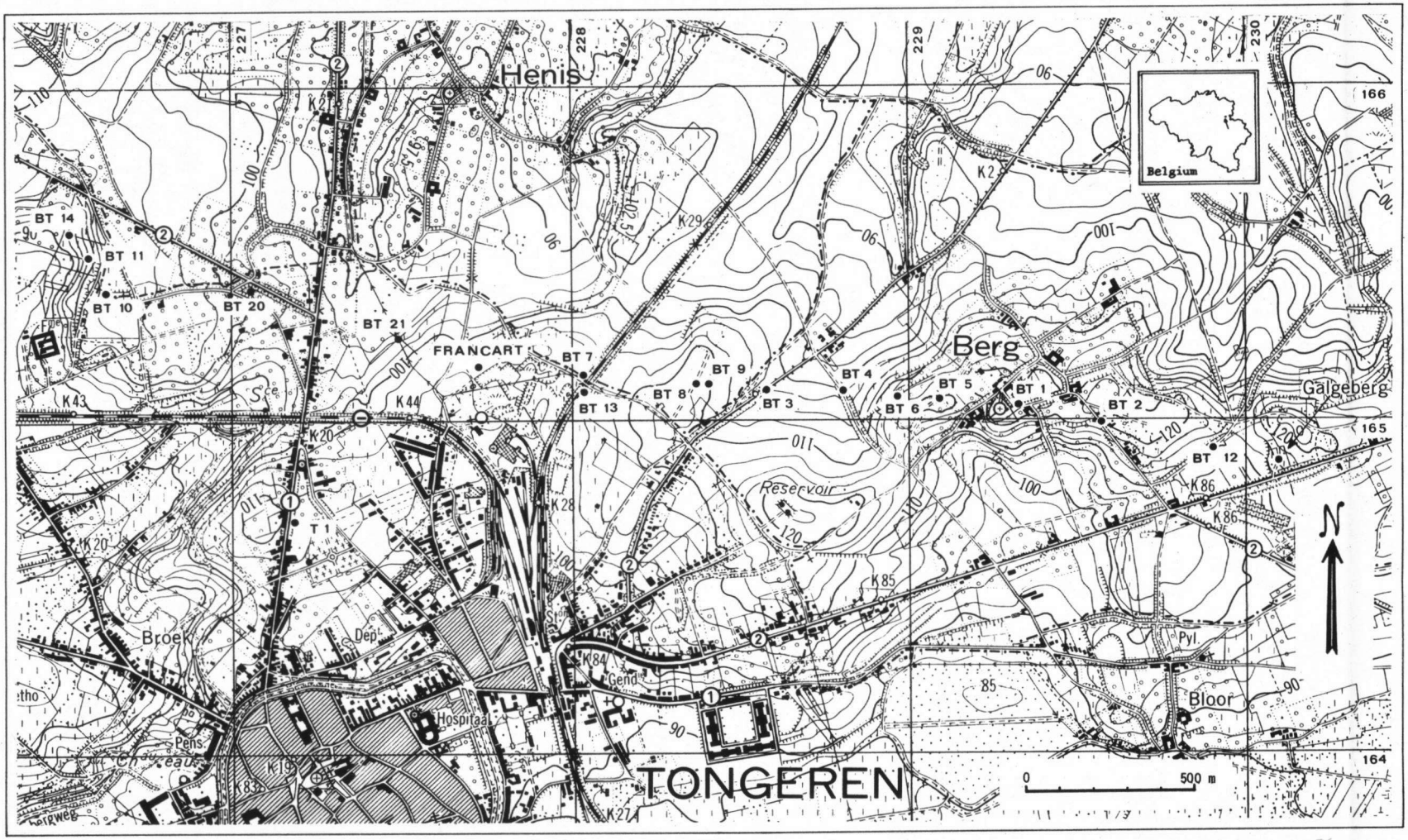


Fig. 1. LOCATION OF BORINGS AND OUTCROPS
used for the construction of the cross-section (Fig. 2), and location of the stratotype of the Atuatuca Formation and the boundary stratotype of the Henis Clay and the Sands and Marls of Oude Biesen (T 1).

LAMBERT CO-ORDINATES (1 KM GRID) HAVE BEEN DRAWN ACCORDING TO MAP-SHEET 34/5

French	English	Dutch
Argile de Boom	Boom Clay	Klei van Boom
Argile sableuse à Nucula comta	Nucula Clay	Nuculaklei
Sables de Bergh	Berg Sands	Zanden van Berg
Sables et Marnes de Vieux Joncs	Sands and Marls of Oude Biesen ')	Zanden en Mergels van Oude Biesen ')
Glaises de Henis (Glaise verte de Henis)	Henis Clay	Klei van Henis
Sables de Neerrepen	Neerrepen Sands	Zanden van Neerrepen
Sables de Grimmertingen	Grimmertingen Sands	Zanden van Grimmertingen.

Tab. 1. Translation of lithostratigraphical denominations.

Julius Caesar in his "De Bello Gallico" (Hondius & Schuursma, 1970, p. 122) Atuatuca (Atuatuca Tungrorum, the present Tongeren) was a fortress of the Eburonians reconquered by Ambiorix (see front-cover) from the Roman occupation in the year 54 B.C. We choose this name because the name Tongeren (French: Tongres) has been used already in stratigraphy ("Tongrien", a stage name in the Oligocene).

DESCRIPTION OF THE SEDIMENTS IN AN EAST-WEST CROSS-SECTION NORTH OF TONGEREN

Fig. 1 gives a survey of borings and outcrops that were used for the construction of the cross-section represented in Fig. 2. The section has a length of approximately 4 km. It is entirely situated within the municipality of Tongeren, in which the former municipalities Henis and Berg are now incorporated.

Van Hinsbergh et al. (1973) and Cadée et al. (1976) gave rather extensive descriptions of the sediments, so only supplementary data will be given here. A general discussion of the Oligocene and Quaternary deposits of the northern part of the Tongeren region can be found in the next chapter in stratigraphical order.

Grimmertingen Sands

The Grimmertingen Sands have not been encountered during the field-work for this cross-section. Their presence in the eastern part of the section (Galgeberg area) has been deduced from the cross-section given by Cadée et al. (1976, Fig. 2). The boundary between the Grimmertingen Sands and the Neerrepen Sands was defined in

') The frequently used spelling "Oude Biezen" is incorrect. We use the Dutch denomination for this locality, because of the fact that it is situated in the Dutch speaking part of Belgium. Also the name "Alde Biesen" is used for this locality.

that section by the occurrence of ghost structures of shells and the absence of sedimentary structures in the top of the Grimmertingen Sands. In the meantime, however, ghost structures of shells have been found in the basal part of the Neerrepen Sands in the neighbourhood of Valkenburg, Limburg, The Netherlands, at a distance of only some 25 km from the Galgeberg area (Buurman & Langeraar, 1975). Therefore only the lack of sedimentary structures remains as an arguement for this boundary. For this reason the boundary between the Grimmertingen and Neerrepen Sands will hardly ever be recognized in borings. Petrological studies of sediment samples from the two deposits neither gave a solution for this boundary (Glibert & de Heinzelin, 1954, p. 308, note 51).

Neerrepen Sands

The Neerrepen Sands have been encountered in the borings Galgeberg, BT 6, BT 3, BT 9, BT 13, BT 21, and BT 20. Furthermore these sands are visible in the Francart clay-pit. At this place the upper 8.15 m of these sands have been penetrated and sampled by means of an auger boring. The basal part of the Neerrepen Sands and the boundary with the Grimmertingen Sands have been studied in the Swennen sand-pit, approximately 500 m north of our present cross-section (see Cadée et al., 1976, p. 50, Fig. 6). Unfortunately this sand-pit has been closed. The thickness of the Neerrepen Sands can only be deduced from the north-south section as constructed by Cadée et al. At the Galgeberg about 11 m of Neerrepen Sands is present.

In the Francart clay-pit approximately 3 m of the upper part of the Neerrepen Sands is visible. One metre of the sand is excavated together with the clay. Moreover at several places in the bottom of the clay-pit the sand is excavated. So this part of the deposit can be studied here rather extensively. The lower part of the visible section of the Neerrepen Sands consists of micaceous quartz sand of a greyish or greenish colour. The sand shows frequently parallel lamination and only very little cross-bedding. Burrows have not been found. On top of the sand with parallel lamination the sand becomes somewhat clayey and darker greenish in colour. The top of the cleyey sand shows in vertical sections many wedge shaped structures, filled with whitish fine quartz sand. Especially the wedges show brown and yellow colouring, respectively caused by the presence of goethite and jarosite. On a clean horizontal surface the wedges show a vague polygonal structure. This part of the section (see Figs. 16 - 17) is covered with the same fine whitish quartz sand that is also present in the wedges. This sand does not contain sedimentary structures. In this sand a very fine fossil soil, the "Neerrepen Soil", is found that can be recognised by the presence of two brownish violet levels. This soil was the subject of a pedological investigation by Buurman & Jongmans (1975; see also Buurman, 1972). Indications for the presence of this soil were found in the higher parts of the Neerrepen Sands in several borings (BT 6, BT 20, T 1, also some borings of the earlier sections).

In the Francart clay-pit the top of the Neerrepen Sands shows clear joints. They are clearly visible in weathered profiles, mainly below the Neerrepen Soil.

Henis Clay and Sands and Marls of Oude Biesen

Lower clay

On top of the Neerrepen Sands a heavy clay has been deposited. In its basal part this clay can still be somewhat sandy or show very thin alternating sand and

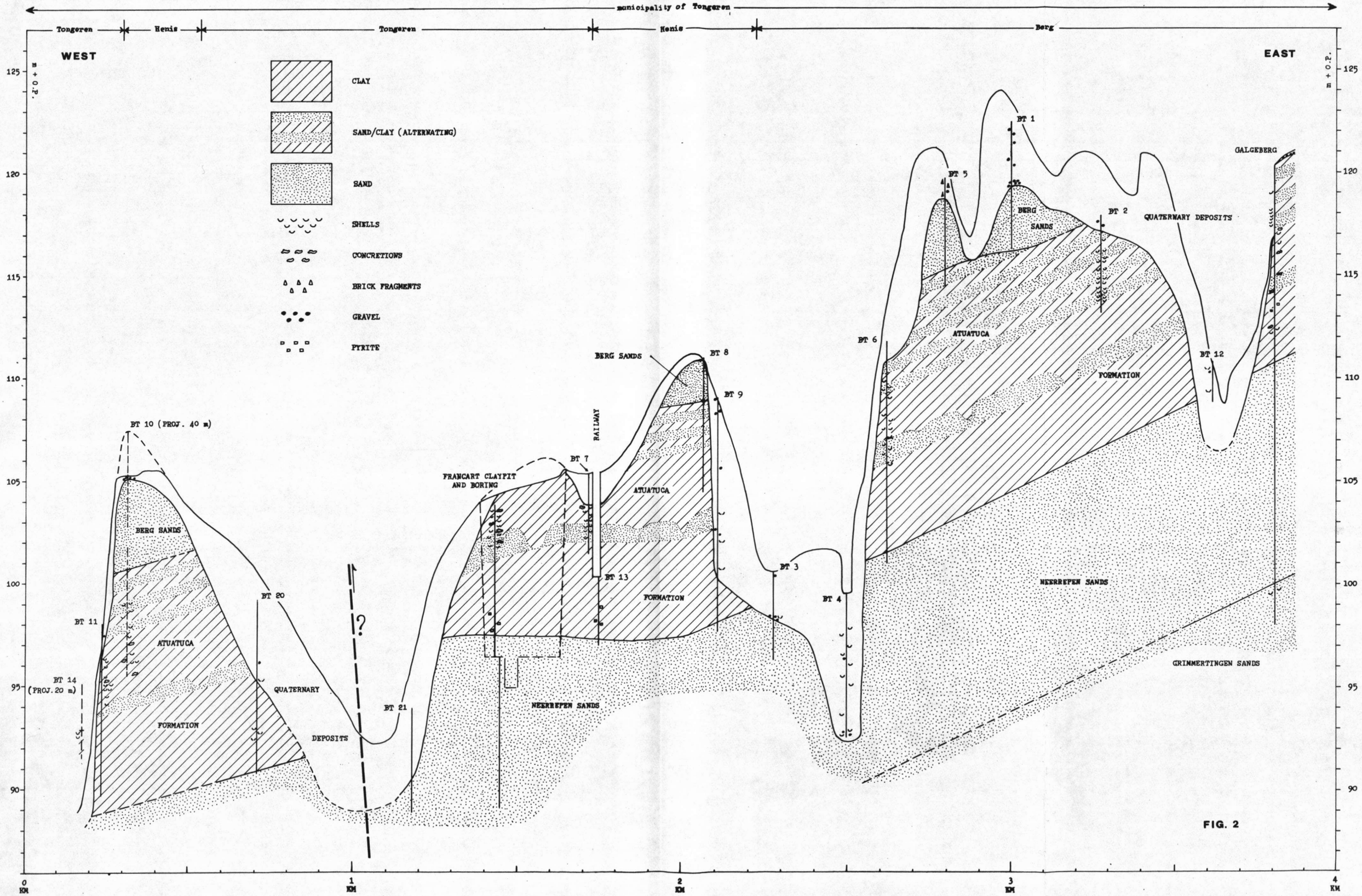

municipality of Tongeren
Tongeren
Henis
Tongeren
Henis
Berg
WEST
EAST
m + O.P.
125
120
115
110
105
100
95
90
CLAY
SAND/CLAY (ALTERNATING)
SAND
SHELLS
CONCRETIONS
BRICK FRAGMENTS
GRAVEL
PYRITE
BT 10 (PROJ. 40 m)
BERG SANDS
BT 11
ATUATUCA
BT 14
(PROJ. 20 m)
FORMATION
BT 20
QUATERNARY
DEPOSITS
?
BT 21
FRANCART CLAYPIT
AND BORING
BT 7
BERG SANDS
BT 8
BT 9
RAILWAY
ATUATUCA
BT 13
FORMATION
NEERREFEN SANDS
BT 1
BT 5
BERG
SANDS
BT 2
QUATERNARY DEPOSITS
BT 6
ATUATUCA
FORMATION
BT 12
BT 3
BT 4
GALGEBERG
NEERREFEN SANDS
GRINMERTINGEN SANDS
0
KM
1
KM
2
KM
3
KM
4
KM

FIG. 2

FILE NR. GEOL. SURV. OF BELGIUM	FIELD NR.	LAMBERT CO-ORD. X	Y	LOCALITY	SURFACE m + O.P.	DATE	DEPTH in m
107 W 92 (1)	Galgeberg	230 100	164 900	Berg	120.23	1.8.1972 8/9.7.1973	10.15
107 W 239 (IIc)	BT 12	229 920	164 920	Berg	110.82	17.8.1974	1.95
107 W 232 (IIc)	BT 2	229 580	164 990	Berg	117.91	9.7.1974	4.75
107 W 100 (1)(IIc)	BT 1	229 340	165 040	Berg	122.45	8.7.1974	6.15
107 W 106 (1)(IIc)	BT 5	229 130	165 080	Berg	119.76	9.7.1974 2.8.1976	5.25
107 W 235 (IIc)	BT 6	228 960	165 080	Berg	111.78	11/12.7.1974	10.75
107 W 234 (IIc)	BT 4	228 820	165 090	Berg	99.55	9.7.1974	7.00
107 W 233 (Id)	BT 3	228 590	165 100	Berg	100.62	9.7.1974	4.25
107 W 236 (1)(Id)	BT 9	228 430	165 120	Henis	109.10	11.7.1974	11.35
107 W 236 (Id)	BT 8	228 390	165 120	Henis	111.00	11.7.1974 1.8.1976	6.70
107 W 194 (2)(Id)	BT 13	228 050	165 080	Tongeren	100.36	17.8.1974	3.25
107 W 194 (1)(Id)	BT 7	228 050	165 140	Henis	105.37	11.7.1974	3.90
107 W 195 (1)(2)	Francart clay-pit	227 750	165 170	Tongeren	103.88	4/10.7.1973	14.20
	BT 21	227 210	165 100	Tongeren	94.02	8/12.7.1975	5.05
	BT 20	227 030	165 160	Tongeren	99.24	8/12.7.1975	8.40
107 W 237 (Ic)	BT 10	226 640	165 390	Henis	107.43	15.7.1974	10.85
107 W 13 (1)(Ic)	BT 11	226 590	165 500	Tongeren	98.00	17.7.1974	8.25
107 W 238 Ic)	BT 14	226 540	165 560	Tongeren	95.12	18.8.1974	3.50
107 W 116 (1)(IVa)	T 1	227 190	164 700	Tongeren	109.16	15/17.7.1974	12.95

Tab. 2. Enumeration of locality data of borings and outcrops used in this paper. See also Fig. 1

clay layers. Nevertheless the boundary with the Neerrepen Sands is a clear disconformity. The basal part of the clay may show rusty coloured spots, mainly in cracks and sandy streaks.

The colour of the clay is a very characteristic blue, with variations from lead-grey to sea-green. In the Francart clay-pit the clay shows a clear change in colour, the basal part being darker than the upper part. The thickness of the clay reaches a little more than 4 m. In the Francart clay-pit the clay is somewhat less thick, especially in the western part.

Regularly a dark brown to blackish horizon is found in the upper part of the clay. This dark horizon is found up to one metre below the top of the clay. In the Francart clay-pit a dark horizon is present about 10 cm below the top of the lower clay, here it closely accompanies the not quite horizontal upper surface of the clay.

In the cross-section described here the lower clay is usually not fossiliferous, only at the Galgeberg and in boring BT 20 some shell remnants have been found. Locally the clay contains many pyrite crystals and gypsum. Pollen and spores are absent (Bremer, 1975).

Our cross-section (Fig. 2) shows that in general the base of the clay is straight, with a dip in a westerly direction. In the Francart clay-pit and in boring BT 13 the base of the clay does not follow this general tendency. In the Francart clay-pit the base of the clay lies approximately 3 m higher than could be expected.

Sandy deposit

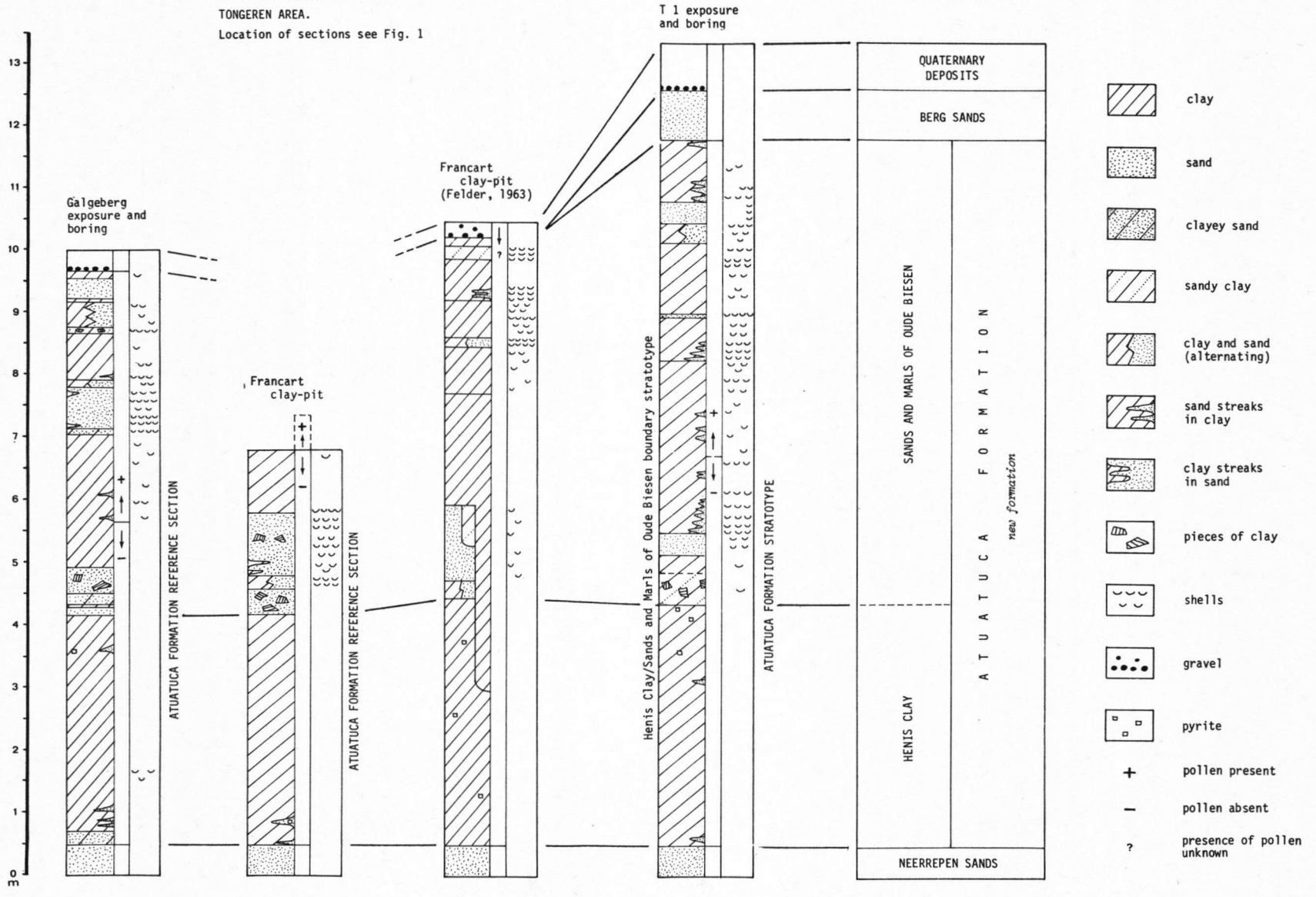
On top of the lower clay rather fine sands of clayey sands have been laid down. The colour of this sand is usually bluish grey, with variations to greenish grey. Their thickness may reach approximately 2 m. Occasionally the lower part of this sand contains small pieces of clay (Galgeberg, Francart section and T 1, see appendix and Fig. 3). This sandy deposit is usually fossiliferous, especially in its upper part. It contains an euryhaline mollusc fauna.

In the Francart clay-pit the sandy deposit is well developed and reaches its maximal thickness. The deposit has been visible here for a long time and we have studied it for five successive years. It has been observed that the sandy deposit contains many gullies (compare Fig. 4a and 4b, deposit "c"). Most of these are filled with sand, sometimes with alternating sand and clay layers. Especially in the sand-filled gullies the mollusc content can be considerable. Once a tooth of the shark *Odontaspis cuspidata* (Agassiz) was found (collection van Hinsbergh, identified by Mr M. van den Bosch, RGM). Locally however, the sandy deposits can be completely unfossiliferous. Some of the gullies are filled with the overlying clay. Felder (1963) described such a gully that cuts through the sand into the lower clay to a depth of 1.50 m. The sandy deposit nor the intercalating clay layers contain pollen (Bremer, 1975).

Upper clay

On top of the sandy deposits described above a heavy clay is found, that varies considerably in colour: light greyish blue, sea-green to olive-green or brownish. Sometimes dark brown to blackish horizons of some 10 cm are present. They are

FIG. 3. LITHOLOGY AND CORRELATION OF SOME SECTIONS IN THE TONGEREN AREA.
Location of sections see Fig. 1



only locally developed and not quite horizontal, they anastomize. In this upper clay an euryhaline mollusc fauna is found. Regularly very thin sand layers are encountered containing many tiny molluscs. Also many calcareous concretions are present, yellowish grey in colour, sometimes containing euryhaline mollusc shells. Sometimes they occur isolated in the clay, but more frequently they are found in horizontal levels (Galgeberg, Francart clay-pit).

Only the uppermost part of this clay contains pollen grains (Bremer, 1975), the lowermost part being barren or yielding some badly preserved pollen grains. The thickness of the upper clay deposit is about 3 m, it can be considerably more in the clay-filled gullies.

Alternating sand and clay deposits

The upper clay is overlain by a succession of alternating sand and clay layers, which may reach a thickness of some 5 m at Berg (Tongeren). At other places this sedimentary complex has a thickness of approximately 3 m only. The clay layers consist of heavy, sometimes crumbling clays. Their colour may vary from bluish grey to brownish black. They contain many well-preserved pollen grains. Sometimes an euryhaline mollusc fauna is encountered in this complex. In the more sandy parts of it molluscs can be so abundant that they occur as crags (e.g. in the Galgeberg exposure) Among the molluscs several terrestrial forms are regularly found. The mollusc content of one bed may show considerable variations over short distances.

The grain size of the sandy parts in this succession varies from rather coarse to rather fine. Sometimes the sand is clayey. The colour of these sands range from pure white, through yellow to reddish brown. Concretions and thin sandstone lenses may occasionally occur.

The succession of sand and clay layers shows considerable differences from point to point. It has not been possible to correlate this sequence in detail, not even over short distances. In the Galgeberg outcrop cross bedding was observed.

Berg Sands

At three places (see Fig. 2) of the present cross-section sediments were found that we consider to belong to the Berg Sands, although they show differences when compared to the Berg Sands at other localities.

The deposit consists of rather coarse, greyish white quartz sand, that can change into reddish brown occasionally. Upwards the grain size decreases to rather fine. Locally clayey intercalations are found in the sand, which is rather unusual for the Berg Sands.

Cadée et al. (1976, Fig. 2) described the occurrence of Berg Sands in the upper part of the Galgeberg section. A re-examination of these sediments, however, revealed that this part of the section does not belong to the Berg Sands as it is overlain by a clay layer containing euryhaline molluscs.

In contrast to other localities the Berg Sands in the present cross-section are not fossiliferous. It can hardly be accepted that molluscs have disappeared by

decalcification of the sand, because no ghost structures of shells could be found, not even in the rather extensive outcrop of the Berg Sands near boring BT 10.

The maximal thickness of the Berg Sands in the present section is about 3.50 m. By the absence of fossils it has been impossible, of course, to distinguish between the two biostratigraphical horizons known from the Berg Sands.

The Berg Sands have also been found in the section of the T 1 construction-pit, where they reach a thickness of only 0.80 m (see appendix).

Nucula Clay and Boom Clay

In the present cross-section no Nucula Clay nor Boom Clay have been observed. These sediments can be found, however, within a distance of approximately 4 km in a northern and north-westerly direction.

Quaternary deposits

On top of the Berg Sands a greyish brown silty sediment is found, that in its basal part is somewhat more sandy and contains a very compact basal conglomerate of flint pebbles, that caused us much trouble to penetrate it with the auger. The maximal thickness of this gravel was about 0.50 m (boring BT 1). It was also encountered on top of the Berg Sands in the T 1 exposure. The silty sediment looks very much like loess and we consider it as a Quaternary deposit in situ.

At many other places the Quaternary deposits overlay sediments older than Berg Sands or Nucula Clay. In such cases the basal conglomerate is usually absent, the sediment contains isolated flint pebbles and fragments and also reworked Tertiary molluscs are frequently found, especially in the basal parts. We consider this sediment as a valley fill, occurring in Quaternary erosion valleys.

GENERAL REMARKS AND DISCUSSION ON THE GEOLOGY OF THE CENOZOIC DEPOSITS IN THE REGION NORTH OF TONGEREN

Grimmertingen Sands

Winkelmolen (1972) devided the Grimmertingen Sands into a "Grimmertingen upper sandy member", a "Grimmertingen clayey fine sandy member" and a "Grimmertingen lower sandy member". The "Grimmertingen upper sandy member" represents in our opinion typical Neerrepen Sands. As far as we know only the "Grimmertingen clayey fine sandy member" has been observed during our investigation. Apart from borings the Grimmertingen Sands could be studied in several outcrops and pits (Grimmertingen type locality near Vliermaal, Broek near Hoesselt, Grote Spouwen, Membruggen sand-pit, Swennen sand-pit at Berg near Tongeren and in the temporary exposure Galgeberg-zuid). The deposits consist of fine, slightly clayey and glauconitic sand in which no primary

sedimentary structures occur due to intense post-sedimentary burrowing. The colour of the sediment is usually yellowish brown to brownish green. Frequently the sand shows reddish brown colouring as a result of oxidation processes.

The Grimmertingen Sands are only sporadically fossiliferous. They contain a mollusc fauna of marine environment, but deposited in rather shallow water. Famous localities are the Grimmertingen type locality near Vliermaal and Broek near Hoeselt. The locality of Leten (or Lethen) near Bilzen has not yet been rediscovered. The fossils are always to a certain degree decalcified, necessitating an improved preparation technique. At other places the sands are barren or (Galgeberg-zuid) showing ghost structures of shells, indicating a total decalcification of the sediment.

The maximal thickness of the Grimmertingen Sands observed by us (Swennen sand-pit) was about 8 m. We had no opportunity to observe the basal part of this deposit. According to the Lexique stratigraphique international (1957, p. 84) the thickness of the Grimmertingen Sands may reach some 20 m.

The boundary with the overlying Neerrepen Sands is a disconformity at all places where it could be observed over some distance, so an unknown part of the sands may have been removed by erosion. At Grote Spouwen (Weert) the top of the Grimmertingen Sands is developed as a hardground (Cadée et al., 1976, Fig. 3).

Together with the Neerrepen Sands, the Valkenburg Deposit and the Grimmertingen Sands make up the Grimmertingen Formation.

Neerrepen Sands

The Neerrepen Sands form a sedimentary complex consisting of fine to rather fine, glauconitic and micaceous sands. The colour varies from pure white and yellowish grey to green. In the basal part of the deposit usually one or two clay levels are found, each consisting of several thin, heavy clay layers. In abandoned sand-pits these clayey horizons are clearly visible, because they are overgrown earlier and more intensively by vegetation.

Characteristic for the Neerrepen Sands are the sedimentary structures. In the basal part frequently cross-bedding and small channel-fillings are present, the higher part does show a distinct parallel lamination and scarcely cross-bedding. Small burrows are mainly found in the basal part of the sands, concentrated in levels. Once we observed in the Membruggen sand-pit a rather thick, vertical burrow, penetrating the Grimmertingen/Neerrepen boundary (lacker peel in the RGM collection; see Cadée et al., 1976, p. 43, Fig. 5).

In the region investigated by us the Neerrepen Sands are always unfossiliferous. Near Valkenburg (Limburg, The Netherlands) the basal part of the Neerrepen Sands contains identifiable ghost structures of shells (see Buurman & Langeraar, 1975, p. 110). Glibert & de Heinzelin (1954) mention two localities of the Neerrepen Sands where ferruginaceous ghost structures of shells have been found.

In the Francart clay-pit the upper part of the Neerrepen Sands is exposed. On top of the sands with distinct parallel laminations a clayey sediment is found,

the top of which shows clearly shrinkage cracks (as described above).

The Neerrepen Sands have been deposited in a shallow marine environment. In a later stage presumably a regression took place, resulting in the deposition of clayey sediments, that arose above sea level by a continuing regression, as is prooved by the occurrence of shrinkage cracks. The cracks are filled with a fine, whitish sand that is also found on top of the clayey deposit. We interprete this as aeolian sand. Presumably low sand dunes have been formed, on which a vegetation has developed, resulting in the accumulation of humic components below the top of the Neerrepen Sands, which is known as "Neerrepen Soil" (Buurman & Jongmans, 1975).

East of the region investigated, in the neighbourhood of Valkenburg in the Dutch province of Limburg subtidal and intertidal sediments are found instead of the upper Neerrepen Sands. They show an abundance of gully systems. They were described by Cadée & Vaessen (1975) and Buurman & Langeraar (1975). The latter authors introduced the name Valkenburg Deposit for these sediments. In the Tongeren area the Valkenburg Deposit has not been encountered.

The boundary with the overlying Henis Clay is a disconformity. The presence of thin sand layers in the basal part of this clay might indicate a slight erosion of the upper Neerrepen Sands.

Henis Clay and Sand and Marls of Oude Biesen (see Fig. 4)

The Henis-Oude Biesen sequence starts with the deposition of a lower clay deposit, as described above. Buurman & Langeraar (1975) suppose a supratidal environment (Dutch: hoogwad) as origin. In our opinion the lower clay deposit has been laid down in a very quiet environment, which was to a high degree isolated from the sea, presumably by a fixed coastal barrier, situated in a westerly direction, most probably somewhere in the region between Leuven and Boutersem (see also Buurman & Langeraar, 1975, Fig. 7). So, the environment was to a high degree comparable with a lagoon or a coastal lake. The thickness of the lower clay (up to somewhat more than 4 m) suggests that depositional circumstances have been constant for rather a long period.

The lack of pollen in this sediment can only be explained by synsedimentary oxidation. Therefore from time to time changes of the water level in the lagoon or coastal lake must have taken place, by which the sediments could dry out. Because no tidal influences may be expexted in an environment with an uninterrupted clay sedimentation we suppose that in this basin evaporation was very strong. A regular supply of sediment can be explained by the flow of replenishing water from the sea.

In such a basin with a high degree of evaporation changes in chloride content and pH will be considerable, which could be an explanation for the very small numbers of molluscan fossils in this clay. In the northern part of the region investigated the mollusc content is higher than more to the south, probably indicating that environmental circumstances were more stationary in the north.

It is obvious from the very fine sediment that hardly any streams from the mainlandwill have debouched into the lagoon, because no sandy intercalations are encountered and because no terrestrial molluscs have been found. Glibert & de Heinze-

EXPLANATION OF FIG. 4a.

1. In a lagoon or coastal lake, separated from open sea by a barrier in the Neerrepen Sands (a), a heavy clay is laid down beyond tidal influence. Because of high evaporation the environment is not suitable for molluscan life, due to large changes in chloride content and pH. Changes in the water level cause complete oxidation of pollen. In this clay, the Henis Clay (b), hardly any molluscs and no pollen are found.

2. Increased influence of the sea causes tidal currents and erosion of the coastal barrier. A sandy deposit containing many gullies is laid down upon the Henis Clay, sometimes eroding the top of it. By the increased marine influence environmental circumstances become more stable, which allows the development of an euryhaline mollusc fauna. No pollen are found in these deposits (c).

3. Renewed clay sedimentation that gradually becomes subtidal, pollen are present in the upper part of this clay (d), above the dotted line. Euryhaline molluscs are still present.

4. Deposition of alternating clay and sand, containing pollen and euryhaline molluscs. The sediments (c), (d) and (e) form together the Sands and Marls of Oude Biesen.

(continued in Fig. 4b)

NOT TO SCALE

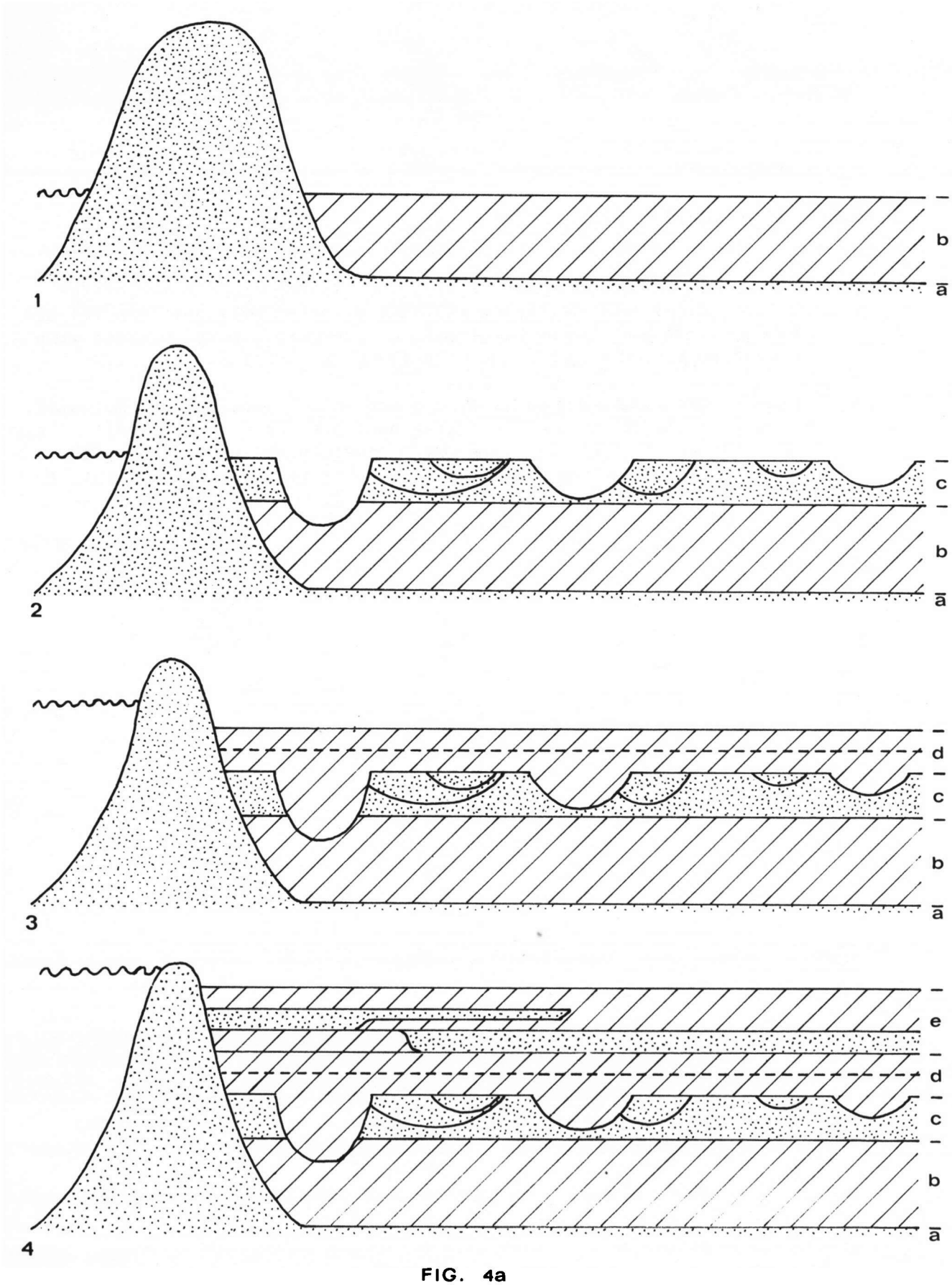


FIG. 4a

EXPLANATION OF FIG. 4b.

5. Transgression of the Berg Sands (f), locally eroding the top of the Sands and Marls of Oude Biesen (e). The reworked molluscs from (e) are abundantly present in the basal part of the Berg Sands, together with a pure marine mollusc fauna in situ (Horizon à Callista kickxi).

6. A further transgressive phase of the Berg Sands concentrates molluscs from higher levels in a compact crag near the top of the deposit. Sandy clay is laid down on top of the Berg Sands: Nucula Clay (g). In the western part of the basin a heavy clay, Boom Clay (g, left part of the scheme) indicates still further transgression.

7. After an erosive phase (not indicated in the scheme) Quaternary deposits with a compact basal gravel (h) are sedimented. Erosion during Late Pleistocene and Holocene times accentuates the hilly landscape.

NOT TO SCALE

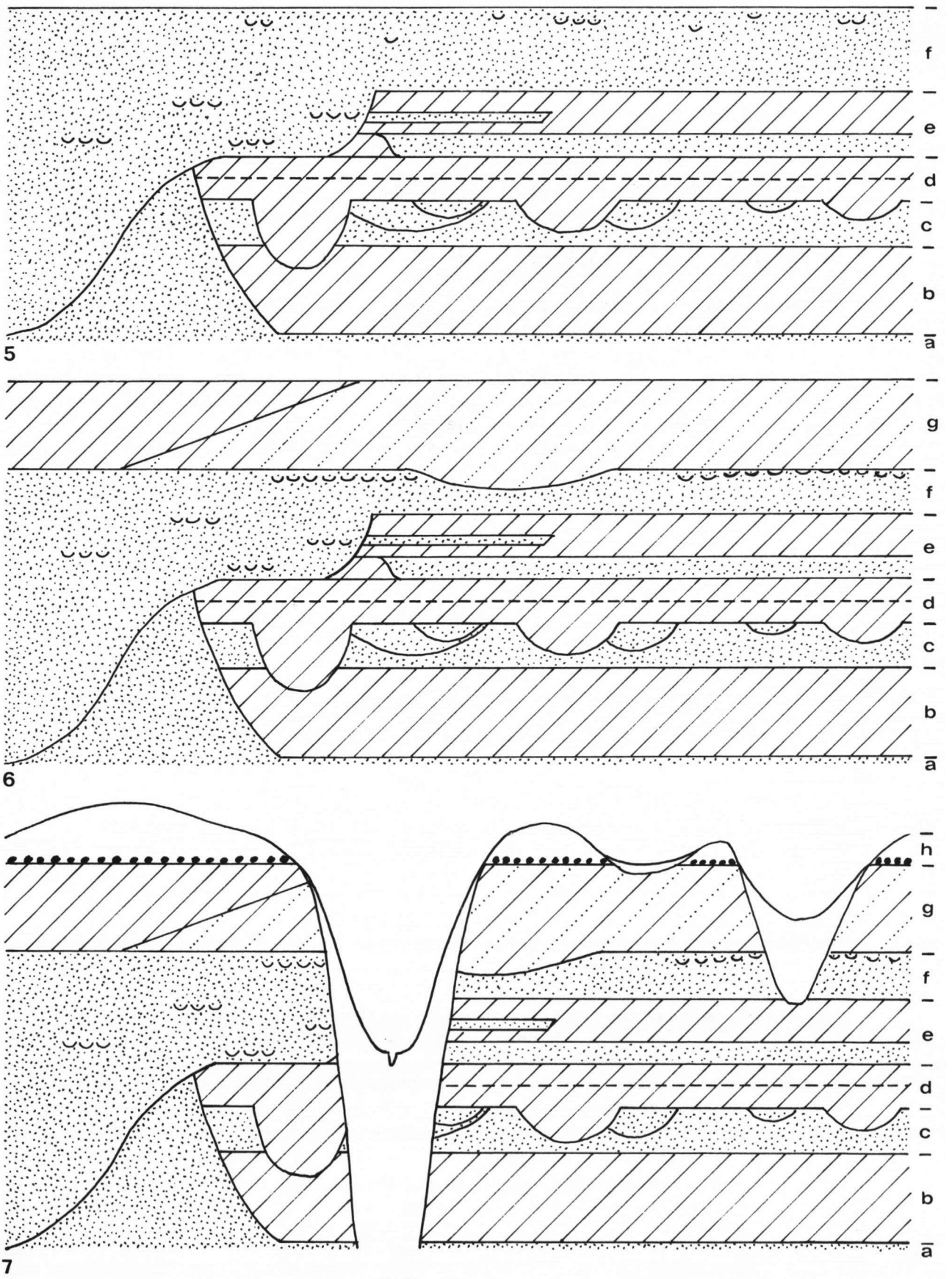


FIG. 4b

lin (1954, p. 387) mention the gastropods *Lymnaea acutilabris* Sandberger and especially *Planorbis schultzianus* (Dunker) from the Henis Clay of Grote Spouwen. From their description of the locality (p. 302) it is not clear from which stratigraphic level these species have been collected.

On top of the lower clay deposit sandy layers are found, suggesting an increased influence of the sea. Frequent gullies demonstrate that these sands have been laid down intertidally. Obviously a rise of the sea level took place as a result of which the coastal barrier was attacked which may have provided the sand. Most of the gullies are filled with sands or with alternating sand and clay layers. The basal deposits in the gullies frequently contain small pieces of reworked clay that could also be recognized in several borings.

The sandy deposit, especially its upper part, contains many euryhaline molluscs. Among these no terrestrial species occur. Compared to the fauna of the lower clay the mollusc fauna is abundant, especially the number of individuals, but also the nmber of species has increased. Apparently the extreme variations in the chloride content and pH have been smoothed out by the increased marine influence.

After the deposition of the sand tidal influence decreases and again the sediment becoms clayey. Remaining gullies in the sandy deposit are filled with clay. Sometimes the upper clay is found immediately upon the lower clay, in cases where deep gullies have eroded the top of the lower clay. In the northern part of the area investigated (Spouwen region) the sandy deposits have hardly ever been encountered. In our opinion the sandy deposits have been eroded here almost completely, as a result of which the upper clay is found directly on the lower clay. This might indicate a more important influence of tides. Most probably the connection to open sea was situated in a more northern direction. This agrees with the observation that molluscs of the lower clay deposits are more abundant in the north than in the south.

The sudden appearance of pollen and spores near the top of the upper clay indicates a continuing rise of the sea level, by which the sediment becomes permanently inundated, thus preventing oxidation of the pollen.

After the deposition of the upper clay alternating sandy and clayey sediments point to rapid changes in the environmental circumstances. Especially the sandy layers contain a concentration of molluscs (*Pirenella, Tympanotonos, Melanoides, Polymesoda* and many others). Occasionally mollusc faunas are found in situ. In these sediments terrestrial molluscs are regularly found, indicating a supply of fresh water from the mainland. The clayey parts of the alternating sand and clay layers still contain pollen, therefore sedimentation must have taken place subtidally.

The sequence described here agrees with the Henis Clay and the Sands and Marls of Oude Biesen. Unfortunately the boundary between these two members is ill-defined in literature (see Lexique stratigraphique international, 1957, p. 89 and p. 199). From descriptions of both members in Glibert & de Heinzelin (1954, p. 310 and p. 312) we conclude that their boundary is situated somewhere in the alternating sand and clay deposits. We came to this conclusion due to the fact that Glibert & de Heinzelin (p. 310) mentioned the presence of pollen in the Henis Clay.

The alternation of sand and clay layers differs so strongly locally that the Henis-Oude Biesen boundary defined in this way can not be recognised. Moreover a direct comparison with type sections is not possible, because adequate stratotypes have never been designated.

We think it convenient to redefine the boundary between the Henis Clay and the Sands and Marls of Oude Biesen at a more adequate level, for which we have chosen the upper boundary of the lower clay deposit. Here a sudden change in the environmental circumstances has taken place. As boundary-stratotype we designate our T 1 section (see appendix). In this section the boundary is situated at 9.00 m below surface.

It is obvious from this discussion that the Henis Clay and the Sands and Marls of Oude Biesen belong to one and the same sedimentary cycle. Therefore, and because of the more practical fact that both members cannot always be separated in borings (e.g. Spouwen region) we introduce here the Atuatuca Formation, comprising the Henis Clay and the Sands and Marls of Oude Biesen as members. As stratotype we designate the part of 1.55 to 12.85 m below surface of the T 1 section at Tongeren. For a detailed description of this new formation see appendix. In Figs. 4a and 4b a schematical representation of the sediments in the Tongeren area is given, starting with the Henis Clay.

Berg Sands

The Berg Sands represent a marine transgression, attacking the upper part of the Sands and Marls of Oude Biesen (see van Hinsbergh et al., 1973, Fig. 2, Cadée et al., 1976, Fig. 2. It is not possible to determine the degree of erosion because of the highly variable alternation of beds in the underlying deposit. From the cross-sections cited above it is clear that erosion differs strongly from place to place.

At places where erosion has been considerable the basal deposits of the Berg Sands contain abundantly reworked euryhaline molluscs from the Sands and Marls of Oude Biesen. Among them a pure marine mollusc fauna is present, for which e.g. *Glycymeris obovata* Lamarck, *G. lunulata* (Nyst), *Arctica islandica rotundata* (Agassiz), *Limopsis goldfussi* (Nyst), *Cyclocardia omaliana* (Nyst), *Callista kickxi* (Nyst), *Sigatica hantoniensis* (Solander), *Athleta rathieri* (Hébert) and many other species are characteristic. The fossils occur in irregular pockets in the sand. Several species are found in living position or at least as bivalved specimens, indicating that this fauna is an autochthonous one. Shark-teeth from this level are usually well preserved.

At many places near the top of the Berg Sands a very compact shell accumulation is found, many components of which show clear traces of transport. Apparently a further transgressive phase has concentrated these fossils from sediments formerly present. The fauna in this upper shell concentration, which is a real crag, differs somewhat from the underlying fauna. For instance both *Glycymeris* species become dominant, *Hilberia hoeninghausi* (Defrance), *Astarte propinqua* Goldfuss (= *A. trigonella* Nyst) and several gastropod species are more common here. The lower fauna has in the literature been indicated as "Horizon à Callista kickxi", the upper shell bed as "Horizon à Astarte trigonella".

Typical sections of the Berg Sands can be found at several places near Kleine Spouwen (the deposit has been named after the hamlet Berg in the former municipality of Kleine Spouwen). More to the west, near Vliermaal and Borgloon, Berg Sands are present in which the upper shell bed is absent, although the Nucula Clay covers the Berg Sands. In the southern part of the area investigated mainly thin erosional remains of the Berg Sands are present in which no faunas have been found. Here the Nucula Clay is absent and the Berg Sands are overlain by Quaternary deposits with a distinct basal conglomerate, indicating a considerable erosion.

Regularly the Berg Sands contain isolated blackish, flat, rounded flint pebbles which are very characteristic for these sands.

Nucula Clay

On top of the Berg Sands in the northern part of the area investigated a sandy clay occurs, containing many specimens of the bivalve *Nucula comta* Goldfuss. This clay, the Nucula Clay, is an indication of further transgression. The transition between the Berg Sands and the Nucula Clay is not always sharp, because of the usually very sandy base of the clay. The colour of the clay is usually yellowish brown. In our boring R 3 (see Cadée et al., 1976, Fig. 2) at Bosselaar (municipality of Spouwen) this clay, except for its basal part, was bluish grey to greyish blue in colour, which is rather exceptional in the region north of Tongeren. In the sand-pit Mommen near Vliermaal, where the Nucula Clay is removed in order to exploit the Berg Sands, comparable colours are found. In this pit approximately 5 m of the Nucula Clay is present, in which some large calcareous concretions occur that are very homogeneous and contain some *Nucula* shells. They may reach a thickness of about 50 cm. In Berg (Kleine Spouwen) we found small calcareous concretions that are frequently empty inside.

The typical mollusc species of this clay, *Nucula comta* Goldfuss, is dominant, but many other, mainly small mollusc species occur. The bivalves *Angulus nysti* (Deshayes) and *Nucinella microdus* (Boettger) are regularly found, the latter only in washing residues. Also the gastropod *Turris duchasteli* Nyst and the scaphopod *Dentalium sandbergeri* Deshayes are not uncommon. The fauna of the Nucula Clay still needs a thorough investigation.

The fact that all larger mollusc shells in the Nucula Clay are fractured has to be mentioned here. Entire specimens are very seldomly found. The maximal thickness of the clay in the area of Spouwen is 6.20 m (in the boring R 3, see above).

Boom Clay

In the cross-sections investigated by us the Boom Clay has not been encountered. According to the geological map (symbol R2) this clay occurs in the western and northern part of the area. This sediment indicates a further transgressive phase.

Miocene sediments

In the municipality of Waltwilder rather coarse to coarse quartz sands were found at two localities (Cadée et al., 1976, p. 46, Fig. 2). These sands may be somewhat clayey and occasionally they contain some fine gravel or flint fragments. The colour of these sands is white to orange brown. They did not yield any fossil.

We derived a Miocene age of these sands from the geological map (symbol Bd). We have not paid much attention to these sands, because the investigation of Oligocene deposits was the scope of our study.

Quaternary deposits

In the northern part of the area investigated loess-like sediments with a distinct basal gravel are found on top of the Nucula Clay. More to the south, in the neighbourhood of Tongeren, the same sequence is found on top of the Berg Sands. We consider these sediments as Quaternary deposits in situ.

In the Membruggen sand-pit (see Cadée et al., 1976, Fig. 1) a very thick basal conglomerate is found on top of the Neerrepen Sands. In our opinion a considerable erosive phase must have taken place before these Quaternary deposits were laid down.

Another younger erosive phase accentuated the hilly landscape. Many valleys have consequently been filled with reworked sediments. The presence of brick fragments at sometimes considerable depth (up to 5 m) indicates that this erosion took also place in recent times and is still in progress now.

In the wall of a sunken road west of Kleine Spouwen (Bosselaarstraat, see van Hinsbergh et al., 1973, p. 16, Fig. 2) a heavy, sea-green clay was found on top of the Nucula Clay and below Quaternary deposits in situ. This clay contains a thin basal gravel and has a thickness of about 70 cm. In this clay no macrofossils have been found. We have not yet succeeded in interpreting the stratigraphical position of this deposit.

Structural geology

In the cross-section given by van Hinsbergh et al. (1973, Fig. 2) no faults have been demonstrated. Sediments in this section show a slight dip in a westerly direction. Cadée et al. (1976, Fig. 2) found a clear fault in the northern part of their section, in the municipality of Waltwilder. This fault is also indicated on the geological map. The sediments in their section dip in a northern direction.

In the east-west section described in this paper (see Fig. 2) the existence of a fault must be accepted in the erosion valley west of the Francart clay-pit, because the level of the lower Henis Clay boundary deviates from the general tendency in that section. The existence of this hypothetical fault is supported by the occurrence of microtectonical features in the Francart clay-pit (see appendix). During the search for fossiliferous Grimmertingen Sands at Leten (municipality of Bilzen, some 8.5 km north of the Francart clay-pit) we levelled the lower boundary of the Henis Clay there. Compared to the relative height of other localities in the Spouwen region this boundary is situated some 3 m higher than expected.

The general dip of the strata in the Spouwen region, as measured on the boundary between the Neerrepen Sands and the Henis Clay by Cadée et al. (1976, p. 42) is 0.29°. The tangent of the dip is 0.0051 which results in a difference of height of about 5.10 m in the direction of the dip per km. The deposits strike in a direction of N 60° E.

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APPENDIX

DESCRIPTION OF THE SEDIMENTS IN THE FRANCART CLAY-PIT AT TONGEREN (see Fig. 14)

File number Geological Survey of Belgium: 107W 195 (1) and (2).

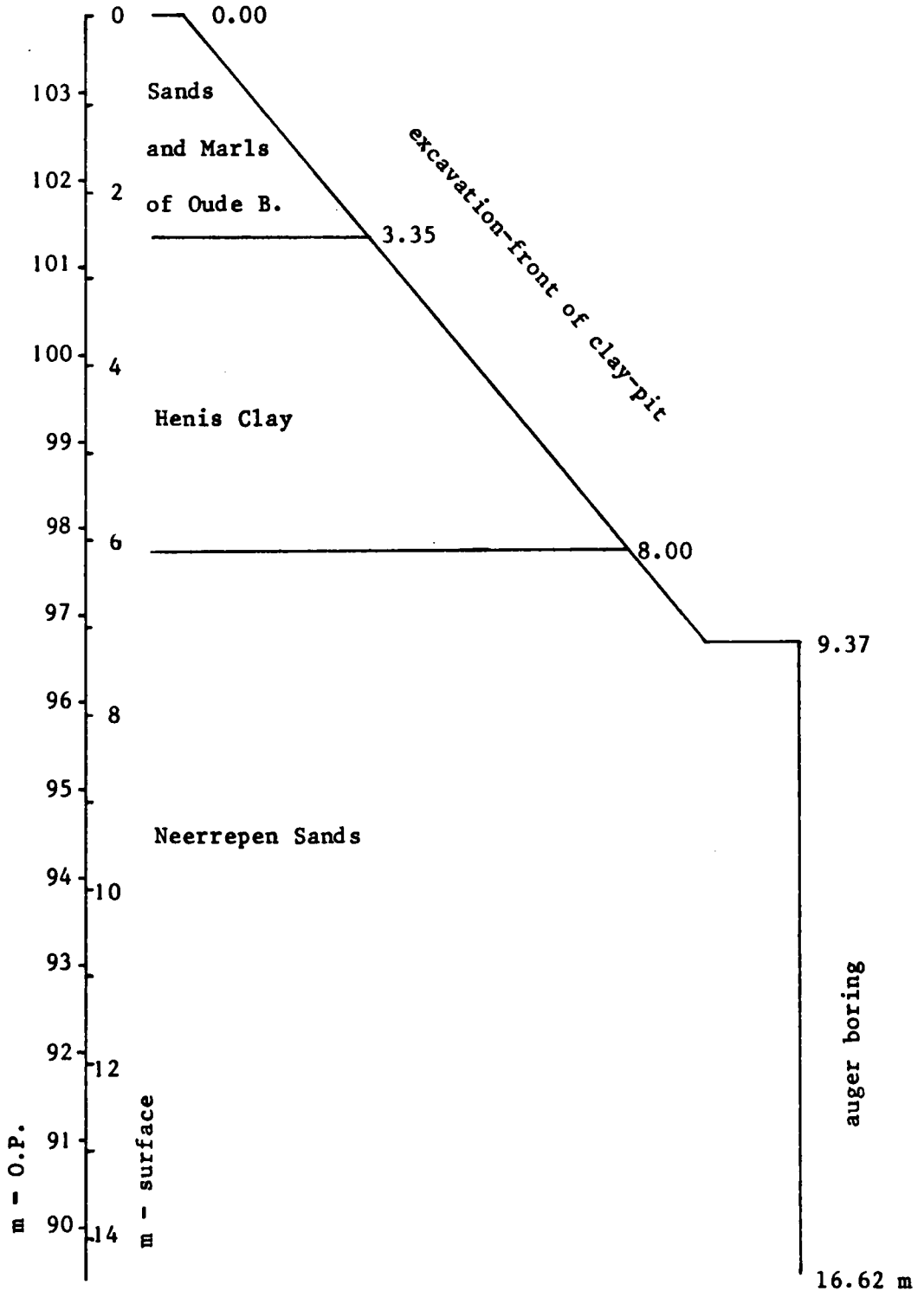
Field number: Francart clay-pit, sections 2 and 3 and boring.
Locality: clay-pit of the Francart Brickworks at Tongeren, about 1225 m north and 475 m east of Tongeren Basilica. Lambert co-ordinates: X = 227 750, Y = 165 170. Province of Limburg, Belgium. Map-sheet 34/5-6 of the Kaart van België, 1:25 000.
Date: July 1973.
Surface level: 103.88 m + O.P.
Levelling: A. C. Janse (Brielle), 28-29 July 1973.
Description of sediments: A. W. Janssen (0.00 - 8.22 m), L. M. B. Vaessen (8.22 - 16.62 m).
Method: the upper 9.37 m of this section have been measured along the sloping front of the clay-pit (50°), vertical depth can be converted with the help of Fig. 5. The part from 9.37 m to 16.62 m has been measured in an auger boring. Colour descriptions partly according to the Standard soil colour chart.

0.00 - 0.04 m dark brown, very heavy clay, humic, barren, with roots of Recent plants.

0.04 - 0.40 m brownish green, very heavy clay, with humus particles, roots of Recent plants. Few white shells, locally at the base with half consolidated, greyish white concretions.

0.40 - 1.10 m (gradual transition) greyish brown, very heavy clay, barren, at the top with much humus, the amount of which decreases downwards. Entire bed with reddish brown spots. Towards the base somewhat more sandy. Some small white concretions.

Fig. 5. SECTION OF THE FRANCART CLAY-PIT



The sediments from 0.00 to 1.10 m do not react in a 10% HCl-solution. Between 0.50 and 0.80 m an undulating shear level (see Fig. 13) was observed under an angle of some 40°. Small white concretions with a diameter of 4 - 6 mm had been rubbed out over a distance of some 3 cm.

1.10 - 1.30 m as above, with very many shells and some soft, greyish white concretions.

1.30 - 1.40 m yellowish grey, very sandy clay, strongly oxidized in thin levels; many shells in thin, horizontal levels, especially the bivalve *Congeria nysti* (Bosquet). Isolated, hard concretions up to 3 cm.

1.40 - 1.60 m greyish green, rather fine sand with many shells, from 1.48 to 1.50 m a concentration of shells.

At 1.30 m lies the top of a vertical joint with a width of some 3 cm, filled with light greyish green, clayey sand. It is at both sides bordered by a reddish brown oxidation zone, and can be seen downwards to 2.40 m.

1.60 - 1.63 m grey brown spotted, extremely sandy clay with very many shells, nests of grey sand, soft concretions and reddish brown oxidation spots.

1.63 - 1.80 m greenish grey sand, mixed with greyish green clay, many shells, many reddish brown oxidation spots.

1.80 - 2.15 m greyish green, slightly clayey, fine sand, for somewhat more than 50% reddish brown oxidized. Three levels of soft concretions at 1.80 m, 2.00 m and 2.15 m. Few shells; at 2.10 m *Abra* in thin horizontal beds.

2.15 - 2.35 m greyish green to light brown oxidized, slightly clayey, fine sand with rather many shells.

2.35 - 2.38 m dark grey, heavy clay with nests of greyish green sand and very many shells.

2.38 - 2.45 m greyish green, rather fine sand with some green clay, very many shells.

In this bed the gastropod *Tympanotonos burdigalinus* (d'Orbigny) was seen while measuring the section.

2.45 - 2.60 m greyish green, rather fine, very slightly clayey sand, with little reddish brown oxidation, very few shells.

2.60 - 2.85 m alternating layers of sandy clay and clayey sand, the sand greyish green, the clay dark greyish green; with undulating oxidation levels; to the base on the average more clayey (and therefore darker), with shell-beds at 2.65 m and 2.75 m, elsewhere few, to the base somewhat more shells. At the base a level with isolated, soft concretions.

2.85 - 3.35 m dark greyish green, clayey sand, mixed with lumps of darker clay; oxidized to brownish green for some 30%; to the base on the average somewhat more clayey. At 2.95 m a level of crowded soft concretions. From 3.10 to 3.15 m much dark brown humus. From 3.30 to 3.35 m strongly oxidized to orange brown. No fossils.

3.35 - 3.70 m very heavy, hard, bluish grey clay, oxidized at the top over 5 cm to yellowish brown, downwards with yellow to yellowish brown veins. No fossils.

3.70 - 3.85 m as above, very dark brown violet (gradual transitions at the base and the top).

3.85 - 8.00 m very heavy, hard, greenish blue clay without fossils. Dark horizons at about4.50 m and 5.60 m. At 6.60 m a quick but gradual transition into dark grey. Locally irregular, very sandy veins, containing many small pyrite crystals.

8.00 - 8.15 m as above, very dark grey with orange brown veins.

8.15 - 8.22 m as above, with extremely many orange brown veins, somewhat more sandy.

8.22 - 8.32 m olive-yellow (5 Y 6/3), rather fine sand, with orange spots and levels, large bright-yellow spots and small gypsum crystals.

8.32 - 8.42 m light yellowish brown (10 YR 7/6), rather fine sand, with large orange and yellow spots. together in a level of about 1 cm neat the top. At the base light grey, rather fine sand (2,5 Y 8/1), with small orange and bright-yellow spots.

8.42 - 8.52 m light grey (2,5 Y 8/1), rather fine sand, with orange and bright-yellow spots.

8.52 - 8.62 m light grey (2,5 Y 8/1), rather fine sand, spotted with dark greyish yellow (2,5 Y 5/2), with orange and bright-yellow spots and small gypsum crystals.

8.62 - 8.72 m light grey (2,5 Y 8/1), rather fine sand, strongly spotted dark greyish yellow (2,5 Y 5/2), with large orange spots and some small bright-yellow spots. At the base dark greyish yellow (2,5 Y 5/2), rather fine sand with small gypsum crystals.

8.72 - 8.82 m greyish brown (5 YR 6/2), rather fine sand, with orange and yellow spots. At the base two 1 cm thick, brownish black clay levels (2,5 Y 3/1), separated by brownish grey (7,5 RA 6/1), rather fine sand.

8.82 - 8.92 m brownish grey (7,5 YR 6/1), rather fine sand, with orange and small bright-yellow spots.

8.92 - 9.02 m light grey (2,5 Y 8/1), rather fine sand, with many greyish yellow (2,5 Y 6/2) spots, with orange and sporadical bright-yellow spots.

9.02 - 9.12 m as above, with more bright-yellow spots.

9.12 - 9.22 m as above, without yellow and orange spots, more greyish yellow (2,5 Y 6/2) spots.

9.22 - 9.37 m as above, downwards less numerous greyish yellow spots (2,5 Y 6/2). From 9.32 m again orange and sporadical bright-yellow spots.

9.37 - 9.87 m greyish brown, somewhat clayey, rather coarse sand, with rather large orange spots. From 9.62 m downwards more greyish and without orange spots, somewhat laminated with light grey.

9.87 -10.27 m clayey sand, greenish grey alternating with light grey. From 9.97 m downwards more greenish and spotted with orange.

10.27 -14.92 m dark greyish green, rather fine sand, slightly clayey and glauconitic. From 10.47 m lighter in colour and finer. Downwards again more greenish with some light grey to white spots, glauconitic and slightly micaceous. From 10.77 m laminated or spotted with grey. At 14.22 m a darkbrown, humic, clayey level of some 5 cm thickness, with small gypsum crystals. To 14.37 m the sand is light grey in colour. At 14.67 m a dark brown, humic level with a thickness of some 5 cm, with distinctly recognizable wood remains and small gypsum crystals. At 14.77 m another humic level of some cm, containing small gypsum crys-

tals. From 14.87 m downwards with orange spots.

14.92 - 15.07 m yellowish green, rather fine sand, with orange spots, glauconitic and somewhat micaceous.

15.07 - 16.62 m light greyish green, rather fine sand, glauconitic and somewhat micaceous.

Stratigraphical interpretation of this section see Figs. 3 and 5.

Additional remarks

The Neerrepen Sands in the Francart clay-pit (at least the visible part of them) contain many vertical joints.

The part above 3.85 m of the section described here contains frequently small displacement faults, with throws of maximally some tens of centimetres (see Figs. 10, 12). Once also intrusion of one sand-body into another could be observed (see Fig. 11). Together with the observed joint and shear level these phenomena indicate slight tectonical movements and in this way they support our opinion that the sediments in the neighbourhood of the Francart clay-pit have been uplifted, as is drawn in Fig. 2. The presence of an important fracture somewhere west of this area seems to be very likely. Because fracture zones are easily attacked by erosion we suppose that it is located somewhere in the deep erosion valley west of the Francart clay-pit.

The complete section described here has been sampled, relevent parts have been double-sampled for palynological investigation. The samples are stored in the RGM collection.

Felder (1963) described a section in the visible parts of the Francart clay-pit. At that time obviously higher strata were present that have been excavated nowadays. The section of Felder is drawn here in Fig. 3.

An isolated sample taken from a high part of the Francart section, not represented in the section described here, contains abundant pollen. This part of the section has not been described because it is situated at some distance from the fresh front of the clay-pit.

In August 1976 the front of the clay-pit had been turned for about 90°. At that time several gullies could be observed. The sandy parts of the section appeared to be partly not fossiliferous.

DESCRIPTION OF BORING BT 6

File number Geological Survey of Belgium: 107W 235 (IIc).

Field number: BT 6.
Locality: 315 m west and 50 m north of the church of Berg, municipality of Tongeren, province of Limburg, Belgium. Lambert co-ordinates: X = 228 960, Y = 165 080.
Date: 11-12 July 1974.

Surface-level: 111.78 m + O.P.
Levelling: A. C. Janse (Brielle), 17-18 August 1974.
Description of sediments: M. C. Cadée and V. W.M. van Hinsbergh.
Method: Auger boring.

0.00 - 0.10 m	arable earth
0.10 - 0.60 m	grey, hard, very clayey sand with many shell fragments (*Pirenella* and *Polymesoda*), small brick fragments.
0.60 - 0.80 m	greenish grey, heavy clay with shell fragments, laminated with many thin layers of rather fine sand. From 0.70 m downwards with many shell fragments.
o.80 - 2.10 m	light grey, heavy clay with rusty spots. At about 0.85 m a thin layer of very fine, grey, clayey sand. From 0.90 m with mother-of-pearl fragments (Mytilidae). From 1.70 m with thin sand layers, containing many small shells: *Pirenella, Corbula*.
2.10 - 2.50 m	greyish yellow, fine sand, with many shells and some thin clay levels. At 2.30 m a thin rusty layer. At 2.40 m a level of black, brown spotted clay, with a thickness of about 5 cm.
2.50 - 3.35 m	blue clay, with rather many shells (*Pirenella*) and brownish green spots, sometimes a thin dark humus level. From 2.70 m to 2.90 m without shells, then with shell remnants. From 3.00 m with very thin (some tenths of a mm) layers of extremely fine sand.
3.35 - 3.70 m	black, heavy clay with shells. At 3.60 m a level with *Hydrobia* shells.
3.70 - 4.40 m	sea-green, very heavy clay with some shells and thin humus levels. Downwards more shells.
4.40 - 4.70 m	dark grey, somewhat sandy clay, with few shells and some concretions. Downwards changing to sea-green and becoming more sandy.
4.70 - 5.95 m	bluish grey, clayey, fine sand, without shells. From 5.00 m with shells (*Pirenella*) and concretions. Between 5.10 m and 5.60 m somewhat more clayey, downwards more sandy again and without shells, concretions still present.
5.95 - 6.20 m	bluish grey, heavy clay, alternating with some thin layers of fine sand with shells. From 6.10 m more sandy.
6.20 - 9.00 m	bluish grey, heavy clay, without shells. From 6.30 to 6.40 m dark grey, then black to 6.70 m, downwards changing into dark grey and bluish grey. From 7.10 m very heavy, greyish blue clay with brown spots.
9.00 - 9.90 m	greyish blue, very heavy clay, darkening downwards to lead-grey and dark grey, with a violet hue. Somewhat more sandy to the base.
9.90 - 10.15 m	lead-grey, sandy clay with thin rusty layers; to the base more sandy.
10.15 - 10.25 m	light grey, very sandy clay, with thin rusty layers and layers of a lighter colour. Sand also in thin streaks.
10.25 - 10.40 m	very fine, clayey sand, light yellow alternating with light grey, with a violet hue and rusty streaks decreasing downwards in number.
10.40 - 10.75 m	green yellowish grey, very fine sand, laminated; somewhat silty and with some rusty spots.

Stratigraphical interpretation:

0.00 - 0.80 m: Quaternary, valley fill
0.80 - 5.95 m: Sands and marls of Oude Biesen
5.95 - 10.25 m: Henis Clay
10.25 - 10.75 m: Neerrepen Sands

The part from 0.80 to 10.25 m is a reference section of the Atuatuca Formation.

DESCRIPTION OF THE T 1 EXPOSURE AND BORING

File number Geological Survey of Belgium: 107W 116 (1)(IVa).

Field number: T 1.
Locality: construction-pit on the Bilzer Steenweg, opposite number 126; about 750 m north and 50 m west of Tongeren Basilica, municipality of Tongeren, province of Limburg, Belgium. Lambert co-ordinates: X = 227 190, Y = 164 700.
Date: 15-17 July 1974.
Surface level: 109.16 m + O.P.
Levelling: A. C. Janse (Brielle), 18 August 1974.
Description of sediments: A. W. Janssen
Method: exposed (temporarily) from 0.00 to 3.47 m below surface. Auger boring from 3.05 m to final depth.

0.00 - 0.75 m brown, sandy clay, at the base many coarse, rolled silex pebbles.

0.75 - 1.55 m yellowish white to yellowish brown, rather fine sand, downwards with orange-brown, more or less horizontal oxidation levels. At the base for some 5 cm clayey, dark brown.

1.55 - 2.25 m heavy, hard clay. From 1.55 to 1.59 m bluish grey with orange-brown sand nests; from 1.59 to 1.69 m very dark grey; from 1.69 to 1.88 m very dark grey with many rusty brown veins; from 1.88 to 2.19 m dark brownish grey with bluish grey spots, locally with shells in lenses (*Polymesoda*); from 2.19 to 2.25 m very dark brown to black with reddish brown, small veins, very brittle.

2.25 - 2.29 m very heavy, dark brown to black clay, alternating with thin layers of rusty brown clayey sand. Clay streaks decreasing in thickness from top to base. Sand streaks at the base with very much white shell-grit.

2.29 - 2.45 m greenish grey, very heavy clay, with few shells. Locally small black spots, especially in the upper part. Rather many sandy veins, reddish brown, with very much fine shell-grit.

2.45 - 2.54 m as above, clay in streaks that decrease in thickness from top to base, alternating with thin layers of rather coarse sand, white to yellowish brown oxidized, with very many shells and much shell-grit.

2.54 - 2.57 m greyish white, rather coarse sand, with many shells and much shell-grit

2.57 - 2.90 m light greyish green, rather fine sand, barren, with numerous thin (to

some mm) irregularly horizontal clayey streaks. No reaction with HCl.

Approximately 30 m more to the east this level contains many shells, especially *Polymesoda convexa*, also preserved as bivalved specimens.

2.90 - 3.22 m alternating thin layers of very heavy, hard, dark grey clay, with a thickness of some mm to maximally 2 cm, and thin layers of rusty brown rather fine sand, with especially near the top many shells.

3.22 - 3.33 m very heavy, hard clay, dark grey with reddish brown, small veins. Barren.

3.33 - 3.42 m hard, sandy clay, dark brownish grey, with very many small shells.

3.42 - 3.62 m grey to bluish grey, somewhat sandy clay, with very many shells in layers, especially many *Pirenella* and *Tympanotonos*. The shells are embedded in reddish brown sand.

3.62 - 4.10 m brownish grey, very heavy clay with rusty brown veins. Some shells near the top, downwards decreasing in number. From 4.05 m with greyish blue veins and nests of reddish brown sand, more shells in streaks, i.a. Mytilidae.

4.10 - 4.35 m bluish grey, very heavy clay, with some rusty veins. From 4.25 m to 4.35 m many shells in sandy streaks.

4.35 - 4.40 m rusty brown, rather fine, clayey sand, with very many shells and much shell-grit.

4.40 - 5.10 m heavy clay, light grey and greyish blue spotted, no fossils. From 4.50 m downwards with shells; at 4.60 m rusty brown, containing many shells. From 4.80 m somewhat fine-sandy. From 4.85 m with streaks of rather fine sand with many shells. The sand is dark greyish in colour. The streaks are downwards more numerous and darker.

5.10 - 7.85 m hard, heavy clay, bluish green, with white shells and some small, dark brownish black spots. From 5.15 m gradually changing into greenish grey, less shells to barren at 5.25 m. From 5.40 m greyish blue, with rather much shell-grit. From 5.75 m with thin, white veins, gradually changing into greyish green, marbled with dark greyish green, gradually darkening downwards. At 5.95 m dark greyish green with thin, sandy streaks. Dark grey at 6.10 m, still darkening downwards. From 6.15 m thin streaks of grey sand with shells. At 6.35 m dark brownish black, heavy clay. At 6.40 m abruptly changing into dark bluish green, with few nests of white shells. From 6.70 m clearly more shells. At 6.75 m abruptly changing into dark greyish green, with a thin level of white shells on the transition, downwards without fossils. At 6.90 m with dark, thin, sandy streaks. At 7.22 m a thin layer of shells. From 7.30 m with thin, very sandy streaks, abruptly lighter in colour, downwards grading to very sandy clay with more shells in streaks. Locally thin streaks of fine slightly clayey sand, light greyish green to bluish green.

7.85 - 8.20 m (gradual transition) slightly clayey, fine sand, greyish green, with shells.

8.20 - 8.50 m (sharp boundary) hard, heavy clay, bluish green, with sandy streaks, barren or with few shells.

8.50 - 9.00 m (gradual transition) very fine-sandy clay, with pieces of hard clay, greyish green, some shells.

9.00 -12.85 m (sharp boundary) hard, very heavy, bluish green clay with dark spots,

marbled with black from 9.05 m, pyrite in nests. From 10.00 m more bluish, from 10.20 m with sandy streaks, from 10.55 m with yellowish green, small spots. Downwards these spots increase in size and number and become dominant. From 12.05 m with purple-grey spots and small black spots. From 12.40 m grey with small black spots. From 12.70 m with streaks of light grey, rather fine sand.

12.85 - 12.95 m rather fine sand, light grey, with a violet hue.

The sandy levels of 7.85 - 8.20 m and 8.50 - 9.00 m contain much water, which made sampling difficult. Samples from these parts are contaminated. This section has been completely sampled (RGM collection), sediments visible in the exposed part have been double-sampled for palynological investigation (see Fig. 7). In the boring samples were taken every 10 cm. A lacker-peel of the upper part (c. 2.25-4.20 m) is in the collection of the RGM (made 8-9 August 1976 by A. W. Janssen and M.C.Cadée).

Interpretation:

0.00 - 0.75 m: Quaternary deposits in situ
0.75 - 1.55 m: Berg Sands
1.55 - 9.00 m: Sands and Marls of Oude Biesen
9.00 - 12.85 m: Henis Clay
12.85 - 12.95 m: Neerrepen Sands

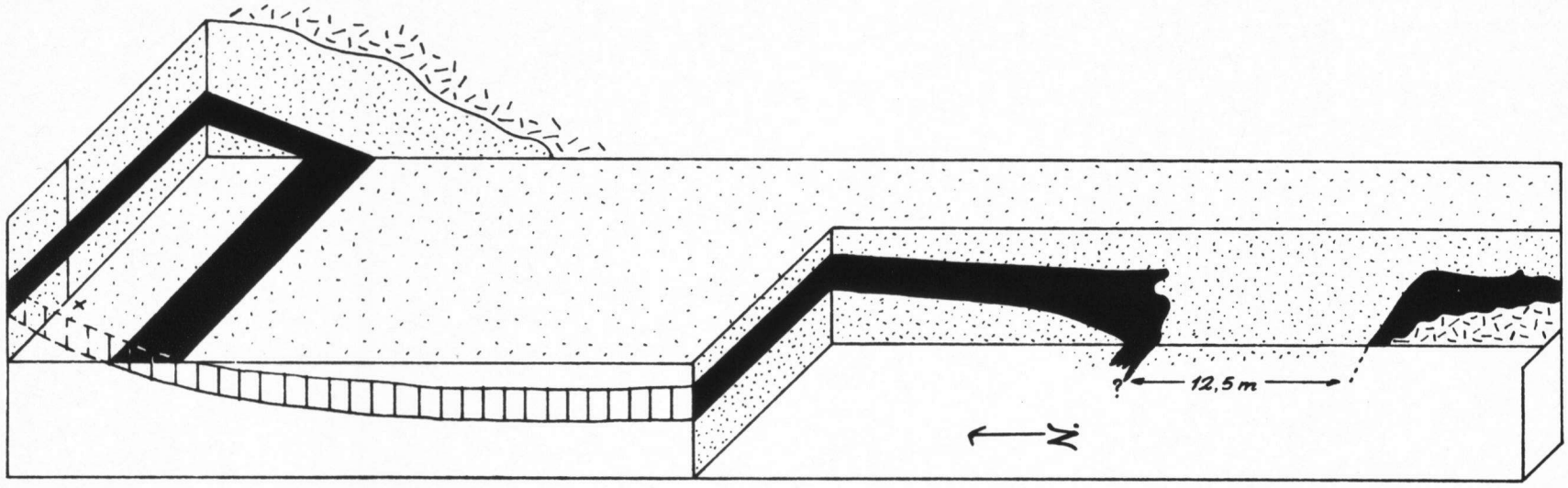
The part of 1.55 to 12.85 m of this section is the stratotype of the Atuatuca Formation. This section is also designated as the boundary stratotype of the Henis Clay and the Sands and Marls of Oude Biesen boundary.

The violet hue of the Neerrepen Sands is an indication for the presence of the Neerrepen Soil.

Additional remarks

The dark clay of 1.55 to 2.29 m below surface is very well visible in the exposure. In the wall and in a part of the bottom of the construction-pit it could be seen that over a distance of about 12.50 m the clay and underlying sediments were interrupted (see Figs. 8 and 9). The gap was filled with the overlying Berg Sands. On both sides of the gap the clay shows slight folding structures and small diapir-like features. Although the other walls and the bottom of the construction-pit could not be studied in detail because of the progressed building activities we are sure that corresponding features do not occur in the other walls. Therefore, it is hardly acceptable that this structure represents a channel or a gully. Regrettably we missed the opportunity to make a boring at this place, so nothing can be said about the structure of the subsurface. In addition it is interesting to note that all sediments visible in the walls of the pit descend towards the gap. We have not succeeded in finding a satisfactory explanation for these features. In our opinion this phenomenon is only of local importance and does not influence the general stratigraphy of the deposits. We should appreciate to receive suggestions which might lead to an explanation.

In August 1976 the construction-pit was no longer visible. Next to the new building the upper part of the section (some 3 m) was still exposed.



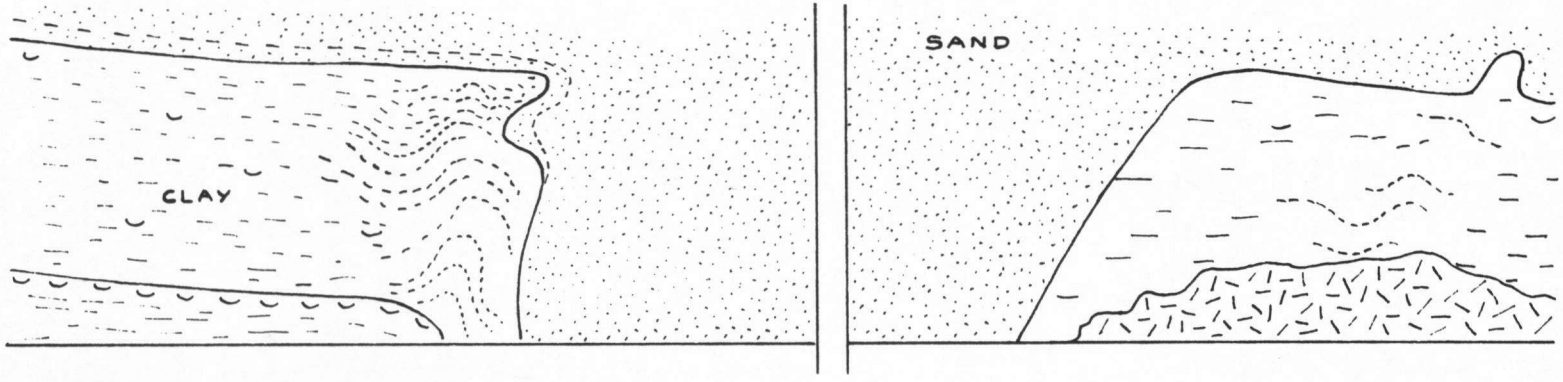


Fig. 6. SCHEMATICAL REPRESENTATION OF THE T 1 EXPOSURE AT TONGEREN, July 1974.
Fig. 6a. Survey of the construction-pit. The black zone is 1.55 to 2.29 m of the lithological description (see text). The section was measured near x.
Fig. 6b. Detail of Fig. 6a.

DESCRIPTION OF THE ATUATUCA FORMATION, *new formation.*

General concept

The Atuatuca Formation consists of a series of clayey and sandy sediments. The basal member, the Henis Clay, consists of very heavy clay, greenish or bluish in colour, that only locally contains eurihaline molluscs. Its thickness may reach some 5 m. It contains regularly small pyrite crystals and no pollen.

The upper member of the Atuatuca Formation, the Sands and Marls of Oude Biesen, starts with a sandy deposit in which a gully system is developed. On top of these sands another clay with a thickness of some 2-3 m is deposited, locally containing small sandy intercalations. Upwards the sequence demonstrates a considerably variable alternation of sandy and clayey levels. The Sands and Marls of Oude Biezen, especially their sandy parts, contain an euryhaline mollusc fauna, also occurring in crags. Many calcareous concretions occur. Pollen are only absent in the basal part.

The lower boundary of the Atuatuca Formation coincides with a disconformity. Below the Atuatuca Formation the Neerrepen Sands occur. The top of the Formation is always attacked by erosion (as far as we know) as a result of the Berg Sands transgression.

The Atuatuca Formation is known with certainty from the region north of Tongeren, eastwards to Herderen, northwards to Bilzen. To the west as far as the neighbourhood of Borgloon (data also from Glibert & de Heinzelin, 1954).

This lithological unit is introduced here as a formation, named after Atuatuca Tungrorum (= Tongeren, see the chapter "Nomenclature of the lithostratigraphical units"), where the stratotype is situated.

Stratotype

Exposure and boring T 1, file numer of the Geological Survey of Belgium: 107W 116 (1)(IVa), depth 1.55 to 12.85 m below surface. Description of sediments and further details see above. Locality-map see Fig. 1. Boring section see Fig. 3.

The stratotype is selected here because it is the most complete section of this formation so far known, and also because both members can be clearly distinguished here.

In the T 1 boring also the boundary stratotype of the boundary between the Henis Clay and the Sands and Marls of Oude Biesen has been defined (this paper).

Reference sections

Boring BT 6 at Berg, Tongeren (see description above), depths 0.80 to 10.25 m below surface.

Galgeberg section (see description in Cadée et al., 1976, p. 54, Fig. 2), depths 0.30 to 9.30 m below surface. The upper part of this section, from 0.30 to 0.75 m was interpreted by Cadée et al. as Berg Sands. Renewed investigation demonstrated this part to belong to the upper Sands and Marls of Oude Biesen.

Boring A 1 near Oude Biesen (Spouwen), file number of the Geological Survey of Belgium: 93W567 IXa (see description in van Hinsbergh et al., 1973, p. 23, Fig. 2).

Francart clay-pit at Tongeren, as described above, see Figs. 3 and 5.

Regional aspects

In the stratotype area the boundary between the Henis Clay and the Sands and Marls of Oude Biesen is distinct. More to the north in the area of Spouwen this boundary is less easily recognized, especially in borings, because of frequent erosion of the basal sandy part of the Oude Biesen Member.

In a westerly direction, more especially west of Borgloon, many deposits, usually indicated in the literature as "glaise verte" (e.g. Glibert & de Heinzelin, 1954) occur, probably also belonging to this formation, but no interpretation has been made yet.

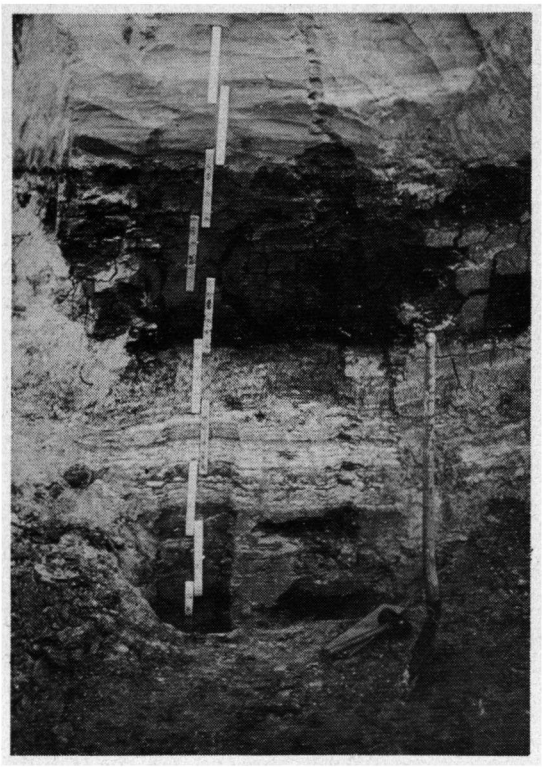
Stratigraphical aspects

We follow van den Bosch et al. (1975, p. 105) in maintaining a three-fold chronostratigraphical subdivision of the Oligocene. We consider the Atuatuca Formation to be of Rupelian age. It belongs, together with the Berg Sands, the Nucula Clay and the Boom Clay to one and the same transgression.

In the Leuven area the Boutersem Sands, the Kerkom Sands and the Hoogbutsel Horizon can roughly be correlated with the Atuatuca Formation. In the Dutch province of Limburg the Goudsberg Deposits can be correlated with the Atuatuca Formation.

Environmental circumstances of the Atuatuca Formation have been discussed above.

Kleine Spouwen/Leiden, August 1976



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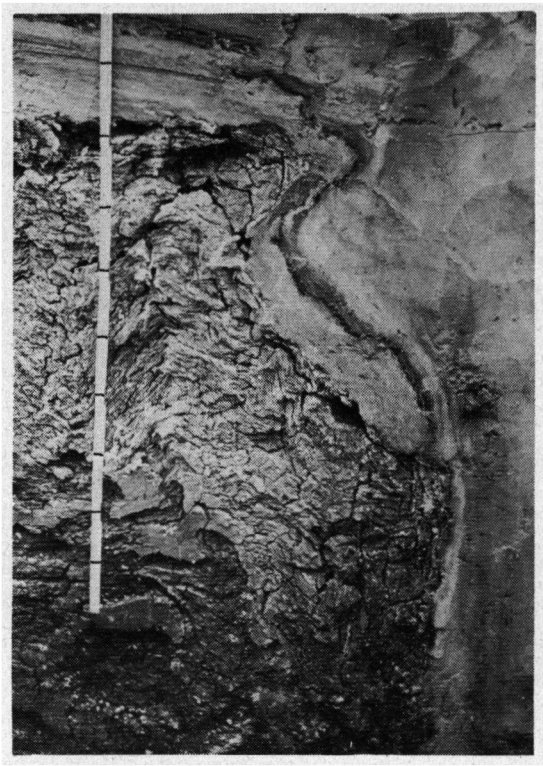

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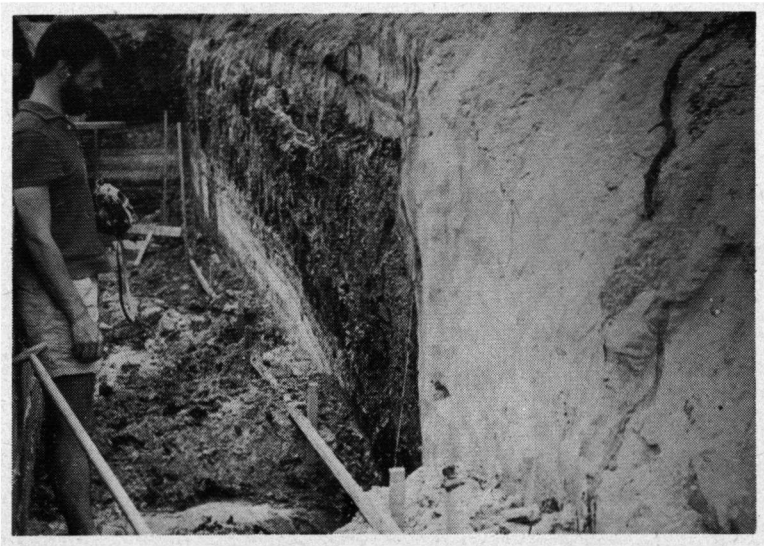

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Fig. 7. Upper part of the Atuatuca Formation stratotype and base of the Berg Sands (on top of the dark clay) in the temporary T 1 exposure at Tongeren.

Fig. 8. Northern part of a gap in the upper clay deposit of the Atuatuca Formation in the temporary exposure T 1 at Tongeren.

Fig. 9. Detail of Fig. 8, showing distorted clay structures.

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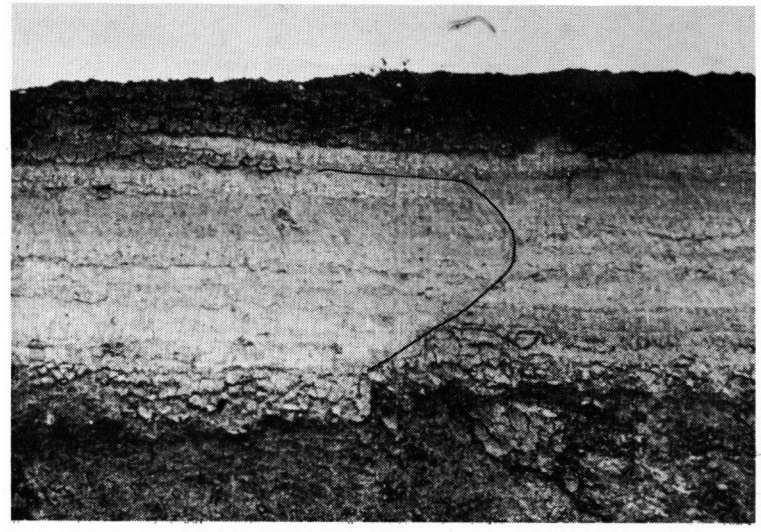

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Fig. 10-13. Microtectonical features in the Francart clay-pit
(see text for explanation)

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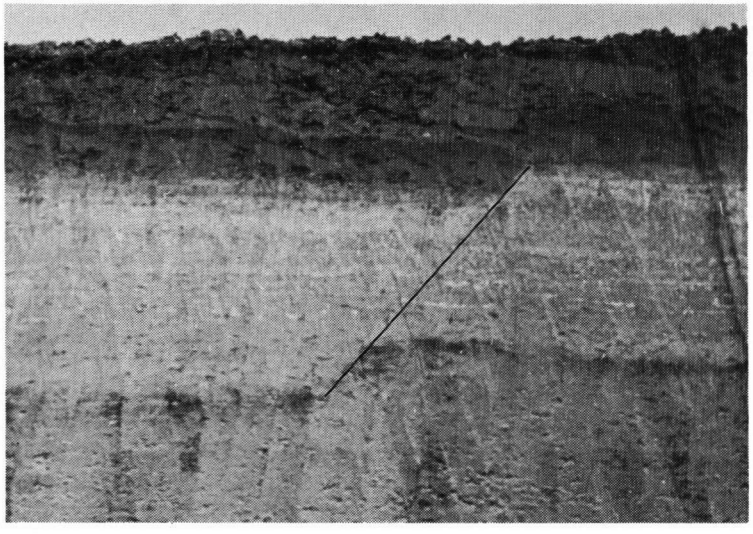

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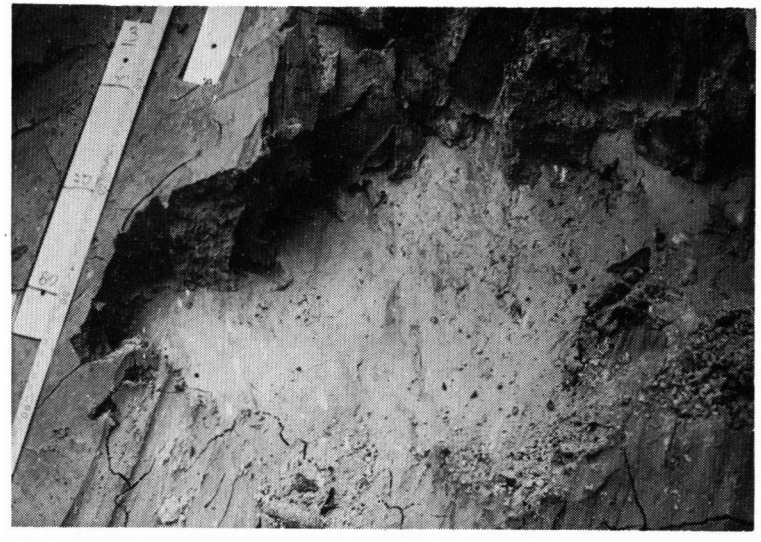


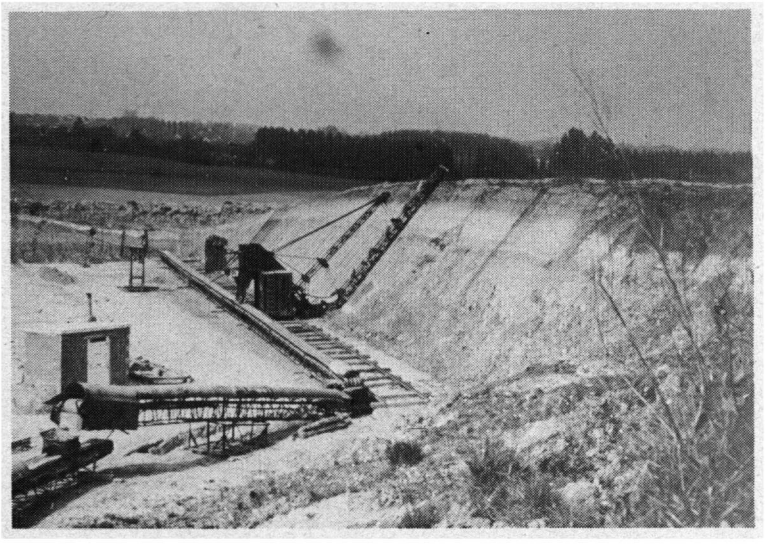
EXPLANATION OF FIGS. 14 - 17.

Fig. 14. The clay-pit of the Francart Brickworks in July 1974.

Fig. 15. Francart clay-pit. Top of the Neerrepen Sands with Neerrepen Soil and base of the Henis Clay.

Fig. 16. Francart clay-pit. Top of the Neerrepen Sands with shrinkage cracks in clayey sands (vertical section).

Fig. 17. Francart clay-pit. Top of the Neerrepen Sands with shrinkage cracks in clayey sands (horizontal section).



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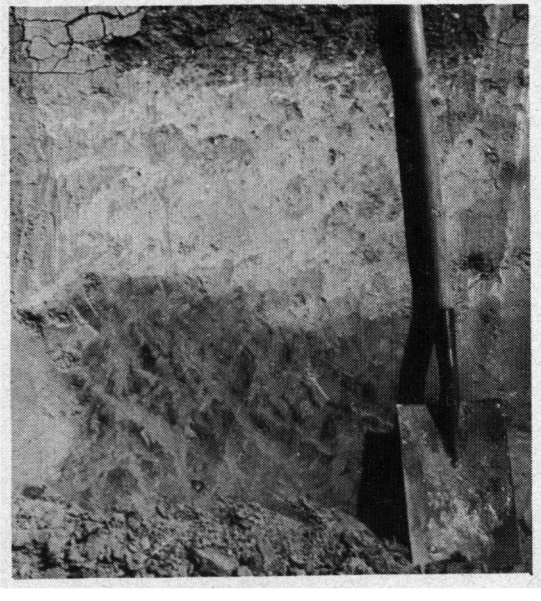

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