INTRODUCTION

The present paper is the second one in a series of micropaleontological studies on the Eocene and Oligocene of Belgium by a team of the Paleontological Department of the Mineralogical-Geological Institute of the State University at Utrecht. The first paper, dealing with the Ostracoda of both Eocene and Oligocene was published by Dr. A. J. KEIJ (1957). The results of the third study, that of Mr. J. P. H. KAASSCHIETER on the Eocene Foraminifera of Belgium will be published in the near future.

The Oligocene of Belgium has special importance for general stratigraphy since it includes the type deposits of the Tongrian and the Rupelian. The deposits of both these units had been included in BEYRICH's original description of the Oligocene.

For our micropaleontological investigation over three hundred samples were taken from numerous pits, smaller outcrops or from auger cores. They cover the various units of the Lower and Middle Oligocene (Tongeren and Rupel formations). The sampling was carried out during altogether three months in Belgium in 1953 and 1954.

In addition to the above mentioned samples collected in the field, some fifty more samples were investigated from borings and mine shafts. They were needed mainly for the foraminiferal associations of the Belgian Upper Oligocene, the so-called sand of Voort, which is unknown from outcrops. For comparison the contents of some Miocene samples were investigated. They were derived from the sand of Antwerp (Anversian) and from the horizon of Houthalen.

Another important series of samples, derived from shaft IV of the coal-mine Hendrik in Dutch South-Limburg, enabled a more detailed study of the microfauna of the Lower Tongeren beds.

For further comparison the foraminiferal contents of some samples from the classic localities of the German Middle and Upper Oligocene, Hermsdorf, Pietzpuhl, Astrup near Osnabrück and Kassel, and of the German Miocene of Dingden are dealt with. In this connection we also incorporated the microfauna of material from two localities of the Middle Oligocene in the eastern Netherlands (Winterswijk and the Kuiperberg near Ootmarsum).

Apart from the results of our investigation of the Foraminifera, remarks are added on the stratigraphy of the Belgian Oligocene. For this purpose several weeks were spent in Brussels among the archives of the Geological Survey of Belgium. The data from many borings enabled the construction of six stratigraphic maps of the Belgian Oligocene deposits. The lack of a sufficient number of reliable data prevented the drawing of definite stratigraphic conclusions; only a number of suggestions can be given.

The author ows much gratitude to Prof. Dr. G. H. R. von Koenigswald, who presented this paper as a thesis for the doctor's degree at Utrecht University.

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FORAMINIFERA OF THE OLIGOCENE OF BELGIUM

CHAPTER I

STRATIGRAPHIC REVIEW

INTRODUCTION

For the reader's orientation a short review will be given of the main Oligocene stratigraphic units of northwestern Europe. In this connection some general remarks are added to the earlier papers dealing with the Foraminifera of these units.

In recent literature on stratigraphic classification (see among others HEDBERG, 1954), it is more and more emphasized that distinction should be made between rock-stratigraphic and time-stratigraphic units. It is stated that the names of the units already have to indicate whether they are rock-stratigraphic or time-stratigraphic.

Up to now it has been unusual in European geology to treat the stratigraphic units in such a way. In many instances rock-stratigraphic and time-stratigraphic units have been confused and the same name was then applied to both categories. The endings of -an or -ian, which were recommended by the International Geological Congress at Paris in 1900 for names of time-stratigraphic units only, thus have often been misused in denoting rock-stratigraphic ones.

In the present study it is tried to make a clear distinction. Rock-stratigraphic units are named after the type locality or after a characteristic fossil with the addition of either general names, such as formation, member and bed(s), or otherwise of nouns that indicate the lithologic nature of the unit. Wherever possible, the name of a time-stratigraphic unit is given the ending of -ian or -an and in most cases it is equally derived from the name of a type locality.

In 1854 BEYRICH introduced the term Oligocene for a separate time-unit in between the Eocene and the Miocene. The newly named unit was based both on field relations of the deposits studied by BEYRICH, and on the distinctness of their fauna (molluscs) with regard to those of Eocene and Miocene. In 1856 BEYRICH published a map (with accompanying text) of the Tertiary deposits in northern Germany, Belgium and adjoining regions. Additional data on the Oligocene were published by its founder in 1859.

For recent and detailed reviews of the European Oligocene, one is referred to the publications of H. ALIMEN (1936), BRINKMANN (1954), VON BUBNOFF (1952, 1956), DENIZOT (1952) and GIGNOUX (1950).

BELGIUM

In the original description of the Oligocene, BEYRICH referred for the Belgian deposits to the classification of DUMONT. This author had created in 1839 the « système Tongrien » which he later subdivided into three separated « systèmes » viz. Tongrian, Rupelian and Bolderian (1849). Finally DUMONT again re-defined his Tongrian and Rupelian in 1851. Tongrian and Rupelian in this sense are about identical with our Tongeren and Rupel formations respectively.

BEYRICH placed the Lower Tongeren beds in his Lower Oligocene, and the Boom clay, which is the most important member of the Rupel formation, in his Middle Oligocene.

Another important article on the Belgian Oligocene was published in 1894 by VAN DEN BROECK. Many members were described and their relations extensively dealt with. The paper ended with a stratigraphic code that for the greater part has been adopted for the later geological maps of Belgium (1 : 40.000 and 1 : 160.000).

FORIR (1901) enumerated all the publications concerning the Belgian Lower and Middle Oligocene that had appeared from 1868 to 1900. This list contains many useful references.

Because of the war, KONING's study (1945) of the petrology of the Belgian Oligocene remained unpublished. Through the courtesy of Prof. Dr. R. TAVERNIER at Gent we were allowed to borrow a copy of the manuscript. In addition to the petrological data it contains a detailed historical review of the literature on the Oligocene of Belgium.

An extensive study of the sediments and the molluscan fauna of the Belgian Lower Oligocene was recently published by GLIBERT and DE HEINZELIN (1954*a*). These authors re-defined the Tongrian stage in the way it was used by DUMONT in 1851. Up to now no such detailed studies of the Middle and Upper Oligocene have appeared.

Very little is known of the Belgian Oligocene Foraminifera. Only some unimportant remarks concerning the presence of Foraminifera in Belgian Oligocene deposits occur in scattered articles of several earlier authors. Recently GULLENTOPS (1956) investigated the foraminiferal contents of a sample Oude-Biezen sand from Borgloon. He described thirteen species, nine of which belong to the family *Miliolidae*.

THE NETHERLANDS

Data concerning the deposits of the Oligocene in the Netherlands are to be found in the paper of PANNEKOEK (1956). This author gave some isopach maps and two sections of the Oligocene in the subsoil of the Netherlands. It has been found that Middle Oligocene clay with septaria, and Upper Oligocene sandy deposits are present under a great part of the country. Lower Oligocene deposits occur only in South-Limburg; they are similar in facies to those in the adjoining part of Belgium.

The Foraminifera of the Dutch Oligocene together with those of the Dutch Miocene were studied by TEN DAM and REINHOLD (1942). These authors did not examine material from South-Limburg, so that associations from the Oligocene units under the Boom clay in the Netherlands were not incorporated in their publication. They described 168 species from Oligocene and Miocene together. About seventy of the species belong to the *Lagenidae* and *Polymorphinidae*.

NORTHERN GERMANY

In Germany occurrences of the Oligocene are found in two large areas, one in northern Germany, the other extending from the Mainz basin to the south. The German Oligocene is made up of many members, most of which are marine. Brackish- and fresh-water deposits and important lignites are also known.

In northern Germany the Oligocene contains at its base the so-called Lattorf beds, mostly sandy deposits that according to BETTENSTAEDT (1949), have about as large an extension as the Middle Oligocene. BEYRICH placed them in his Lower Oligocene.

The Foraminifera of these sediments have been studied by FRANKE (1925), who described 73 species from Magdeburg. REUSS (1856) and BORNEMANN (1860) described a few species, but no associations, from the German Lower Oligocene.

According to several authors (H. ALIMEN, 1936; CORNET, 1923; DAVIES, 1934) the mollusc fauna of these Lattorf beds resembles fairly well the fauna of the Lower Tongeren beds in Belgium. Some other authors, BEYRICH included, pointed to the resemblance of the mollusc fauna of the Lattorf and Lower Tongeren beds to the fauna of the Barton beds (Late Eocene).

On top of these Lower Oligocene beds and underlying the Septaria-clay, several deposits have been found. Among them there are the Walsumer Meeressand and the Magdeburger Sand. These members have a similar stratigraphic position as the Berg sand in Belgium. They are the lower sands of the Middle Oligocene sand-clay-sand sequence in northern Germany described by WÖLK in 1941.

The most important member of BEYRICH's Middle Oligocene and equivalent of the Belgian Boom clay, is known under several names, such as Septarienton, Rupelton and Ratinger Ton. It is present in a vast region in northern Germany. This member is directly connected with the corresponding clays in the Netherlands, Belgium and Poland. Its thickness may reach 200 m.

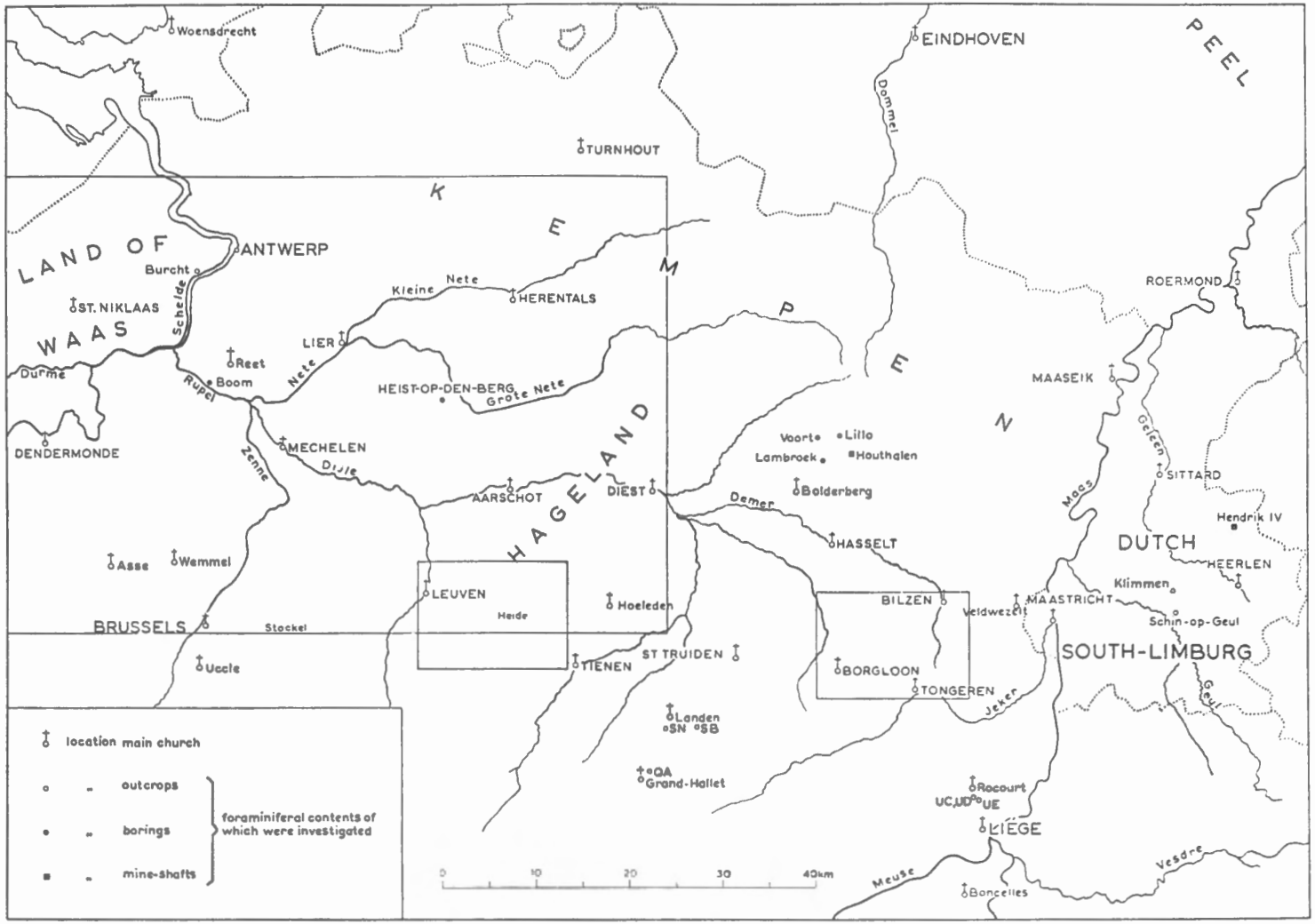
The Stettiner Sand (just as the R2d sand in Belgium) is generally included among the upper sands of the Middle Oligocene sand-clay-sand sequence.

The publications of REUSS (1851, 1852, 1866, 1870) and BORNEMANN (1855) on the foraminiferal fauna of the German Septaria-clay are as yet the most detailed papers on this subject. These authors studied material from several localities among which the most important are Hermsdorf and Pietzpuhl. REUSS (1870) counted 244 species of Foraminifera in the Septaria-clay, 164 of which occur in Pietzpuhl. More than 50 per cent of the total number of species belong to the families *Lagenidae* and *Polymorphinidae*.

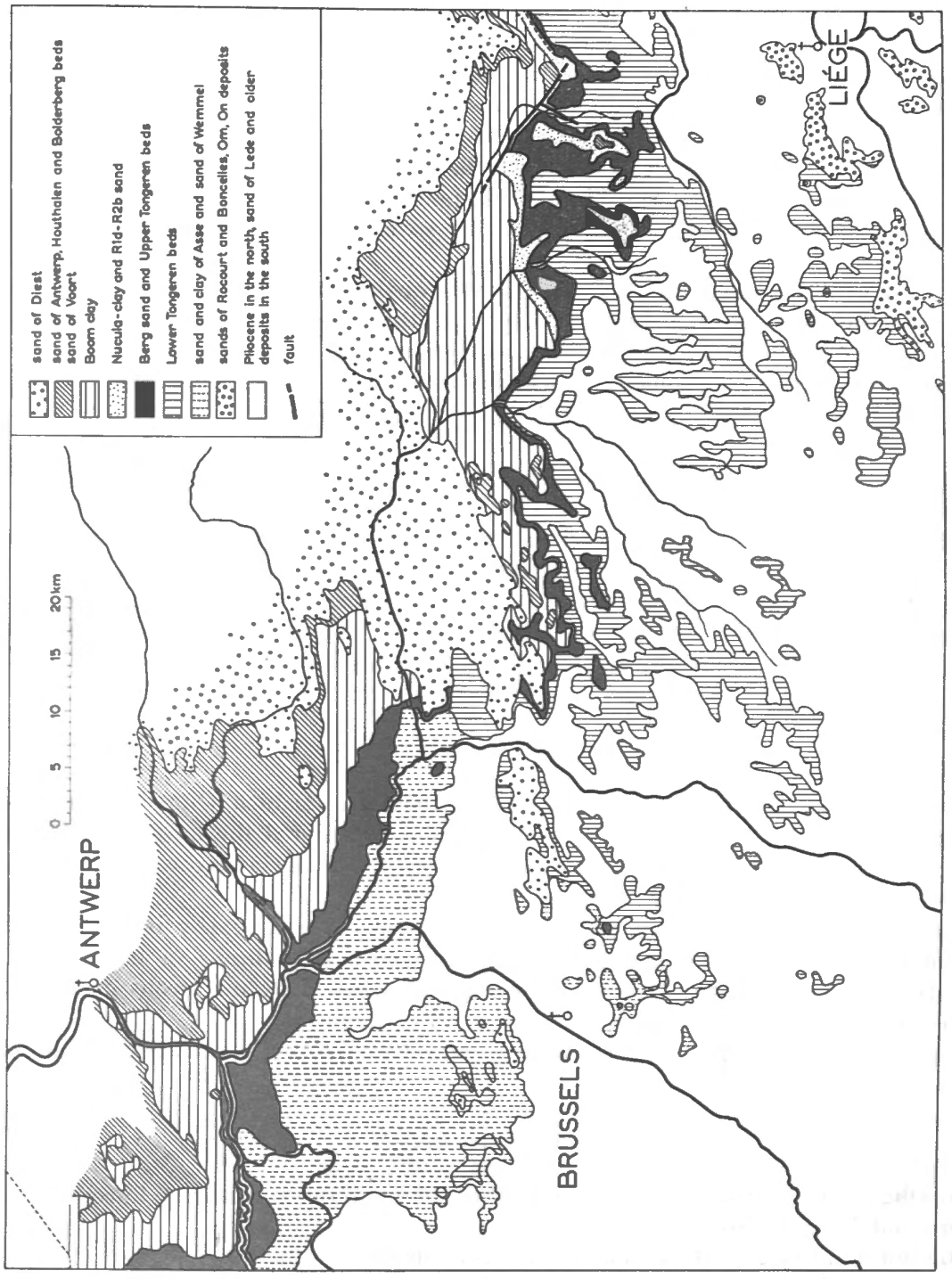
The Middle Oligocene sand-clay-sand sequence in northern Germany is overlain by Upper Oligocene deposits often referred to as Chattian. They are marine sandy sediments, the molluscan fauna of which shows much resemblance with those of Miocene deposits. Already BEYRICH pointed to these relations.

The Foraminifera of the Upper Oligocene were studied by ROEMER (1838), REUSS (1856, 1865), LIENENKLAUS (1891) and HOSIUS (1894, 1895). The number of species described is smaller than the number met with in the Septaria-clay. Many of the recorded species again belong to the *Lagenidae* and *Polymorphinidae*.

A more general treatment of the Oligocene microfauna has been given by STAESCHE and HILTERMANN (1940) who published illustrations of associations and of single specimens from various units of the Oligocene in their paper on the Tertiary microfaunas of northern Germany.



MAP 1. — General geographic map.



Map 2. — Geologic map.

MAINZ BASIN AND ALSACE

In between the areas of the Oligocene in the Mainz basin and of the Oligocene north of Kassel there are several isolated occurrences of « Rupelton » (WENZ, 1921). Correlation of the strata in the Mainz basin and near Kassel can thus again be based on the Middle Oligocene Septaria-clay.

WENZ, in a detailed study of the Mainz basin (1921) mentioned a thickness of 125 m for the Rupelton. It closely resembles the typical Boom clay, both in lithology and in fauna. The Meeressande von Alzey are considered to represent near-shore equivalents of the clay. In the entire Mainz basin these marine deposits are overlain by brackish-water and lacustrine sediments.

In southward direction the Oligocene deposits of the Mainz basin are connected without interruption with those in the Rhine valley. In this region the marine, brackish and lacustrine series of the Pechelbronn beds are usually placed in the Lower Oligocene. They are overlain predominantly by marine beds with mediterranean fauna components, the Middle Oligocene Amphisyle and Meletta-beds. This Middle Oligocene is again covered by fresh-water sediments.

The Foraminifera associations from the Oligocene of the Mainz basin and Rhine Graben were studied by several authors. REUSS (1863), ANDREAE (1884), SPANDEL (1909), PAALZOW (1912, 1924) and in more recent publications PAUL (1938), BARBIER (1938), DOEBL (1954) and THURSCH (1956) are the most important among them. The four later authors and also ANDREAE (1898), HERRMANN (1898, 1903, 1917) and BÖHL (1928), emphasized more strongly the associations they found than the systematic treatment of the separate species. Many of the species recorded by them occur also in the Oligocene of northern Germany.

DENMARK

According to SORGENFREI and BERTHELSEN (1954) the Danish Oligocene consists of a series of marine deposits. The so-called Søvind marl is considered the lowermost member.

The Middle and Upper Oligocene are represented by Septaria-clay with glauconitic and micaceous, fine-grained sands and clays on top.

These Oligocene deposits are present in Jutland and some nearby islands off the east coast. Outcrops are found only along the northern and eastern limits of this area. In the greater part of the country the Oligocene sediments are covered by micaceous clays and sands of the Miocene.

There are as yet no publications dealing with foraminiferal associations of the Danish Oligocene.

HAMPSHIRE BASIN

No Oligocene deposits have been found in between the north-west European and the Hampshire and Paris basins.

The foraminiferal contents of the British Oligocene, the occurrences of which are restricted to the Isle of Wight and the Hampshire coast, have recently been investigated by BHATIA (1955), who described 64 species and varieties. On Isle of Wight a series of fresh- and brackish-water deposits with some marine intercalations are known as the sequence of Headon, Osborne, Bembridge and Hamstead beds. They overlie the Late Eocene Barton beds.

PARIS BASIN

The Oligocene of the Paris basin consists of three units : the type Sannoisian, the type Stampian and a third one that did not give rise to a stage name. The Sannoisian is considered to consist of a series of continental and brackish deposits ending with marine sediments. It contains a brackish-water mollusc fauna resembling that of the Belgian Upper Tongeren beds.

The Stampian deposits are extensively dealt with in the thesis of Miss H. ALIMEN (1936). They consist of marine sediments, namely the so-called Oyster-marl and the sand of Fontainebleau, which is locally fossiliferous and which overlies the Oyster-marl.

The Oligocene series of the Paris basin end with lacustrine or lagoonal calcareous deposits : the « calcaires de Beauce ».

The Foraminifera of the Stampian deposits were studied by CUSHMAN (1928), who found 23 species and varieties.

Several more recent papers treat the Foraminifera from Oligocene occurrences in southern Europe : COLOM (1946, Spain), CUVILLIER and SZAKALL (1949, Aquitaine basin, France), HAGN (1952, Bavaria), DI NAPOLI ALLIATA (1953, Italy), EMILIANI (1954, Italy) and KAASSCHIETER (1955, Aquitaine basin, France).

Some Miocene foraminiferal associations are also discussed in our paper. They are derived from samples of the Antwerp sand (Anversian of authors) and of Dingden in western Germany. Eerlier data on the microfauna from these localities have been published by REUSS (1861, 1863), HOSIUS (1892, 1893) and TEN DAM and REINHOLD (1942).

CHAPTER II

BELGIAN ROCK-UNITS

INTRODUCTION

In the present chapter the various rock-units of the Belgian Oligocene are described in relation with our field observations. Data from the literature and from the archives of the Geological Survey at Brussels are included. The latter contain many unpublished descriptions of borings and mine shafts. The extension of some of the units into the Netherlands is also dealt with.

STRATIGRAPHIC MAPS

Six maps (maps 4-9) illustrate the distribution of some features of the members and the area in which these members occur. They have been prepared with the aid of the geological maps of Belgium and data from the literature and from the archives of the Geological Survey at Brussels. Another map (map 3) shows the locations of the borings and mine shafts that have been used and the numbers they have in the archives.

The geological maps that have been used are the map 1 : 40.000 published between 1890 and 1910, the map 1 : 160.000 that appeared in 1920, and the recent map 1 : 500.000 of DE BÉTHUNE, which is incorporated in the Atlas of Belgium (1954).

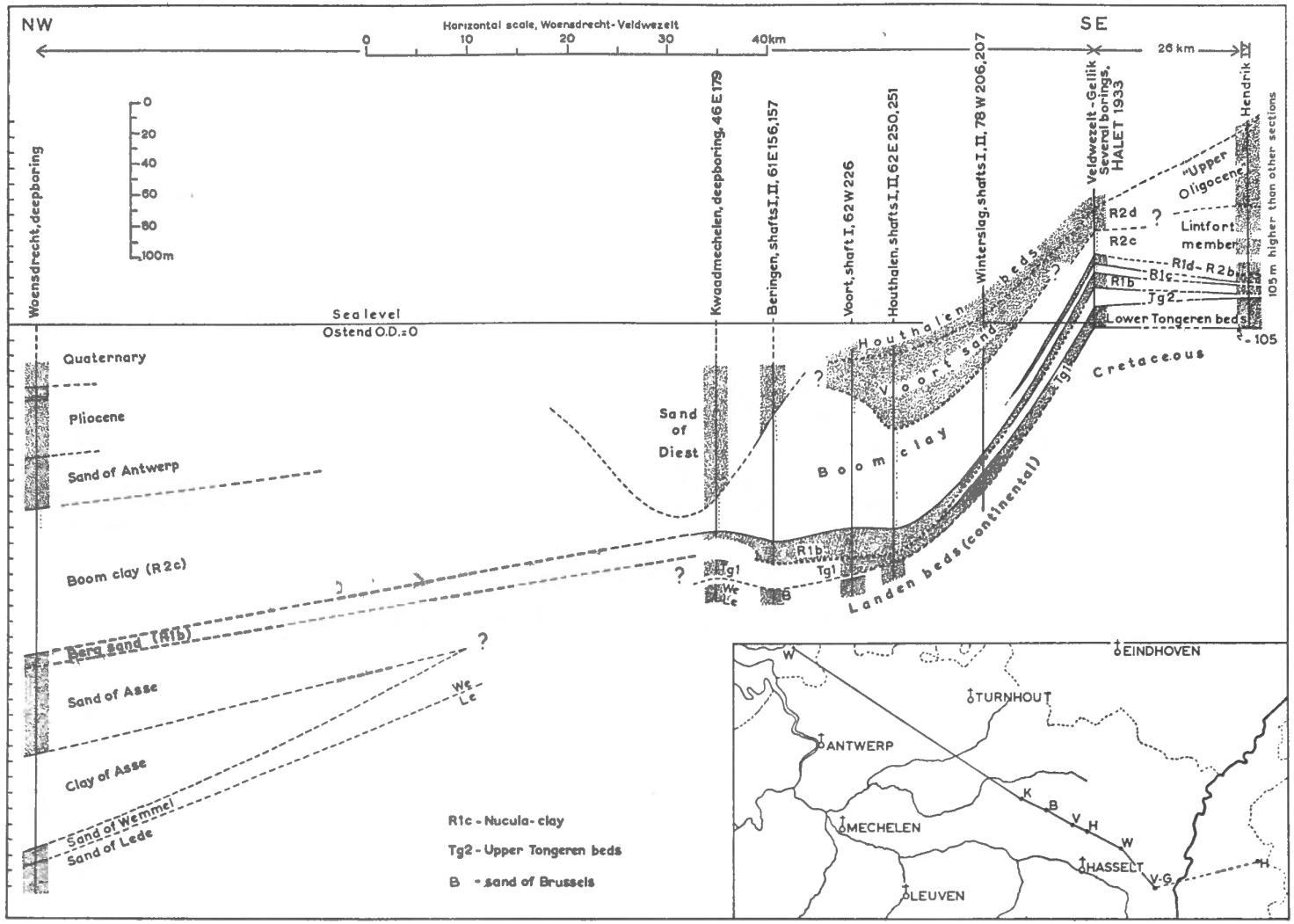


FIG. 1. — Section through the Oligocene deposits from Woensdrecht to Limburg (partly after GULINCK, 1954). Vertical scale exaggerated.

The following remarks on the value of the data must be taken into account when consulting the maps.

The greater part of the descriptions of the borings and mine shafts was collected from the archives of the Geological Survey during a stay of two weeks at Brussels. The borings that were chosen for the construction of the maps nearly all penetrated the Boom clay. Only a few south of the present southern limit of that clay have been used as well. The data of only a small number of the borings have been published.

A great number of data is present in a rather narrow, west-east strip from the Land of Waas to Dutch South-Limburg, parallel to the southern limit of the Boom clay. Most of the data in this region are from water borings. Many of these were flush borings and therefore less reliable. Where both dry and flush borings were present side by side, only the data from the dry ones have been used.

North of this strip the water borings were not deep enough to encounter the Oligocene deposits. For that region there are only data available from some widely spaced deepborings, nearly all of which were flush borings. For the Oligocene these data were considered so unreliable that they have not been used.

Furthermore it should be emphasized that the descriptions in the archives of the Geological Survey are not uniform. They have been made by several authors, who reported on samples that were often collected by the foremen of the borings. As to the formations penetrated by the borings, the descriptions are usually accompanied by an interpretation, often called « probable ».

In most cases we accepted this « probable » interpretation.

LIST OF ROCK-UNITS

The Oligocene deposits of Belgium are commonly subdivided as is shown in the table below. The underlying and overlying strata are also indicated.

Pleistocene		« Scaldisian ».
Pliocene ?		Sand of Diest (D).
Miocene		Sand of Antwerp (A). Houthalen beds (H).
Oligocene ...	.....	Sand of Voort (V).
	Rupel formation	Boom clay (R2c). Sand locally present in between Nucula- and Boom clays (R1d-R2b). Nucula-clay (R1c). Sand of Berg (R1b).
	Upper Tongeren beds	Sands and marls of Oude-Biezen (Vieux-Joncs) (Tg2o). Clay of Henis (Tg2n). Sands and marls of Boutersem (Tg2m). Sand of Kerkom (Tg2k).
	Lower Tongeren beds	Horizon of Hoogbutsel (Tg1n). Sand of Neerrepen (Tg1d). Sand of Grimmertingen (Tg1c).

Upper Eocene	Sand of Asse . / Clay of Asse .	(As).
	Sand of Wemmel	(We).
	Sand of Lede	(Le).
Middle Eocene	Sand of Brussels	(B).
Lower Eocene	Ieper beds	(Y).

The sequence in the above list is not a time-stratigraphic one. Some of the members have to be considered as laterally equivalent to one another.

LOWER TONGEREN BEDS

From West to East the Lower Tongeren beds in Belgium and Dutch South-Limburg cover a series of formations that rangs from sand and clay of Asse, sand of Wemmel, sand of Lede (Upper Eocene), sand of Brussels (Middle Eocene), Ieper beds (Lower Eocene), Landen beds (Paleocene) to Cretaceous and Carboniferous deposits. They are known with certainty only in the region east of Leuven.

Especially in Limburg they locally contain a basal gravel. Outside this province this gravel was observed at Grand-Hallet (QA), at Landen (SN), and probably also at Blanden (LAD). At the places where it is absent, the lower part of the Lower Tongeren beds, i.e. the sand of Grimmertingen, often shows a gradual transition to the underlying Eocene or Landen deposits.

THE SAND OF GRIMMERTINGEN

The sand of Grimmertingen (sands of Vliermaal, Hoeselt and Leten of some authors) occurs with certainty only in the Leuven-Tongeren-Dutch Limburg region. Its thickness generally does not exceed 20 m. We observed it near Leuven (LA, LN, LP, LQ), at its type locality (SG), near Hoeselt and Leten (TL, TM, TN), near Membruggen (TJ) and at some more southern points, such as Grand-Hallet (QA) and Gingelom (SB).

The sand of Grimmertingen is a fine-grained, mostly non-calcareous, often clayey sand with abundant mica and some glauconite. After the washing, the residues [1] appeared to be strikingly rich in mica. Scarce glauconite and silex fragments are usually present. Quartz grains of the second wash residue are often flat and sharply angular; well rounded grains were found as well.

At places where the beds are fossiliferous, *Ostrea ventilabrum* Goldfuss and *Turritella crenulata* Nyst are the most common.

The molluscs are concentrated in layers in the sand. Some of these layers are indurated and ferruginous, e.g. the layer from which our sample SG 193 was taken. According to Glibert and de Heinzelin (1954*a*), such layers may be interpreted as hardgrounds which correspond to a submarine hiatus (« lacune sous-marine »).

The molluscs of the Belgian sand of Grimmertingen were dealt with by Glibert and de Heinzelin (1954*a*), the Bryozoa by Canu and Bassler (1931). On the basis of material from Dutch South-Limburg, molluscs and Bryozoa of the sand of Grimmertingen were also described by Albrecht and Valk (1943).

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[1] All our samples, except for those from Hermsdorf and Pietzpuhl, have been washed with the help of three sieves; meshes 0,75 mm, 0,25 mm and 0,125 mm.

Among the organic components in the wash residues are echinoid spines, small fragments of vertebrate bones, scarce fish otolites and elongate, angular calcareous prisms, sometimes many together in plate-like structures, which are probably fragments of *Pinna* shells.

Only two of our Belgian samples contained a few Foraminifera and Ostracoda. Occasionally they yielded single Foraminifera reworked from Cretaceous deposits.

In addition to all the above mentioned components, the sand of Grimmertingen in shaft IV of the Hendrik mine in Dutch Limburg generally contained Bryozoa, small glittering pyrite aggregations and small white gypsum crystals. Foraminifera and Ostracoda are much more common than in the Belgian samples.

THE SAND OF NEERREPEN

The sand of Neerrepen, the total thickness of which is seldom more than 10 m, overlies the Grimmertingen sand in the Leuven-Tongeren region. It is nearly always unfossiliferous, very fine-grained, micaceous sand with small quantities of glauconite grains and minute silex fragments. The occasional fossils are ferruginous and indistinct (see GLIBERT and DE HEINZELIN, 1954*a*). The sand is very thin-bedded and the individual layers are clearly visible by the unequal distribution of the glauconite. The sand locally contains tubular structures and thin clay intercalations. These tubes and other structural features of the sand were described in most detail by GULINCK (1950). This author compared the sand of Neerrepen with recent « Wadden »-deposits without finding a complete resemblance, however.

We observed the sand of Neerrepen at the type locality (SL), near Leuven (LA, LN, LP, LQ), Pellenberg (LD), Boutersem (LE), Hoogbutsel (LF, LM and ?LG), Kerkom (LAL), Vissenaken (LJ), Overrepen (SM), Tongeren (TC, TD, TR) and probably also at Klimmen (Dutch Limburg).

The thin clay intercalations were found to contain either scarce mollusc fragments or very small complete shells of *Cerithium* and Pelecypoda. In one sample from such a clay bed a single ostracode was found [Tongeren (TR)]. None of the samples from the sand itself contained microfaunal elements.

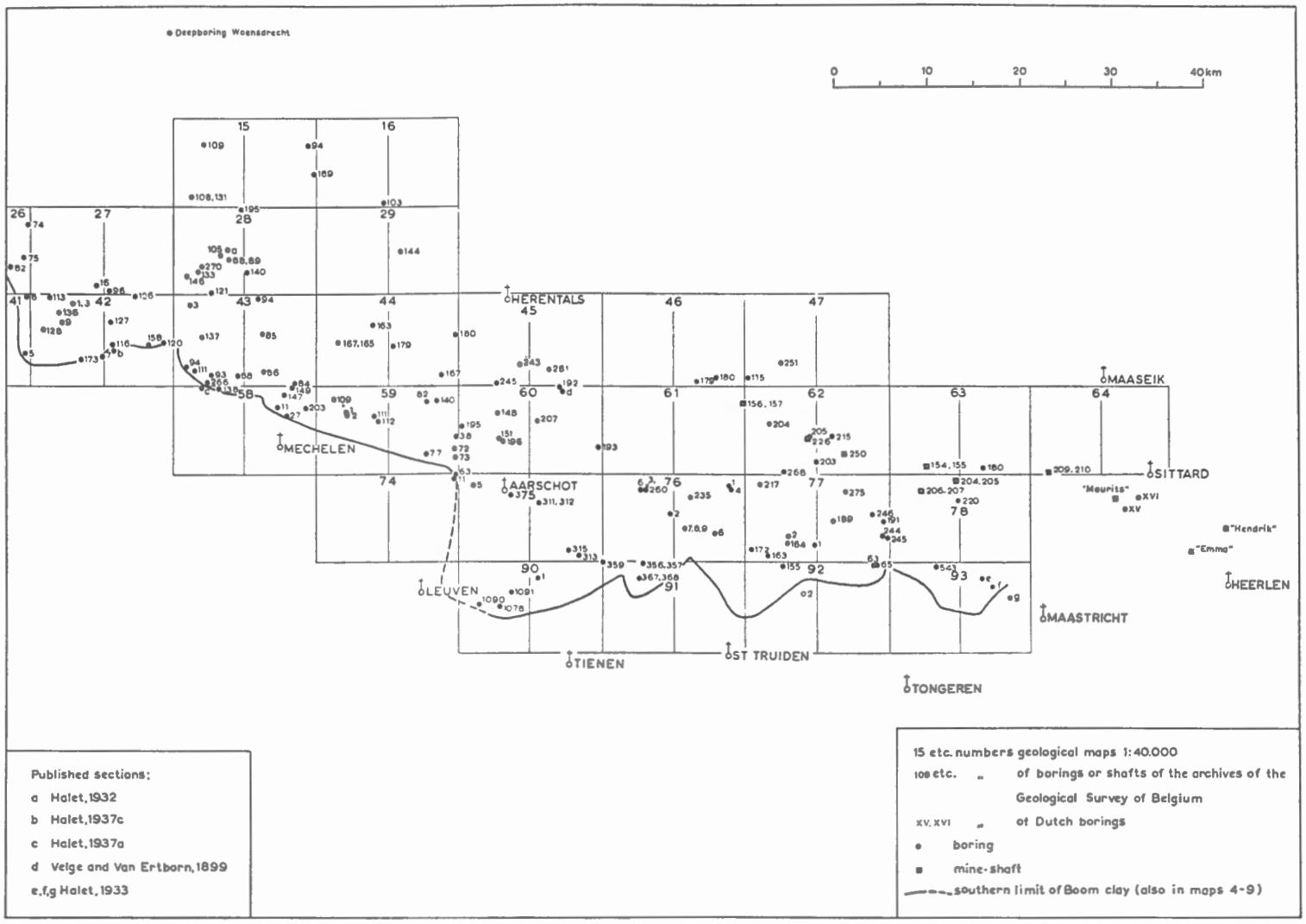
THE HORIZON OF HOOGBUTSEL

Just in between the sand of Neerrepen and the overlying brackish water deposits of the Upper Tongeren beds, GLIBERT and DE HEINZELIN (1952, 1954*a*, 1954*b*) recently discovered the horizon of Hoogbutsel. This member has so far only been observed at Hoogbutsel and at Hoeleden, two localities north of Tienen.

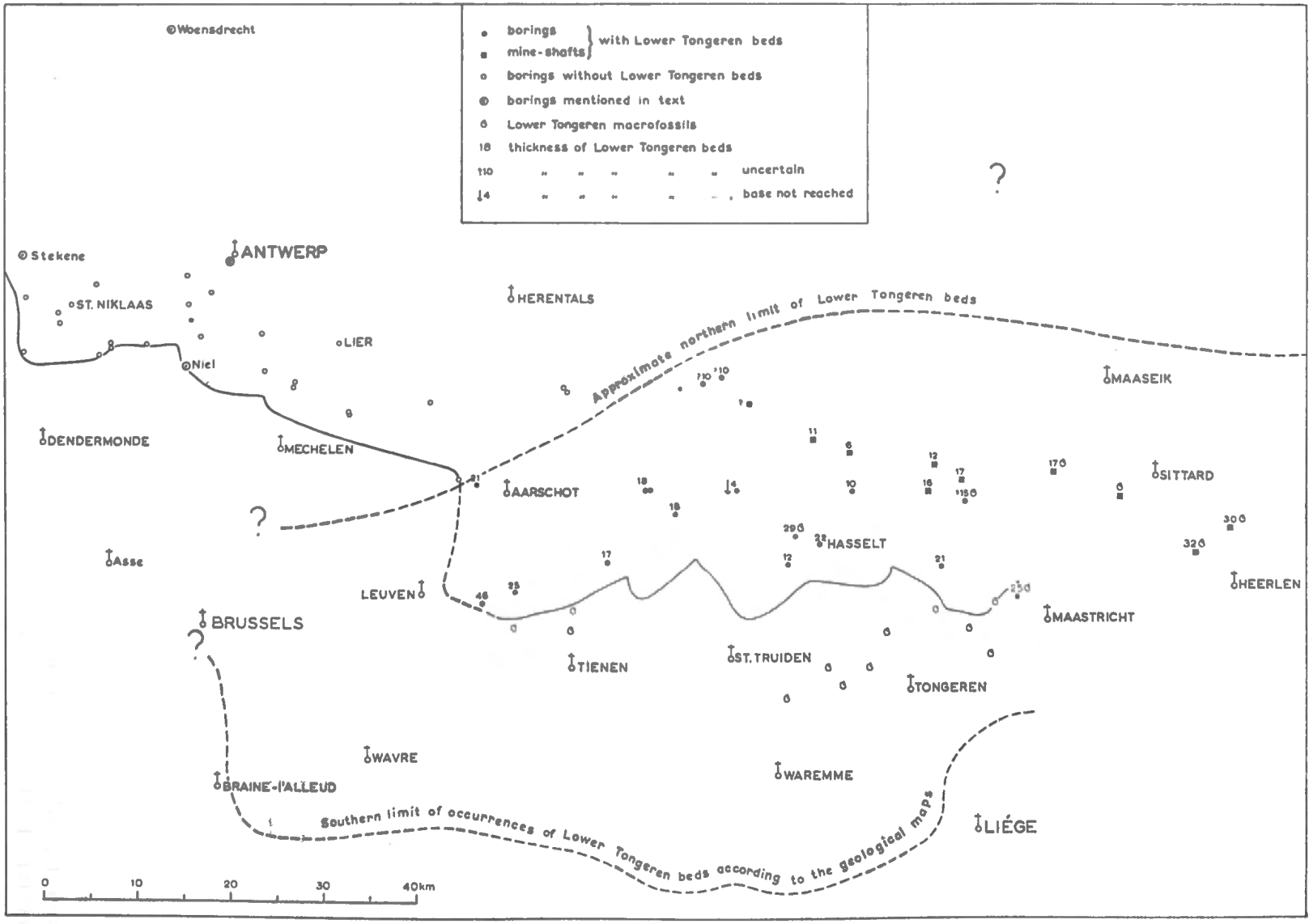
At Hoogbutsel, the type locality (LF), we found a vertebratebearing bed of dark brittle clay of 10 cm thickness, which covers some 30 cm of clay with fresh-water molluscs, chiefly *Nystia*. The latter clay is the so-called « horizon à bithinies » of GLIBERT and DE HEINZELIN (1952). Only one species of Ostracoda : *Haplocytheridea helvetica* (LIENENKLAUS), which is fairly common, and no Foraminifera were found.

At Boutersem (LE) a thin layer of dark clay was observed. According to GLIBERT and DE HEINZELIN (1952) it is the equivalent of the horizon of Hoogbutsel. A sample from this layer appeared to be devoid of microfauna.

GLIBERT and DE HEINZELIN (1954*a*) placed the horizon of Hoogbutsel in between the Lower and Upper Tongeren beds. According to these authors the horizon represents the transition from the marine (Lower) to the continental (Upper) Tongeren beds. We are of the same opinion. The horizon of Hoogbutsel is only treated at this place for reasons uniformity.



MAP 3. — Location borings and mine-shafts, used for the stratigraphic maps 4-9.



MAP 4. — Stratigraphic map of the Lower Tongeren beds.

THE GEOGRAPHIC EXTENSION OF THE LOWER TONGEREN BEDS

Outcrops of distinct Lower Tongeren beds occur only in the Leuven-Tongeren region (see map 4), where they consist of the sand of Grimmertingen and the sand of Neerrepen.

North of this region the extent of the Lower Tongeren beds is vague. They were not encountered in the Dutch borings of the Peel region, but they have recently been met with in mine-shafts near Erkelenz, 26 km ESE of Roermond, in Western Germany (HERBST, 1954). At this place they have the same mollusc fauna as in Dutch South-Limburg.

Towards the south the former extent of the Lower Tongeren beds is unknown because of later erosion.

The extension of the Lower Tongeren beds in western direction is problematical. West of Leuven two elongate occurrences of Lower Tongeren beds have been marked on the geologic maps. Both are on hills, with bad exposures and covered by Diestian (according to the authors of the maps) and Quaternary deposits. No fossils have been recorded.

One of the occurrences extends from Leuven towards the south-west as far as Sint-Genesius-Rode and Braine-l'Alleud. It covers Asse and Wemmel deposits in the north and sand of Lcdc in the south.

The other reaches with many interruptions the region of Asse where it rests on Asse sand. This sand is hardly different from the micaceous, sandy and clayey deposits, interpreted as Lower Tongeren beds on the geological maps 1 : 40.000 and 1 : 160.000.

THE ASSE DEPOSITS

Since a close relation between the Lower Tongeren beds and the sand of Asse must be considered very likely, this Asse sand will be dealt with in some more detail.

Asse is the type locality of the Asse clay, which consists of about 10 m of grey or green, slightly pyrite-bearing clay, that overlies the sand of Wemmel. Especially in its lower part the Asse clay is rich in glauconite. It becomes sandy both at the base and near the top.

Upward the Asse clay grades into glauconitic sand with clayey intercalations. This is the sand of Asse. The Asse sand has a gradually increasing mica content towards the top.

The presence of mica in the upper part of the Asse sand was also noted at various other places (e.g. in several borings at Mechelen (HALET, 1911), in a boring at Westerlo (VELGE and VAN ERTBORN, 1899), at Uccle (LERICHE, 1938) and in other borings that penetrated Boom clay and Berg sand (Kontich, 43 E 85 and Waarloos 43 E 86, archives Geological Survey).

Another interesting feature of the Asse sand is the presence of some dispersed thin layers of gravel.

Fossils, among which Foraminifera and Ostracoda, are usually present in the clay of Asse. The sand of Asse, however, is mostly barren. The occasional fossils found are identical with those met with in the sand of Wemmel.

THE LOWER TONGEREN BEDS IN BORINGS WEST OF THE HAGELAND

For the region west of the Hageland there are but a few records of Lower Tongeren beds underlying Boom clay and Berg sand. Most of the borings that penetrated the Boom clay and Berg sand are said to have yielded Asse sand and Asse clay directly underneath. The absence of Tongeren deposits in the Land of Waas-Aarschot region was noticed earlier, among others by FOURMARIER (1934) and GULINCK (1954).

The following records of Lower Tongeren beds in this area could be found :

1. In 1914 HALET described a dry boring with « Tongrien inférieur » (Tg1) near Stekene in the Land of Waas (archives 26 E 75). Underlying the Berg sand he mentioned a « banc d'*Ostrea ventilabrum*

avec concrétions pyriteuses et gréseuses et débris de bois lignitifié » in a complex of grey, glauconitic sand of 3,90 m tickness. In between the Berg sand and this sand he interpreted as Lower Tongrian, HALET mentioned 35 cm of greenish-grey, micaceous clay. The sample from the oyster-bed (no. 23) was available at Brussels. The wood in the sample appeared not lignitified. In our opinion the oysters that are slightly pyritized, do resemble *Ostrea ventilabrum* GOLDFUSS.

As yet however, there is no comparative study of *Ostrea ventilabrum* and related species, such as *Ostrea wemmelensis* GLIBERT from the sand of Asse and the sand of Wemmel. We are therefore not convinced of the value of HALET's oysters as index fossils, especially if these fossils are the only indication for Lower Tongeren beds in the area involved.

From these data it appears that the deposits, which HALET interpreted as Lower Tongeren beds, might just as well belong to the sand of Asse with a micaceous clayey layer at the top.

2. Another, again uncertain occurrence of Lower Tongeren beds is the « Tongrien ? » in the borings at Antwerp, described by RUTOT and VAN DEN BROECK (1892). This « Tongrien? » has lithologic features that are thought more characteristic for Asse clay and sand. It constitutes a 44 m of greenish sands and clays with pyritized fossils. MOURLON (1880) stated that the Boom clay in one of the borings is directly overlying « sables chamois wemmeliens » (that is Asse deposits of our nomenclature).

3. The « Tongrien » in the deepboring Woensdrecht in the Netherlands, about 25 km NNW of Antwerp, is also indistinct. HALET, TESCH and VAN WATERSCHOOT VAN DER GRACHT (1919) made mention of 57 m of « Tongrien » beneath the sand below the Boom clay and overlying 59 m of Asse clay. It is greenish-grey, glauconitic, somewhat clayey sand with pyrite accretions and two oyster beds. The fragmented oysters might be *Ostrea ventilabrum* according to the authors.

These very deposits were interpreted by TESCH (1912) and by TEN DAM (1944) as the upper part of the « Asschien » and « Bartonien » respectively (both the equivalent of the Asse sand of our nomenclature).

In our opinion this view is supported by the presence of glauconite and some pyrite in the sand, while no mica has been recorded.

4. From a dry boring at Niel (43 W 94 in the archives) HALET described in 1923 fine-grained, somewhat clayey, very micaceous sand between 30,60 and 32,90 m, underlying 12 m of Berg sand that, in turn, are covered by Boom clay. The sand is underlain by 1,10 m grey, micaceous clay, that rests on Asse sand. HALET interpreted these beds as « Tongrien? ». This « Tongrien? » again might just as well be regarded as micaceous beds at the top of the Asse sand.

Concluding, it is apparent that the few data favouring the presence of Lower Tongeren deposits under the area west of the Hageland are but very meagre. Very few occurrences of *Ostrea ventilabrum* and of micaceous sediments are the only favourable indications, neither of which can be considered reliable evidence. This is especially true, when these few doubtful occurrences are weighed against the numerous other borings in which only the Asse deposits were found to underlie the Rupel members. In our opinion, it is very likely that the distinct Lower Tongeren beds are absent in the area involved.

UPPER TONGEREN BEDS

The Upper Tongeren members consist for the greater part of brackish water deposits : sands and clays with, among others, many individuals of *Cerithium*, *Sinodia* and *Corbicula*. The mollusc fauna has recently been fully dealt with in the paper of GLIBERT and DE HEINZELIN (1954*a*). The Upper Tongeren beds again have a limited distribution : about 100 km from east to west and maximally 25 km in north-south direction in Belgium and the adjoining part of Dutch Limburg. The brackish water deposits include the following members : sand and marls of Boutersem, clay of Henis and sands and marls of Oude-Biezen. A fourth member is the sand of Kerkom, a fluviatile deposit. The areal distribution of these members together with indications concerning their thickness and the presence of fossils are given on map 5.

THE SANDS AND MARLS OF BOUTERSEM

This is a complex of sand, clay and marl, variable in proportions and with a total thickness of 3-5 m. We observed it at Hoogbutsel (LG). Probably it occurs also at Vissenaken (LJ).

The sand is fine-grained and slightly glauconitic. Minute silex fragments and mica are rare. It contains *Cerithium, Corbicula semistriata* (DESHAYES) and scarce *Nystia* specimens. No Foraminifera were found; *Haplocytheridea helvetica* (LIENENKLAUS) is the only ostracode species.

The marl was observed at Hoogbutsel (LG) where it is rich in *Nystia*. No Foraminifera and scarce *Haplocytheridea helvetica* were found in the samples. The clay component of the Boutersem member was possibly exposed at Vissenaken (LJ). It was not found to contain any microfauna.

The Boutersem member is present in the area between Leuven and Sint-Truiden. To the south it has been eroded, to the north it is locally replaced by the Kerkom sand. Its extension in eastern direction is indistinct. Possibly it is still present near Tongeren, though in a less characteristic facies. HALET (1933) recorded it from borings near Veldwezelt, east of Tongeren, where it is said to underlie the Henis clay.

THE CLAY OF HENIS

The Henis clay itself is plastic and green with few small quartz grains and often with big, well-developed gypsum crystals. In one sample some pyrite was found. Locally there are dark-brown lignitiferous beds intercalated in the clay.

Whenever molluscs were present, they appeared concentrated in more or less distinct, often sandy, light-grey, whitish or bluish beds. *Cerithium, Corbicula semistriata* (DESHAYES) and *Sinodia indrassata* (SOWERBY) are the most common macrofossils. Furthermore there occur *Natica, Nystia, Bayania, Aloidis* and also barnacle remains. Scarce silex fragments and very small pyrite aggregates are present in the washing residues of samples from these shell-bearing beds.

Only in samples from such mollusc-beds that are not or slightly sandy, as well as from the lignitiferous beds, Ostracoda and scarce Foraminifera were observed. Samples from the pure clay were devoid of microfauna.

The clay of Henis is very well exposed in the claypit of the tileworks Francart between Henis and Tongeren (TA). It was furthermore observed at Tongeren (TB and TR), at Kortessem (SK), near Oude-Biezen (TG), in several of the BZ-borings near Kleine-Spouwen, at Schin-op-Geul (Dutch South-Limburg), and may probably be present also near Overrepen (SJ).

The thickness of the Henis clay in Belgium generally is about 8 m. HALET (1933) recorded up to 16 m of the clay on top of 4 m of sands and marls of Boutersem from borings in the region of Veldwezelt. The thickness diminishes rapidly northwards. In Dutch South-Limburg the clay of Henis is known as Cerithium-clay. It has a similar thickness as it has in Belgium.

The geographic area of these deposits is rather distinct. Fossil-bearing, distinct Henis clay is absent west of Sint-Truiden. To the north it was found to be absent in several mine shafts of the Kempen and Dutch South-Limburg, so that its boundary in these directions is rather sharp. East of Sittard it is unknown because most of the borings did not reach the Henis (or Cerithium-) clay level in the Central graben. In Belgium the southern limit is due to later erosion. In Dutch South-Limburg this southern limit is connected with faults.

It may be remarked that from two flush borings near Diepenbeek (92 E 63 and 65) and a dry boring (93 W 543) at Munsterbilzen all situated in the Henis clay area, no such clay was recorded.

THE SANDS AND MARLS OF OUDE-BIEZEN

This member consists of alternating fossiliferous sands and marly clays. Actually it is only exposed at Tongeren (TA). We furthermore observed it in boring 26 BZ at the type locality and in some other BZ-borings near Kleine-Spouwen.

The sand is white, fine-grained and very fossiliferous, with *Cerithium*, *Bayania nysti* (NYST), *Nystia*, *Sandbergeria cancellata* (NYST) and *Natica*. *Corbicula semistriata* (DESHAYES), *Aloidis* and some other molluscs are rare. Barnacle fragments are occasionally present.

No distinct marls of the Oude-Biezen member were met with at the type locality during our field work. In boring 29 BZ near Kleine-Spouwen a marly clay was found intercalated in the Oude-Biezen sand. It was furthermore observed at Tongeren (TA).

In the Oude-Biezen member Ostracoda are often abundant; Foraminifera are less numerous. Scarce silex fragments, glauconite, mica and very rare echinoid spines and bone fragments are present in the washing residues.

The Oude-Biezen member overlies the most southern area of the Henis clay in the region Borgloon-Tongeren-Bilzen; an area of about 20 × 8 km. Its thickness is about 4 to 5 m.

Sands at Zavelberg

The sands on the Zavelberg near Tongeren (TB and TQ) at one place overlying the Henis clay and at the other below the basal gravel of the Rupel formation, probably belong to the same rock-unit. In both outcrops we found white sand with small silex fragments and rare mica. No microfauna was observed in our single sample (TQ 577). The whole complex may belong to the sand of Berg, which in this case, however, locally would have a thin gravel near its middle. The thickness of the sand is estimated to amount to about 4 meters (3-6?).

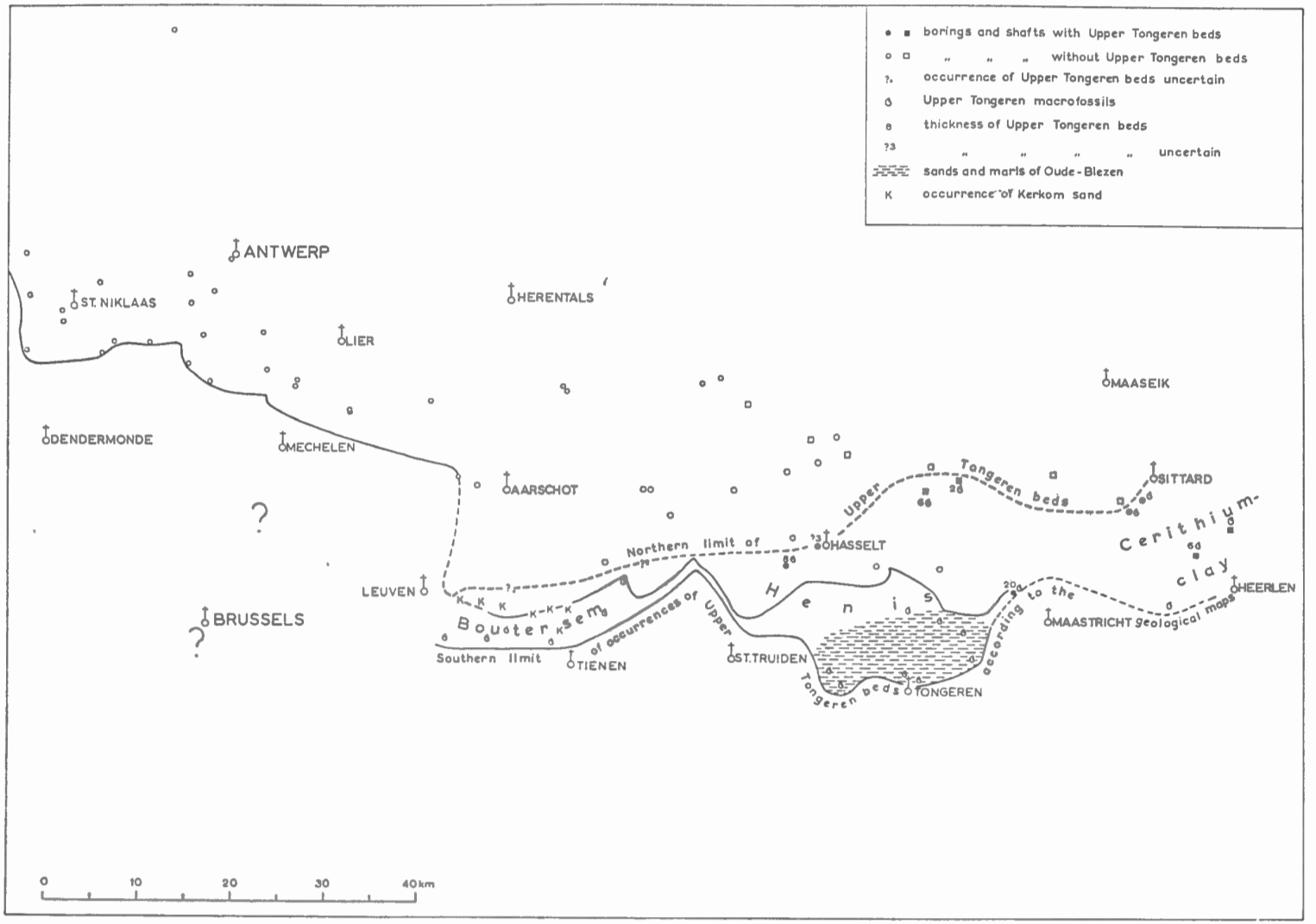
THE SAND OF KERKOM

The sand of Kerkom is a complex of current-bedded sand with thin intercalations of clay and gravel and locally with a basal gravel of silex and clay pebbles. Small silex fragments are often present, glauconite and mica are rare. According to GLIBERT and DE HEINZELIN (1954*a*), the thickness of the Kerkom sand may somewhat exceed 15 m. In none of our samples was a microfauna observed.

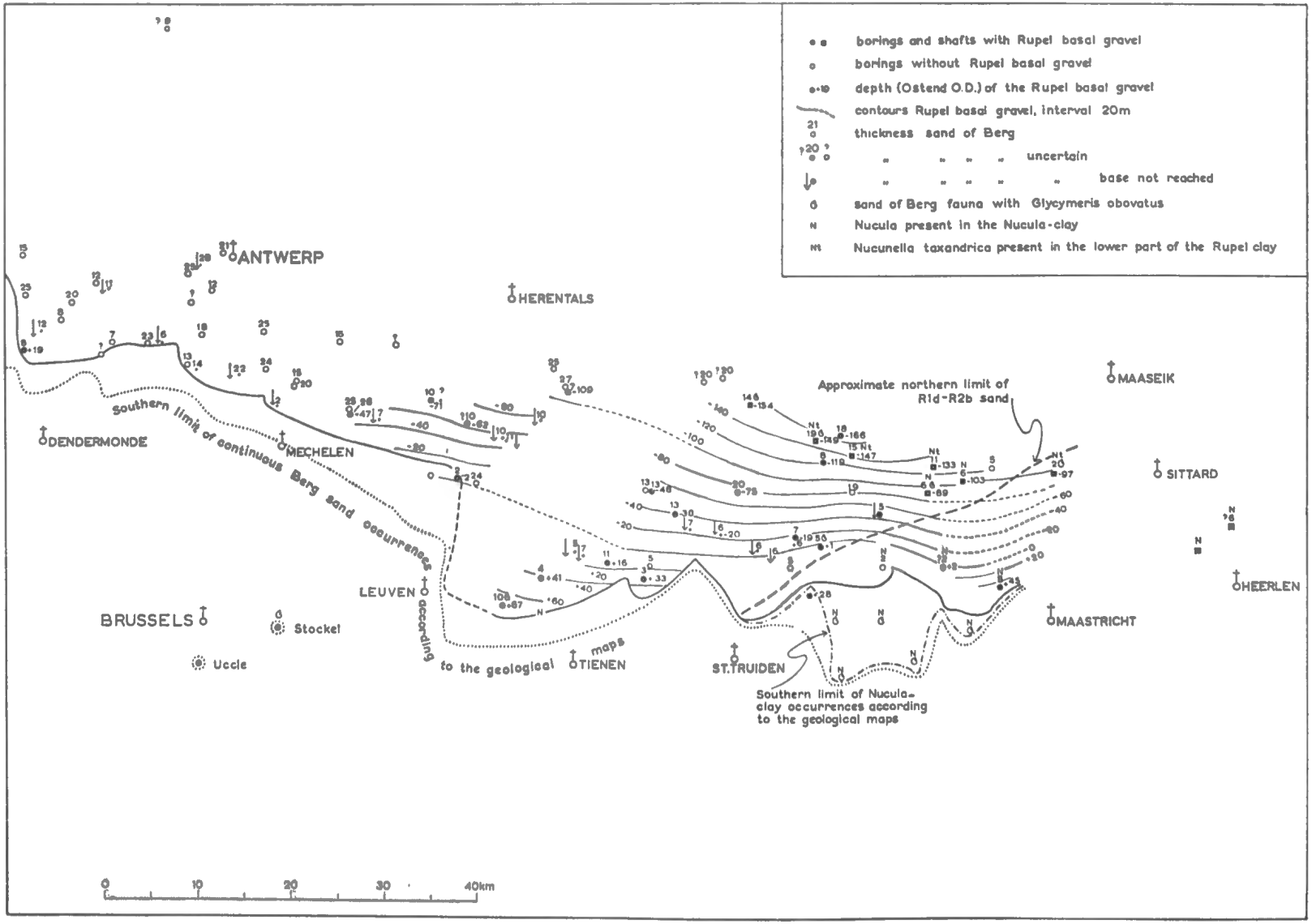
The sand of Kerkom is found in the region between Leuven and Tienen, where we observed it at the type locality (LH), at Pellenberg (LD) and at Vissenaken (LJ). At the latter locality we observed some clayey intercalations with badly preserved molluscs. They may have been reworked from the Boutersem member.

At Boutersem (LE) up to 45 cm of fine-grained, yellowish, thin-bedded sand with scarce glauconite was exposed under a 10 cm clay bed. The clay bed probably represents the horizon of Hoogbutsel (GLIBERT and DE HEINZELIN, 1954*a*). The sand contained rounded greenish-grey clay pebbles in its lower part. It covers a wavy layer of silex pebbles which in turn overlies sand of Neerrepen.

This complex of silex, gravel and sand has much resemblance with the characteristic Kerkom sand. It would indicate that a similar fluviatile environment as that in which the Kerkom sand was deposited, was present before the sedimentation of the clay, which is thought to represent the horizon of Hoogbutsel at Boutersem.



MAP 5. Stratigraphic map of the Upper Tongeren beds.



MAP 6. — Stratigraphic map of the Rupel basal gravel, Berg sand and Nucula-clay.

VAN DEN BROECK (1894) reported chocolate-coloured, horizontally bedded quartz sands from Heide and from Sint-Martinusberg (Heyde and Mont-Saint-Martin), both villages between Pellenberg and Boutersem, NW of Tienen. He thought these sands to represent lateral equivalents of the upper part of the Kerkom sand. HALET recorded such sands from a mine-shaft at Eisden (64 W 209), where they occurred at about 4 m below the basal gravel of the Rupel formation. At Tongeren (TA and TR) we observed chocolate-coloured sands under the Henis clay. The chocolate colour is caused by a thin, ferruginous coating on the fine grains (quartz and silex) of the sand.

THE RUPEL FORMATION

THE RUPEL BASAL GRAVEL

The Rupel formation is commonly considered to include a basal gravel, often referred to as R1a. This gravel has been observed over a vast region.

East of Brussels it has been more frequently met with than west of this town. VANDERVEE (1953) mentioned only three R1a occurrences in the western part of the Land of Waas. In the greater part of the borings in this region, which penetrated the Rupel beds, no indications of gravel were observed.

West of the Hageland but a few occurrences have been recorded from the borings (archives of the Geological Survey) and another from Stockel near Brussels (LERICHE, 1930). Yet another occurrence of the gravel west of the Hageland was described by LERICHE (1938) from Uccle, a southern suburb of Brussels. At this place the gravel occurred at the base of a sand, incised in the Asse clay. It was overlain by Quaternary deposits. According to LERICHE, the sand should be the sand of Berg and the gravel, the Rupel basal gravel. In contrast to the occurrence of Berg sand and gravel at Stockel no molluscs were observed in the sand and gravel at Uccle.

In some of the borings in the Hageland, the gravel was equally met with. East of this region, there are many more observations of the gravel, both in Belgium and in Dutch South-Limburg, but there are also data from several places where the basal gravel is lacking.

The components of the Rupel basal gravel are characteristically flattened, dark silex pebbles and coarse quartz grains. The latter gave rise to the name of rice-grain gravel. Shark teeth and mollusc shells are only occasionally present. Among the molluscs *Cyprina rotundata* BRAUN is said to be characteristic.

In outcrops the basal gravel was encountered near Leuven (LN, LP, LQ) and less distinctly at Pellenberg (LD), Kerkom (LH) and Tongeren (TR).

At some places a second or even a third gravel is present higher up in the lower part of the Rupel formation. The gravel observed near Borgloon (SE) is possibly an occurrence on top of the Nucula-clay.

In the mine-shafts Emma (Eindverslag Rijksopsporing van Delfstoffen, 1918) and Hendrik IV in Dutch South-Limburg a gravel of silex pebbles was observed in between the Nucula-clay and a sandy equivalent of the Boom clay. VAN RUMMELEN (1955) mentioned three Rupel gravels in each of two borings near Heerlen.

According to GULINCK (1954) a splitting of the basal gravel of the Rupel beds would often occur close to the regions where the sand of Kerkom is present.

The occurrences of the R1a gravel in some outcrops and in borings that penetrated the Boom clay, and at some places mentioned in the text are shown on map 6. From the data it appears that the contours of the basal gravel are fairly regularly distributed. In the region of the coal-mines of the Kempen there is an increase of the northward dip.

The assumption that the silex pebbles on the surface, or directly under the loess on the plateaus and hills between Liége and Gent, would be remainders of the Rupel basal gravel (LERICHE, 1930) is considered doubtful. According to LERICHE (1938) and GLIBERT and DE HEINZELIN (1954*a*) these silex pebbles have been reworked from several gravels intercalated in the Tertiary deposits of Belgium. Moreover, GLIBERT and DE HEINZELIN pointed to the resemblance of the silex pebbles at the base of the Ieper deposits (« Yprésien ») to those of the Rupel basal gravel. Other gravels with silex pebbles occur in various members of the Eocene, Oligocene and Neogene deposits of Belgium.

THE SAND OF BERG

In Belgium the sand of Berg is found under the Rupel clays (Boom clay and Nucula-clay) and on top of the Rupel basal gravel. Its type area is the region of Tongeren.

West of the Hageland this sand is rather fine-grained, greenish-grey, with scarce glauconite and silex fragments. Locally it is fossiliferous. From Sint-Niklaas, Boom, Reet, Heist-op-den-Berg and other localities molluscs have been recorded (ERTBORN, 1901; MOURLON, archives 43W5-13). These molluscs occur also in the typical Berg sand in Limburg. *Pycnodonta callifera* (LAMARCK) is a characteristic species west of the Hageland, but *Glycymeris obovatus* (LAMARCK) is absent in this region.

The thickness of the sand of Berg west of the Hageland is about 20 m. In many places neither the contact with the overlying Boom clay, nor that with the underlying sand and clay of Asse is sharp. Samples from a dry boring at Boom (archives 43 W 266) yielded scarce Foraminifera in the Berg sand. They belong to the same species, that are common in the overlying Boom clay and the samples are therefore considered to be probably contaminated during the boring. Two other samples of mollusc-bearing Berg sand from borings near Boom (43W6 and 43W12), which could be examined at the Geological Survey at Brussels, contained no microfaunal elements.

In the sand of the above mentioned boring 43W266 a layer of phosphatic concretions with mollusc moulds was present. It is remarkable that a similar layer occurs in the eastern parts of the Dutch provinces Overijssel and Gelderland, also in the sand under the Boom clay. At this place it is usually interpreted as the base of the Oligocene deposits (PANNEKOEK, 1956, see also DIETZ and HILTERMANN, 1950).

East of the Hageland the sand of Berg is more variable than to the west. Some samples were obtained from the type locality and its surroundings by means of handborings (BZ). The sand was furthermore observed in outcrops east of Leuven (LN, LO, LP, LQ), less distinctly at Pellenberg (LD) and at Kerkom (LH), and also at Tongeren (TQ, TR), Kleine-Spouwen (TE) and near Overrepen (SJ).

The sand is rather fine-grained, yellowish-white, sometimes fossiliferous. It contains small silex fragments, some reworked Cretaceous Foraminifera, scarse mica, lignite and glauconite. Ferruginous cementing of the grains is rather common. In some samples a few larger fragments and pebbles of silex were observed. Occasionally fish otolites and single ray teeth were found. In some of the samples Ostracoda and Foraminifera are present, but they are always rare. The samples of the Berg sand from the deepboring at Lillo also contained scarce Foraminifera. Berg sand samples from the deepborings at Lambroek and Voort were devoid of microfauna.

The molluscs we found are chiefly *Glycymeris obovatus* (LAMARCK), *Astarte*, *Pecten hoenighausi* DEFRANCE, *Nucula comta* GOLDFUSS, *Leda gracilis* DESHAYES and *Limopsis goldfussi*

(Nyst). Furthermore species of *Cerithium* and of other genera that are common constituents of the brackish Upper Tongeren beds; they are usually fragmentary. According to Van den Broeck (1894), the species of *Cerithium* and other Upper Tongeren molluscs in the sand of Berg must be reworked components. Actually we observed them at the type locality most frequently at or near the base of the Berg sand.

The thickness of the sand of Berg east of the Hageland decreases in eastward direction. It is about 20 m under the Boom clay but maximally 8 m when the sand is overlain by Nucula-clay.

In Dutch South-Limburg the Berg sand member is less distinct, because the Nucula-clay is frequently very sandy in this region. The Rupel basal gravel then is often overlain by clayey sand or sandy clay with *Nucula comta*, so that characteristic sand of Berg with *Glycymeris obovatus* is wanting (Jongmans, 1931).

According to Muller (1943) the 10 to 40 meters of sandy deposits under the Boom clay in the Peel region can be considered as equivalents of the sand of Berg. The gradual transition from these sands to the overlying Rupel clay in the Netherlands, makes a delimitation of both units arbitrary.

THE NUCULA-CLAY

In part of Belgium and Dutch Limburg the clayey Rupel deposits commence with a more or less sandy clay with numerous *Nucula comta* Goldfuss, the mother-of-pearl of which is preserved and very characteristic. We observed the clay at the type locality Kleine-Spouwen and its surroundings in several handborings (BZ) and in two outcrops (TE, TK). It was probably also encountered near Borgloon (SE).

The Nucula-clay is brownish-grey to greyish-blue, usually sandy and mostly with many fragile shells of *Nucula comta* Goldfuss and *Leda gracilis* Deshayes. *Dentalium*, *Glycymeris*, *Pecten hoenighausi* Defrance and *Cardita kickxii* Nyst and Westendorp are less common constituents of the fauna. Fish otolites and small bone fragments are rare. In the second wash residues rounded quartz grains, fairly common echinoid spines, and some lignite and silex fragments were found. Scarce, reworked Cretaceous Foraminifera, mica, very rare glauconite and occasionally some pyrite aggregates may equally be present. Ostracoda are very well preserved and often abundant; Foraminifera are fairly common. In the third residue of some of the samples Foraminifera are abundant, while Ostracoda are almost lacking. In part of the samples there occur numerous white, small, autigenous gypsum crystals.

In the Nucula-clay outcrop of the Katteberg near Bilzen (TK), there is an indurated marly layer in the clay.

In the BZ borings the contact Berg sand and Nucula-clay is distinct; in the outcrop Kleine-Spouwen (TE) there is a gradual transition between both members.

The limits of the extension of the Nucula-clay are uncertain. Partly this clay has been defined in combination with the R1d-R2b sand, which separates Nucula- and Boom clay. Furthermore *Nucula comta* is a characteristic fossil.

The R1d-R2b sand wedges out in northwestern direction. Outside the R1d-R2b area unspecified *Nucula* has been reported from the lower part of the Boom clay in the mine-shafts of Winterslag and Waterschei (archives Geological Survey).

The Nucula-clay evidently grades into the lower Boom clay in which it continues as a marly, often sandy clay with *Nucunella taxandrica* Vincent, as has been illustrated by Gulinck (1954). The Nucula-clay therefore is best regarded as an offshoot of the Boom clay.

According to the Geological map 1 : 40.000 there are still some other occurrences of clay with *Nucula comta* at some places in between Leuven and Sint-Truiden.

The Nucula-clay attains its maximal thickness of 10 m in the region Veldwezelt-Borgloon. At Diepenbeek (archives 92E63 and 65) from two flush borings 15 and 10 m of Nucula-clay have been recorded by HALET.

In Dutch South-Limburg the entire Rupel formation is always sandy. As has already been remarked in treating the sand of Berg, sandy clay with *Nucula comta* is often present directly above the Rupel basal gravel in this region. The thickness of this more or less sandy complex is about 10 m.

The Nucula-clay has neither been recorded from the Peel region nor from the Netherlands farther north.

THE SAND BETWEEN THE NUCULA- AND BOOM CLAY (R1d-R2b)

In the southern part of Belgian Limburg a complex of sand separates the Nucula-clay and the Boom clay (see map 6). The thickness of the sand is maximally 10 m. According to GULINCK (1954) it contains occasional fossiliferous beds with *Glycymeris*.

Locally a gravel of silex is present in the sand. It separates the R1d and R2b and it is itself referred to as R2a. This gravel has been mentioned already in the paragraph on the Rupel basal gravel.

The lower part of the sand was observed near Bilzen (TK) and in some of the BZ borings at Berg near Kleine-Spouwen. It is medium to rather fine-grained, brownish-yellow to light-grey with rounded to angular quartz grains in the second wash residue. Mica, small silex fragments and glauconite are rare. Except for very rare Foraminifera reworked from Cretaceous deposits, no microfaunal elements were found. Small lignite fragments are occasionally present.

Probably the present member was met with at Borgloon (SE), where it is separated from the underlying sandy clay by a thin layer of silex pebbles.

Perhaps the sand from a pit at the southern side of the railroad incision at Kerniel (SF) also belongs to the R1d-R2b member, which at this place is known as sand of Kerniel. No microfauna was present in the samples. The exposure did not allow for any conclusion as to the stratigraphic position of this sand.

Intercalations of sands were sometimes found to occur in Dutch South-Limburg in between the sandy Nucula-clay and a sandy equivalent of the Boom clay, but they are not separated as a distinct member in this region.

THE BOOM CLAY

This is the most important and distinct member of the Belgian Oligocene. It was observed in 26 clay pits. In the pits west of the Hageland, it has its characteristic facies.

The clay is dark to light-grey with more or less regularly alternating plastic and silty or slightly sandy layers of some tens of centimeters each. When the wall of the pit was wet by rain or by water from the covering sands, the various layers were often visible only from a distance. On approaching the wall, the slight colour differences wholly disappeared. This must be taken into account in considering the various drawings of the sections of the Boom clay pits (figs. 6-8). When the wall of a pit is dry, the plastic layers are more heavily cracked than the less fine-grained ones. It was often observed that in one part of a pit a layer was darker, and in another part of the very pit, of lighter colour than the adjoining layers. Correlation of the sections of various pits on the basis of the alternation of silty and plastic layers and on the spacing of septaria-beds appeared impossible.

Only at one locality, Ramsel (AD), could a dip of the layers be observed, maximum 8° in outcrop. In other pits the layers are apparently horizontal except for some very slight local deviations within the area of the pit.

Pyrite is always present in the Boom clay. It occurs as small glittering, occasionally somewhat honeycomb-like aggregates, as dull or glittering cylindrical bodies with a diameter of up to 3 mm and as irregularly shaped, roughly cylindrical or rounded accretions. They reach largest dimensions in the region between Mechelen and Aarschot, where pyrite bodies of 20 cm diameter were found. In the centre of one such a big accretion an irregularly bordered mass of yellowish-brown marl was observed. Furthermore pyrite is often present in septaria, molluscs, Foraminifera and in wood fragments.

Gypsum is rare in the Boom clay. In Belgium we only found it at Ramsel (AD), at Betekom and at Loksbergen. In Betekom large, well-developed, clear gypsum crystals and crystal aggregates up to 10 cm occur dispersed in non-calcareous Boom clay. The gypsum crystals at Loksbergen were much smaller and rare. In the Boom clay pits in the eastern Netherlands (Winterswijk, Ootmarsum) gypsum was also observed.

A very characteristic feature of the Boom clay are the septaria. In Germany and in the Netherlands they gave rise to the name Septaria-clay for the Boom clay.

The septaria are internally cracked, flattened, rounded calcareous bodies, the thickness of which was found to vary between 7 and 38 cm and the diameter from 30 cm to somewhat more than 2 m.

They occur in both plastic and silty layers of the clay, in beds parallel to the stratification planes. Some of these beds are rich in septaria, in others only a single septaria is visible within the area of one clay pit.

The characteristic septaria are made up of calcareous claystone. They contain the same inclusions as the surrounding clay viz molluscs, occasionally with pyrite filling, pyrite accretions, pyritized wood and Foraminifera. No gypsum was observed. The inclusions may be only partly incorporated in the septaria, whilst the rest is in the clay around it. In the septaria and in the clay there is no distinct difference in concentration of these elements.

In several cases a gradual transition in colour and in hardness was observed between the septaria and the surrounding clay. Furthermore, the clay effervesced more strongly with HCl in the direction toward the septaria than away from it.

The cracks in the septaria are generally normal to the surface of the septarian body. They disappear within a distance of 1,5-3 cm from the septarian surface. They border polygonal columns with a diameter in between 2 and 10 cm. The cracks are often partly or completely filled with calcite and pyrite. When both minerals occur together, it is the pyrite that is present towards the centre of the crack.

At Kemzeke-Hol (JE) a septaria was found in the wall of the pit, the cracks of which were filled with clear water.

A number of various calcareous bodies in the Boom clay is considered to represent either growing septaria or decalcification products of septaria. Among others there are grey, flat, irregularly shaped bodies, up to 60 cm in diameter and about 10 cm thick, which were observed at Kruibeke. In these bodies, which are hardened and calcareous, only scarce and narrow cracks without filling occur. The surrounding clay is mainly non-calcareous. It only effervesced with HCl very close to the calcareous bodies.

Other, still less septaria-like calcareous structures occur at Lier and at Herselt (AE), again in non-calcareous clay. In the clay near the bottom of the pit at Lier, there is a 10 cm bed of irregularly bordered, hard, crumbly, whitish, calcareous substance. In this bed a 10 cm thick, not internally cracked, calcareous body was observed. In the clay at Herselt (AE) three layers occur with scattered, hard, well-bordered, calcareous balls that are not cracked.

Especially near the top of several outcrops there are in non-calcareous Boom clay, brown, non or slightly calcareous septaria, the cracks of which are only partly filled with pyrite.

An abnormal septaria was furthermore observed at Boom (MA) in 1954. The specimen, 210 cm of diameter, reached a total thickness of 38 cm owing to a 12 cm mass of hard, calcareous septarian

material on the greater part of its upper surface. A number of the broad cracks in the main septaria continued in this added part as much narrower cracks, that were only incompletely coated with a thin calcite layer. The broad cracks in the lower part of the septaria showed a complete, thick coating of calcite.

During the field survey of 1954, the $CaCO_3$ contents of the clay were minutely examined with HCl. Non-calcareous zones appeared to occur irregularly dispersed and furthermore often at the top of the exposures. The clay of septaria-beds was in most cases distinctly calcareous, and often marked by a thin, light-grey band in between the septaria.

As the samples have been taken in order to examine the microfauna, most of them have been taken from $CaCO_3$-bearing clay.

In relation to the quantity of sediment, fossils appeared very rare in the Boom clay. Among the molluscs the famous index fossil *Leda deshayesiana* (Nyst) was most frequently met with. Furthermore *Cardita kickxii* Nyst and Westendorp, *Astarte kickxii* Nyst, *Nucula* sp., *Pecten hoenighausi* Defrance and *Ostrea paradoxa* (Nyst) were occasionally found. We often encountered both valves of the Pelecypoda individuals together.

Gastropods were less common. *Gemmula selysii* (De Koninck) *dominates*; *Streptochetus elongatus* (Nyst), *Euthriofusus multisulcatus* (Nyst), *Aporrhais speciosus* Schlotheim and other rare species have also been found.

A distinct mollusc-bearing layer was observed only at Schriek (AA). It contained many small *Aloidis* specimens. At Herselt (AE) a badly preserved pyritized nautilus was found in the clay. Lignitified wood fragments are rare.

Because of the intensive exploitation of the clay, vertebrates have occasionally been found. Leriche (1910, 1948, 1951) described the fishes. Other vertebrates, among which *Halitherium*, turtles and various birds have been mentioned by Van den Broeck (1894). Gutinck (1954) mentioned *Aceratherium*.

Locally the uppermost part of the Boom clay is of brown colour. In the Land of Waas this brown clay is used for flowerpot industry. We observed it in small pits near Elversele (JD) and Kwakkel (OB). Halet (1938) described the exposures and listed some chemical analyses.

The wash residues of the plastic and slightly sandy Boom clay are always very small, except for samples with indurated marly bodies, taken from a septaria-bed.

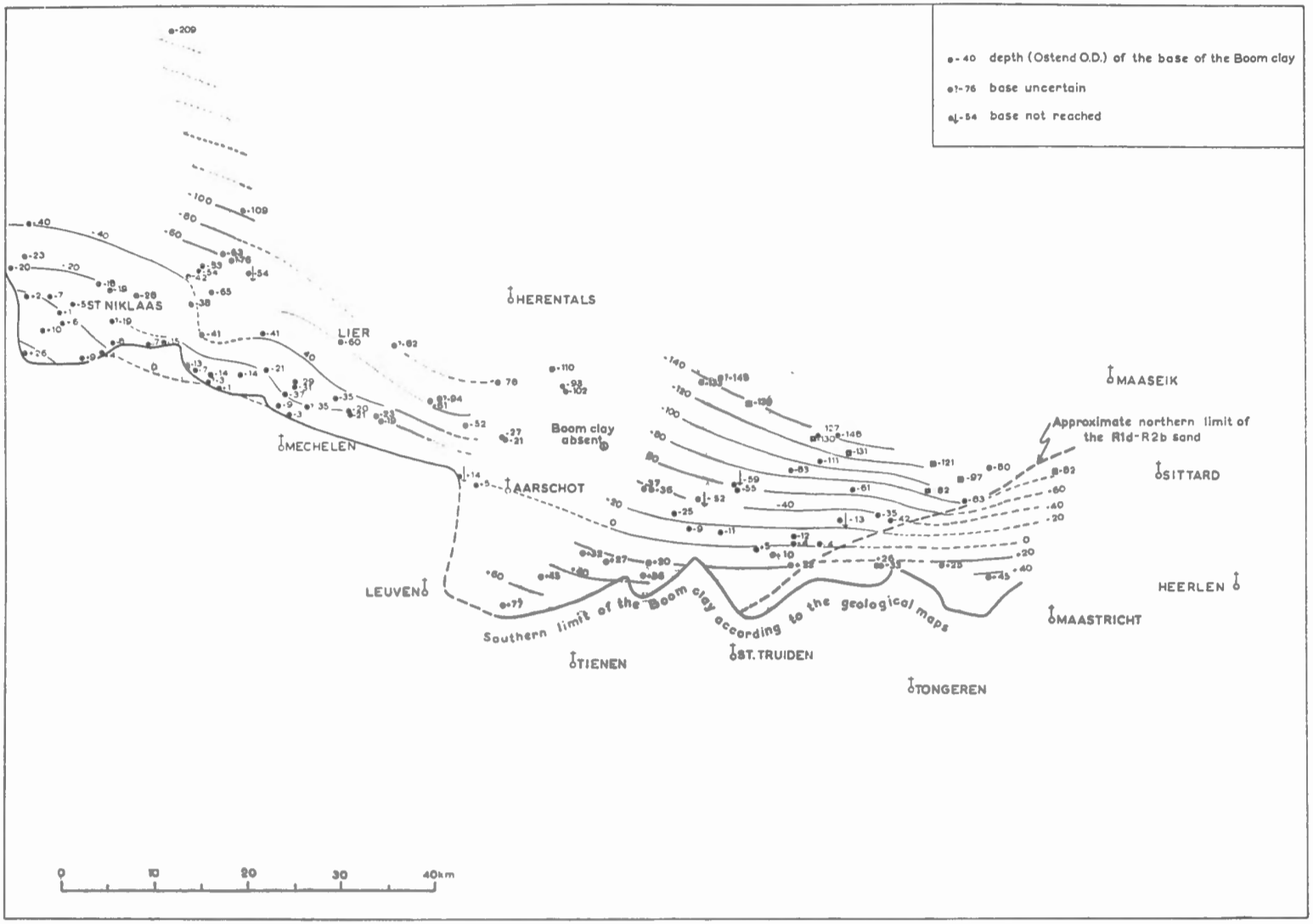
A first residue is often absent or it contains some coarse pyrite accretions, sometimes mollusc fragments and rare *Lenticulina* specimens.

The second and third residues together are less than 0,5 cm^3 per 300 cm^3 of clay. They chiefly contain pyrite. In a few samples Foraminifera are the dominating component of the finer residues. Mica and glauconite are present in the smaller part of the samples. Mica is often common in silty layers, though it is also found in samples from layers that were considered in the field to be plastic. Glauconite is abundant in a few samples, which for the greater part have been derived from silty layers. In some other samples glauconite was observed as a rare constituent.

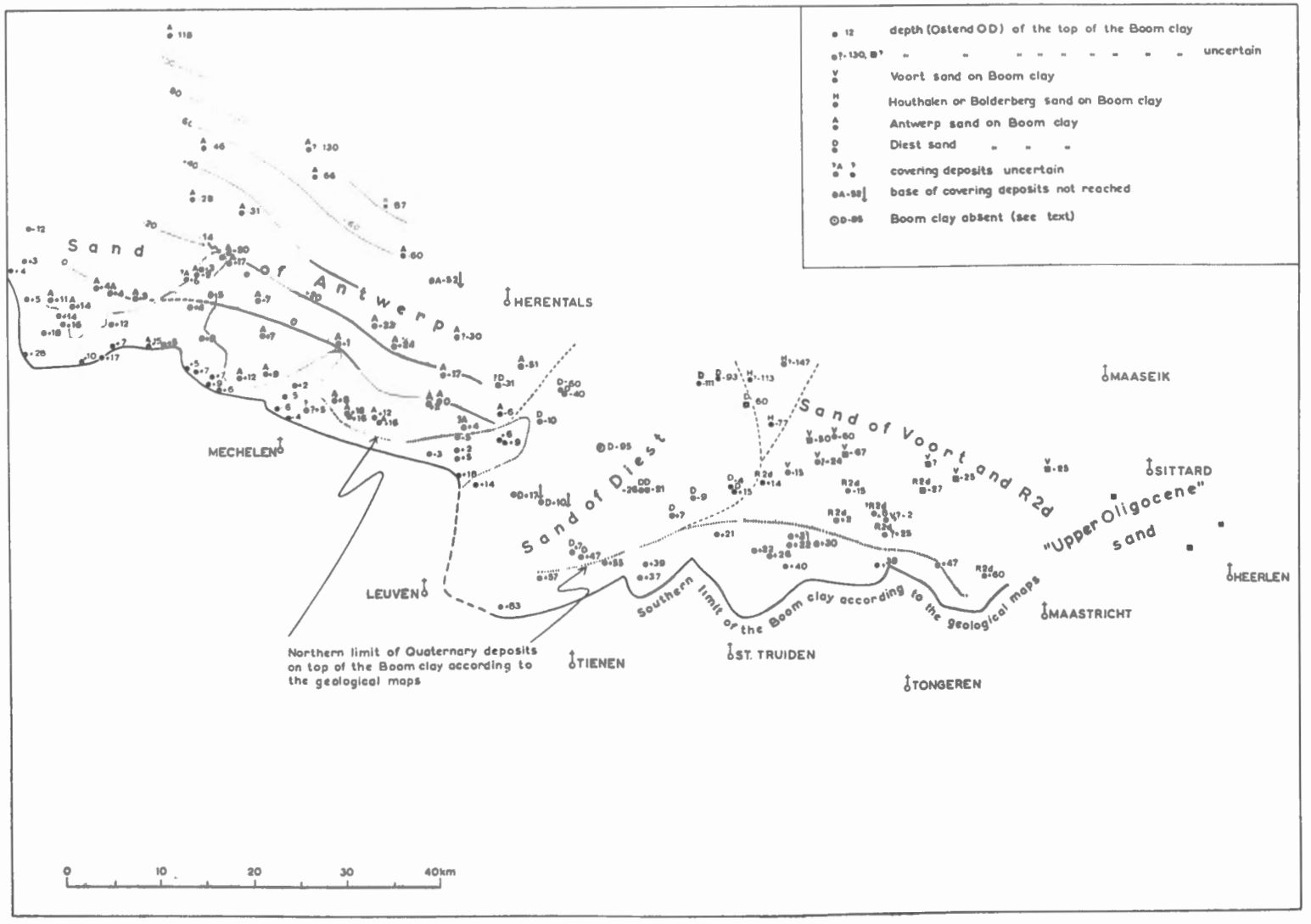
Small indurated clay particles, commonly grey but in some samples of rusty-brown colour, are present in part of the residues.

In the wash residues of typical Boom clay quartz is absent or very rare.

Apart from the Foraminifera, organic components are rare in the Boom clay wash residues. Small bone fragments are present in nearly all samples. Fish otolites, small fish teeth and echinoid spines were less frequently met with. Bryozoa were never observed.



MAP 7 — Contour map of the base of the Boom clay.



MAP 8. — Contour map of the top of the Boom clay and areal distribution of the covering deposits.

East of the Hageland the Boom clay was observed in many borings and mine-shafts. Outcrops are rare. There are still two active exploitations, one at Loksbergen and another at Kortenaken. At these localities the Boom clay is light-grey to brownish, sandy and nearly always non-calcareous. It resembles the pot-clay in the Land of Waas. Small calcareous concretions and only one single septaria were observed. The sample from Loksbergen shows an aberrant microfauna type and small oxydized rusty-brown pyrite accretions. The Boom clay pit at Wijer and the pit near Bilzen, which formerly showed a series of Nucula-clay, sand with gravel and Boom clay (archives 92W1, MOURLON, 1896), are both abandoned nowadays and without exposed Oligocene.

In the Limburg borings and mine-shafts the Boom clay is more sandy than it is in the pits west of the Hageland. There is a gradual lateral transition to the sandy « Septaria-clay » in Dutch South-Limburg, where, as was stated by MULLER (1943), plastic Boom clay is wanting. MULLER assigned the sandy « Septaria-clay » of this region to the « Lintforter series ». The Lintfort beds are mainly sandy deposits with *Leda deshayesiana* in the Middle Oligocene of the German Lower Rhine region. They are underlain by Ratingen clay which is also equivalent of the Boom clay.

The contours of the base of the Boom clay are shown on map 7. They have the same trend as the contours of the Rupel basal gravel. Their dip equally increases in the region of the coal-mines of the Kempen.

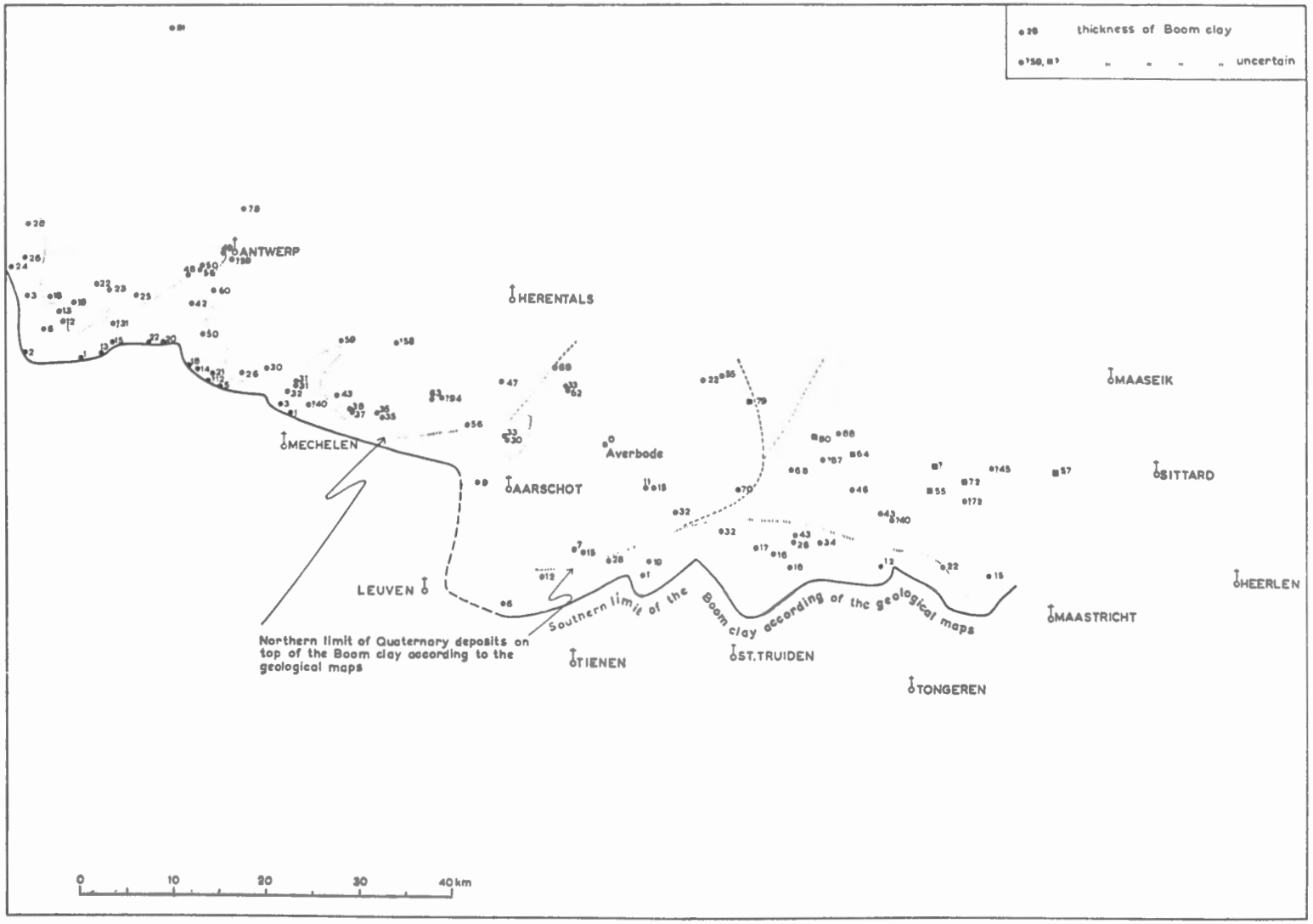
In the area south of Antwerp no contours could be drawn since there are a number of deviating records of the base of the Boom clay in that area. They are possibly due to the indistinct Asse clay — Asse sand — Berg sand — Boom clay sequence, in which stratigraphic boundaries are difficult to establish. In the records of the archives of the borings, 43 E 94 and 60 E 207, the base of the Boom clay is evidently confused with the base of the Asse clay. The stated depths of the Boom clay base in these borings, fit well into a map with contours of the base of the Asse clay (personal communication of Mr. J. P. H. KAASSCHIETER).

Map 8 shows the areas of the formations covering the Boom clay, and the depths at which the contact of these formations with the Boom clay were observed. East of the Hageland the covering formations are the R2d-sand and the sand of Voort. The former is said to be a sandy equivalent of the uppermost Boom clay. There are frequent transitions beween Boom clay, R2d-sand and sand of Voort. It is therefore impossible to draw contours of the top of the Boom clay for the area east of the Hageland.

The descriptions of some deepborings near the coal-mine of Beringen-Kleine Heide mention « Bolderian » deposits as covering of the Boom clay. In other places this « Bolderian » or « Houthalean » has also been found on top of the sand of Voort.

In the Hageland the Boom clay is overlain by the sand of Diest. The depth-records of the top of the Boom clay under that sand are irregular. The thickness of the Boom clay (see map 9) in this area is locally smaller than expected. It varies between 7 and 15 m in borings of the region Diest-Aarschot. In one place the Boom clay is entirely absent : a flush boring at Averbode (60E193) penetrated the sand of Diest down to —95 m. Under this sand again another sandy complex was observed, which according to TAVERNIER (description of the boring in the archives of the Geological Survey) is probable sand of Wemmel (Upper Eocene). The level expected for the base of the Boom clay at Averbode is —60 m.

As a result it is considered probable that the sand of Diest locally fills a depression in the top of the Boom clay (see fig. 1). This depression has also been figured by GULINCK (1954) and earlier authors.



MAP 9. — Thickness of the Boom clay.

In most places west of the Hageland the Boom clay is overlain by the Miocene sand of Antwerp. The few data concerning the level of the top of the clay under this sand, are regularly distributed. The contours are shown on map 8.

Quaternary deposits cover the Boom clay in a strip along the entire southern border of the clay and also along the river Scheldt. These deposits are mainly continental : loess, sand and gravel. In the Land of Waas and near Antwerp they include a marine deposit, the so-called Scaldisian. A few isolated occurrences of the sand of Antwerp on top of the Boom clay are present along the southern limit of that clay in the Land of Waas.

Data concerning the thickness of the Boom clay are shown on map 9. They do not allow for the drawing of isopach contours. There is a distinct decrease of thickness in the southernmost part of the area and in the Hageland.

The Boom clay is the most wide-spread member of the Oligocene in northwestern Europe. It extends from Belgium and the Dutch province Zeeland to Denmark and Poland, with southern extensions into the Lower Rhine area and the Mainz basin. Its northern and western boundaries are unknown. They must be somewhere under the North and the Baltic seas.

THE SAND OF VOORT

This member was discoverd in 1909 by SCHMITZ and STAINIER in three deepborings in the Kempen. These authors referred to it as sand no. 3 and they placed it in the Upper Oligocene (Aquitanian in their opinion). This determination was based both on the mollusc fauna and on the gradual transition of the sand no. 3 into the underlying Boom clay. At present this sand no. 3 is usually referred to as sand of Voort (or as Chattian).

Through the courtesy of the Geological Survey at Brussels we could examine samples from the three classical borings of the sand of Voort, viz the deepborings at Lambroek, Lillo and Voort. Additional samples of the sand from two mine-shafts at Houthalen were kindly put at our disposal by Dr. M. GLIBERT.

The sand of Voort is a medium- to fine-grained, often clayey, brownish-grey to greenish-black, glauconitic sand with dispersed beds with molluscs and phosphatic concretions. The concretions often contain mollusc shells. The most commonly recorded species are *Cardium cingulatum* (GOLDFUSS), *Cyprina rotundata* BRAUN, *Pecten decussatus* GOLDFUSS and *Pycnodonta callifera* (LAMARCK).

The samples from the sand of Voort usually yielded a first wash residue, that mainly consisted of mollusc fragments. Small mollusc shells, bone fragments, fish otolites, large Foraminifera (*Lagenidea*) and some Bryozoa were observed. Furthermore echinoid scale fragments and in a few samples barnacle fragments.

Anorganic components of the first wash residue are small pyrite aggregates, part of them oxydized and rusty-brown; coarse rounded quartz and glauconite grains, and bodies of small glauconite and quartz grains cemented by brown, probably phosphatic, or greyish-white calcareous material. Part of the quartz grains are greenish. Some coarse silex fragments were also observed.

The second and third residues contain mainly dark-green to brown glauconite and quartz grains, that are well rounded in the second residue. Foraminifera, pyrite and slightly

rounded silex fragments are rare. Ostracoda (²), bone fragments, echinoid spines, Bryozoa, mica, partly green and small gypsum crystals are still scarcer. In general the volumes of the second and third residue are about equal.

The presence of the sand of Voort in Belgium has only been established with certainty in the area east of the Hageland (see map 8). In southward direction it disappears because of later erosion. To the north and the east the sand of Voort continues as the sandy deposits of the Upper Oligocene in the subsoil of the Netherlands.

In its type region, the district of the coal-mines in the Kempen, the thickness of the sand of Voort varies between about 20 and 50 m. Because of the gradual transition into the Boom clay, however, the stated thickness is often more or less arbitrary.

Towards the north and in Dutch South-Limburg, the sand of Voort is usually referred to as Chattian or Upper Oligocene. The thickness of this member varies considerably in relation with the tectonic pattern. In the Central graben the thickness amounts to 400-500 m and even more.

THE SAND OF ROCOURT

The member occurs as an isolated mass of sand, northwest of Liège and just south of Rocourt. We observed it in two large pits (UD, UE) and in two smaller outcrops (UC), all near the stadium of Rocourt. Its stratigraphic placement has been a matter of discussion; it has often been assigned to the Oligocene.

The sand of Rocourt is a fine-grained, white or yellowish to rusty-brown, micaceous sand with indistinct stratification and locally with capriciously shaped, rusty-brown, indurated ferruginous incrustations.

None of our twelve samples from the sand yielded a first wash residue. The second residue is always very small and consists chiefly of coarse mica flakes. Quartz grains, usually angular and a small part of them rounded, silex fragments, white opaque calcareous grains are always present. In part of the samples we furthermore found a little glauconite, Foraminifera, among which chiefly *Nummulites* and miliolid casts, some of them with glauconite filling, rare Ostracoda, echinoid spines and small molluscs. Fragmentary and siliceous Foraminifera reworked from Cretaceous deposits were also encountered. Ferruginous cementing of the grains was found to occur in some of the samples.

The finest wash residue consists of angular quartz grains and very few silex fragments, mica, white, opaque, calcareous grains and glauconite. Foraminifera are extremely rare.

The greatest thickness we observed for the present member was 12 m in the pit UE. Big silex stones were found to occur at the base of the sand. They are probably weathering products of the underlying Cretaceous chalk. This silex layer was very badly exposed. The covering beds of the sand of Rocourt are Pleistocene loess and gravel.

The extension of the sand of Rocourt is uncertain. On the geological maps of Belgium 1 : 40.000 and 1 : 160.000, the sand of Rocourt is included in the Om and On deposits. The latter are marked at many isolated places, scattered over a vast area north of the Meuse between Liège and Namur and in the northwestern part of the Ardennes between Liège and the Belgian-French frontier. Whether these occurrences belong together from a time-stratigraphic point of view is uncertain, however.

The age of the sand of Rocourt (and Om, On deposits) is not known with certainty. Most earlier authors have regarded them with more or less doubt to be of Oligocene age. On the map of DE BÉTHUNE (1954, scale 1 : 500.000), which is the most recent geological map of Belgium, the sand of Rocourt is considered to belong to a series of isolated masses of Pleistocene (Moséen) deposits on both sides of the Meuse in the region between Namur and Liège.

(²) Dr. A. J. KEIJ kindly determined the following species from samples of the deepboring Lillo (81, 83, 84, 98, 105 and 107) : *Bairdia subdeltoidea* (VON MÜNSTER), *Cytheridea mülleri* (VON MÜNSTER), ?*Cythereis latimarginata* (SPEYER), *Cythereis plicatula* (REUSS), *Echinocythereis hirsuta* (LIENENKLAUS), *Leguminocythereis scrobiculata* (VON MÜNSTER), *Xestoleberis* cf. *subglobosa* (LIENENKLAUS).

From the microfauna however, yet another age determination must be considered. The species of Foraminifera and Ostracoda, the latter kindly determined by Dr. A. J. KEIJ, are listed below (UC, UD, UE) :

Foraminifera :

Quinqueloculina parisiensis D'ORBIGNY,
Spiroloculina obscura CUSHMAN and TODD,
Triloculina angularis D'ORBIGNY,
undeterminable miliolid casts,
Globulina gibba D'ORBIGNY,
Nummulites aff. *variolarius* (LAMARCK),
Rotalia armata D'ORBIGNY,
Rotalia audouini D'ORBIGNY,
Cancris aff. *auriculus primitivus* CUSHMAN and TODD,
Ceratobulimina sp.,
Asterigerina cf. *bartoniana* TEN DAM,
Anomalina grosserugosa GÜMBEL,
Cibicides lobatulus (WALKER and JACOB),
Cibicides cf. *ypresiensis* TEN DAM,
Cibicides sp.,

Ostracoda :

Bairdia sp. (juvenile specimen),
Aulocytheridea faboides (BOSQUET),
Cuneocythere (*Monsmirabilia*) *foveolata* (BOSQUET),
Leguminocythereis striatopunctata (ROEMER),
Trachyleberis (*T.*) *aculeata* (BOSQUET).

Both the Foraminifera and the Ostracoda point to a late Eocene (possibly Ledian) age for the sand of Rocourt.

Up to now, the most eastern occurrences of Upper Eocene deposits, known in Belgium, are west of the line Anderlues-Diest. If the sand of Rocourt is of Ledian age, the general opinion concerning the Belgian Upper Eocene has to be rather thoroughly modified.

Rocourt is at a distance of at least 50 km from the nearest occurrence of Upper Eocene deposits. This distance is thought to be too great for reworking of the microfauna of Rocourt out of this Eocene. Moreover, the re-disposition would have been active in an upstream direction, at whatever time it might have been. As far as we know, it is most likely that this direction did not change since the Late Eocene.

For a description of the other Om and On sediments one is referred to CALEMBERT (1954). Besides the sand of Rocourt these deposits include the sand of Boncelles with scarce mollusc moulds, the clay of Andenne with plant remains and various other scattered occurrences of sand, gravel and clay.

A few samples from the sand of Boncelles and from a clayey layer in this sand, taken in two pits just east of Boncelles, yielded no microfauna.

Mr. R. MARÉCHAL at Gent, who studied the geology of the Condroz (northwestern Ardennes in the field, kindly informed us that he did not know of occurrences of calcareous Oligocene sand in that region.

MIOCENE

THE HOUTHALEN BEDS

East of the Hageland mainly sandy, marine and continental deposits cover the sand of Voort. They have usually been referred to as « Bolderian » (TAVERNIER, 1954), but recently the name « Houthaléen » was proposed for them (see DE HEINZELIN, 1956). They contain the so-called horizon of Houthalen (GLIBERT, 1945), a marine mollusc-bearing layer, which occurs in the lower part of the Houthalen beds (the « Houthaléen »). According to GLIBERT (1945, 1952) the expert on Belgian Tertiary molluscs, the age of the Houthalen beds is Middle Miocene.

The relations between the Houthalen beds and the equally Middle Miocene Antwerp sand west of the Hageland are as yet indistinct.

THE SAND OF ANTWERP

The sand of Antwerp, usually referred to as Anversian, has been recorded from many borings and also from outcrops in the area west of the Hageland. It was always found directly on top of the Boom clay.

The Antwerp sand consists of two smaller units. The so-called horizon with *Panopaea menardi* or the sand of Edegem, is the lower one of them. It is very rich in molluscs. The macrofauna enables correlation with the Dindener-Reinbecker Stufe in north-western Germany (TAVERNIER, 1954, DE HEINZELIN, 1956). According to GLIBERT (1945, 1952), the age of the horizon with *Panopaea menardi* is Middle Miocene.

The second unit is the horizon à *Glycymeris pilosus*. This horizon has a much less diversified mollusc-fauna. Its age is not known with certainty, but it is commonly considered to be also Middle Miocene.

CHAPTER III

LOCALITY DETAILS

The legend of the figured sections of both outcrops and borings is to be found in fig. 10. The stratigraphic symbols indicated at the left of the lithologic column, are listed below.

Q ..... : Quaternary.
T ..... : Tielrode sand.
D ..... : Diest sand.
A ..... : Antwerp sand.
H ..... : Houthalen and Bolderberg beds.
V ..... : Voort sand.
R2c ..... : Boom clay.
R1d ..... : R1d sand.
R1c ..... : Nucula-clay.
R1b ..... : Berg sand.
R1a ..... : Rupel basal gravel.
Tg2o .... : Oude-Biezen member.
Tg2n .... : Henis clay.
Tg2m ... : Boutersem member.
Tg2k .... : Kerkom sand.
Tg1n .... : Horizon of Hoogbutsel.
Tg1d .... : Neerrepen sand.
Tg1c .... : Grimmertingen sand.

BELGIUM

LEUVEN-TIENEN REGION

(Map 10)

LA Abandoned sandpit on the Kesselberg, 3.100 m N, 1.450 m E of St.-Peter's church at Leuven. See fig. 2.
Point 89E66 of the archives of the Geological Survey.
Visited August 1953.

Coarse, glauconitic, current bedded sand of Diest has at its base 20 cm gravel of black silex pebbles. The upper limit of the gravel is flat, its lower surface is less regular.

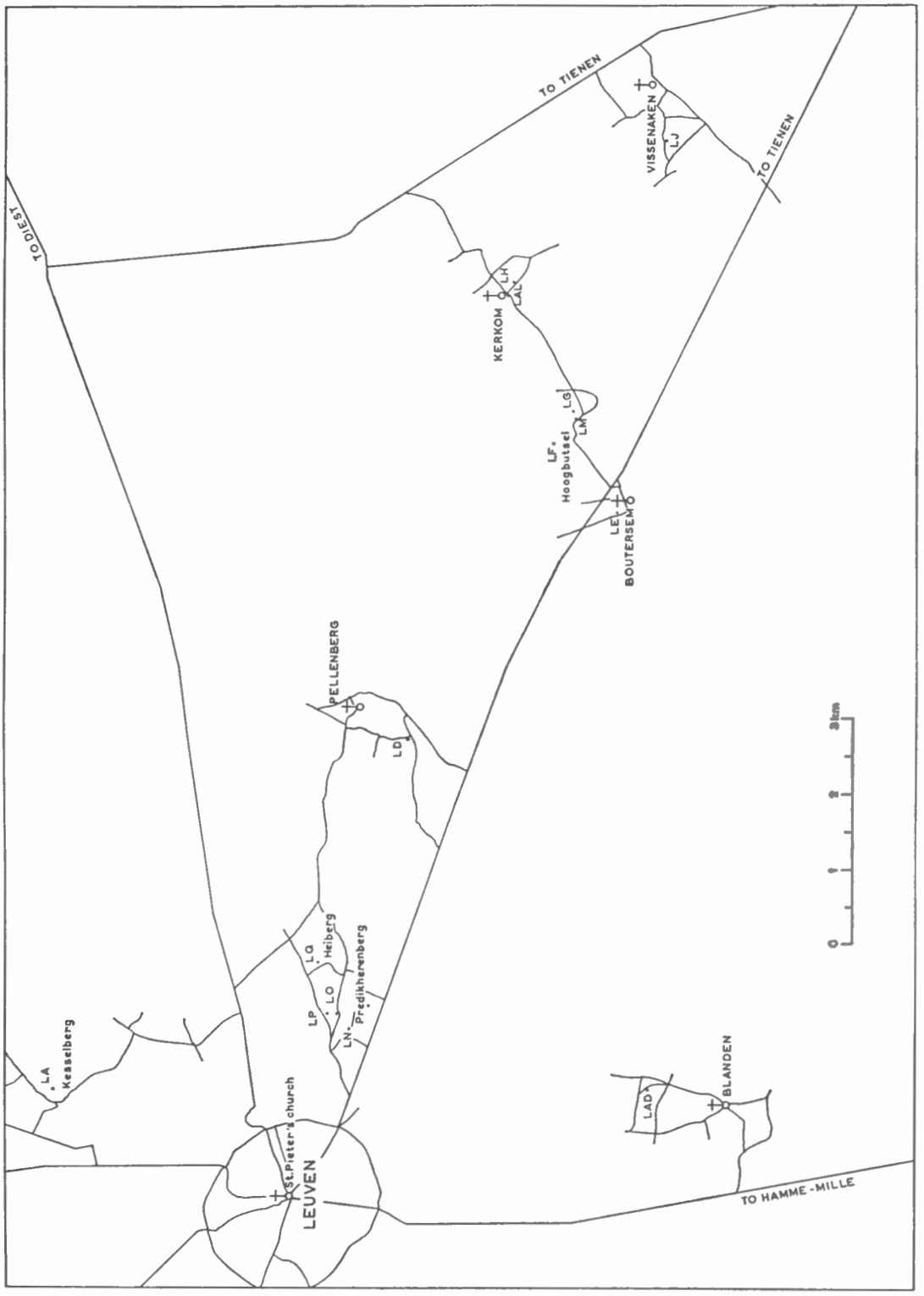
Under the gravel there is medium-grained, greenish-grey to rusty-brown, thin-bedded sand. In the sand there are ferruginous incrustations and capricious « clay veins ». The uppermost sample from this sand is rich in dark-green glauconite. Moreover, it contains mica and small silex fragments. The coarser quartz grains are angular to rounded. The sand probably belongs to the sand of Neerrepen.

Downward there is more finely grained, locally clayey and mostly rusty-brown sand with much mica : sand of Grimmertingen. The samples from this sand contain few clay particles and silex fragments and some glauconite. No microfauna.

LD Sandpit of Mr. GILIS ARSENE on hilltop, 600 m S, 400 m W of the church of Pellenberg. See fig. 2.
Point 38 of GLIBERT and DE HEINZELIN (1954*a*).
Visited August 1953.

Under Quaternary loess with silex pebbles at its base there are exposed some 70 cm of greyish-yellow, coarse- to medium-grained sand, becoming downward very coarse with well rounded quartz grains. The sand is probably sand of Berg.

It has a thin layer of flattened, dark silex pebbles at its base. This is considered to be the Rupel basal gravel.



MAP 10. Locality map Leuven-Tienen.

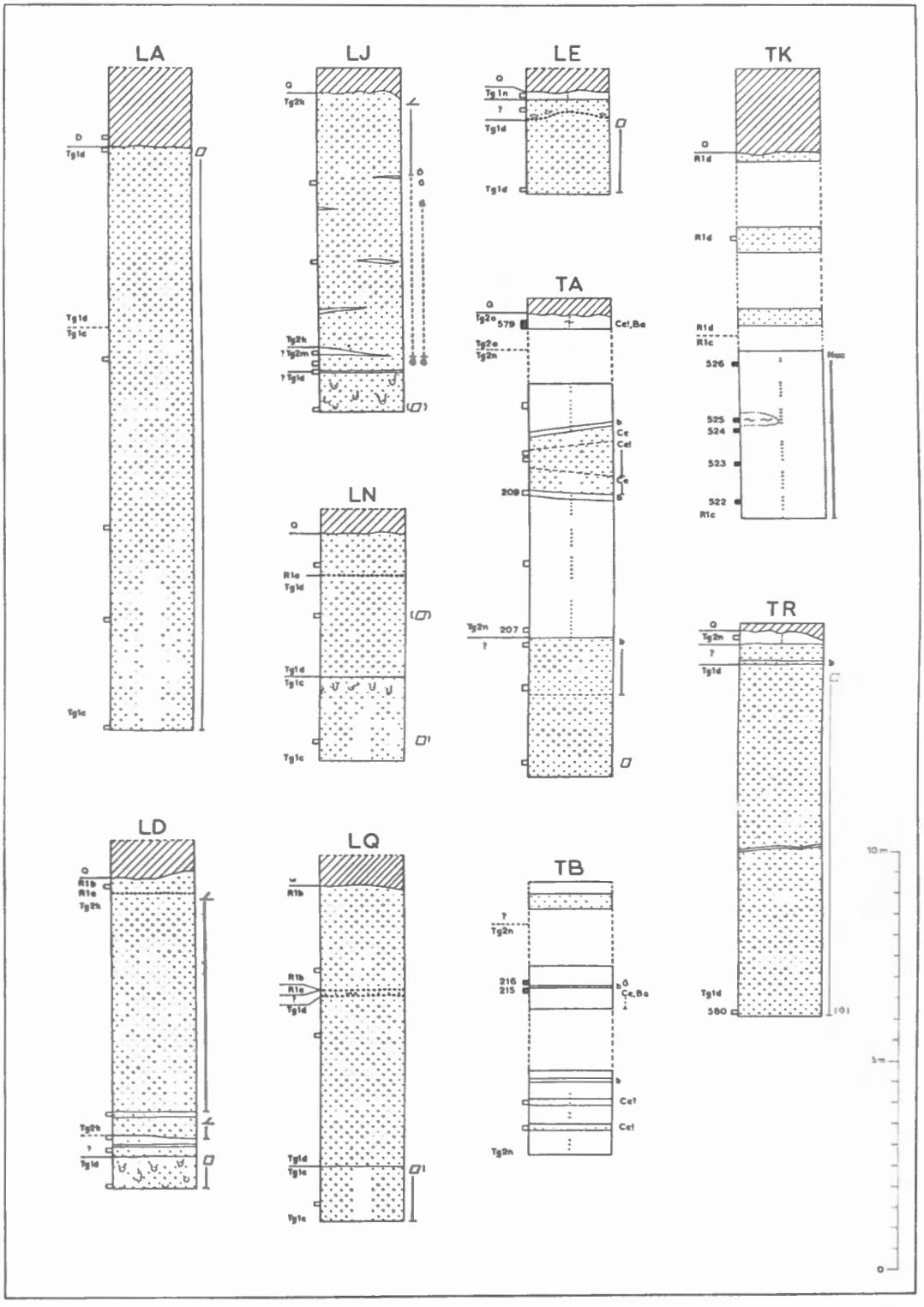


FIG. 2. — Sections of outcrops in the Leuven-Tongeren region.

This is turn covers about 6 m of current bedded, greyish-white sand of variable grain size. It contains layers of gravel and a few clayey intercalations. A sample from a clayey intercalation contains rounded quartz, a few small silex fragments and no microfauna. Kerkom sand.

Under the distinct Kerkom sand we found from top to bottom a complex of alternating very thin layers sand and clay, 5 cm clay bordered by ferruginous incrustations and about 20 cm of white sand, which is very coarse near the top. The quartz grains of this sand may reach a diameter of 5 mm.

This sand again covers distinct sand of Neerrepen : fine-grained, thin-bedded, micaceous sand with tubular structures. The sand contains some glauconite and silex fragments.

LE Small sandpit, 175 m N, 150 m W of the church of Boutersem. See fig. 2.
Point 5 of GLIBERT and DE HEINZELIN (1952, 1954*a*).
Visited August 1953.

Under the basal gravel of the Quaternary a bed of 7-15 cm dark-brown and -green, hard and brittle clay with a few small shell fragments is exposed. This is probably an equivalent of the horizon of Hoogbutsel.

The stratigraphic position of the sand under this clay bed is uncertain. The sand is thin-bedded and yellowish-white. It contains few small silex fragments, some glauconite and very little mica. At its base there is a thin and wavy bed of silex pebbles with some rounded, greenish-grey clay lenses in the sand just above it.

This gravel overlies about 2 m of fine-grained and thin-bedded, greyish-green, micaceous sand with some glauconite. Distinct sand of Neerrepen.

LF Small outcrop, 1.000 m N, 750 m E of the church of Boutersem.
Type locality of the vertebrate-bearing horizon of Hoogbutsel, described by GLIBERT and DE HEINZELIN (1952, Bull. Inst. Roy. Sci. Nat. Belgique, vol. 28, no. 52). See fig. 5 of these authors.
Visited August 1953.

LF 144. — Sample 3 cm over the top of bed « GL.N » of GLIBERT and DE HEINZELIN : light-greyish-green, thin-bedded, fine-grained sand with angular quartz grains and small quantities of mica, glauconite and small silex and shell fragments. No microfauna. The sand is rusty-brown and hard at its base, upwards it becomes whitish.

LF 143. — Sample from the middle of the « horizon à bithinies »; greyish-green, locally mollusc-bearing clay. The molluscs are chiefly *Nystia*, furthermore *Planorbis*, *Limnaea* and doubtful fragments of *Corbicula semistriata* (DESHAYES). The second and third residues contain shell and bone fragments, among which small vertebrae and abundant *Haplocytheridea helvetica* LIENENKLAUS, a few fine quartz grains and some mica. No Foraminifera.

LF 142. — Another sample from the « horizon à bithinies »; just below the overlying black, brittle clay. Few *H. helvetica* and some glauconite. In all other respects like LF 143.

LF 141. — 20 cm under the base of the « horizon à bithinies » in the sand of Neerrepen. Angular quartz, rather much glauconite, a little mica and small silex fragments. No microfauna.

LG Small outcrop in the garden of Mr. VLEMINCKX, 750 m N, 1.200 m E of Boutersem church. See the description by GULINCK (1951, Bull. Soc. Belge Géol., vol. 60, pp. 207-210).
Point 2 of GLIBERT and DE HEINZELIN (1954*a*); 90W1093 in the archives of the Geological Survey.
Visited August and September 1953.

LG 149. — Sample 7 cm over the top of unit I in the section of GULINCK :whitish, sandy marl with *Nystia*. Wash residues contain shell fragments and mostly rounded quartz and some glauconite, mica, small bone and silex fragments and *Haplocytheridea helvetica* (LIENENKLAUS).

LG 148. — From horizon Ia of GULINCK's section; a mollusc-bearing layer with *Cerithium*, *Aloidis gibba* (OLIVI) and *Corbicula semistriata* (DESHAYES) in greenish, fine-grained sand with glauconite and some mica. No microfauna.

The above mentioned samples are both from the Boutersem member.

LG 424. — Sample from the lower par of GULINCK's unit I, 60 cm under the base of the sandy marl with *Nystia* (II); yellowish-green, fine-grained, slightly clayey, micaceous sand with some glauconite and small silex fragments. No microfauna. Sand of Neerrepen or possibly sand of Boutersem.

LG 145. — Was taken from a small pit in the NW corner of the garden. Fine-grained, clayish, yellowish-green sand with *Cerithium*, *Corbicula semistriata* and rare *Nystia* specimens. Some glauconite and mica and only rare *H. helvetica*. No Foraminifera.

Just above the level of LG 145 there is a thin layer of brownish-green clay covered by reworked soil. Sample LG 145 is probably from horizon III*d* of GULINCK (Boutersem member).

Another sample from yet another small pit in the garden of Mr. VLEMINCKX, was taken in fine-grained, thin-bedded, glauconitic, green and white sand, probably sand of Neerrepen. It appeared devoid of microfauna.

LH Sandpit, 150 m S, 200 m E of Kerkom church. Point 15 of GLIBERT and DE HEINZELIN (1954*a*).
Visited August 1953.

In the upper part of the exposure Quaternary loess and gravel cover some 120 cm of rusty-brown sand with a gravel at its base. Under this gravel there are 110 cm rather fine-grained, yellowish sand with another thin bed of silex pebbles at its base.

A sample, 10 cm above the base of the lower sand contains besides the quartz grains (rounded in the second wash residue) some glauconite, small silex and shell fragments, and very little mica. No microfauna was found.

This sand and the brown sand above it probably belong to the sand of Berg. Both gravel layers probably constitue a double Rupel basal gravel.

Under the lowermost gravel some eight meters of the sand of Kerkom are exposed. The sand is locally coarse, but otherwise fine-grained and current-bedded, with thin beds of clay and gravel and with big, capriciously shaped, ferruginous incrustations. Three samples from the Kerkom sand were found to contain a few small silex fragments, very little mica and no microfauna.

LJ Sandpit of Mr. HALZEN, 150 m S, 750 m W of Vissenaken church. See fig. 2.
Locality 65 of GLIBERT and DE HEINZELIN (1954*a*).
Visited August 1953.

Under the Quaternary loess and gravel of silex pebbles, about 6 m of Kerkom sand are exposed. The sand is distinctly current-bedded in the uppermost part. Downward the stratification is less distinct and more irregular. The grain size shows considerable variation. Furthermore the sand contains some clayey intercalations as well as partly decalcified molluscs, both dispersed and also concentrated in lenses. Two samples from the sand contain silex fragments, a little glauconite and mica, and no microfauna.

This Kerkom sand overlies a thin clay — sand — clay complex with a wavy mollusc-bearing bed in the middle. The molluscs are fragmentary and partly decalcified. Three samples from this complex, that may be interpreted as belonging to the Boutersem member, contain some small silex fragments, glauconite and mica; no microfauna.

At the bottom of the pit, there are exposed 80 cm of greenish-grey, fine-grained sand with tubulate structures, which probably belong to the sand of Neerrepen. The sample from this sand contains glauconite and a little mica; it is devoid of microfauna.

LM Talus on NE side of the road, 750 m N, 1.100 m E of Boutersem church. LM lies east of locality 4 of GLIBERT and DE HEINZELIN (1952 and 1954*a*).
Visited September 1953.

In the small outcrop about 1 m distinct sand of Neerrepen is exposed under the Quaternary loess. The sand is yellowish to brownish and fine-grained. It contains much mica, and small greyish-white clayey particles, glauconite and silex fragments. The two samples taken here, contain no microfauna.

LN Sandpit on the western slope of the Predikherenberg, about 850 m S, 2.225 m E of St.-Peter's church at Leuven. See fig. 2.
Visited May 1954.

Under Quaternary loess with scattered pebbles is exposed a greenish-yellow, generally rather fine-grained, locally somewhat clayish sand with few small silex fragments and very scarce glauconite and mica. The size of the grains in the sample that was taken from the lowermost coarser part of this sand, reaches up to 7 mm.

The sand covers a thin layer of black silex pebbles and coarse white quartz grains : the Rupel basal gravel.

The sand under the gravel is indistinct sand of Neerrepen. It is yellowish-white and fine-grained with small silex fragments and some glauconite and mica. It contains rusty-brown bands.

The contact of this sand with the underlying sand of Grimmertingen is distinct by the difference in grain size. The latter sand is a brownish-yellow, very fine-grained, clayey sand or sandy clay with abundant mica. Furthermore some rounded quartz grains, a few whitish-grey indurated clay particles, a little glauconite and (?fossil) plant remains were observed in the sample from this sand.

In the uppermost part of the sand of Grimmertingen there are tubular structures with a diameter of up to 3 cm.

LO Small outcrop in the road side, 675 m S, 2.400 m E of St.-Peter's church at Leuven; about 250 m NE of, and some meters higher than our locality LN.
Visited May 1954.

Under the soil are exposed about 50 cm of light-grey, brittle, sandy clay with some yellowish patches at its base. This clay probably belongs to the Boom clay. In a sample from the clay were observed a few quartz and clay particles and very little glauconite and mica. No Foraminifera.

The clay overlies fine-grained, yellowish-brown, slightly micaceous sand, one meter of which was visible in the outcrop. This would represent the sand of Berg. At the contact of the sand and the overlying clay there is a hard, ferruginous layer of some 5 cm.

LP Sandpit on the NNW slope of the Predikherenberg, 500 m S, 2.425 m E of St.-Peter's church at Leuven.
Visited May 1954.

Under a mass of sand that resembles the Berg sand at LN and LO, is exposed the so-called rice-grain gravel, which is considered the base of the Rupel formation. This gravel contains rounded, white quartz grains, up to 7 mm, as well as dark silex pebbles. It has a thickness of 20 cm and in some places it is double. Locally ferruginous incrustations were found.

The gravel overlies Neerrepen and Grimmertingen sands just as it does at locality LN. From the Grimmertingen member a sample was taken of brown, very fine-grained, clayey sand, situated about 5 m below the rice-grain gravel. This sample contains abundant mica and a little glauconite. No microfauna was observed.

LQ Sandpit of Mr. DONKERS on the N slope of the Heiberg, 400 m S, 3.100 m E of St.-Peter's church at Leuven. See fig. 2.
Visited May 1954.

Under the soil there is exposed a light-grey, mottled, fine- to medium-grained sand with white coarse patches. It is considered to represent indistinct Berg sand. It contains few silex fragments, a little glauconite and very scarce mica. No microfauna. The quartz grains of the second wash residue are rounded.

At the base of the sand there is a thin bed of silex pebbles and coarse quartz grains, which in turn overlies about 15 cm of white sand with smaller pebbles in it. The sample from this coarse sand contains rounded quartz grains and rounded fragments of agate and silicious oölite up to 1 cm in diameter. Glauconite is rare. The gravel is the Rupel basal gravel, the underlying coarse sand may belong to the same gravel, but it may as well be considered as an equivalent of the Kerkom sand.

This coarse complex overlies some 4 m of Neerrepen sand. This sand is fine-grained with small silex fragments and very scarce glauconite and mica.

This in turn covers greenish, very fine-grained, clayey sand with much mica and some glauconite and whitish, indurated clay particles (sand of Grimmertingen).

LAD Side of hollow road, 1.050 m N, 200 m E of the church of Blanden.
Sample taken by Mr. J. P. H. KAASSCHIETER in June 1954.
Point 89E42 of the archives of the Geological Survey.

The sample was taken at a level about 5 m below the surface, and 70 cm above the road level, from a brownish-green, coarse sand. The quartz grains in the first and second residues are well rounded. Part of those of the third residue are rounded as well. The latter residue moreover contains

glauconite and very little mica. No microfauna. According to the geological map 1 : 40.000 the coarse sand belongs to the basal gravel of the Tongeren formation (Tg1a).

LAL Road talus on NW side of road at Kerkom, 50 m S of the church of Kerkom.
Locality 13 of GLIBERT and DE HEINZELIN (1952 and 1954*a*).
Visited 1954.

A sample was taken 160 cm below the surface, 80 cm above the road level, from fine-grained, light-greyish-green sand with glauconite and mica. No microfauna. This is considered to be distinct sand of Neerrepen.

OUTCROPS NEAR LANDEN

(Map 1)

QA Sandpit about 1.100 m N, 1.500 m E of the church of Grand-Hallet.
Point 119W446 of the archives of the Geological Survey.
Visited August 1953.

Two meter of Quaternary loess with scattered quartzitic sandstone plates and with some silex pebbles at the base, are visible in the upper part of the exposure. According to the discription by GULINCK in the archives, the sandstones in the loess have possibly been reworked from the Landen formation.

The loess covers 6 m of very fine-grained, clayey, greenish-yellow, micaceous sand : distinct sand of Grimmertingen. A sample from this sand contains abundant mica and some glauconite.

At the base of the Grimmertingen sand there is a gravel of about 20 cm thickness, with many, slightly rounded black silex stones and coarse quartz grains, together in a sandy matrix. This is the basal gravel of the Tongeren formation.

The gravel overlies 10 tot 150 cm dark-green clay with rather coarse, sandy intercalations at some places. The sample from this clay contained rather many small silex fragments and much ferruginous material. Furthermore a little glauconite and no microfauna.

Under this clayey layer about one meter of current-bedded, medium-grained sand with some small clay lenses and with indistinct tubular structures was exposed. In the description of the pit by GULINCK, this is considered continental Upper Landen sand. A sample from 20 cm beneath the top of the sand was found to be strikingly rich in small dark-grey silex fragments.

SB Small outcrop in talus on N side of road on Ilsenberg, 225 m S, 900 m W of Gingelom church.
Points 105E17*a* and 105E432 of the archives of the Geological Survey.
Visited August 1953.

Under 2,30 m of loess with a 10 cm, wavy layer of silex pebbles at the base, are exposed about 30 cm of yellowish-brown, very fine-grained, micaceous sand. The sample from this sand, 20 cm under the base of the Quaternary, appeared very rich in mica. In addition it contains some quartz and glauconite and a number of distinct sponge spiculae. No microfauna. Distinct sand of Grimmertingen.

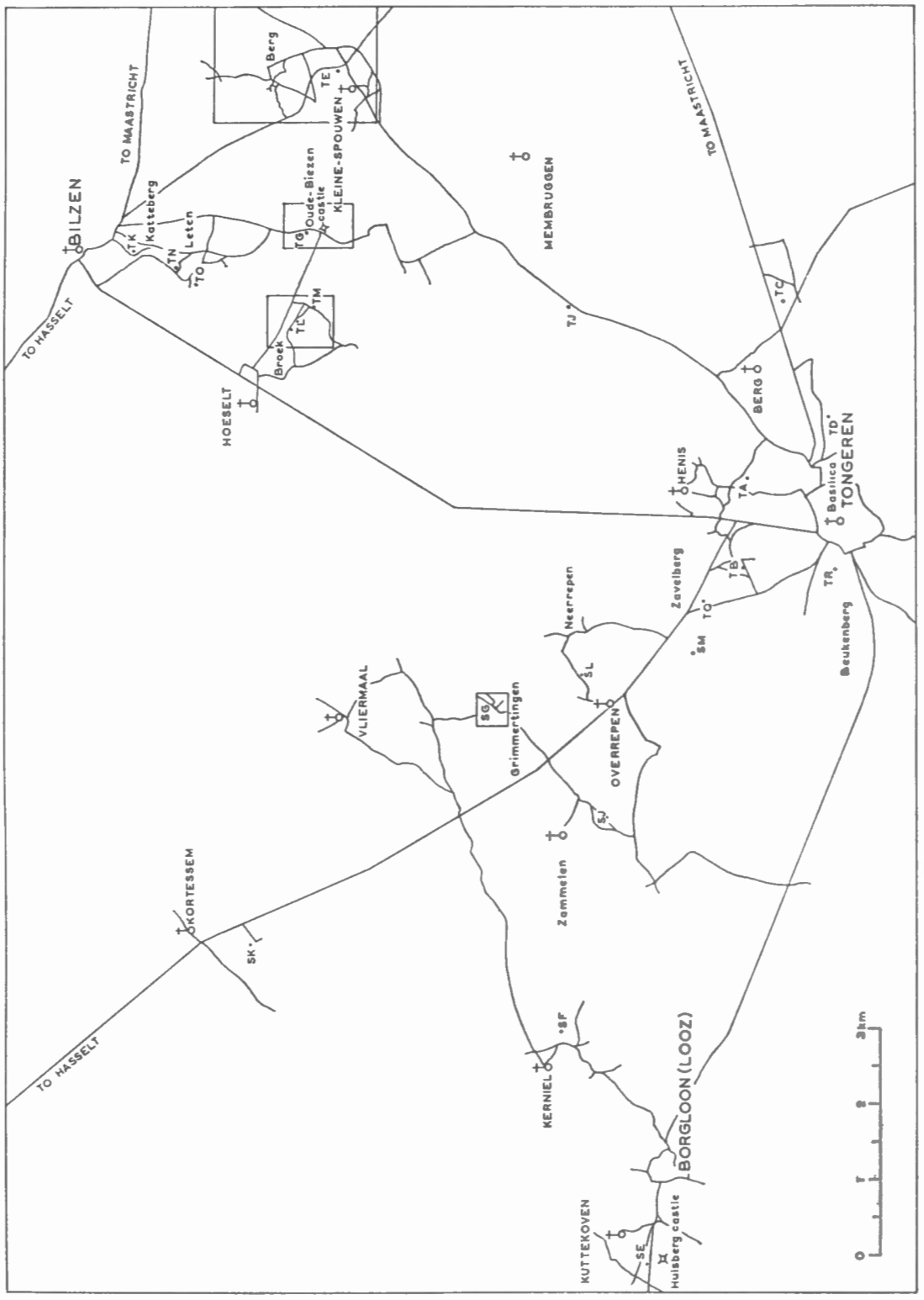
SN Sandpit of Mr. FRISON, 1.175 m S, 400 m W of the church of Landen.
Sample taken by Mr. J. P. H. KAASSCHIETER, July 1954. See GULINCK (1948) for a description of the pit.
Point 105W304 of the archives of the Geological Survey.

On top of the Landen beds the basal gravel of the Tongeren formation is exposed. A sample was taken 30-40 cm above the base of this gravel in yellowish-brown, coarse-grained sand with intercalations of thin clay beds and fine gravels of silex and quartz, with grain size up to 5 mm. The sample contains some mica and no microfauna.

TONGEREN REGION

(Maps 11-14)

SE Outcrop at the northern side of the road north of Hulsberg castle near Borgloon (French : Looz), 350 m S, 450 m W of the church of Kuttekoven.
This outcrop is a slight distance west of point 154 of GLIBERT and DE HEINZELIN (1954*a*).
Visited August and September 1953.



MAP 11 Localities near Borgloon-Tongeren-Bilzen

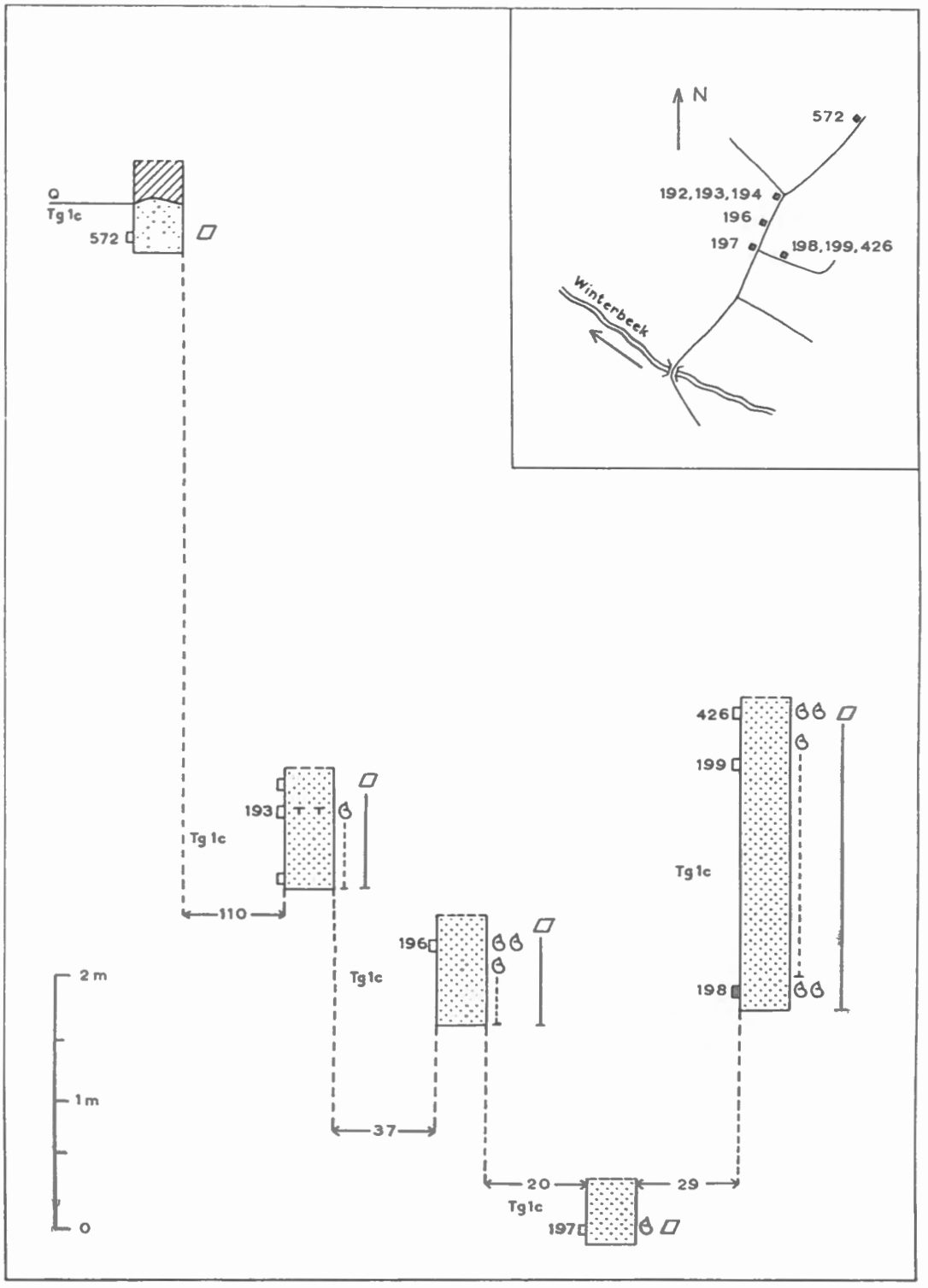


FIG. 3. — Location of samples from Grimmertingen (SG).

A small pit had to be dug out in order to obtain a sufficiently large exposure. It is possible that there has been some contamination in the encountered deposits. They locally contain « loamy » patches that remind of the Quaternary loess.

The exposure showed about 55 cm of brownish-yellow, medium-grained, mollusc-bearing sand with dispersed silex pebbles at its base. It overlies some brownish and greenish-grey, sandy clay with shrinkage cracks.

Two samples were taken from the sand. Of these especially the uppermost one is rather rich in molluscs, the larger specimens of which are mostly fragmentary : *Cerithium*, *Sandbergeria cancellata* (NYST), *Bayania nysti* (NYST), *Aloidis gibba* (OLIVI), *Nystia*, *Glycymeris* and scarce other molluscs among which a fragment of a taxodont Pelecypode with preserved mother of pearl (? *Nucula comta*, ? *Leda gracilis*).

The coarser quartz grains are well rounded. Neither of the two samples contained traces of microfauna.

The sample from the clay underneath yielded few *Cerithium* and *Aloidis* specimens and one valve of the ostracode *Paracyprideis rarefistulosa* (LIENENKLAUS). According to KEIJ (1957) the latter species was found in Belgium only in the Nucula-clay. The coarser quartz grains of the clay are well rounded.

It is considered likely that the clay is Nucula-clay and the overlying sand represents the R1d-sand.

SG Several exposures in hollow road sides near Grimmertingen, about 1.900 m S. of the church of Vliermaal. This is the type locality of the sand of Grimmertingen. See fig. 3.
Also point 101 of GLIBERT and DE HEINZELIN (1954*a*), while many observations were found listed in the archives of the Geological Survey (92E, several numbers).
Visited in 1953 and 1954.

The stratigraphic relation between the isolated exposures is obscured by the vegetation. The horizontal distances are established by pacing; the vertical ones are determined with the help of a Breithaupt compass and a centimeter scale.

The type sand of Grimmertingen is very fine-grained to clayey with dispersed coarser quartz grains. It is yellowish-brown to yellowish-green and it is usually rich in mica. Locally the sand is fossiliferous. The molluscs, chiefly *Ostrea ventilabrum* GOLDFUSS and *Turritella crenulata* NYST, are for the greater part concentrated in layers. One of these layers was found to be indurated and ferruginous.

Sample SG 198 is rich in organic components, whilst the other samples are less so. SG 198 contains entire and fragmented molluscs, echinoid spines and shale fragments and small vertebrate remains. Scarce Foraminifera and a single valve of *Leguminocythereis striatopunctata* (ROEMER) were met with.

Just as near Broek (TL, TM) many reworked Oligocene molluscs were found at the base of the loess on top of the Grimmertingen sand of SG 572. In the loess of this locality they occur together with silex pebbles and green, sandy clay fragments with brackish water molluscs, evidently derived from Upper Tongeren deposits. The following mollusc-association was found : *Glycymeris*, *Sinodia incrassata* (SOWERBY), *Corbicula semistriata* (DESHAYES), *Aloidis gibba* (OLIVI), *Natica*, *Cerithium*.

SJ Series of small outcrops in a hollow road, 100 m N, 1.500 m W of the church of Overrepen.
Point 139 of GLIBERT and DE HEINZELIN (1954*a*).
Visited August 1953.

SJ 201. — Sample from a heap of clay, evidently dug out from a very small pit filled with water, at the eastern side of the road.

The clay is dark-grey, plastic, and it contains *Cerithium*, *Sinodia incrassata* (SOWERBY), *Aloidis gibba* (OLIVI) and fragments of other molluscs. Dr. A. J. KEIJ observed common *Haplocytheridea helvetica* (LIENENKLAUS) and rare *Cytheridea pernota* OERTLI and KEIJ in the sample, which yielded no Foraminifera. The clay probably belongs to the clay of Henis.

Two samples from the sand overlying the Henis clay and exposed in two small talus outcrops appeared devoid of microfauna. They are from rather fine-grained, yellow sand with *Cerithium*, *Glycymeris obovatus* (LAMARCK), *Limopsis goldfussi* (NYST), *Aloidis gibba* (OLIVI), *Astarte henckelusiana* NYST and *Leda gracilis* DESHAYES, often fragmentary. This is distinct sand of Berg.

SK Pit of the tileworks of Mr. VAN OOSTAYEN, 800 m S, 200 m W of the church of Kortessem.
Visited May 1954.

The Quaternary covering in this pit consists of loess with silex pebbles at its base, which locally overly ferruginous sand with dispersed layers of silex pebbles. It rests on 2 m of hard, brittle, greenish-grey, slightly sandy clay. A sample 60 cm above the base of this clay contains no microfauna.

Sample SK 570, 20 cm below the base of the clay, has been derived from fine-grained, white sand with very little glauconite and mica. Dr. A. J. KEIJ observed rare *Cytheridea pernota* OERTLI and KEIJ. Further a few Foraminifera were found : two worn nummulites (probably *N. laevigatus* LAMARCK), one *Cibicides* specimen, one *Globulina gibba* D'ORBIGNY, two worn specimens of some *Rotalia* species (probably *Rotalia audouini* D'ORBIGNY) and a miliolid fragment. These Foraminifera possibly are reworked elements from Eocene deposits (sand of Rocourt?).

Mr. VAN OOSTAYEN kindly informed us about the remaining part of the section in his pit, which section is only fully exposed in winter. Under the uppermost layer of clay, observed by us, the sand (SK 570) has a thickness of 60-70 cm. Under this sand some 3 m of clay are said to contain a dark layer with « wood and shells », about 170 cm under the top as well as a hard, calcareous bed some 30 cm under the dark layer. The clay overlies again sand, which has been observed down to 60 cm below the base of the clay.

The entire complex is considered to belong to the Henis clay, which locally would have a sandy intercalation.

SL Small abandoned sandpit, 400 m N, 400 m E of the church of Overrepen. Sand of Neerrepen, type locality.
Probably point 107 of GLIBERT and DE HEINZELIN (1954*a*).
Visited May 1954.

Fine-grained, thin-bedded sand with mica, glauconite and a few silex fragments. No tubular structures were visible in the sand, 2 m of which are exposed.

The two samples from the Neerrepen sand we took in this pit, appeared devoid of microfauna.

SM Sandpit 1.050 m S, 750 m E of Overrepen church.
Visited May 1954.

Under the soil are exposed about 4,50 m of fine-grained, greenish-grey, locally rusty-brown, micaceous sand with a few, thin (± 5 cm), dark-brown, brittle clay beds intercalated. This is probably sand of Neerrepen.

Two samples were taken, the lowermost one from a clay bed near the bottom of the pit. It contains mollusc fragments and a very small Pelecypode valve in addition to scarce mica, small silex fragments and some glauconite. No microfauna.

The second sample, this one from the sand 100 cm higher than the previous sample, is equally devoid of microfauna. It contains some mica, silex fragments and glauconite.

TA Pit of the tileworks FRANCART, 1.250 m N, 550 m E of the tower of Tongeren basilica. See fig. 2.

In 1953-1954 the best exposure of Henis clay, situated in between Tongeren and Henis.
Point 121 of GLIBERT and DE HEINZELIN (1954*a*).
Repeatedly visited in 1953 and 1954.

The Foraminiferal content (abundant *Rotalia canui* CUSHMAN) of the sandy and marly clay with *Cerithium*, *Sandbergeria*, *Bayania*, *Nystia* and *Aloidis gibba* (OLIVI), sampled near the top of the exposure and directly under the soil (TA 579), indicates that this clay belongs to the Oude-Biezen member.

The underlying clay contains a sandy, greyish intercalation with *Cerithium*, *Natica* and *Corbicula*, that are all mostly fragmentary. This intercalation completely wedges out in the NW wall of the pit. Above and below it is bordered by two beds of coffee-brown clay, both with a thickness up to 10 cm. Sample TA 209 from the lowermost of these beds yielded a single specimen of *Haplocytheridea helvetica* (LIENENKLAUS). The same ostracode species was encountered at the base of the Henis clay. The clay contains many large gypsum crystals and it is characteristically green in the part under the sandy intercalation. In the sample from the clay on top of this intercalation some pyrite was found. No Foraminifera have been encountered in the samples of the Henis clay of this pit.

The sand directly under the Henis clay is chocolate-brown. The colouring is due to a ferruginous coating of the sand grains. Under the brown sand there is a less fine-grained, grey sand with fairly common, small silex fragments and a few small gypsum crystals, some glauconite and mica and occasional Foraminifera reworked from the Cretaceous. It is not clear to which member or members these sands under the Henis clay must be assigned.

TB Abandoned claypit on the southern side of the Zavelberg, 1.300 m N, 625 m W of the tower of Tongeren basilica. See fig. 2.
Locality TB is situated in between points 115 and 117 of GLIBERT and DE HEINZELIN (1954*a*).
Visited August 1953.

In the upper part of the poor exposure there is white sand, possibly belonging to the same member as the sand under the gravel in the near-by sandpit (TQ) close to the top of the Zavelberg.

Sample TB 216 is from dark, brownish-grey clay with *Corbicula* and *Bayania*. It contains many Ostracoda, a few Foraminifera and occasional small bone fragments. This clay is separated from the underlying light-greyish-green clay with *Cerithium* and *Aloidis* by a very dark-brown bed of about 7 cm thickness. The more light-coloured clay (TB 215) equally contains many Ostracoda, a few Foraminifera and some small bone fragments.

The lowermost exposed clay in the pit is greyish-green with thin brown laminae. It contains a dark-brown bed and two mollusc-bearing layers, in the samples of which small glittering pyrite aggregations were observed. The uppermost one of these layers contains *Cerithium* and *Corbicula semistriata* (DESHAYES) and no *Sinodia*. On the contrary the lowermost one is rich in *Sinodia incrassata* (SOWERBY), partly bivalve, as well as in *Cerithium*. Furthermore, *Natica* and fragmentary other molluscs were met with.

TC Sandpit south of the Galgenberg, 750 m N, 2.950 m E of the tower of Tongeren basilica.
Point 128 of GLIBERT and DE HEINZELIN (1954*a*); 107W91 archives Geological Survey.
Visited August 1953.

In the pit about 10 m of distinct sand of Neerrepen are exposed under the covering Quaternary loess with pebbles. The sand is fine-grained, horizontally and thin-bedded, light-greenish-grey with brown patches and some clayey intercalations. Tubular structures occur in the lowermost part of the exposed sand.

Four samples, taken at intervals of approximately 2 m, contain small silex fragments, mica and some glauconite. No microfauna.

TD Sandpit of Mr. J. THIJS, east of and adjoining the new barracks, 200 m N, 1.400 m E of the tower of Tongeren basilica.
Visited August 1953.

Quaternary loess with a strongly wavy layer of silex pebbles at its base covers about 7 m of distinct Neerrepen sand. The sand is greenish, fine-grained, micaceous and thin-bedded. Some thin clay beds and also tubular structures occur dispersed in the sand.

Three samples from this pit, one of which was derived from a thin clay bed, all contain mica, glauconite and small silex fragments. No microfauna.

TE Outcrops in the abandoned tramway incision, 225 m N, 250 m E of the church of Kleine-Spouwen.
Visited August and September 1953. In 1955 definitely lost due to constructions covering the site.

Two small pits were dug in order to re-find the fresh Nucula-clay, generally known from this locality. Two samples (TE 224, 428) have been obtained from distinct Nucula-clay with molluscs, Ostracoda, Foraminifera and echinoid spines.

In one of the small pits the brownish-grey Nucula-clay grades downward into clayey, fine-grained, yellowish-brown sand with *Glycymeris* and other molluscs. The sample from this sand (TE 427) contains fragments of *Nucula comta* GOLDFUSS and other molluscs, echinoid spines, Ostracoda, Foraminifera and very little glauconite and mica. This sand is considered to belong to the sand of Berg.

Sample TE 428 was taken 20 cm above TE 427, and about 15 cm below the level of TE 224.

TG Outcrops in road talus, about 150 m NNW of the castle of Oude-Biezen, in the neighbourhood of locality 201 of GLIBERT and DE HEINZELIN (1954*a*).
Visited August 1953.

Distinct clay of Henis is exposed in several small outcrops on both sides of the road.

Two samples were taken from brownish-green, plastic clay with many small, whitish, calcareous concretions up to 1 cm in diameter. It contains very few molluscs, but no microfauna.

A third sample TG 228, from a 5 cm bed of light, greenish-grey clay with fragmentary *Cerithium*, *Sinodia incrassata* (SOWERBY), *Corbicula semistriata* (DESHAYES), *Bayania* and barnacles, contains abundant *Haplocytheridea helvetica* (LIENENKLAUS) and some Foraminifera. This mollusc-bearing bed, which also contains calcareous concretions, is intercalated in dark-greenish-grey clay.

TJ Outcrop in western road side, slightly south of kilometerstone 4, 600 m S, 2.000 m W of the church of Membruggen.
Visited in September 1953.

One sample was taken from fine-grained, micaceous, yellowish sand with rusty patches, 2,50 m of which were exposed. It contained much mica, and few whitish, indurated, clay particles, small pyrite aggregates, small gypsum crystals, glauconite and plant remains (fossil?). No microfauna. Probably sand of Grimmertingen.

TK Abandoned claypit at the Katteberg, 700 m S of the church of Bilzen. See fig. 2.
Point 194 of GLIBERT and DE HEINZELIN (1954*a*), point 93W32 of the archives of the Geological Survey.
Visited May 1954.

Under the loess and gravel of silex pebbles there is a poor exposure of fine-grained, yellowish-white, locally rusty-brown sand. The contact of this sand, probably R1d, with the underlying Nucula-clay is concealed.

The Nucula-clay in this place is only slightly sandy. It is brownish-grey and it contains several specimens of *Nucula comta* GOLDFUSS. All our samples from the clay were found to contain Ostracoda and Foraminifera. Sample TK 525 was taken from a 30-40 cm marly, light-grey and rather hard inclusion in the clay, possibly a kind of septaria. The outline of this inclusion is concealed. In the three lowermost samples occur many small white gypsum crystals.

The base of the Nucula-clay and the underlying strata are not exposed. At the bottom of the pit we found reworked Upper Tongeren clay with *Cerithium* and other molluscs.

TL, TM Outcrops in hollow road at Broek, about 500 m S, 950 m E of the church of Hoeselt. In this place are the classic outcrops of the sand of Hoeselt (equivalent of the sand of Grimmertingen). See map 13.
Point 192 of GLIBERT and DE HEINZELIN (1954*a*); 93W502 of the archives of the Geological Survey.
Visited May 1954.

In several outcrops fossiliferous sand of Grimmertingen is exposed. The sand is fine-grained, greenish, rich in mica and glauconite and locally it contains *Ostrea ventilabrum* GOLDFUSS and a few *Turritella* specimens.

It is overlain by loess with a 30-40 cm layer of silex pebbles and mollusc shells at its base. The faunal components have been derived from both the Tongeren formation and the sand of Berg. The molluscs belong among others to *Ostrea ventilabrum* GOLDFUSS, *Sinodia incrassata* (SOWERBY), *Corbicula semistriata* (DESHAYES), *Astarte*, *Glycymeris*, *Pecten*, *Cerithium*, *Bayania nysti* NYST and *Natica*.

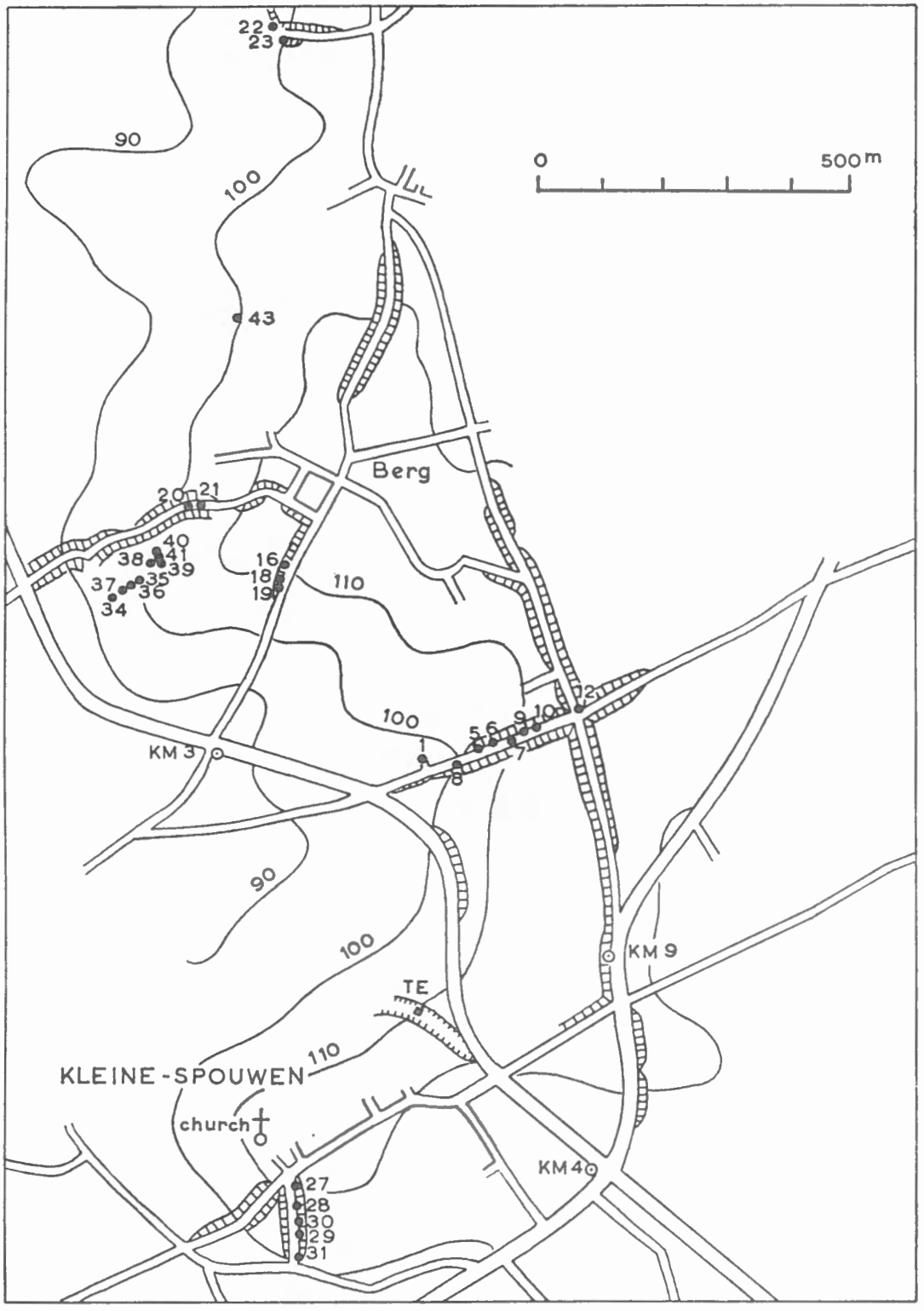
TL 528 was taken 25 cm under the base of the Quaternary and about 2 m above the road level in Grimmertingen sand with *Ostrea ventilabrum*. No microfauna.

TL 529 came from 15 cm under the base of the Quaternary, at road level, in sand of Grimmertingen with *Ostrea ventilabrum* and *Turritella*. Scarce Foraminifera and other organic components.

TM 530 was obtained 25 cm under the Quaternary base, about 50 cm above the road-level, in sand of Grimmertingen. Barren.

TN Small outcrop in talus on N side of hollow road at Leten, 1.275 m S, 250 m W of the church of Bilzen.
Visited May 1954.

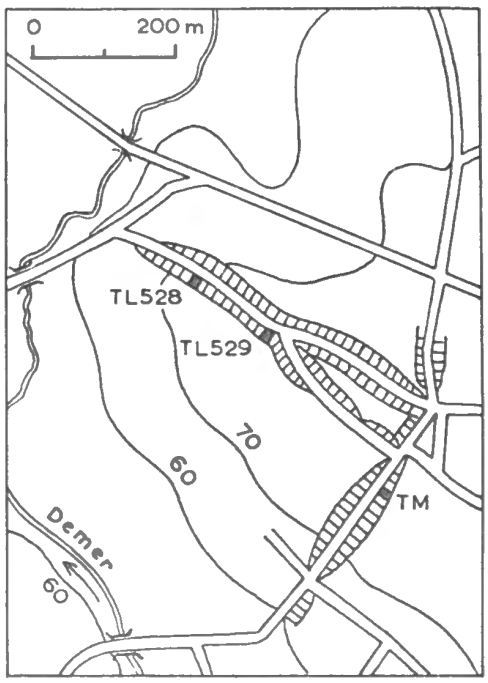
One sample was taken 1 m above the road-level in fine-grained, greenish-grey sand with mica and glauconite and some rusty-brown mollusc moulds. No microfauna. Sand of Grimmertingen.



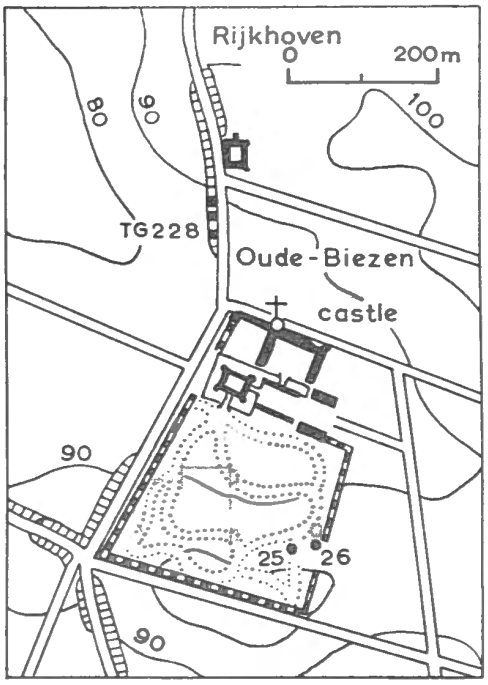
MAP 12. — Location of BZ borings near Kleine-Spouwen and Berg.

TO Outcrop in a very small pit in talus on southern side of road at Leten, 1.550 m S, 250 m W of the church of Bilzen. About 20 m above the level of TN.
Visited May 1954.

One sample was taken at road-level, 25 cm under the base of the Quaternary loess with a layer of silex pebbles and fragile shells in its lower part. The sample is from fine-grained, greyish-green sand with glauconite and mica. No microfauna. This belongs either to the sand of Grimmertingen or the sand of Neerrepen.



MAP 13. — Locality map of Broek near Hoeselt.



MAP 14. — Locality map of Oude-Biezen.

TQ Sandpit on the Zavelberg, 1.850 m N, 1.050 m W of Tongeren basilica tower.
Point 112 of GLIBERT and DE HEINZELIN (1954*a*), point 3 on fig. 7 of LERICHE (1922).
Visited May 1954.

Under the covering of 2 m Quaternary loess with a basal gravel or silex pebbles about 2 m of sand are exposed with a layer of gravel in the middle.

The sand on top of the gravel is rusty-brown and rather fine-grained. It contains small silex fragments and very little mica. A sample appeared devoid of microfauna. Probably sand of Berg.

The gravel (in places up to 5 cm) contains coarse quartz grains and dark silex pebbles reaching a diameter of 2 cm. At some places in the pit it is absent. It resembles fairly well the gravel observed near Leuven (LN, LP, LQ) and it is probably the basal gravel of the Rupel formation.

The sand under the gravel is fine-grained, white with some rusty-brown bands. The sample from this sand, the stratigraphic position of which is unknown, contains silex fragments, very little mica and no microfauna.

TR Sandpit near the east end of the Beukenberg, 75 m N, 600 m W of the tower of Tongeren basilica. See fig. 2.
The uppermost 3 m of the section are from a small pit, very close to the southeastern part of the great sandpit.
Visited May 1954.

Directly under the soil in the small pit there are up to 30 cm of grey clay with sandy, yellow and ferruginous patches. This clay very much resembles that of the base of the Henis clay as found in the area between Tongeren and Henis (TA).

The clay is underlain by 40 cm of white sand overlying a dark-brown sand bed of 10 cm. The dark-brown bed covers nearly horizontally stratified, fine-grained, greenish-grey sand with small silex fragments, mica and glauconite; the latter is distinct sand of Neerrepen. The uppermost part of this sand has a pinkish colour. A thin clay intercalation was found in the middle of this lower sand-complex.

Sample TR 580 from the bottom of the great pit contains scarce fragments of small Gastropoda (*Cerithium*?) and of small Pelecypoda and a single valve of *Cytheridea pernota* OERTLI and KEIJ.

BZ Handborings in the surroundings of Kleine-Spouwen. See figs. 4, 5, maps 12, 14.

Since the outcrops at the type localities of the Oude-Biezen member, of the sand of Berg and of the Nucula-clay are very poor, these localities were examined with an auger. This was done in May 1954 with the help of an auger of the type used by the « Stichting voor Bodemkartering » at Bennekom (Netherlands).

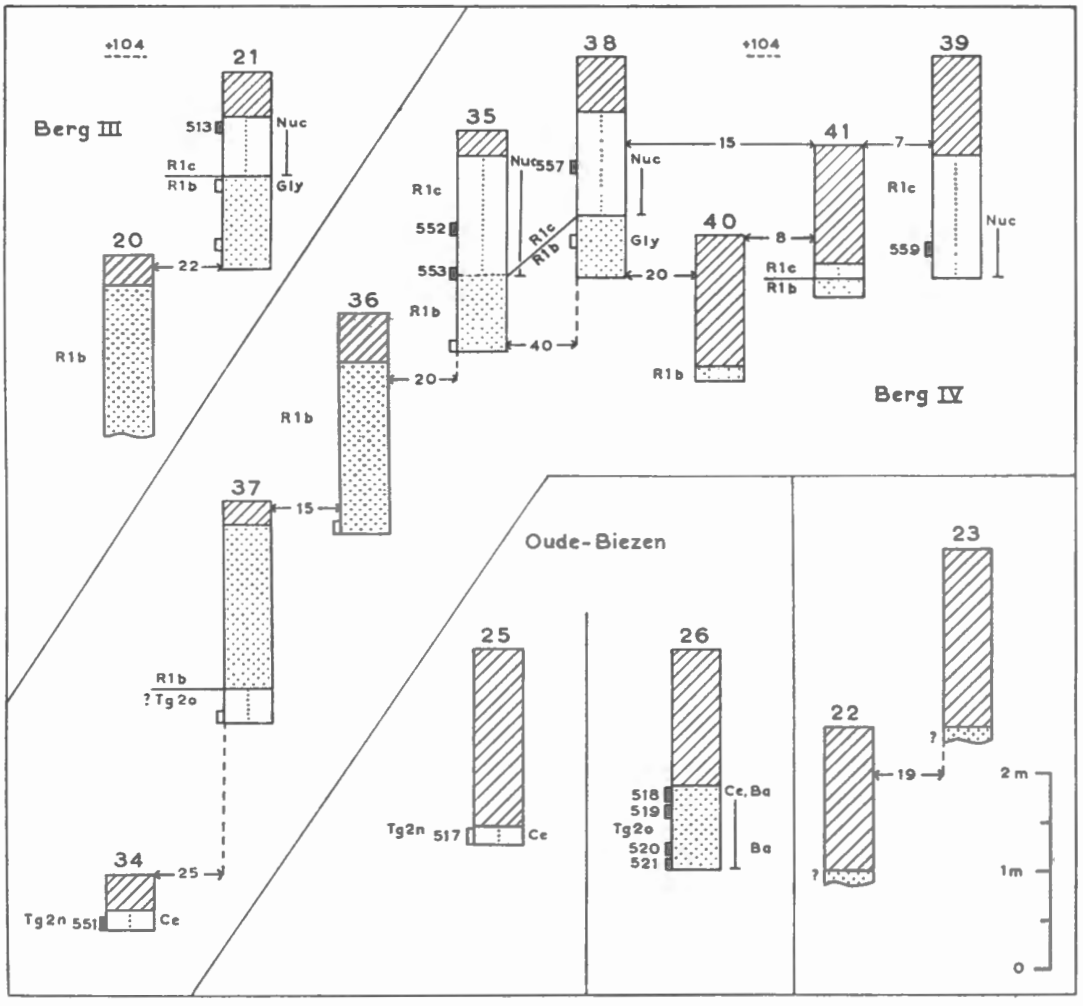


FIG. 4. — Sections of BZ borings.

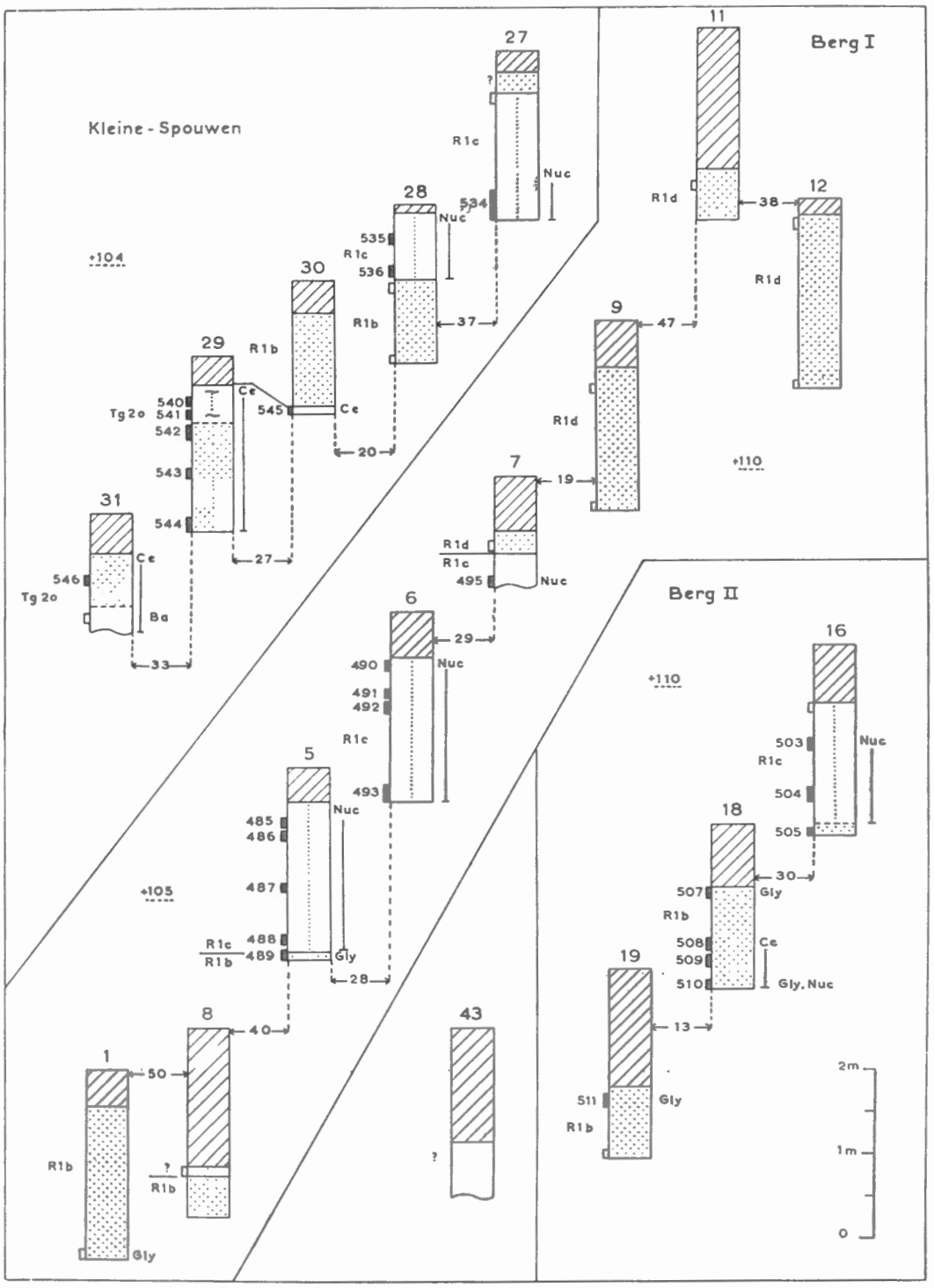


FIG. 5. — Sections of BZ borings (continued).

With our auger fairly pure cores, 15 cm high and 5,50 cm in diameter, could be obtained from a maximum depth of 2,25 m and from sand as well as from clay. Only cores from very wet sand and clay were badly contaminated. Generally very wet sand slipped out of the auger when the instrument was lifted out of the bore hole.

In thirty four out of the fourty four holes we drilled, Oligocene deposits were encountered. From these deposits sixty one samples (BZ 484, etc.) were taken. In the other ten holes the base of the Pleistocene loess and gravels was not reached.

The relatively large scale of the Belgian topographic map, 1 : 10.000, did not allow for an exact location of the borings with respect to the topographic contours. Moreover, many of our borings were situated in hollow roads. The estimated altitude of the sections above sea level as indicated in our figures is therefore only approximate.

Few of the borings at Berg and in the garden of the castle of Oude-Biezen reached the clay of Henis. This is greenish-grey and plastic clay with in places *Cerithium* and some other brackish water molluscs.

The Oude-Biezen member was encountered at the type locality (boring 26) and at Kleine-Spouwen. It consists of nearly white, if weathered yellowish-brown, fine-grained sand with many molluscs : mostly *Cerithium*, *Nystia*, *Bayania nysti* (NYST), *Corbicula semistriata* (DESHAYES) and *Sinodia incrassata* (SOWERBY). Locally there are marly intercalations in the sand.

The sand of Berg was met with in the borings at the type locality (borings 16, 18 and 19) and at several other places in the region of Kleine-Spouwen. The sand is yellowish, on places brownish or greyish, and rather fine-grained. In some borings *Glycymeris obovatus* (LAMARCK) and some other molluscs were observed.

At the type locality we found an intercalation of a layer with some dispersed silex pebbles and many specimens of *Cerithium* and other molluscs, that are also present in the Upper Tongeren beds. The molluscs probably are reworked elements from the Upper Tongeren beds. Under the layer with *Cerithium* there is again characteristic sand of Berg, with some fragments of *Glycymeris* and *Nucula comta* GOLDFUSS.

In many borings near Kleine-Spouwen and near Berg the Nucula-clay was encountered. It is brownish to bluish-grey, more or less sandy clay, in which *Nucula comta* is often present. Other molluscs are rare.

The R1d sand was observed in some borings at Berg. It is medium- or rather fine-grained brownish-yellow to greyish sand. No fossils were encountered in it.

ROCOURT

(Map 1)

UC Outcrops in abandoned sandpit, 1.200 m S, 75 m W of the church of Rocourt. The bottom of the pit has been transformed into a football field.
Visited September 1953.

UC 438 is a sample out of the western pitwall, about 1 m above the level of the football field, and 1 m under the base of 2,50 m loess covering. Fine-grained, yellowish-white, micaceous sand. Rare Foraminifera and Ostracoda. Sand of Rocourt.

Another sample from the same sand out of the eastern wall of the pit appeared to be devoid of microfauna.

UD Sandpit, belonging to Mr. GRITTEN, 950 m S, 25 m E of the church of Rocourt.
Visited May 1954.

In this pit 8 m of fine-grained, micaceous, white to brownish sand of Rocourt are exposed under 1,50 to 5 m of loess and gravels with a wavy base.

Four samples were taken :

UD 563 : 160 cm below the base of the covering gravel and loess, rare Foraminifera;

UD 562 : 240 cm below UD 563, very rare Foraminifera;
UD 561 : 200 cm below UD 562, rare Foraminifera;
UD 560 : 215 cm below UD 561, but in another part of the pit than the three higher samples. The sample was taken at the bottom of the pit, slightly above a very poorly exposed layer of silex stones. One fragmentary *Nummulites* specimen was encountered.

UE Sandpit, belonging to Mr. GRITTEN, 1.350 m S, 875 m E of the church of Rocourt.
Visited May 1954.

About 12 m of fine-grained, greyish-white, micaceous sand are exposed under a mass of gravel and loess, the thickness of which is not constant. Like the sand in UD this sand is again sand of Rocourt.

Part of the covering gravels probably belongs to the so-called Onx of the geological map.

In the sand occur many hard, irregular, ferruginous incrustations.

Six samples were taken from the sand :

UE 569 : ±3,50 m under the surface, one ostracode fragment;
UE 568 : ±4,30 m under the level of UE 569, one *Nummulites* specimen;
UE 567 : 150 cm below UE 568, barren;
UE 566 : 160 cm below UE 567, barren;
UE 565 : 160 cm below the level of UE 566, one *Nummulites* individual and some reworked Cretaceous Foraminifera;
UE 564 : 150 cm below UE 566 at the bottom of the pit. Rare Foraminifera and Ostracoda.

Because of the steepness of the walls of the pit and the undulating nature of both the bottom of the pit and the surface it appeared impossible to take the samples in a straight vertical series. The correlation between the sampled places was done with the help of a Breithaupt compass and the more or less regular, horizontal, ferruginous, infiltrated zones in the sand.

LAND OF WAAS

(Map 15)

JA Small claypit of the « N.V. Antwerpsche Machiensteenfabrieken », just north of the brickworks, 400 m N, 600 m W of Tielrode church. See fig. 6.
Visited September 1953.

The uppermost 1,50 m of the Boom clay in this pit are weathered and rusty-brown.

JC Claypit of the brickworks SCHEERDERS and VAN KERCHOVE, 500 m S, 1.500 m W of the main church of St.-Niklaaas. See fig. 6.
See also HALET (1938, Bull. Soc. Belge Géol., vol. 48, p. 484, fig. 6).
Visited June 1954.

The covering consists of about 3 m of ill visible yellow sand with a fine-grained, black, basal gravel, that contains shark teeth and bone fragments. 8 m of mainly silty Boom clay are observable.

JD Small claypit of Mr. GHIJSELINCK-DE MOOR, 750 m N, 150 m W of the church of Elversele.
Visited June 1954.

In the pit 2 to 3 m of plastic, brown and non-calcareous clay were exposed. No doubt this clay is weathered Boom clay. A sample (JD 594) from a heap of similar, but calcareous clay with concretions and *Leda deshayesiana* NYST yielded a distinct Boom clay Foraminifera association (*Spiroplectammina carinata*, *Cibicides dutemplei* var. *praecinctus*, *Cibicides sulzensis*, *Alabamina perlata* and other species) together with many specimens of *Elphidium minutum* and *Rotalia beccarii*. The latter species are unknown from the Boom clay. They have certainly been derived from the covering sand. This sand was not exposed but the observed presence of *Astarte* individuals, bone fragments, shark teeth and small black silex pebbles, points to a similar Pleistocene mollusc bed as the one that was observed at Tielrode (JG, JH). According to the workmen of the pit this sand is occasionally observable. It fills former erosion channels in the uppermost part of the clay.

JE Claypit of the brickworks « De Vrede » at Kemzeke-Hol, 150 m N, 300 m W of the church of St.-Gillis-Waas. See fig. 7.
Visited June 1954.

2 m of yellowish-brown sand with a fine-grained basal gravel cover the Boom clay.

JF Claypit of the brickworks « De Herleving » at Kemzeke-Hol, about 600 m NNW of the claypit of the brickworks « De Vrede » (JE) and 700 m N, 3.150 m W of the church of St.-Gillis-Waas. See fig. 7.
Visited June 1954.

Yellowish-brown sand with gravel and with a very wavy base covers up to 6 m of Boom clay with pyritized wood fragments and big pyrite accretions reaching up to 15 cm diameter.

JG Abandoned claypit of the « N.V. Antwerpsche Machiensteenfabrieken » 950 m N, 250 m W of the church of Tielrode. This pit and the pit JA, about 600 m SSW of it, are also known as « Nieuw Gelaag ». See fig. 7.
Visited June 1954.

The covering layers of the Boom clay are well exposed. They have recently been described by VANDERVEE (1953, pp. 73-75). They consist of 3 m of yellowish-brown sand with a very coarse-grained layer of 1 m thickness at the base. This layer contains many molluscs [among which *Neptunea contraria* (LINNÉ)], bone fragments, shark and ray teeth, black small pebbles and lumps of glauconite sand. The layer is considered to belong to the so-called Scaldisian (Pleistocene).

The Boom clay is less easily accessible. The clay above the septaria is hardened and marly. The lateral extension of this marly clay in the pit could not be established.

JH « Oud Gelaag », claypit of brickworks at Tielrode, 1.800 m W of the church of Temse. See fig. 7.
Visited June 1954.

Similar sediments as those in Tielrode (JG) cover the Boom clay, but they are less well exposed.

JJ Claypit of the brickworks at Steendorp, 350 m N, 500 m W of the church of that village. See fig. 7.
Visited June 1954.

Judging from the molluscs, the bone fragments and he small pebbles occurring in he uppermost, concealed part of the exposure, a similar mollusc bed as that found at Tielrode (JG, JH) must be present.

The uppermost part of the Boom clay is less calcareous and contains more and bigger pyrite accretions than the lower eight meters.

JK Abandoned claypit near the fortress of Kruibeke, 1.800 m N, 300 m E of the church of that village.
Visited June 1954.

The exposure is poor. About 8 m under the surface there is a bed with flat, hardened, marly stones with few narrow, internal cracks. These stones are supposed to represent either a growing or a decalcification stage of septaria. Sample JK 628 was taken from the marly clay surrounding such a septaria. As far as it is exposed, the clay more remote from this septaria is non-calcareous.

OA Claypit of the brickworks of Mr. VAN DER STEICHEL, 450 m S, 900 m E of the church of Stekene. See fig. 8.
Visited June 1954.

The Boom clay is covered by brownish-yellow sand with a fine-grained basal gravel. The contact sand — Boom clay is very wavy and locally it is accompanied by vivianite crystals. The isolated shark teeth and bone fragments in the pit are probably derived from the covering sand, which is considered to belong to the sand of Tielrode (JG, JH).

OB Small claypit, 1.800 m S. 700 m W of the church of Kemzeke. See also HALET (1938, Bull. Soc. Belge Géol., vol. 48, p. 486, fig. 7).
Visited June 1954.

About 2,50 m of plastic, brown, locally greyish, non-calcareous clay are exposed. The clay is weathered Boom clay. It contains a few small whitish calcareous concretions and *Leda deshayesiana* NYST. No sample was taken.

RUPEL-LIER REGION

(Map 15)

JB Claypit of the brickworks De Neef, 775 m S, 1.700 m E of the church of Niel. See fig. 6.

The samples were taken in September 1953. The position of the alternating silty and plastic layers and of the septaria bed were measured in June 1954.

The figured position of the five uppermost samples in relation to the plastic and silty layers may be slightly different.

JL Claypit of the brickworks « Neerland » at Wilrijk, 2.300 m N. 300 m W of the church of Aartselaar. See fig. 7.
Visited June 1954.

Under 2 m of yellowish sand with 10 cm of fine-grained gravel at the base, there is mainly non-calcareous and blackish-grey Boom clay with few molluscs and pyrite accretions. The uppermost part of this clay is brownish and weathered.

JM Claypit of the brickworks Bal Bros., 1.400 m S, 100 m W of the church of Schelle. See fig. 7.
Visited June 1954.

Nearly 5 m of very calcareous, mostly greenish-grey Boom clay are exposed in the lower part of the pit. It contains two beds with many big septaria.

JN Claypit of the brickworks of Mr. E. de Bruyn, 850 m E, 1.250 m W of the church of Kontich. See fig. 8.
Visited July 1954.

Ferruginous, glauconitic sand with a fine-grained gravel at the base, cover Boom clay that is mainly non-calcareous and blackish-grey, with extremely rare molluscs.

MA Claypits of the brickworks Druk and Verstrepen, about 500 m N, 1.250 m E of the church of Boom. See fig. 8.
The samples MA 367-386 were taken in September 1953; those numbered MA 648-652 in July 1954. The plastic and silty layers in the lowermost pit (firm Verstrepen) were measured in 1954.

The pits of the brickworks Druk and Verstrepen at Boom are near the centre of an almost continuous series of exposures of Boom clay in the pits of several brickworks between Niel and Rumst, north of the Rupel river.

Glauconitic, green sand that is brownish-black at the base, covers the Boom clay. The ten uppermost samples of that clay are mostly without microfauna. The clay from which these samples were taken, is less rich in molluscs and pyrite accretions than the clay in the lower part of the exposure.

ME Claypit of the « N.V. Steenfabrieken Rupel en Nethe », 1.100 m N, 150 m E of the church of Rumst. See fig. 8.
Visited June 1954.

This is the easternmost one of the series of claypits along the Rupel. The Boom clay is covered by poorly exposed sand. At the base of the sand there is a coarse layer with shark teeth.

VA Claypit of the brickworks near the brewery Cuyckens, 560 m S, 1.600 m W of St.-Gommarus's church at Lier. See fig. 8.
Visited June 1954.

Soil, loess and fine-grained, horizontally bedded sand with a thin gravel at the base cover the Boom clay. Near the bottom of the pit the clay locally contains a hardened marly layer with slightly internally cracked stones.

There is some doubt concerning the distance between the uppermost silty layer in the Boom clay and the base of the overlying sand, the field notes being obscure.

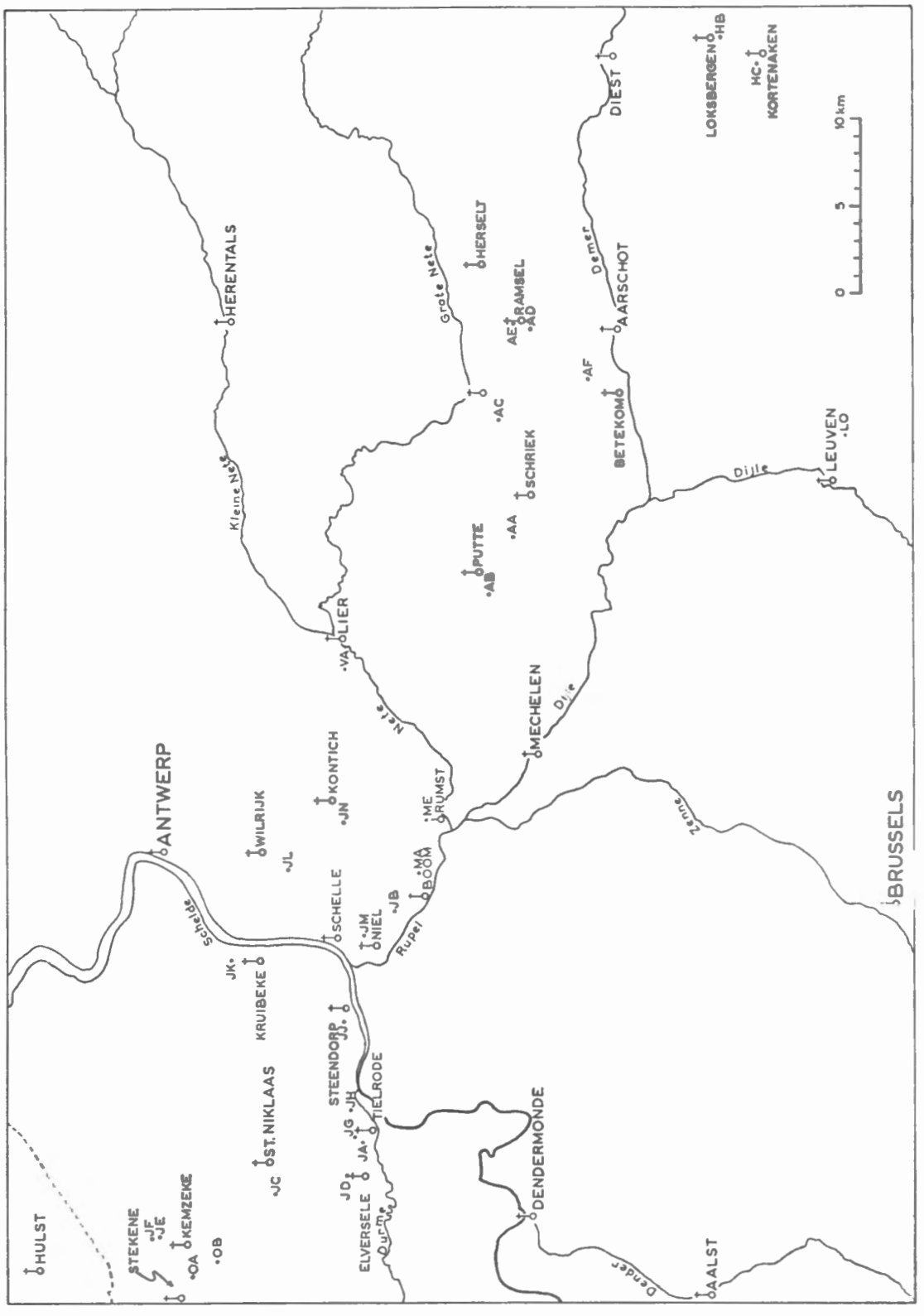


Fig. 1. — Localities mentioned in the Boom clay

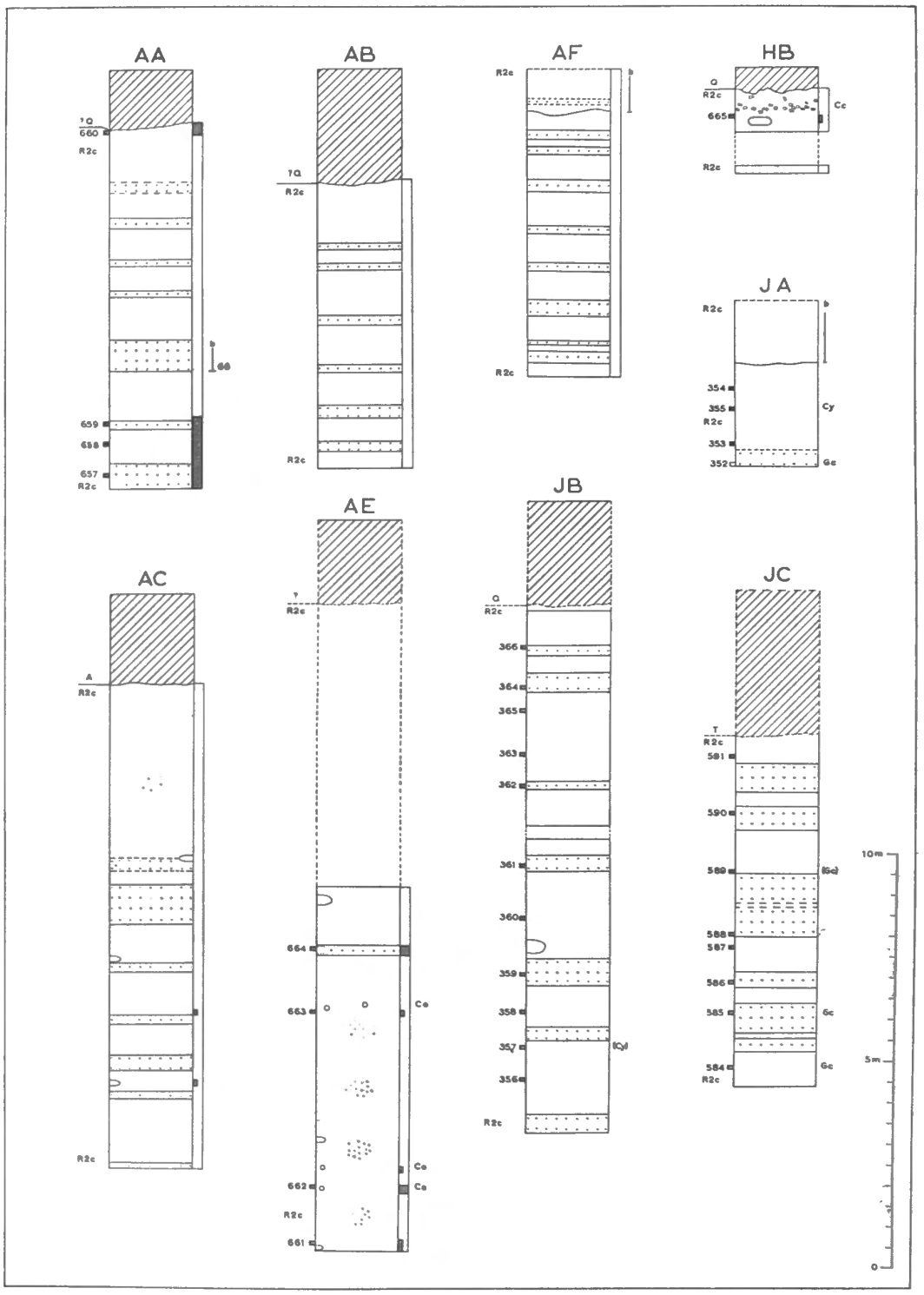


FIG. 6. — Sections of Boom clay pits, AA-JC.

MECHELEN-AARSCHOT REGION

(Map 15)

AA Claypit of the brickworks of Mr. L. HOOGHE, 1.200 m N, 2.200 m W of the church of Schriek. See fig. 6.
Visited July 1954.

Under about 1 m of horizontally stratified, greenish, glauconitic sand with a fine gravel at its base, are exposed some 8 m of mainly plastic and non-calcareous Boom clay.

At the base of a brownish and silty layer in this clay there is a thin bed with many small *Aloidis* specimens.

AB Claypit of the brickworks « Klein Boom », 600 m S, 1.300 m W of the church of Putte. See fig. 6.
Visited July 1954.

About 2,50 m soil and greenish-brown, horizontally sratified sand cover nearly 7 m of mainly non-calcareous Boom clay with very few molluscs.

No samples were taken.

AC Claypit of the brickworks HERMANS Bros., 1.100 m S, 1.600 m W of the church of Booischot. See fig. 6.
Visited July 1954.

Coarse, glauconitic, greenish to rusty-brown, current-bedded sand with a few molluscs and big bones up to a length of 75 cm, covers nearly 12 m of mainly non-calcareous Boom clay with pyrite accretions up to 20 cm in diameter.

Some of the septaria fragments on the bottom of the pit contain pyritized wood remains.

AD Claypit of the brickworks SMITS, 450 m S, 250 m W of Ramsel church.
Visited July 1954.

The section of the Boom clay in this pit was not measured and no samples were taken. The clay is non-calcareous. It consists of alternating plastic and silty layers, which dip 8° S in the eastern wall of the pit.

Besides big pyrite accretions and small gypsum crystals there occur several layers with big accretions, that effervesce slightly if at all with HCl. They are brown or greyish and often show a distinct concentric lamination. In all other Boom clay pits we visited, such concretions were never observed.

Few septaria with narrow internal cracks were found as well.

The clay was covered by wet glauconitic sand with ferruginous concretions at the base.

AE Claypit of the brickworks HERMANS Bros., in the municipality of Herselt, 400 m N of the church of Ramsel. See fig. 6.
Visited July 1954.

Because of the rain it was impossible to ascertain whether the darker and lighter layers in the clay were silty or plastic. The exposed part of the clay contains besides big pyrite accretions and a few molluscs, among which an ill-preserved nautilus specimen, three levels with some spherical, calcareous concretions of about 10 cm diameter and without internal cracks.

AF Claypit of the brickworks L. BONTE and FR. ROMPUY, 2.000 m N, 600 m E of Betekom church. See fig. 6.
Visited July 1954.

The non-calcareous Boom clay contains many big crystals and aggregates of clear gypsum up to 10 cm diameter, and some pyrite accretions. No molluscs were observed. Some fragments of calcareous septaria were found at the bottom of the pit.

The uppermost part of the clay under the surface is weathered, greyish-brown with yellow patches. This brownish layer is absent in the eastern part of the pit, where the clay is covered by green glauconitic sand.

REGION OF DIEST

(Map 15)

HB Claypit of the tileworks of Mr. JORISSEN, 400 m S of Loksbergen church. See fig. 6. Visited July 1954.

Under some Quaternary loess with dispersed silex pebbles about 1 m of sandy, light-grey clay with brownish patches is exposed in the small outcrop. Only one septaria was observed, 20 cm high, 70 cm in diameter. A zone of small white calcareous concretions occurred slightly higher. Only the clay near the septaria effervesced with HCl.

Rusty-brown pyrite accretions, smaller than 1 cm, and some gypsum crystals were met with. No molluscs were observed.

The clay is an equivalent of the distinct Boom clay west of the Hageland.

HC Claypit of the tileworks R. VEULEMANS, 1.200 m W, 250 m N of the church of Kortenaken. Visited July 1954.

In the pit there are about 1,50 m of non-calcareous, light-grey, in places weathered and brownish, clay with small whitish calcareous concretions under a covering of 50 cm of loess with silex pebbles at the base. The clay is an equivalent of the Boom clay west of the Hageland. It resembles the clay at Loksbergen (HB). No sample was taken.

BORINGS AND MINE-SHAFTS, SAND OF ANTWERP.

(Map 1)

Boom Waterboring at the « Boomse Metaalwerken », described by GULINCK in the archives of the Geological Survey (43W266) in 1954.

Samples obtained from the Geological Survey of Belgium.

The dry boring penetrated from the surface (+10 m Ostend O.D.) down to 24 m a complex of Boom clay and Berg sand, sixteen samples of which have been investigated. The samples had been taken at intervals of 1 m. Those from 6-10 m, from 12-14 m and from 16-23 m were available. In the upper 7 the clay is plastic, with pyrite and a distinct Boom clay foraminiferal association. From 8-13 m the clay becomes gradually more sandy; Foraminifera are rare or absent, but always the same species as those found in the overlying Boom clay.

At 13 m depth there is a layer of phosphatic concretions with mollusc moulds in greyish sand.

The sand below 13 m is light-grey, medium-grained, slightly glauconitic and somewhat calcareous. It contains small silex fragments and occasionally some pyrite, echinoid spines, molluscs [*Aloidis gibba* (OLIVI), *Cardita* sp. and *Tornatellaea simulata* (SOLANDER)] and bone fragments. In the sample from 18 m three Foraminifera specimens were found, belonging to *Spiroplectammina carinata*, *Cibicides dutemplei* and *Cibicides sulzensis*. These species are common constituents of the Boom clay fauna. Their presence in this sample may be due to contamination.

Heist-op-den-Berg Waterboring near Government Secondary School at Heist-op-den-Berg (at + 26 m Ostend O.D.), described in the archives of the Geological Survey (59E140) by GULINCK (1954). This was a dry boring only down to 76 m.

Samples of the Geological Survey of Belgium.

According to GULINCK the deposits that overlie the Boom clay, are sand of Diest from 1-22 m and sand of Antwerp from 22-26,50 m depth. Our sample from 26 m shows very glauconitic sand with shell fragments, echinoid spines, Bryozoa, rather common Foraminifera and rare Ostracoda.

Thirteen samples from the Boom clay have been studied : 28 m, 30,50 m, 36 m, 40,50 m, 50,50 m, 60,50 m, 70 m, 80,50 m, 90,50 m, 101 m, 110 m, 119,50 m and 120,50 m. They are from distinct Boom clay with pyrite, septaria and Foraminifera. The samples are contaminated, however. At 110 m species distinct for sand of Antwerp, such as *Asterigerina gürichi* var. *staeschei* and *Elphidium inflatum* were still found together with a Boom clay Foraminifera association.

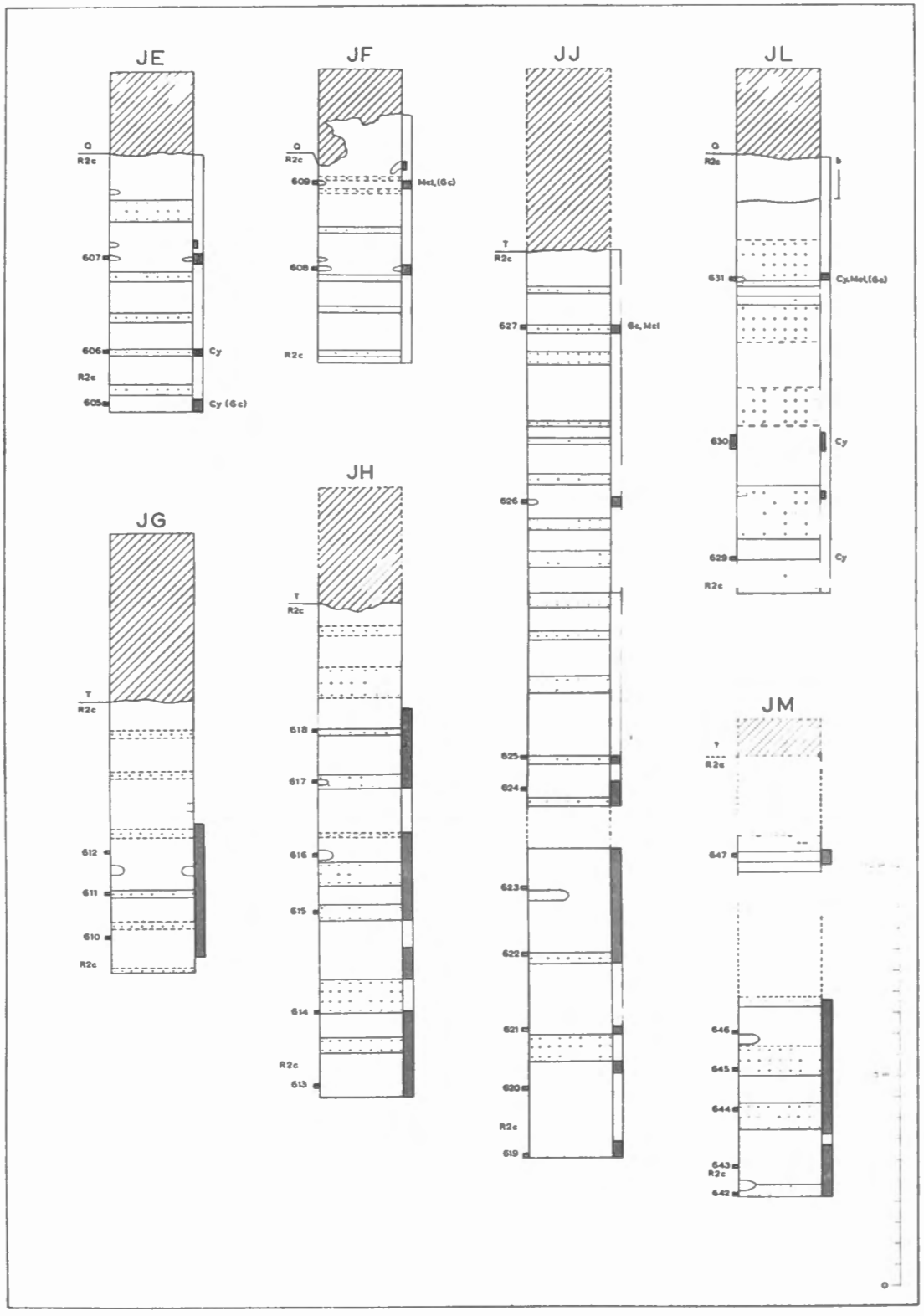


FIG. 7. — Sections of Boom clay pits, JE-JM.

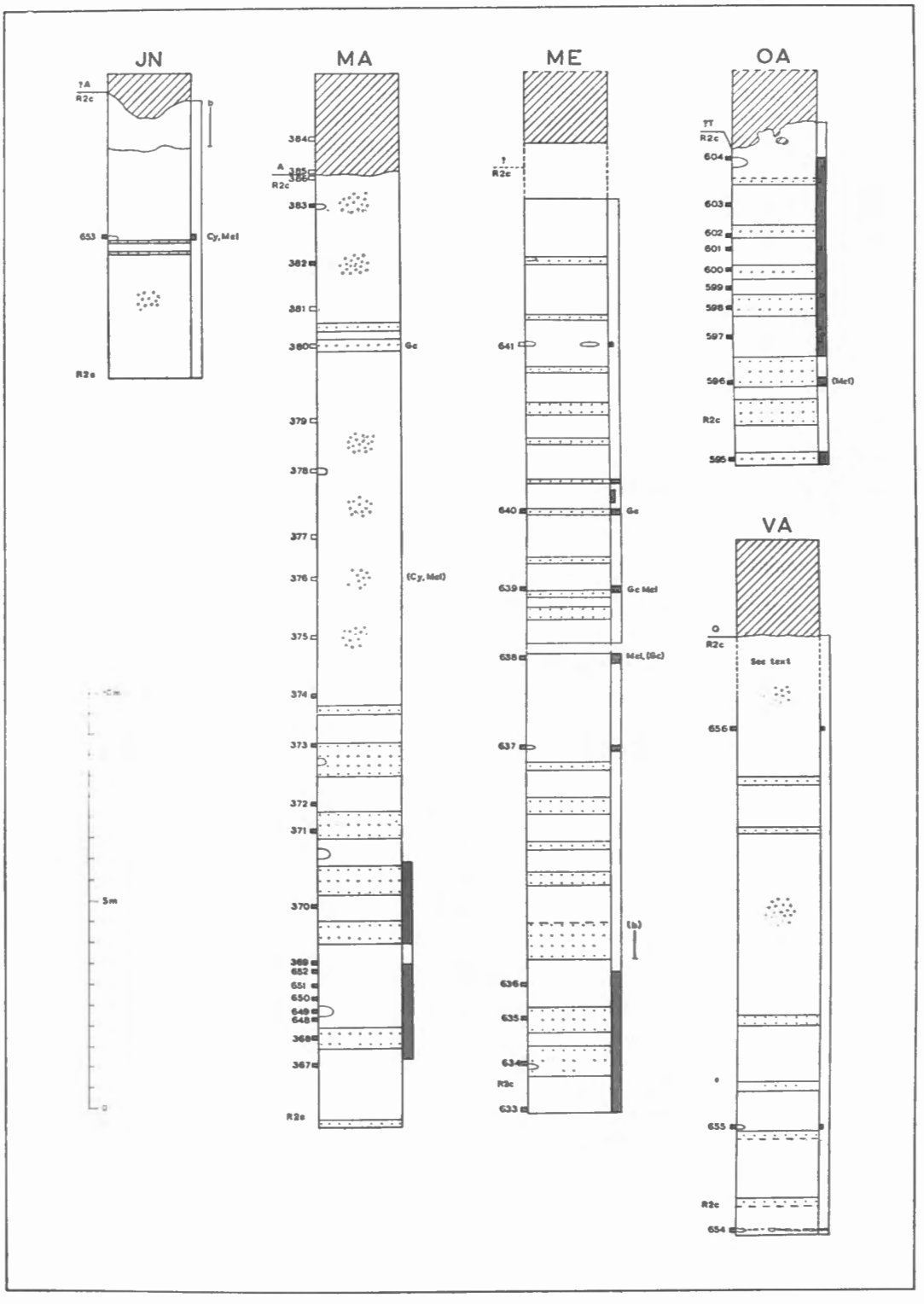


FIG. 8. — Sections of Boom clay pits, JN-VA.

The Boom clay overlies Eocene sand with Foraminifera and Ostracoda at 120,50 m depth.

It must be doubted whether the series of samples is representative for the sequence of the strata met with. It would be abnormal that the Boom clay rests directly on the Eocene without sand of Berg in between. Moreover, the base of the Boom clay in the boring is 30 m below the level expected from the data of surrounding borings.

Houthalen Shafts I and II of the coal-mine at Houthalen. The horizontal distance between the shafts is 70 m; they are both on the same topographic level, +62 m Ostend O.D. See GLIBERT (1945, Mus. Roy. Hist. Nat. Belg., Mém. 103, pp. 6-7) for a detailed description of shaft I.
Samples of the Institut Royal des Sciences Naturelles de Belgique.

The relative position of the samples in both shafts is given below :

	Shaft I (62E250).	Shaft II (62E251).
Miocene :	—	—
horizon of Houthalen (GLIBERT, 1945)	80,25-80,79 m	—
Oligocene :		
sand of Voort	81-84 m 98-100,50 m	84-88 m (3)

In shaft I there is a gravel at the base of the sand of Voort at 129-129,50 m.

The samples from both the sand of Voort and the horizon of Houthalen are from glauconitic sand with Bryozoa, Foraminifera, Ostracoda, echinoid spines, fragmentary molluscs, occasionally fish otolites and small bone fragments, and rare pyrite.

Lambroek Deepboring 70, 62W203 archives Geological Survey. The sand of Voort part of the boring is figured, see fig. 9.
Samples of the Geological Survey of Belgium.

According to SCHMITZ and STAINIER (1909) the base of the Miocene, « Bolderian », sands is at 43 m depth (= —3 m Ostend O.D.). These sands cover 22 m of Voort sand, designated as sand no° 3 by SCHMITZ and STAINIER. Several samples of the sand of Voort contain Foraminifera. Pyrite was observed in many of the samples, which are in general less rich in glauconite than the sand of Voort in the deepboring Lillo.

Downward there is a gradual transition from the Voort sand into the Boom clay. The sample from 79,50-81 m contains a distinct Boom clay Foraminifera association with few individuals however.

A sample from sandy clay with pyrite and glauconite at 150-151 m also contains some Boom clay Foraminifera. The base of that clay is at 152 m.

Twelve samples from in between 152 and 205 m, fine sand with some layers of quartz gravel and clay from 159 to 165 m, are devoid of microfauna.

Lillo Deepboring 73, 62E215 in the archives of the Geological Survey. The sand of Voort part of the boring is figured, see fig. 9.
Samples of the Geological Survey of Belgium.

SCHMITZ and STAINIER (1909) designated the sand between 66 m (= —14 m Ostend O.D.) and 111 m depth as their sand no. 3, which now is sand of Voort. The samples of the sand contain more fossils (among which Foraminifera, Ostracoda and barnacles), and more glauconite than the samples from the same sand of the boring Lambroek.

Downward the Voort sand becomes clayey. Sample 113 is the lowermost in the series with a distinct Voort sand Foraminifera association. Sample 115 from sandy clay shows a rather poor, but distinct, Boom clay association with *Angulogerina gracilis* var. *tenuistriata*, *Alabamina perlata*, *Sphaeroidina bulloides*, *Lenticulina*, *Nodosaria emaciata* and *Nodosaria soluta*. Sample 116 on the

(3) The foraminiferal content of another sample, shaft II, 80,50-81,52 m, is not incorporated in the distribution tables.

contrary, is from rather coarse, glauconitic sand with fragmentary molluscs and a number of distinct specimens of *Asterigerina gürichi* and *Nonion boueanum*. This indicates sand of Voort facies.

Samples 117 and 118 are again in sandy clay with pyrite and a poor, but distinct Boom clay Foraminifera association.

Hence, there is either an interfingering contact of Boom clay and Voort sand or there has been a contamination of the samples in this part of the dry boring.

Between 117 and 200 m there is a continuous mass of plastic to sandy Boom clay. The lowermost sample from that member (199-200 m) is sandy clay with some glauconite, pyrite and marly particles. It still contains a distinct Boom clay Foraminifera association.

The Boom clay overlies 18 m of medium-grained, slightly glauconitic sand with scarce mica, small silex fragments, pyrite, and mollusc and bone fragments. According to the archives of the Geological Survey some quartz gravel occurs at the base of the sand (218 m). Probably this is the Rupel basal gravel, while the overlying sand is Berg sand. The seven samples from the sand yielded very few Foraminifera, viz a single *Spiroplectammina carinata* and some *Lenticulina* specimens.

Also from 218-230 m sand with quartz gravel is present. Eight samples from glauconitic, partly clayey sand with some pyrite between 230 and 246 m contain no microfauna and but very little mica.

Voort Deepboring 79, 62W205 of the archives of the Geological Survey.
Samples of the Geological Survey of Belgium.

Three samples (number 8, 9 and 10 from the interval 25-60 m) of the Miocene « Bolderian » are devoid of microfauna. The basal gravel of this « Bolderian », a dark sand, is at 72 m (= —19,50 m Ostend O.D.).

Only one sample is available from the sand of Voort, originally described by SCHMITZ and STAINIER (1909) from in between 72 and 101 m. It is without microfauna.

In the samples from 101-127 m only a single *Elphidium subnodosum* was found.

The few other samples we investigated are nearly all devoid of microfauna. Only the sample 178,98-179,08 m contains Foraminifera. It shows a distinct Boom clay association.

Antwerp Excavation for the tunnel under the Scheldt at the Brouwersvliet (Canal des Brasseurs), Antwerp. See the section of HALET (1932, Bull. Soc. Belge Géol., vol. 41, p. 174, pl. 3, fig. A).
Samples of the Institut Royal des Sciences Naturelles de Belgique.

Very glauconitic sand with fragmentary or small molluscs, echinoid spines and rare Bryozoa, Foraminifera, fish otolites and pyrite.

The sand is Miocene sand of Antwerp. It may belong to the so-called « horizon à *Glycymeris pilosus* ».

Burcht Claypit of the cementworks at Burcht, about 6 km WSW of Antwerp centre.
Sample of the Institut Royal des Sciences Naturelles de Belgique.

Glauconitic sand with fragmentary molluscs, echinoid spines, Foraminifera, Ostracoda and rare Bryozoa. The washed sample we had at our disposal yielded no first residue after rewashing.

The sand belongs to the « horizon à *Panopaea menardi* DESHAYES » of the Miocene sand of Antwerp (Anversian). It probably directly overlies the Boom clay.

NETHERLANDS

SOUTH-LIMBURG

(Map 1)

Klimmen Sandpit on the north side of the road, near the house, numbered A 132, 200 m N, 1.050 m W of the church of Kimmen.
Visited April 1954.

About 10 m of fine-grained, mostly yellow to rusty-brown sand are exposed. The sand, possibly sand of Neerrepen, is approximately horizontally bedded. It contains a 5 cm bed of dark-grey, plastic clay with rusty-brown patches at about half the height of the exposure. A sample from this clay and the sand just below and above, contains a few shell and wood fragments, but no microfauna.

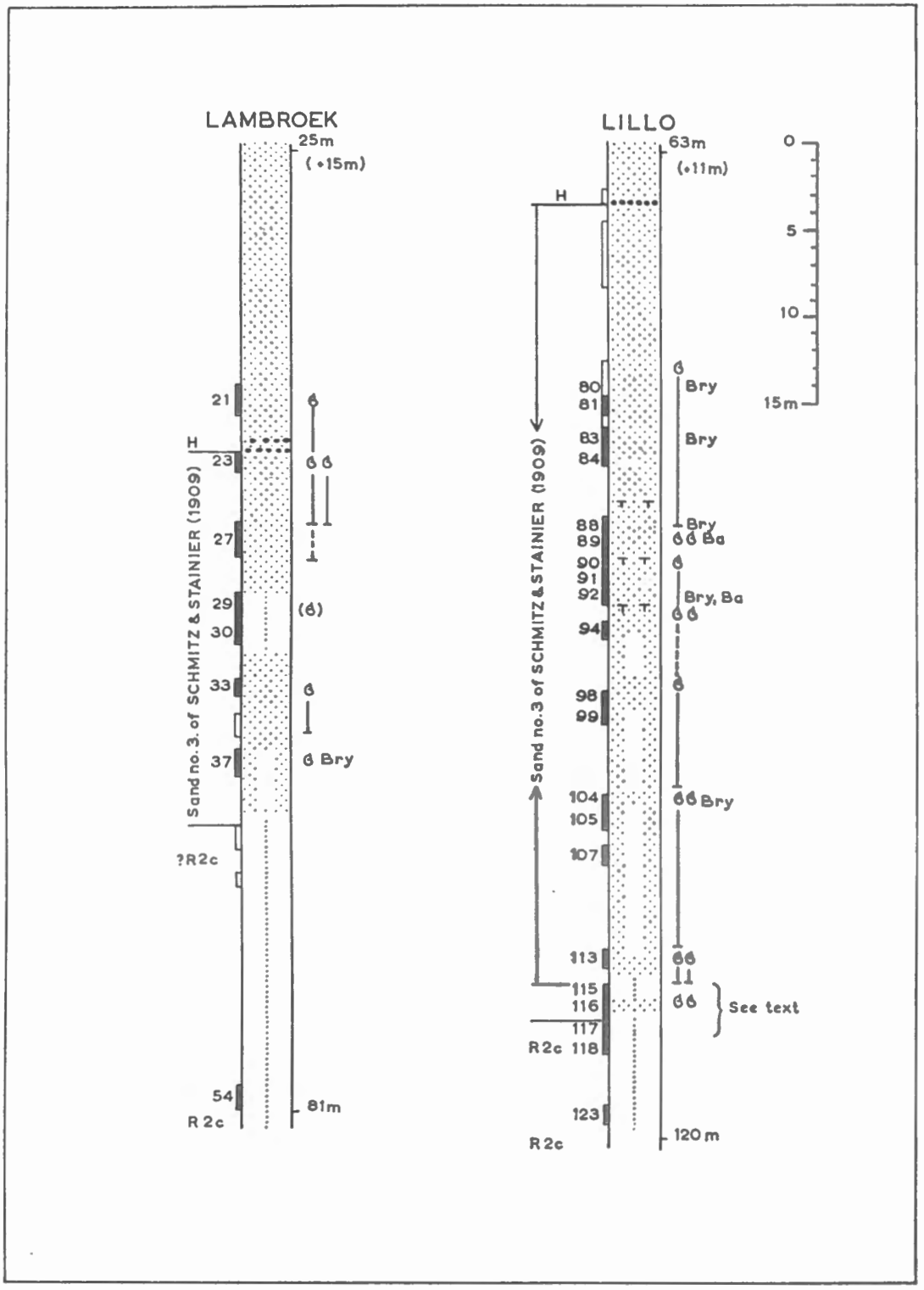


FIG. 9. — Sections of the Voort sand in the deepborings of Lambroek and Lillo.

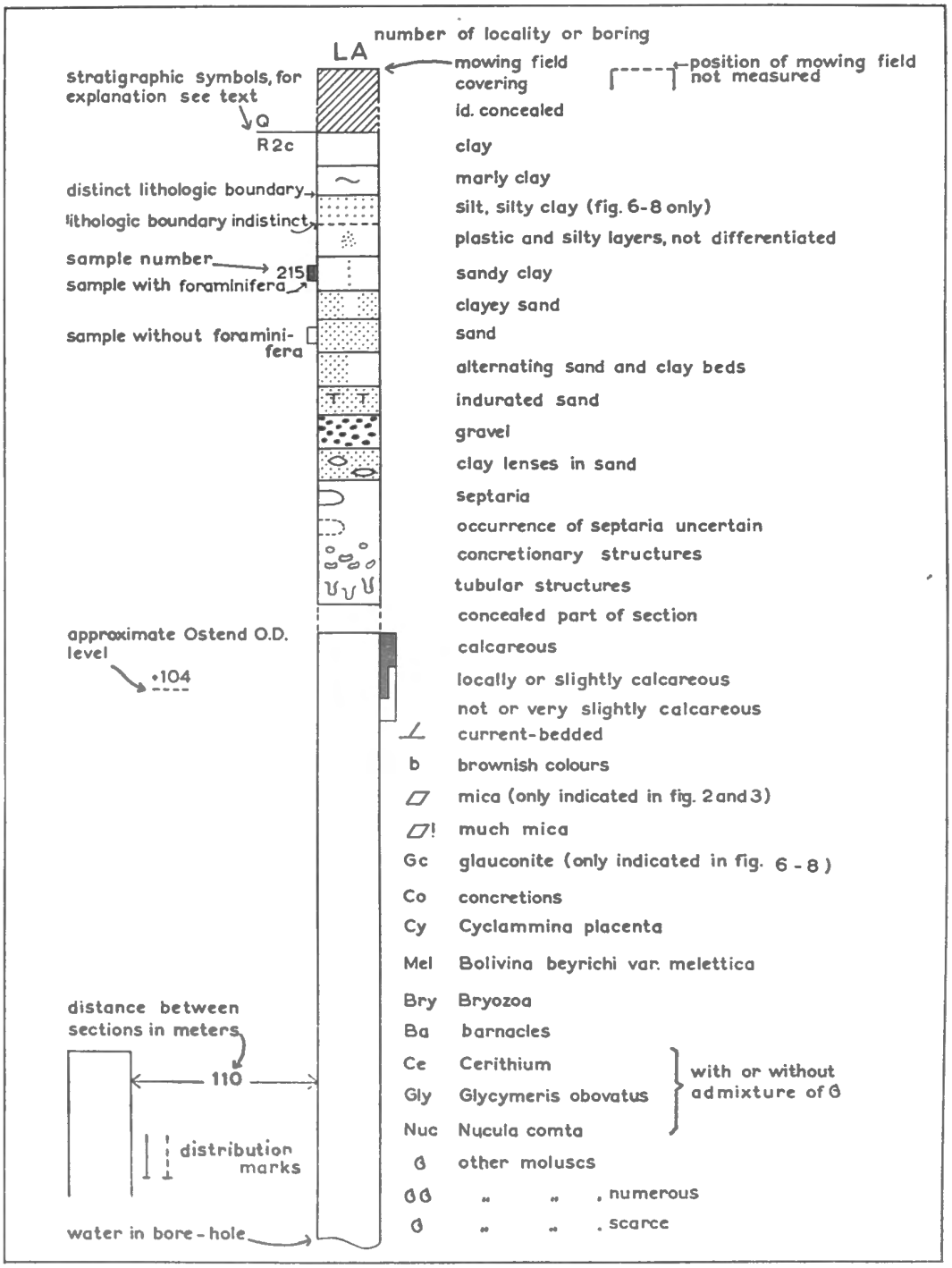


FIG. 10. — Legend for figs. 2-9.

Schin-op-Geul (NLD 471) Abandoned claypit, 650 m NNE of the railway station of Schin-op-Geul. Visited April 1954.

The exposure is poor. It shows reworked dark-brownish-grey clay with *Sinodia incrassata* (SOWERBY), *Corbicula semistriata* (DESHAYES), *Aloidis gibba* (OLIVI), *Cerithium*, *Bayania nysti* (NYST) and *Natica*. Sample NLD 471, from rather pure clay, contains a single valve of *Haplocytheridea helvetica* (LIENENKLAUS), but no Foraminifera.

The clay is distinct Henis clay, or « Cerithium-clay » of Dutch authors.

Hendrik IV Shaft IV of the coal-mine « Hendrik » at Brunssum constructed in 1954-1955. Samples of the Geologisch Bureau voor het Mijngebied, Heerlen.

Only the samples from below the Rupel basal gravel at 178,50 m (= —81,50 m Amsterdam O.D.) have been investigated. The two uppermost ones (178-179 and 179-180 m) are from sandy, pyritic clay with *Cerithium*, that is an equivalent of the Henis clay in Belgium. These samples were devoid of microfauna.

The sands underlying the « Cerithium-clay » are the equivalents of the Lower Tongeren beds (sand of Grimmertingen). At 210 m they overlie the Cretaceous Kunrade chalk. These Lower Tongeren beds are greenish or greyish, fine-grained, micaceous sands with mollusc beds at 188 and 190 m. In many of the samples occur molluscs, often fragmentary, Bryozoa, Foraminifera, Ostracoda, echinoid spines, pyrite and glauconite. In general the samples from 180-183 and from 186-190 m are poor in organic components. The samples from 183-186 m and from 204-205 m were not available.

The strata overlying the Rupel basal gravel are 14 m of sand, with some lignite. In the middle there are some meters of sandy and distinct Nucula-clay with a second gravel on top. This gravel is overlain by clayey sand and sandy clay with *Leda deshayesiana* NYST and other molluscs and with septaria beds at 139 and 151 m. These deposits belong to the Lintfort member, an equivalent of the Boom clay. At 121,60 m they are covered by gravel. This gravel is the base of a sand that is possibly an equivalent of the sand of Voort in Belgium.

GELDERLAND AND OVERIJSSEL

Kuiperberg (NLD 668-673) Claypit on the top of the Kuiperberg, near Ootmarsum (Overijssel). Samples taken by Mr. G. J. BOEKSCHOTEN, June 1954.

Under some 5 m sand with gravel were exposed 5 m of grey, plastic clay with pyrite accretions, septaria, *Leda deshayesiana* NYST and *Cardita kickxii* NYST. This is distinct Boom clay. The clay is folded by glacial action.

From the clay five samples were taken at vertical intervals of one meter. They are numbered from bottom to top NLD 669-673. The uppermost sample is just below the top of the clay. All these samples show the common Boom clay Foraminifera association.

The base of the Boom clay is exposed in the western part of the pit. It is underlain by a few meters of brownish-yellow sand. At the base of this sand there is a 50 cm layer of phosphatic gravel with scarce fossils, usually interpreted as marker of the Eocene-Oligocene boundary.

Winterswijk (NLD 458-460) Claypit of the brickworks TE SIEPE and SCHULTE, 1.400 m S, 720 m W of the watertower of Winterswijk (Gelderland).
Samples taken by Mr. G. J. BOEKSCHOTEN in 1954.

About 2,50 m of plastic, grey clay with pyrite accretions and septaria are exposed. This is again distinct Boom clay.

Three samples were taken at vertical intervals of 95 cm. They are numbered in downward direction : NLD 458, 459 and 460. The uppermost sample, 70 cm below the base of the overlying sand, is barren. The other samples have a common Boom clay Foraminifera association.

GERMANY

Hermsdorf 10445 Septaria-clay. « Sammlungsmaterial aus der ehemaligen Ziegeleigrube Lübars. » Sample of the Amt für Bodenforschung, Hannover.

The wash residue of this sample from the Septaria-clay contains Foraminifera and whitish, but also brownish, indurated marly clay particles. Echinoid spines, bone fragments, Ostracoda, fragmentary molluscs and pyrite are less common.

Hermsdorf 13438 « Septarienton der ehemaligen Ziegeleigrube Lübars (heute Schwimmbad), SW Ecke des Mesztischblattes Schönerlinde. »
Sample of the Amt für Bodenforschung, Hannover.

The second sample from the Hermsdorf locality contains Foraminifera and quartz grains, usually roughened, some of them reaching 2 mm in diameter. Echinoid spines, clayey particles, pyrite, fragmentary molluscs, as well ar rare small bone fragments and a few Ostracoda were found.

Pietzpuhl 10447 Septaria-clay. No details of the locality are given.
Sample of the Amt für Bodenforschung, Hannover.

The sample from this famous locality about 15 km NW of Magdeburg, contains many Foraminifera and whitish, light-greyish or brownish, indurated marly clay particles. Mica, lignite fragments, echinoid spines and a few quartz grains and Ostracoda were also found. Pyrite appeared to be very rare.

Astrup 17538 Abandoned marlpit on the estate of Astrup, 1.500 m N, 600 m E of the northernmost church of Belm near Osnabrück (« Westwand der Mergelgrube Astrup bei Osnabrück. Glauconitische Mergelsande mit *Terebratula grandis*; legit H. HILTERMANN, Mai 1954 »).
Sample of the Amt für Bodenforschung, Hannover.

The sample contains many organic components : fragmentary molluscs, Foraminifera, Bryozoa, echinoid spines, small echinoids, Ostracoda and a few fragmentary barnacles, furthermore calcareous particles, glauconite, quartz (partially very coarse) and small, flat and rounded, light- or dark-green calcareous pebbles up to 1 cm, of clayey (?) material.

Kassel 11315 « Kasseler Meeressand. Brunnen-Aushub am Südhang des « Gelben Berges » westlich des Einganges zur Sandgrube, Hangendes des Rupeltones; legit H. HILTERMANN, Sept. 1951. »
Sample of the Amt für Bodenforschung, Hannover.

Chiefly fragmentary molluscs; further Foraminifera, Bryozoa, Ostracoda, fish otolites and echinoid spines. The quartz grains in the sample may reach a diameter of 5 mm; calcareous particles are common, glauconite and mica rare.

The Kasseler Meeressand is Chattian, Upper Oligocene.

Kassel 12667 « Kasseler Meeressand. Am Westfusz des Brandkopfes im Ahnetal; legit LOUIS SCHULZE, ca. 1910. »
Sample of the Amt für Bodenforschung, Hannover.

The sample contains chiefly fragmentary or small molluscs. Furthermore, partially coarse, quartz, glauconite, ferruginous and calcareous particles, Foraminifera, Ostracoda, Bryozoa, and echinoid spines are common.

Dingden (456) Brook incision very close to the « Künigsmühle », east of Dingden in Westfalen [near Bocholt (Westf.), Germany]; type locality of the « Dingdener Stufe » (Miocene).
The sample was taken by Mr. G. J. BOEKSCHOTEN in the spring of 1954.

Dark-brownish-grey, clayey, micaceous silt with a little glauconite. The sample contains many Foraminifera and Ostracoda. Furthermore there were found molluscs, fish otolites, bone fragments and echinoid spines.

CHAPTER IV

REVIEW OF THE FORAMINIFERAL ASSOCIATIONS

INTRODUCTION

In the final chapter the accounts are given of some 140 species. Their distribution in the samples is shown in four tables.

The quantitative indications in these tables were gained by counting the number of specimens of each species on a tray of 12 cm^2 sprinkled for about one quarter of the surface with particles of the wash residue. The frequencies of the species in a single counting are expressed as follows : r (rare) = 1-4, C (common) = 5-20, A (abundant) = 21-60 and V (very abundant) = more than 60 specimens.

Besides the discussions of the assemblages and some conclusions concerning depositional environments based on them, this chapter also contains the comparison with the few associations described from adjoining regions.

LOWER TONGEREN BEDS

(See table 1)

Some twenty species of Foraminifera were found in the samples from shaft IV of the coal-mine Hendrik in Dutch South-Limburg. Our Belgian material yielded only very few individuals.

The assemblage is usually dominated by three common species : *Cibicides dutemplei*, *Asterigerina bartoniana* and *Nummulites germanicus*. Less frequent but important other species are *Cancris turgidus*, *Alabamina wolterstorffi* and *Elphidium subnodosum*. Furthermore there are *Textulariidae*, chiefly *Spiroplectammina carinata*, and Lagenidea in many of the samples.

The assemblages shows very close resemblance to the associations of the Upper Eocene Asse clay of western Belgium (J. P. H. Kaasschieter, personal communication). *Asterigerina bartoniana* is a common species in that clay. *Nummulites germanicus* is considered very close to, if not identical with *Nummulites wemmelensis* De la Harpe and Van den Broeck, another species of the Asse clay. *Cancris turgidus*, and *Rotalia canui* are equally present in the clay of Asse. *Alabamina wolterstorffi* was found in the Upper Eocene sand of Wemmel in a boring at Zellik near Wemmel, while the so-called characteristic Oligocene species, *Elphidium subnodosum* was found to be also present in the Late Eocene Barton clay from the type locality.

Another association, resembling that of the Lower Tongeren beds, was described from the German Lower Oligocene of Lattorf and of Magdeburg by Franke (1925) (4). Franke's

(4) Possibly Franke had not only Lower Oligocene material, but also samples from Upper Oligocene deposits.

material included all characteristic species of the Lower Tongeren beds mentioned above, with the exception of *Asterigerina bartoniana*. The assemblage differs from our Hendrik IV material in the much more diversified Lagenidea and in the presence of *Miliolidae*, some *Discorbidae*, *Ceratobulimina contraria*, *Gypsina globulus* and a rugose *Uvigerina* species.

Apart from *Textularia* cf. *T. gramen*, *Alabamina wolterstorffi*, *Asterigerina bartoniana* and *Nummulites germanicus*, all Lower Tongeren species were also found in our material of the Middle and Upper Oligocene. These species have a fairly long vertical range which includes the Belgian Upper Eocene. *Alabamina wolterstorffi*, *Asterigerina bartoniana* and *Nummulites germanicus* are only known from Eocene and the Lower Tongeren and Lattorf deposits.

Thus the Foraminifera content of the Lower Tongeren and Lattorf beds shows definitely more relations with the assemblages of the Upper Eocene than with those of Middle Oligocene deposits. The same holds true of the Ostracoda in the Lower Tongeren beds. Dr. A. J. KEIJ, who kindly determined the Ostracoda of the Hendrik IV material ([5]), informed us that the twelve species he found, constitue a distinct Asse clay assemblage.

As for the depositional environment of the Lower Tongeren beds we refer to the remarks of BETTENSTAEDT (1949) on the paleogeography of the German Upper Eocene. According to this author, the presence of *Nummulites*, Bryozoa, reticulated Ostracoda, together with dispersed *Glycymeris*, *Natica* and *Pecten*, and but slight pyrite contents, indicate oxygenous, warm shallow water and fully marine environment. The existence of this environment evidently ended with the deposition of the sand of Neerrepen and the brackish Upper Tongeren beds.

THE HENIS CLAY

(Table 2)

In but four of our Henis clay samples were altogether six species of Foraminifera found. They are always rare, except for *Nonion granosum* and *Rotalia kiliani* in sample BZ 551.

In our material *Rotalia kiliani* is restricted to the Henis clay. The species was also recorded from several Middle Oligocene deposits (Meletta-beds, Rupelton, Schleichsand, Corbicula-marls, and Cerithium-sands) of the Mainz basin and Alsace. BHATIA found it in the Headon beds of Wight, which he considered to be of Early Oligocene age.

The other Henis clay species are also present in the Oude-Biezen member.

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usually assumed for the deposition of the Henis clay (GLIBERT and DE HEINZELIN, 1954*a*, KEIJ, 1957). The presence in several samples of many Ostracoda individuals of only few species without accompanying Foraminifera, also points to a depositional environment of low salinity.

THE OUDE-BIEZEN MEMBER

(Table 2)

The sands and marls of Oude-Biezen yielded twelve species, five of which were found in but a single sample. *Quinqueloculina parisiensis*, *Scutuloris oblongus* and *Rotalia canui* are the most common.

([5]) See table 1, for the distribution of the species.

Besides most of the species found by us, GÜLLENTOPS (1956) mentioned *Spirolina cylindracea* LAMARCK and species of *Verneuilina* and *Articulina* from a sample of Oude-Biezen sand at Borgloon.

None of our species is restricted to the Oude-Biezen member. Except for *Quinqueloculina parisiensis* and the very rare *Quinqueloculina impressa*, *Bulimina elongata* and *Cibicides dutemplei* (three species of longer range) they all occur also in the Nucula-clay or in the sand of Berg. *Quinqueloculina parisiensis* is an Eocene species, which in Belgium evidently still existed during the earlier part of Oligocene time.

As a whole the foraminiferal content of the Oude-Biezen member shows close affinities to the assemblages of part of the Nucula-clay samples. It mainly differs from these Nucula-clay associations in the absence of *Spiroplectammina carinata*, Lagenidea and *Nonion affine* and in the presence of *Quinqueloculina parisiensis*. This difference is considered to be due to the different depositional environments of Oude-Biezen member and Nucula-clay, the environment of the latter being less brackish.

The depositional environment of the Oude-Biezen member was of low salinity. This is indicated by the assemblages of Foraminifera and Ostracoda and also by the extreme variability of *Quinqueloculina parisiensis*. The mollusc contents point in the same direction (GLIBERT and DE HEINZELIN, 1954*a*). Since they contain a somewhat more diversified microfauna, the sands and marls of Oude-Biezen as a whole are probably deposits in an environment, less brackish than that in which the Henis clay was laid down.

THE SAND OF BERG

(Table 2)

The sand of Berg contains only very few Foraminifera : *Spiroplectammina carinata*, seven species of the Lagenidea, *Nonion affine*, *Nonion granosum*, *Cibicides sulzensis* and a *Globigerina* species. Although it is much less diversified, the poor assemblage resembles the foraminiferal associations of the Nucula-clay fairly well. Such mutual resemblance also exists for the associations of Ostracoda (KEIJ, 1957) and of molluscs (GLIBERT and DE HEINZELIN, 1954*a*). In general the sand of Berg is richer in molluscs, but poorer in microfauna than the Nucula-clay.

THE NUCULA-CLAY

(Table 2)

Most of our Nucula-clay samples contain Foraminifera, some thirty species of which could be determined. Two different types of associations were distinguished.

The former, the carinata-affine assemblage was found in the greater part of the samples. These samples contain all or some of the following species as relatively common contituents : *Spiroplectammina carinata*, *Lenticulina* spp., *Saracenella böttcheri*, *Nodosaria soluta*, *Guttulina problema*, *Pyrulina fusiformis*, *Glandulina aequalis* and *Nonion affine*. *Cibicides lobatulus*, *Globulina gibba* and *Globigerina* spp. are rare in these samples. *Rotalia canui* is very rare or absent, while *Nonion granosum* is mostly scarce, when compared to its frequency in the eight samples of the second type.

The samples of this second type (BZ 490-493, TK 522-524 and BZ 552) are rich in *Nonion granosum* and *Rotalia canui*, whilst *Spiroplectammina carinata*, Lagenidea and *Nonion affine* are absent or rare. They were called granosum-canui samples. *Miliolidae* and *Discorbis globularis* are more frequent in these granosum-canui than in the carinata-affine assemblages.

The existence of the carinata-affine and the granosum-canui samples is probably not caused by the fact that *Spiroplectammina carinata,* the Lagenidea and *Nonion affine* are chiefly of second residue size, whilst *Nonion granosum* and *Rotalia canui* are found in the finest residues only. The differences in volume of the residues of the various samples do not correspond to the differences in assemblage (except possibly for BZ 552).

Nonion granosum and *Rotalia canui* are frequent in the Oude-Biezen member, which certainly was deposited in an environment of low salinity. Their abundance in the granosum-canui assemblages of the Nucula-clay evidently points also to an environment of lower salinity than that of the water in which the clay with carinata-affine assemblages was laid down. We therefore assume a depositional environment with inconstant salinity for the Nucula-clay. This agrees with the opinion of KEIJ (1957), who studied the Ostracoda-content of our samples. KEIJ considered it likely that the Nucula-clay was deposited in an open bay, in which occasional salinity decrease did occur.

There is no apparent relation between the stratigraphic position of the granosum-canui samples and the Nucula-clay as a whole.

Apart from the longer range species, the Nucula-clay contains some characteristic Oligocene species : *Bolivina beyrichi, Bolivina fastigia, Angulogerina gracilis* and *Rotalia propingua.*

THE GERMAN SEPTARIA-CLAY

(Table 3)

The three samples from Hermsdorf and Pietzpuhl contain over fifty species of Foraminifera. This number is far below that given by REUSS and other authors for the amount of species in the Septaria-clay. The difference is especially caused by our different determination of the Lagenidea. REUSS (1870) mentioned more than a hundred species of this superfamily, whereas in our grouping only some twenty species of the *Lagenidae* and *Polymorphinidae* are distinguished. Our different, wider species concept also somewhat reduces the number of species in other families.

In the Hermsdorf and Pietzpuhl material the following species are the most frequent :

Spiroplectammina carinata, Karreriella siphonella, Nodosaria emaciata, Turrilina alsatica, Bolivina beyrichi, Angulogerina gracilis, Cassidulina subglobosa var., *Pullenia bulloides, Sphaeroidina bulloides, Nonion affine, Eponides umbonatus, Valvulineria petrolei, Gyroidina soldanii, Rotaliatina bulimoides, Cibicides ungerianus, Alabamina tangentialis, Ceratobulimina contraria* and *Globigerina* spp.

All these species are also important constituents of the Boom clay fauna. Only a few of the other species of Hermsdorf and Pietzpuhl are thus far restricted to the German Septaria-clay (*Loxostomum teretum, Loxostomum minutissimum, Pleurostomella alternans* and some species of *Lagena*). They were all found in the sample from Pietzpuhl. *Nonion granosum, Nonionella lobsannensis* and *Discorbis globularis,* three other species from Pietzpuhl, were found neither in the Boom clay nor at Hermsdorf, but they occur in the Nucula-clay, which is considered a more near-shore equivalent of part of the Boom clay.

The rare individuals of *Globigerinella micra* and *Gümbelina gracillima* in the sample of Pietzpuhl, have probably been reworked from older deposits.

Further information on the Foraminifera of the German Septaria-clay and on the faunistic relations of this clay with other Oligocene deposits in Europe is to be found in the following paragraph.

THE BOOM CLAY

(Table 3)

Some hundred samples, only few of which were devoid of Foraminifera, yielded altogether over sixty species. In the distribution chart the data from the samples of most pits were combined, so that frequency mentions had to be omitted. The following species were the most frequently met with :

Spiroplectammina carinata, Karreriella siphonella, Lenticulina spp., *Nodosaria soluta, Guttulina problema, Globulina gibba, Angulogerina gracilis, Pullenia bulloides, Sphaeroidina bulloides, Nonion affine, Eponides umbonatus, Gyroidina soldanii, Cibicides dutemplei, Cibicides sulzensis, Globigerina* spp.

All or most of these species occur together in samples, which will be referred to as samples of the MA-type or MA-samples. The samples MA 648-652 from Boom are characteristic representatives. The MA-type of Foraminifera assemblage is by far dominant in our material.

Less common than the above mentioned species in the MA-samples are :

Nodosaria intermittens, Nodosaria ludwigi, Nodosaria emaciata, Pyrulina fusiformis, Glandulina laevigata, Turrilina alsatica, Bolivina beyrichi, Cassidulina carapitana, Nonion buxovillanum, Eponides pygmeus, Valvulineria petrolei, Rotaliatina bulimoides, Epistomina elegans, Alabamina perlata, Alabamina tangentialis, Ceratobulimina contraria.

Many of the species of the MA-samples occur also in the other assemblages, discussed below.

Epistomina elegans deserves special mentioning, since it is common in only some ten samples, whereas it is absent or very rare in all others (6). Most samples rich in *Epistomina elegans* are of the MA-type. In all respects they seem to be scattered at random among our large number of samples.

A different assemblage was found at Loksbergen (HB 665) in very sandy Boom clay. It differs from the characteristic MA-assemblages by the commonness of *Nodosaria emaciata* and *Cibicides ungerianus*, whereas *Chilostomellidae* are rare and *Cibicides sulzensis* is absent. Moreover the sample yielded a few species, not found in our other Boom clay material, such as *Martinottiella* sp. and *Sigmomorphina regularis*.

Another, somewhat aberrant assemblage was met with at Kruibeke (JK 628). This sample contained, besides a number of the common MA-species, some rare *Miliolidae*, of which *Quinqueloculina juleana* and *Pyrgo bulloides* were not found in other Boom clay samples. The presence of *Haplophragmoides latidorsatus* is another singular feature.

A number of samples is characterized by the presence of *Bolivina beyrichi* var. *melettica*. JF 609 and JN 653 are good examples. Such samples with *Bolivina beyrichi* var. *melettica* have been marked « Mel» in the sections of the Boom clay pits on figures 6-8. This variety is especially abundant in samples with glauconite. It was, however, found as well in samples without this mineral, while some samples from glauconitic clay yielded no *Bolivina beyrichi* var. *melettica*. Besides this characteristic form the assemblages with *Bolivina beyrichi* var.

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(6) Samples rich in *Epistomina elegans* : JB 362, MA 371, 383, NLD 459, 460, OA 601, JF 609, ME 638, JM 646, AE 661, 663.

melettica contain several species, that occur in the MA-samples. Some of the samples contain no or only few individuals of *Spiroplectammina carinata* and *Cibicides dutemplei*.

Another remarkable species in only relatively few samples is *Cyclammina placenta* (indicated « Cy » in the sections of the Boom clay pits). Apart from *Cyclammina placenta* these samples contain many of the species that constitute the assemblages of the MA-samples. In some cases, e.g JN 653, *Cyclammina placenta* and *Bolivina beyrichi* var. *melettica* were found together.

Other faunistic differences may exist. Our material however, does neither allow for a more detailed study of relations between sediment and Foraminifera, nor does it enable conclusions on the quantitative proportions of various species, because the samples are too thick. Most Boom clay samples measure 8 cm in thickness. Very thin samples would be necessary, but this meets with sampling difficulties because of the great quantities of clay that are needed for a sufficient amount of residue.

For conclusions on the sedimentary environment we can resume the Foraminifera content of the Boom clay as follows. *Textulariidae*, Lagenidea, *Uvigerininae*, *Chilostomellidae*, *Nonionidae*, *Discorbinae*, *Anomalinidae* and *Globigerinidae* are nearly always present, and their representatives are common. In relatively few samples *Lituolidae*, *Miliolidae*, *Turrilininae*, *Bulimininae*, *Cassidulinidae*, *Epistominidae* and *Ceratobuliminidae* were found. The representatives of these families and subfamilies are usually rare; they are common in some of the samples only. *Haplophragmiidae* finally, are rare in very few samples.

This fauna fairly well resembles the associations in bottom samples from the mud-covered shelf north of Trinidad and the Paria peninsula (7). This muddy platform measures about 150 × 50 sq. km with its longer diameter parallel to the coast. The deepest part is about 155 m below sealevel.

The difference between the Boom clay and these Trinidad sediments are the presence of arenaceous Foraminifera and of pyrite in the former. The Trinidad material contains only rare arenaceous specimens and but a little pyrite. Among the *Nonionidae* the Trinidad samples mainly contain a species of the *Nonion boueanum* group, whereas in the Boom clay *Nonion affine* is predominant. *Globigerinidae* are somewhat more frequent on the Trinidad mud shelf than in the Boom clay.

Probably the Boom clay, like the Trinidad mud, was deposited in an open shelf sea, although this Oligocene sea must have had constant characteristics over an enormous area. The fine-grained sediment and the pyrite point to quiet bottom water. The presence of pyrite in this case certainly does not involve anaerobe conditions at the sediment-water interface; such a rich benthonic fauna would then have been impossible. Pyrite evidently originated somewhat below the top of the already deposited clay.

The following species are restricted in our material to the Boom clay. Most of them were found also in the samples from Hermsdorf and from Pietzpuhl.

Haplophragmoïdes latidorsatus, Karreriella siphonella, Cyclammina placenta, Quinqueloculina ludwigi, Pyrgo bulloides, Frondicularia seminuda, Nodosaria ludwigi, Nodosaria spinescens, Nodosaria ewaldi, Siphonodosaria hirsuta, Turrilina alsatica, Bulimina alsatica, Robertina declivis, Cassidulina carapitana, Allomorphina sp., *Nonion buxovillanum, Eponides pygmeus, Rotaliatina bulimoides, Alabamina perlata, Pseudoparrella oveyi.*

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