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Dinantian Rocks in the subsurface North of the Brabant and Ardenno-Rhenish massifs in Belgium, the Netherlands and the Federal Republic of Germany

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with an appendix by R. Conil *et al.*:

INTERNATIONAL CORRELATION OF DINANTIAN STRATA

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41 figures, 4 tables, 20 plates, 3 enclosures

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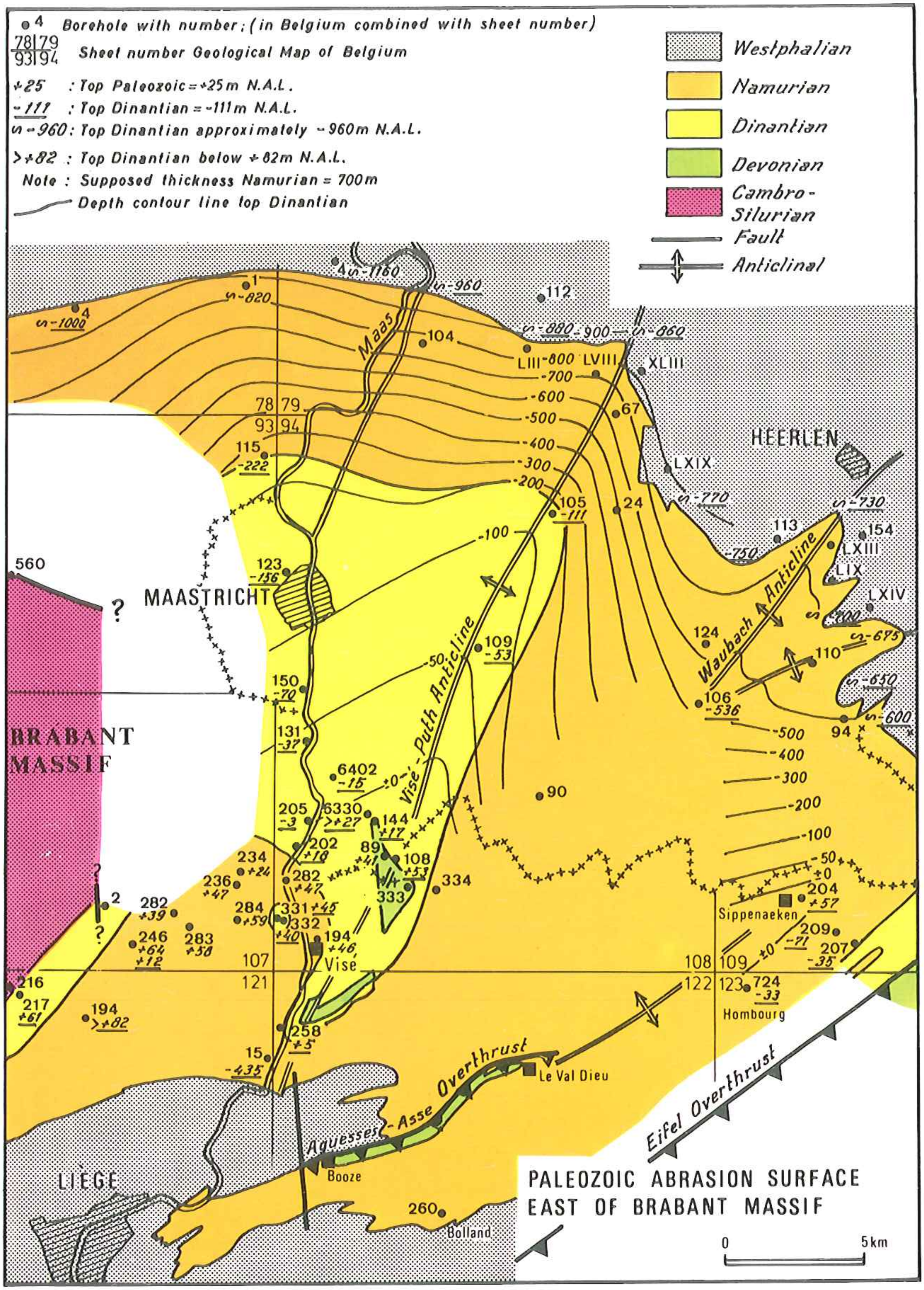

4 Borehole with number; (in Belgium combined with sheet number)
78|79 / 93|94 Sheet number Geological Map of Belgium
+25 : Top Paleozoic = +25m N.A.L.
-111 : Top Dinantian = -111m N.A.L.
∽-960: Top Dinantian approximately -960m N.A.L.
>+82 : Top Dinantian below +82m N.A.L.
Note : Supposed thickness Namurian = 700m
Depth contour line top Dinantian
Westphalian
Namurian
Dinantian
Devonian
Cambro-Silurian
Fault
Anticlinal
Maas
MAASTRICHT
HEERLEN
BRABANT MASSIF
Visé-Puth Anticline
Waubach Anticline
Visé
Sippenaeken
Hombourg
Le Val Dieu
Aguesses-Asse Overthrust
Eifel Overthrust
LIEGE
Booze
Bolland
PALEOZOIC ABRASION SURFACE
EAST OF BRABANT MASSIF
0
5km

Enclosure 1

ABSTRACT

The Dinantian of several boreholes in the Campine-Brabant and Ruhr Basins has been restudied. This study has yielded new data on microfossils and biostratigraphy which permit an attempt to draw a rough outline of the paleogeographical development of these basins from uppermost Devonian into lowermost Silesian times.

RÉSUMÉ

La révision de quelques sondages des bassins de Campine et de la Ruhr, a apporté de nouvelles précisions micropaléontologiques et biostratigraphiques concernant ces régions; ces données sont maintenant suffisantes pour tenter une approche schématique de l'évolution paléogéographique de ces bassins, depuis le Dévonien le plus supérieur jusqu'au Silésien inférieur.

ZUSAMMENFASSUNG

Das Dinantium mehrerer Bohrungen aus dem Campine-Brabant Becken und aus dem Ruhr Becken ist nochmals untersucht worden. Diese Untersuchung hat zu neuen Ergebnissen über die Mikrofossilien und die Biostratigraphie geführt. Sie erlaubt die paläogeographischen Entwicklung dieser Becken vom obersten Devon bis in das unterste Silesium grob darzustellen.

1. PREFACE

In contrast to the hundreds of boreholes, which penetrated the Silesian subsurface North of the Brabant and Ardenno-Rhenish Massifs, there are only some twenty to twenty-five boreholes, which have reached down into the Dinantian within the same area (fig. 1). There are several factors, which have influenced the limited interest of geologists in the Dinantian subsurface.

At the end of the nineteenth and beginning of this century, geologists had only to look for coal. Finding Dinantian rocks in a borehole was merely considered as a negative indication when searching for productive coalmeasures. For example, VAN WATERSCHOOT VAN DER GRACHT (1913) stated explicitely that the Woensdrecht borehole had been drilled in order to gather information about the possibilities that productive Carboniferous occurred at acceptable depth in the southwestern part of the Netherlands. And again in 1924, TESCH wrote that several boreholes in the southwestern area of South Limburg had been made in order to investigate how far the productive Carboniferous extended towards the South-West.

If we neglect some less reliable boreholes from the past century, only three boreholes (Lanaken, Kessel, Wijvenheide) in the Belgian Campine, six in the Netherlands (of which five in South Limburg) and one in Germany (Vingerhoets-93) had hit the Dinantian around 1940. The absence of apparent economic interest and the poor megafauna encountered in most of them did not stimulate further research.

The discovery of the Slochteren gasfield in the northern Netherlands and the subsequent hypothesis that the gas had been derived from the underlying coalmeasures initiated a second period of intensive exploration activities. But according to the conception of potential reservoirs, most boreholes were stopped in the Lower Permian or higher Silesian. Except for an undeep well for hydrogeological research in South Limburg (GB6402 borehole = Eysden), no exploration borehole penetrated the Dinantian subsurface in the Netherlands during that second period. But in the Belgian Campine, the Dinantian was investigated in the boreholes Turnhout, Booischoot, Rillaar, Loksbergen, Halen and Heibaart (= Loenhout). Also in the Federal Republic of Germany, the Dinantian subsurface has been explored now and then, notably in the boreholes Wachtendonk-1, Münsterland-1, Versmold-1 and Isselburg-3.

It may be expected that within the next future the growing need for oil and gas will force the geologist to investigate deeper lying and older formations. In this context it seems logical that the Dinantian – predominantly developed in a carbonate facies in most of the boreholes mentioned above – will be subject of further study.

It is unfortunate therefore that no comprehensive review of the data obtained thus far had been published. For the non-specialist, it is difficult to compare, for example, the macrofossil lists from the Dutch Houthem borehole (DÉLÉPINE 1928; DORSMAN 1945) with the conodont biostratigraphy of the German Münsterland-1 borehole (ZIEGLER 1963) and the foraminifer zonation of some Belgian boreholes (CONIL 1964). Lithostratigraphic correlations may cause even more problems. This is especially true if we observe how different the age of the top of the Carboniferous interval in some boreholes in South Limburg has been interpreted during the past fifty years (fig. 2).

The basis for the present report form the updated published information on German and Belgian boreholes on the one hand and new litho- and biostratigraphical work on essentially six Dutch boreholes (DB17, DB105, DB108, DB109, DB123 and GB6402) on the other, supplemented by additional biostratigraphical investigations of some other boreholes in the Belgian Campine and Germany. These data are incomplete inasfar as work on foraminifer assemblages of Belgian and German boreholes by BOUZET and LONGERSTAEY is still going on. The results of their work will be publish-

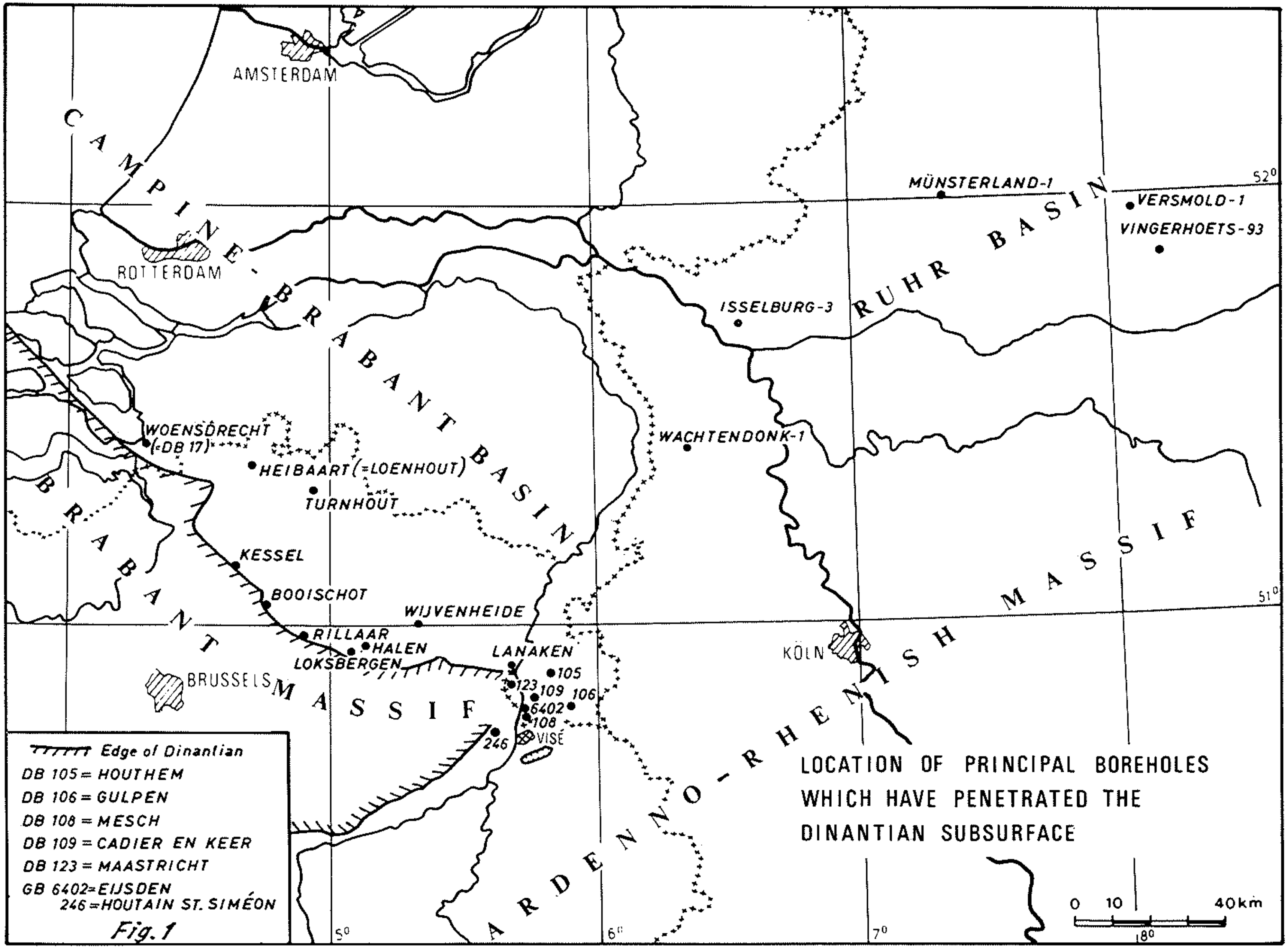

LOCATION OF PRINCIPAL BOREHOLES
WHICH HAVE PENETRATED THE
DINANTIAN SUBSURFACE
Edge of Dinantian
DB 105 = HOUTHEM
DB 106 = GULPEN
DB 108 = MESCH
DB 109 = CADIER EN KEER
DB 123 = MAASTRICHT
GB 6402 = EIJSDEN
246 = HOUTAIN ST. SIMÉON
AMSTERDAM
ROTTERDAM
BRUSSELS
KÖLN
VISÉ
CAMPINE-BRABANT BASIN
RUHR BASIN
BRABANT MASSIF
RHENISH MASSIF
ARDENNO-RHENISH MASSIF
MÜNSTERLAND-1
VERSMOLD-1
VINGERHOETS-93
ISSELBURG-3
WACHTENDONK-1
WOENSDRECHT (=DB 17)
HEIBAART (=LOENHOUT)
TURNHOUT
KESSEL
BOOISCHOT
WIJVENHEIDE
RILLAAR
HALEN
LOKSBERGEN
LANAKEN
105
123
109
106
6402
108
246
52°
51°
5°
6°
7°
18°
0
10
40km

Fig. 1

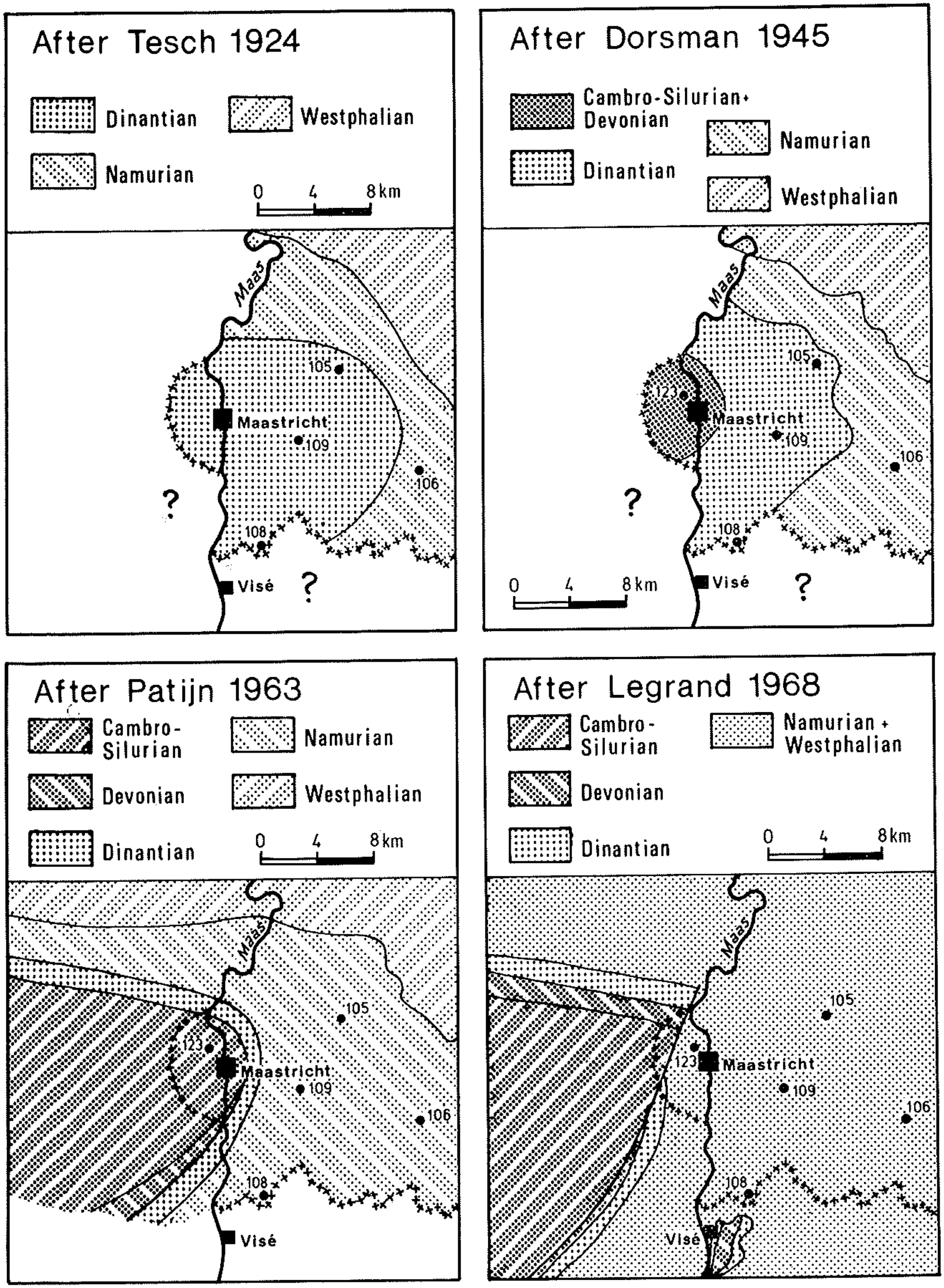


Fig 2 – Reconstruction of Paleozoic abrasion surface East of Brabant Massif.

ed in separate monographs in due time.

The reader should be aware of the fact that the paleogeographical interpretations are highly speculative because of the scarcety of data available thus far. Any forthcoming borehole into the Dinantian subsurface may well change the concepts put forward in this paper.

We wish to express our sincere thanks to the Director of the Geological Survey of the Netherlands, Ir. B. P. HAGEMAN, for his permission to publish this report in the Mededelingen Rijks Geologische Dienst, and to the Chief of the Service Géologique de Belgique, Inspecteur-Général Ir. A. DELMER, who enabled us to collaborate in this report and use data from the Service Géologique de Belgique. We also wish to thank Ir. G. M. GRAULICH, and Dr. R. LEGRAND, Directors at the Service Géologique de Belgique, for their stimulating suggestions and permission to use their unpublished information, and to Dr. W. F. M. KIMPE, head of the Geologisch Bureau of the Geological Survey of the Netherlands, for permission to use unpublished information on the Namurian-Westphalian contact in the Maurits Coalmine area. Thanks are also due to Dr. H. PIETZNER, Dr. H. WERNER and Mr. A. STREHL (all Geologisches Landesamt Nordrhein-Westfalen at Krefeld) for their helpful analysis of sclerotioid grains. The Nederlandse Aardolie Maatschappij BV (NAM, Assen) kindly permitted us to use unpublished data of the Rijsbergen-1 borehole. Messrs. BOUZET, CORNET and LONGERSTAEY wish to thank also LABOFINA (Brussels) for permission to publish this report. IRSIA is thanked for financial support to Messrs. Ph. BOUZET and P. J. LONGERSTAEY. Not in the last place we wish to mention Messrs. Ph. BERTRAND, L. R. FUNCKEN, H. J. KASTERMANS, M. LHODE and P. MANFROYD for their preparation of the illustrations.

2. SILESIAN-DINANTIAN CONTACT

2.1. NAMURIAN TRANSGRESSION

In Northwestern Europe, the Namurian is defined according to the decisions of the Second Carboniferous Congress at Heerlen in 1935. The base should be taken at the first appearance of the goniatite genus *Cravenoceras*. A sequence of goniatite stages, zones and subzones has been proposed at first by BISAT (1924), and later by RAMSBOTTOM (1969) for Great Britain and BOUCKAERT (1971) for Belgium (table 1). The use of the goniatite stages (Pendleian, Arnsbergian, Chokierian, etc.) is preferred above the old terms Namurian A, B and C as proposed at Heerlen 1935.

Lithologically, the Visean-Namurian contact is characterized by a distinct change in the rock type, which consists of carbonates in the Viséan and terrigenous shales in the Namurian. Usually, the basal Namurian shales are rich in pyrite ("ampélites"); sometimes, they are silicified ("phtanites").

	Stage	Zone
C	YEADONIAN (G1)	*G. cumbriense* (G_{1b}) *G. cancellatum* (G_{1a})
B	MARSDENIAN (R2)	*R. superbilingue* (R_{2c}) *R. bilingue* (R_{2b}) *R. gracile* (R_{2a})
	KINDERSCOUTIAN (R1)	*R. reticulatum* (R_{1c}) *R. nodosum* (R_{1b}) *R. circumplicatile* (R_{1a})
	ALPORTIAN (H2)	*Ht prereticulatus* (H_{2c}) *H. undulatum* (H_{2b}) *Hd. proteus* (H_{2a})
A	CHOKIERIAN (H1)	*H. beyrichianum* (H_{1b}) *H. subglobosum* (H_{1a})
	ARNSBERGIAN (E2)	*N. nuculum* (E_{2c}) *Ct. nitidus* (E_{2b}) *E. bisulcatum* (E_{2a})
	PENDLEIAN (E1)	*C. malhamense* (E_{1c}) *E. pseudobilingue* (E_{1b}) *C. leion* (E_{1a})

Table I – Subdivision of the Namurian.

The oldest recognizable Namurian deposits in the Dinant Basin are of early Arnsbergian (E2a) age (BOUCKAERT & HIGGINS 1963). In the Ruhr Basin, there is a complete sequence from Viséan into Pendleian rocks (PAPROTH 1971). In the Namur and Campine basins, BOUCKAERT (1967) recognized a slow transgression of Namurian rocks over the flanks of the Brabant Massif. Such a transgression can be shown by the recognition of isohypses corresponding to homotaxial shorelines (fig. 3). This general picture confirms the observations of GRAULICH (1964) that the Sudetic movements have influenced the deposits and the nature of the Carboniferous in the Namurian basin and that the folds become younger from South to North along the southeastern flanks of the Brabant Massif.

The age of the oldest dated Namurian in the boreholes Turnhout and Wijvenheide is Upper Arnsbergian (E2c). The same age was also found in some boreholes of the Vesdre Massif (Sippenaeken, Bolland and Soumagne). The E2c has not been identified with absolute certainty at Val Dieu, where a horizon with *Cravenoceratoides* sp. underlying beds with *Homoceras beyrichianum* (Chokierian) occurs. It is supposed however that this is also of Upper Arnsbergian age (E2c) (LAMBRECHT & VAN LECKWYCK 1959). A slightly older age (E2a-b) is found in the Gulpen borehole (see 3.17.) and at Eschweiler (HERBST 1952). An Alportian-Visean contact is supposed to exist in the Woensdrecht borehole (see 3.1.).

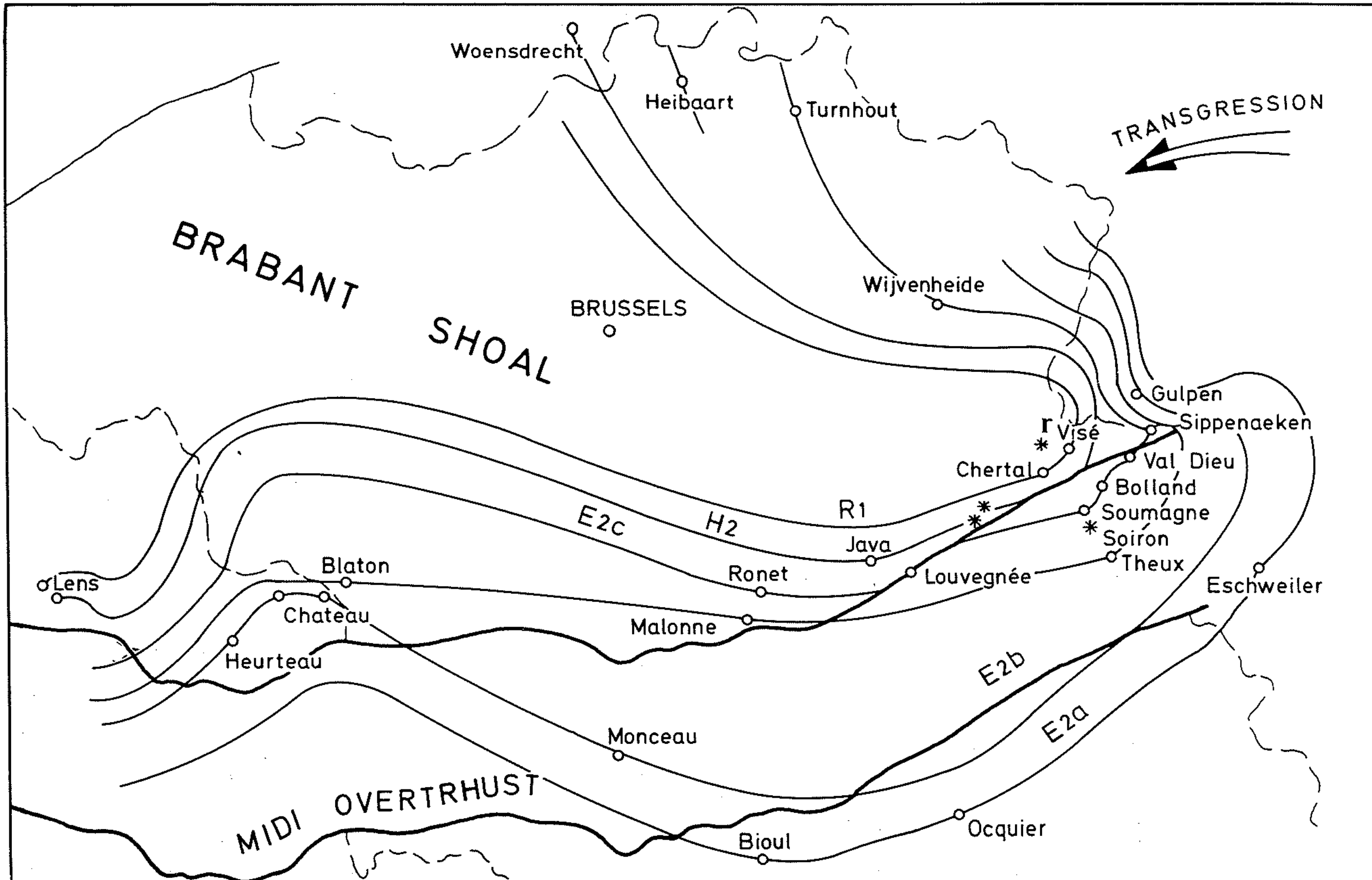


Fig. 3

NAMURIAN TRANSGRESSION
(Homotaxial shore-lines)

2.2. LATE VISEAN UPLIFT

At different places in the eastern part of the Namur Basin, the top of Visean limestone shows dissolution phenomena consisting in large caves filled up with Namurian shales and often characterized by an enrichment of radio-active minerals (fig. 3). These Namurian shales are always of Middle Arnsbergian age (E2b).

In the southeastern part of the Campine (Wijvenheide borehole), topmost Visean (V3c) limestone occurs below E2c shales. Further to the West in the Woensdrecht borehole, topmost Visean strata are absent, the highest limestone having been dated as V2b-V3a (see 3.1.). These are overlain by H2 shales.

It is suggested here, that the Upper Visean-basal Namurian uplift affected especially the western part of the Brabant Massif and became less important towards its eastern spur. The subsequent Namurian transgression covered first the less uplifted eastern flanks of the Brabant Massif and did not reach the western part before the Alportian or Kinderscoutian (fig. 4). From the subcrop map of the pre-Permian floor in the southern North Sea published by EAMES (1975) it can be deduced that still further westwards an even larger part of the Visean and also of the Lower and Middle Namurian will be missing.

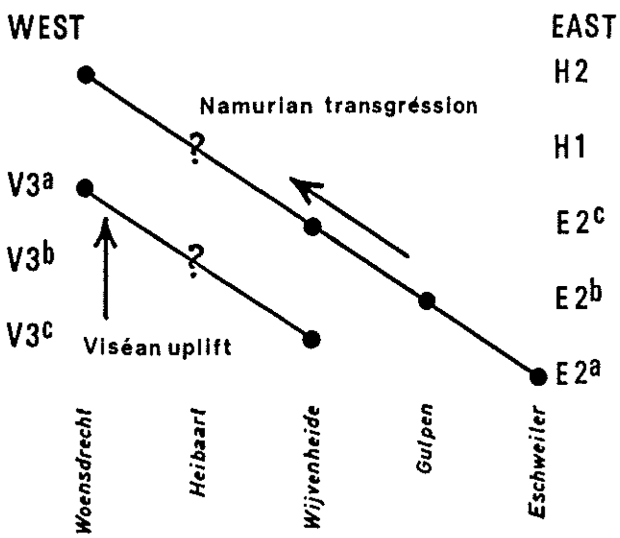


Fig 4 – Relation between Visean uplift and Namurian transgression along northern flank of Brabant Massif.

2.3. PALEOZOIC ABRASION SURFACE EAST OF BRABANT MASSIF

Little agreement exists amongst the various authors about the nature of rocks bordering the eastern spur of the Brabant Massif (cf. fig. 2). This is in part due to the fact that the age of rocks encountered in various boreholes was lithologically determined without checking any paleontological evidence, and in part of the fact that different reconstructions of the Paleozoic abrasion surface are possible because of the sparsely distributed boreholes which have reached the Paleozoic in this area. Apart from the authors referred to in fig. 2 (TESCH 1924, DORSMAN 1945, PATIJN 1963 and LEGRAND 1968) we should also mention VAN WATERSCHOOT VAN DER GRACHT (1938), SAX (1946) and VAN LECKWIJCK (1956), who published on the Paleozoic rocks around the eastern spur of the massif. The problem is tackled here again because of the recognition of foraminifers of undiscutably Dinantian age in the topmost Paleozoic strata of four Dutch boreholes (DB108, DB109, DB123 and GB6402). This permits us to believe that rocks formerly described as "ampelite debris" in the Dutch boreholes DB105, DB 108, DB109, DB123, DB150 and GB6330 (see Enclosure 1) are in fact silicified shales and limestones of Dinantian age. The same may be true for the Belgian boreholes 108W131, 108W202-205 and 108W331-332. The Belgian borehole 108W333 penetrated black marine shales of presumably Devonian age (GROESSENS, unpublished), which may be compared with rocks of presumably Frasnian age in the La Folie Quarry (cf. PIRLET 1967a) and along the Berneau railway (cf. FOURMARIER 1923). Comparable rocks have been mentioned from the Dutch boreholes DB89 (cf. HARZÉ 1899) and DB144 (cf. JONGMANS, KRUL & VOS 1941) and are here also interpreted as presumably Devonian. No samples of these latter two boreholes have been preserved.

This means that the Paleozoic abrasion surface between the boreholes 93E155 (Lanaken), DB105 (Houthem) and the area around Visé is of Dinantian age with some windows of Devonian rocks in the South. North-West of Visé an erosion hole in the Namurian abrasion surface reaches a Dinantian subcrop. The easternmost boreholes which have penetrated the Cambro-Silurian of the Brabant Massif are 93W560 and 121W216. LEGRAND (1968) suggested that the Brabant Massif is limited respectively North and South of these boreholes by large faults. This northern fault is known from several boreholes and coalmines in the Campine. Its eastern prolongation is unknown. The southern fault or "faille bordière" (border fault) with a general East-West direction should turn towards the North-North-East according to LEGRAND, who argumented that this fault should pass directly West of the 107E2, borehole, where conglomerates derived from Cambro-Silurian rocks have been recognized on presumably Dinantian rocks. In our opinion this may be also a short transverse North-South directed fault. Such faults are common throughout the studied area. On the other hand, the North-North-West deviated border fault suggested by LEGRAND should have an abnormal direction unknown for such an important fault in this region. Construction of

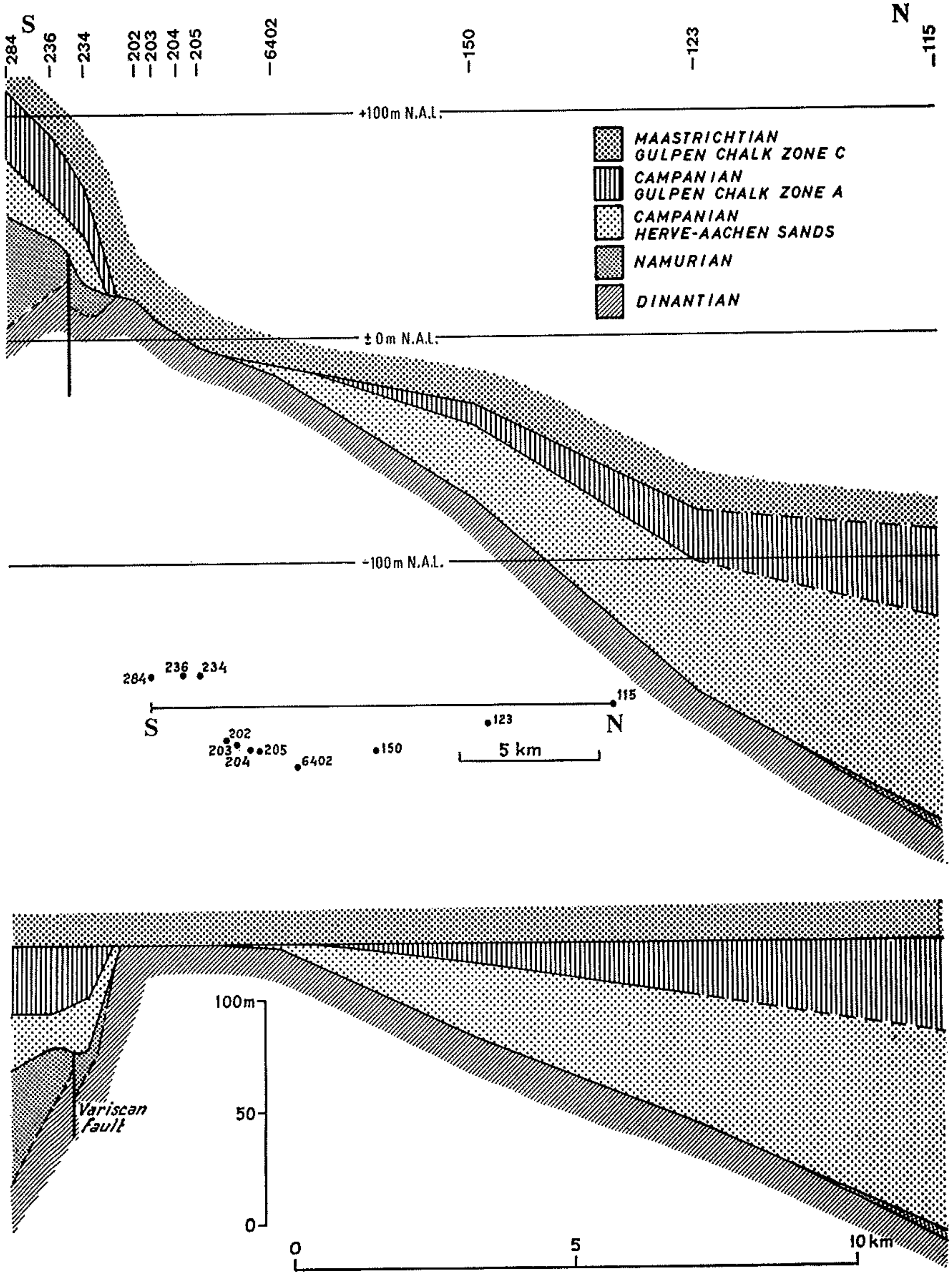


Fig 5 – North-South section through western flank of Visé-Puth Anticline. The unconformable Campanian-Maastrichtian contact is taken as datum-line in the lower half of the figure in order to show that the Visé-Puth Anticline was repeatedly uplifted as shown by unconformable Namurian-Campanian, Herve/Aachen Sands-Gulpen Chalk Zone A and Campanian-Maastrichtian contacts.

depth contour lines for the top Dinantian in the area between Visé and Heerlen yields an anticlinal structure East of the Brabant Massif, the Visé-Puth Anticline, with in its core two small tectonic windows with Devonian rocks. As will be argumented in chapter 5.2., this must have been an in origin synsedimentary Dinantian to Silesian high. In between this high and the by boreholes proven Cambro-Silurian of the Brabant Massif, we have a strip of some ten kilometers without any boreholes. In this strip, the eastern border of the Brabant Massif must be located. We virtually do not know if the Massif is overlain in that area by Devonian or Dinantian rocks, nor if in between the Brabant Massif and the actual Visé-Puth Anticline a Namurian trough existed.

The Visé-Puth Anticline (eventually connected with the Brabant Massif) must have been still an active high in Campanian time as can be deduced from a North-South section on the western flank of the anticline (fig. 5).

In contrast to the Cambro-Silurian Brabant Massif, the Visé-Puth Anticline has a core of Upper Devonian (Frasnian) rocks. This suggests that these two structures are independent from each other. The windows of Frasnian rocks in the Visé area cannot be compared with the classic Theux Window (FOURMARIER 1954) inasfar as the Dinantian is not overlying the Devonian as a nappe-like structure, but has transgreded several times over the Devonian ridge of the Visé High. These windows are characterized by the fact that they are in part bordered by several faults with different directions. We expect that several more of such windows occur further North in the core of the Visé-Puth Anticline. This type of windows is also known around diapiric structures. Therefore, it may be assumed, that evaporitic sediments of pre-Frasnian age may occur in the core of the Visé-Puth Anticline and that this structure eventually represents a dome built on a small evaporitic basin formed after Cambro-Silurian and before Frasnian times. It is known that evaporitic rocks occur in the Middle Devonian strata of the Namur Basin on the southern flank of the Brabant Massif near Tournai in the Leuze borehole. (LEGRAND, unpublished section of the Leuze borehole) and Tournai borehole (VAN TASSEL 1960).

2.4. DEPTH OF DINANTIAN SUBCROP

Fig. 6 shows the depth at which the top of the Dinantian was reached in boreholes. The same figure also tries to prognosticate the possible depth of the Dinantian subcrop further to the North. This prognosis is based on the following arguments:

1) – The depth of the Carboniferous subcrop is known from the numerous boreholes which penetrated it (for the Campine e.g. DELMER 1963, LEGRAND 1968; for the Netherlands e.g. THIADENS 1963, VAN WIJHE & BLESS 1974; for Germany e.g. FABIAN 1971) and from the depth contour map by HEYBROEK (1974).

2) – There is no indication that the Westphalian A, B, C and D stages considerably surpass a thickness of each say 1000 m. Only locally, their thickness may be reduced as shown for the Rijsbergen-1 borehole (VAN WIJHE & BLESS 1974). From the maps of the Carboniferous subcrop published by DELMER (1963), HEDEMANN & TEICHMÜLLER (1971), KARRENBERG (1971) and VAN WIJHE & BLESS (1974) the approximate age of this subcrop at each place is known.

3) – Combination of the knowledge mentioned under 1) and 2) makes it possible to construct within reasonable limits of error a depth contour map for the base of the Westphalian (fig. 7).

4) – The thickness variations for the Namurian within the German area and adjacent parts of the Netherlands have been more or less satisfactorily reconstructed by FABIAN (1971) and HEDEMANN & TEICHMÜLLER (1971). The thickness of the Namurian in the Campine and South Limburg (600 to 800 m) is rather constant (BOUCKAERT & HERBST 1960, DELMER 1963). A tremendous increase in thickness towards the North has been observed in the Rijsbergen-1 borehole, where more than 1800 m of Namurian rocks have been penetrated (information kindly furnished by the Nederlandse Aardolie Maatschappij, NAM). However, it is not impossible that this enormous increase within a distance of less than 30 km from the Turnhout borehole is due to mass slides along the northern slope of the Brabant Massif. In this context one should be aware of the fact that only 30 km towards the West, the topmost Visean and Lower Namurian are absent in the Woensdrecht borehole. This suggests that the Woensdrecht area was a high in late Visean-early Namurian time. The thickness of the Namurian rocks in the Rijsbergen-1 borehole may therefore turn out to be a rather local phenomenon and not be taken as indicative for the thickness development of Namurian rocks further to the North in the Netherlands. On the other hand, the Namurian in South Limburg and the Campine is incomplete since the Pendleian and basal Arnsbergian strata are missing (BOUCKAERT 1967). It is to be expected that these strata further to the North do occur as in Great Britain and Germany. A total thickness for the Namurian in the southwestern Netherlands somewhere between 1000 and 2000 m may well be possible. This would agree with the development North of the Brabant Massif in England (RAMSBOTTOM 1969).

5) – Parallel to the development in Great Britain and Germany, we may presume that in between the Brabant Massif and the Fenno-Sarmatian continent in the North there was not a uniform basin in Namurian time as suggested by HEDEMANN & TEICHMÜLLER (1971). It seems more likely to be-

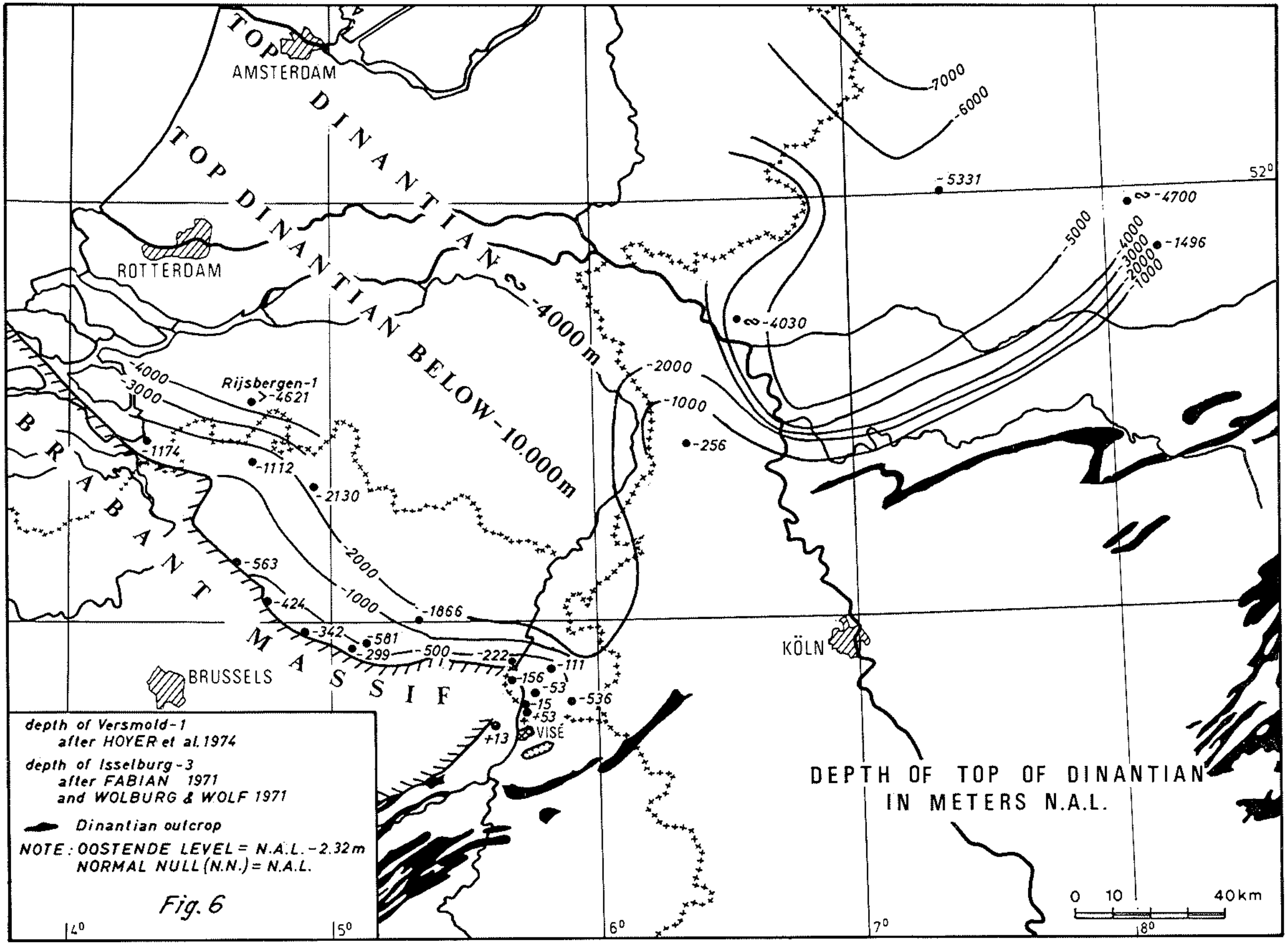

TOP DINANTIAN ≈ -4000 m
TOP DINANTIAN BELOW -10.000 m
AMSTERDAM
ROTTERDAM
BRUSSELS
KÖLN
VISÉ
BRABANT MASSIF
Rijsbergen-1 >-4621
-1174
-1112
-2130
-563
-424
-342
-581
-299
-1866
-222
-111
-156
-53
-536
-15
+53
+13
-256
≈ -4030
-5331
≈ -4700
-1496
-4000
-3000
-2000
-1000
-500
-5000
-6000
-7000
4°
5°
6°
7°
8°
52°
0 10 40 km
DEPTH OF TOP OF DINANTIAN IN METERS N.A.L.
depth of Versmold-1 after HOYER et al. 1974
depth of Isselburg-3 after FABIAN 1971 and WOLBURG & WOLF 1971
Dinantian outcrop
NOTE: OOSTENDE LEVEL = N.A.L. -2.32 m
NORMAL NULL (N.N.) = N.A.L.

Fig. 6

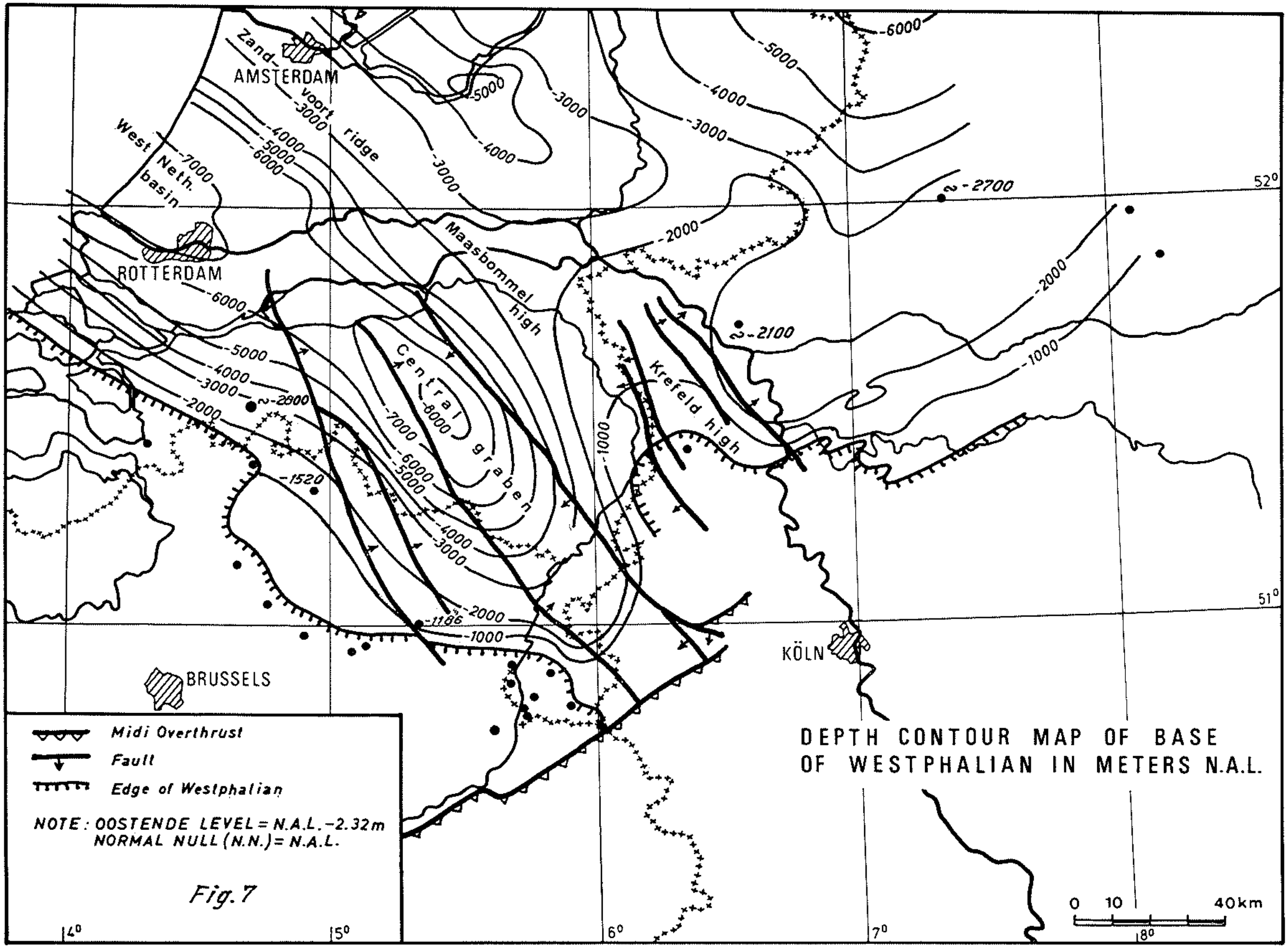

DEPTH CONTOUR MAP OF BASE
OF WESTPHALIAN IN METERS N.A.L.
Midi Overthrust
Fault
Edge of Westphalian
NOTE: OOSTENDE LEVEL = N.A.L. -2.32m
NORMAL NULL (N.N.) = N.A.L.
AMSTERDAM
ROTTERDAM
BRUSSELS
KÖLN
Zandvoort ridge
West Neth. basin
Maasbommel high
Central graben
Krefeld high
-2700
-2100
-2800
-1520
-1186
-8000
-7000
-6000
-5000
-4000
-3000
-2000
-1000
4°
5°
6°
7°
8°
51°
52°
0
10
40km

Fig. 7

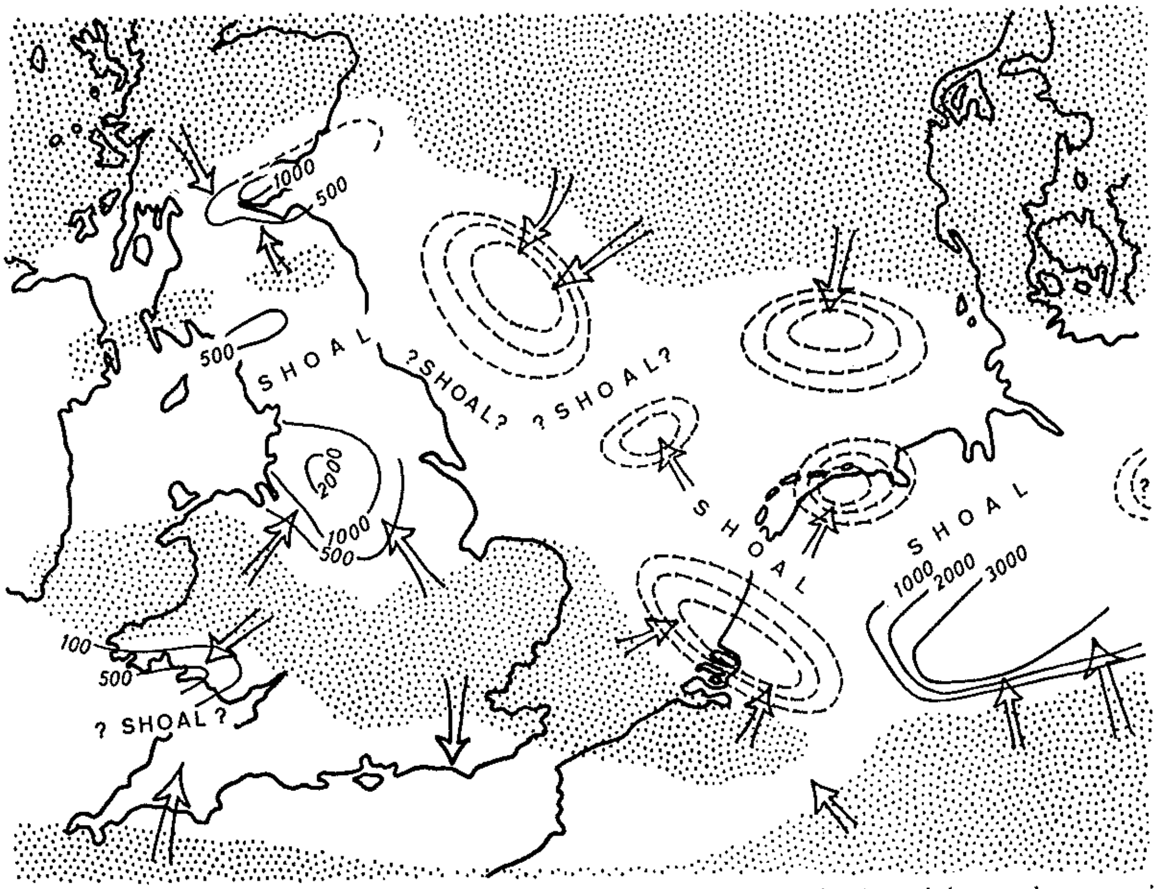


Fig 8 – Namurian paleogeography. Interrupted lines: isopachs of suggested basins of similar size and shape as those recognized in Great Britain. In between, several eventually erosive shoals may have existed. These suggested basins should not be compared with the Ruhr Basin or Subvariscan Foredeep with a different tectonic history. It should be noted that shape and location of the suggested basins are highly arbitrary.

lieve that several more or less independent sedimentation areas existed which were separated by emerged islands supplying eroded detrital material, or submerged shoals with a condensed sedimentation due to block movements. An attempt to reconstruct such basins within northwestern Europe is given in fig. 8. Such a shoal or even emerged area may have existed at the place of the actual Zandvoort–Maasbommel Ridge or slightly further North at the place of the actuel IJsselmeer High. That one of these highs may have been a mobile area as far back as the Carboniferous has been argumented for the Zandvoort–Maasbommel Ridge by Bless & Streel (1976). In such an area, the Namurian rocks may possess a thickness well below 1000 m.

6) – A prognosis of the depth at which the Dinantian subcrop may be reached can now be made by adding up the expected depth of the base of the Westphalian with the presumable thickness of the Namurian.

3. BOREHOLE DESCRIPTIONS

The description of twenty-two boreholes consists of a brief review of previous work, a macroscopic description of the lithology, distribution of ecologically significant macrofossils and listing of stratigraphically diagnostic foraminifers and conodonts. The occurrence of these and other important fossils is discussed in the chapter on biostratigraphy.

Unless otherwise indicated, borehole depth (BD) is used in the text. With few exceptions, depth is given in whole meters.

Inasfar as samples have been preserved, their actual storage is indicated for each borehole. Foraminifers have been stored either with the paleontological collections (reference number of thin section "RC") or the general geological collections (reference number of thin section "FKJ") of the University of Louvain-la-Neuve. The numbers between brackets on plates 8–12 refer to the photograph collection of the Laboratoire de Paléontologie of the University of Louvain-la Neuve.

Fig. 9 shows the legend used for borehole descriptions in figures 11 to 27.

3.1. WOENSDRECHT BOREHOLE (DB17)

The Woensdrecht borehole (= DB17) has been

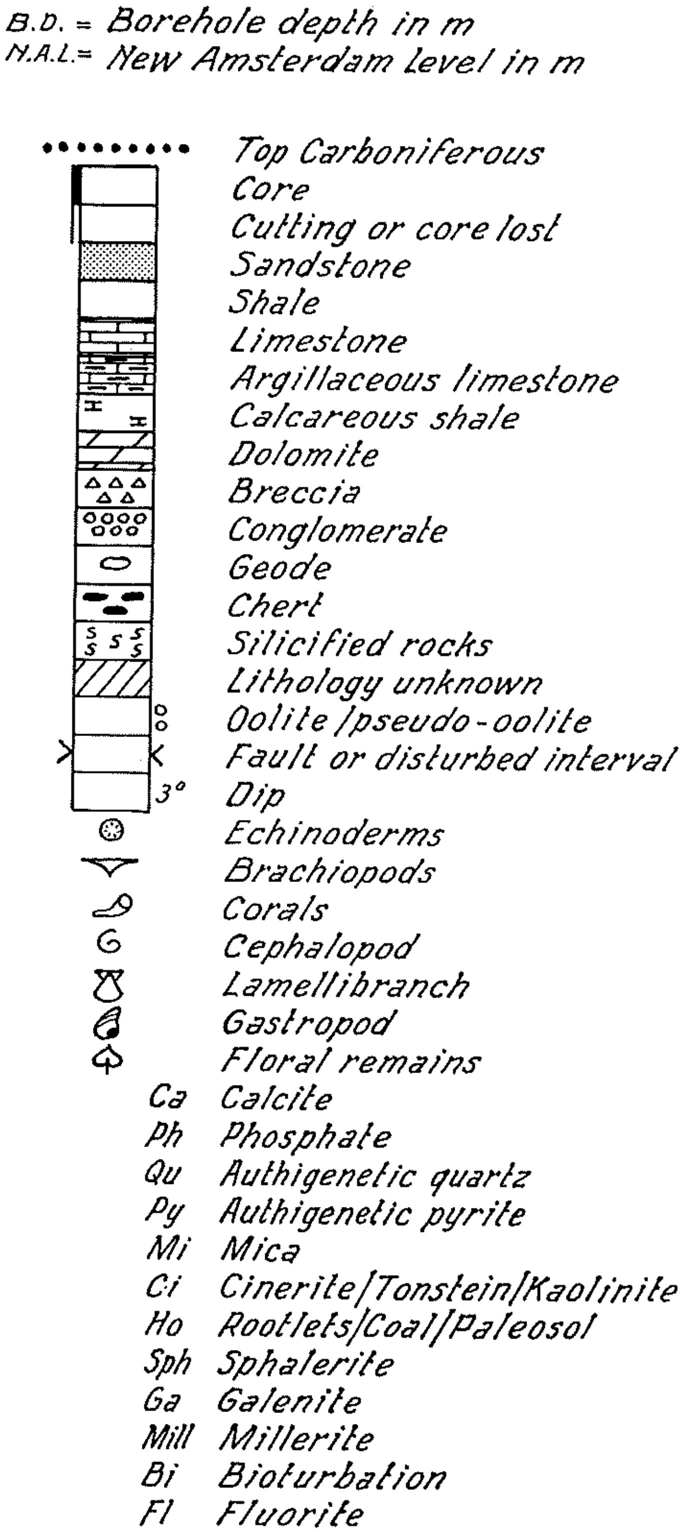


Fig 9 – Legend to figures 11-27.

drilled between 1912 and 1914 for the "Rijksopsporing van Delfstoffen in Nederland". Top Carboniferous was reached at 919 m (= −917 m NAL). The sequence between 919 m and 1176 m consists of shales and sandstones containing several fragments of macroflora and near the base a marine fauna of crinoids, fish scales and arthropods. From 1176 to total depth at 1205 m (= −1203 m NAL), light grey to grey fossiliferous limestone occurs. A detailed lithological description of the Carboniferous was given by VAN WATERSCHOOT VAN DER GRACHT (1914). JONGMANS (1914, 1918) concluded that the macroflora of the sequence between 919 m and 1176 m might be of Lower Namurian age. The limestone was compared with rocks of Visean age. PRUVOST (1922, 1930) described a new crustacean species from the dark shale at 1164 m. CONIL & LYS (1964) figured a foraminifer species of presumably V3 age. Reference to the borehole has been made also by DELMER (1963) and THIADENS (1963) without adding new observations.

It had been concluded by VAN WATERSCHOOT VAN DER GRACHT (1914) that no stratigraphic hiatus exists between the limestone and the overlying clastic sequence. However, the poor macroflora described by JONGMANS (1918) suggests that basal Namurian rocks are absent. The three relevant species identified by JONGMANS are *Mesocalamites roemeri, Paripteris gigantea* and *Alethopteris lonchitica.* All other species are either labeled "cf." or "sp." and therefore of less value for stratigraphic purposes. *Mesocalamites roemeri* (from 1054 m) is said by JONGMANS to be restricted to the Dinantian. But STOCKMANS & WILLIÈRE (1953) mention this species also from the Arnsbergian and Kinderscoutian of Belgium, whereas HARTUNG & PATTEISKY (1960) stated that they recovered many specimens from the Middle Arnsbergian of the East Sudetic area. FIEBIG & LEGGEWIE (1974) found the species also in the Chokierian to Yeadonian of the Ruhr district. *Paripteris gigantea* (from 921 m to 1157 m) and *Alethopteris lonchitica* (from 1110 m) have

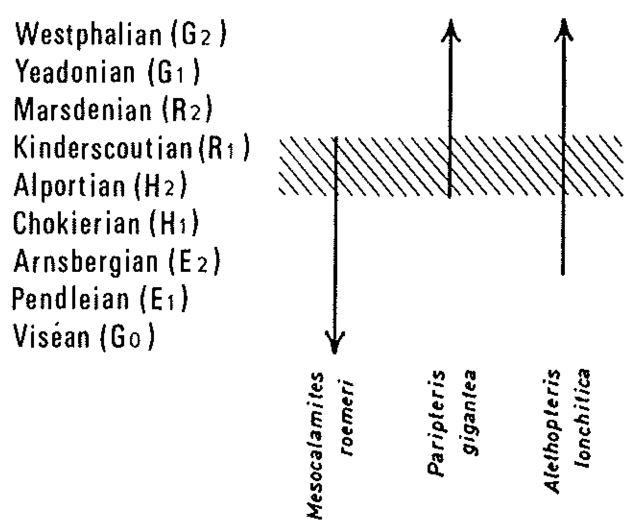
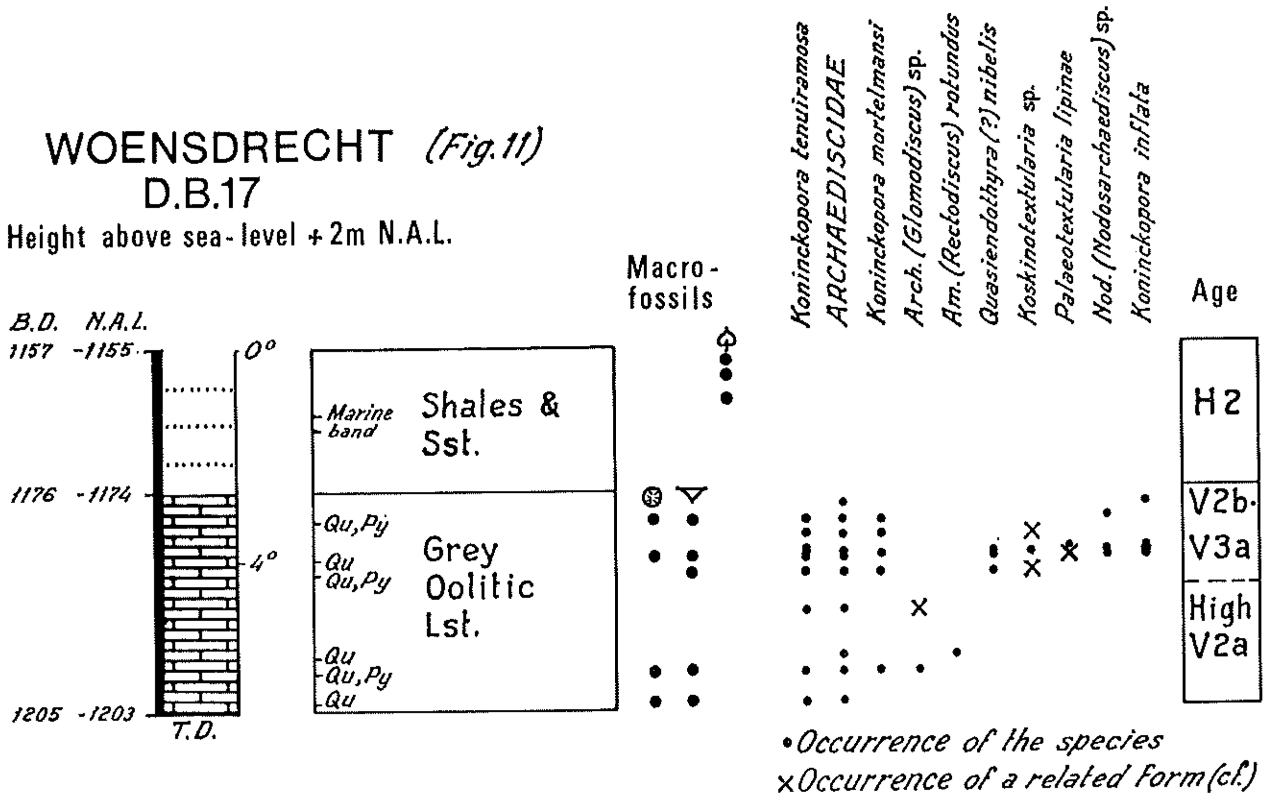


Fig 10 – Concurrent range zone of Namurian plant fossils from Woensdrecht borehole.



been cited from respectively the Marsdenian and Arnsbergian onwards in Belgium by STOCKMANS & WILLIÈRE (1953). They start above the Chokierian in the Sudetic area (HARTUNG & PATTEISKY 1960) and in the Ruhr district, these species have been recovered recently by FIEBIG & LEGGEWIE (1974) from the Kinderscoutian (Hagen Beds). These latter authors refer to unknown sources, where *P. gigantea* should have been mentioned already in Chokerian rocks of that area. In the Gulpen borehole (DB106), the oldest appearance of *P. gigantea* is in the Alportian (cf. JONGMANS 1927). An Alportian to Kinderscoutian age seems thus the most likely for this macroflora (cf. fig. 10). The sequence between 919 m and 1159 m may thus be placed in the Alportian. The immediately underlying marine band (with fossils at 1164 m and 1166 m) does not contain a stratigraphically diagnostic fauna, nor does the clastic sequence below the marine band. Since the Visean age for the limestone interval has been confirmed, it must be concluded that the Lower Namurian (Pendleian to Chokierian) is either missing or condensed into less than 15 m.

Samples have been stored with the collections of the "Geologisch Bureau" at Heerlen, the "Service Géologique de Belgique" at Brussels and the University of Louvain-la-Neuve.

From 1176 to 1202 m, 11 levels have been sampled and 29 thin sections have been cut for study of algae and foraminifers.

Three species of *Koninckopora* are very well represented throughout the whole interval: *K. inflata* from 1176 to 1183 m, *K. tenuiramosa* from 1178 to 1202 m and *K. mortelmansi* from 1178 to 1198 m.

From 1190 to 1202 m, we can observed the presence of typical V2a, evolved primitive *ARCHAEDISCIDAE*, namely *Rectodiscus rotundus*, *Glomodiscus* sp. and *Archaediscus pulvinus*. These forms disappear when others representative of V2b-V3a appear, such as *Quasiendothyra*(?) *nibelis* (at 1185 m), *Koskinotextularia* sp., *Palaeotextularia lipinae*, abundant *Nodosarchaediscus*. No typical V3b form has been encountered.

Here is the microorganisms assemblage recovered from 1202 to 1190 m:

Koninckopora tenuiramosa WOOD
Koninckopora mortelmansi MAMET

Pachysphaerina pachyspaerica (PRONINA)
cf. *Pseudolituotuba gravata* (CONIL & LYS)
Earlandia vulgaris (RAUSER & REITLINGER)
Earlandia minor (RAUSER)
TOURNAYELLIDAE
Mstiniella orientalis (N. TCHERNYSHEVA)
Pseudolituotubella sp.
Brunsia sp.
Pseudoammodiscus sp.
Archaediscus (Glomodiscus) sp.
Archaediscus (Archaediscus) chernoussovensis MAMET
Archaediscus (Archaediscus) convexus GROZDILOVA & LEBEDEVA
Archaediscus (Archaediscus) pulvinus CONIL & LYS
Archaediscus (Archaediscus) stilus GROZDILOVA & LEBEDEVA
Ammarchaediscus (Rectodiscus) rotundus (N. TCHERNYSHEVA)
Ammarchaediscus (Ammarchaediscus) subgen. *A* CONIL & PIRLET
PALAEOTEXTULARIIDAE
cf. *Biseriella* sp.
Endothyra sp.
Endothyranopsis sp.
Plectogyranopsis dendrei (CONIL & LYS)
Eostaffella sp.
Mediocris sp.

Kamaena sp.
Issinella sp.

The following forms have been encountered between 1185 and 1176 m:

Koninckopora inflata (DE KONINCK)
Koninckopora tenuiramosa WOOD
Koninckopora mortelmansi MAMET

Archaesphaera inaequalis (DERVILLE)
Pachysphaerina pachysphaerica (PRONINA)
Parathurammina suleimanovi LIPINA
Pseudolituotuba gravata (CONIL & LYS)
Earlandia vulgaris (RAUSER & REITLINGER)
Earlandia minor (RAUSER)
cf. *Eotextularia diversa* (N. TCHERNYSHEVA)
Forschiella sp.
Lituotubella sp.
Pseudolituotubella sp.
Brunsia sp.
Pseudoammodiscus sp.
Archaediscus (Archaediscus) chernoussovensis MAMET
Archaediscus (Archaediscus) convexus GROZDILOVA & LEBEDEVA (of V2b type)
Archaediscus (Archaediscus) cf. *reditus* CONIL & LYS
Archaediscus (Archaediscus) stilus GROZDILOVA & LEBEDEVA
Nodosarchaediscus (Nodosarchaediscus) sp.
Palaeotextularia aff. *lipinae* CONIL & LYS
Koskinotextularia sp.
Tetrataxis sp.
Pseudotaxis sp.
Endothyra sp.
Endothyra (Spinoendothyra) sp.
cf. *Dainella* sp.
Endothyranopsis sp. (primitive)
Plectogyranopsis sp.
Plectogyranopsis ampla (CONIL & LYS)
cf. *Endospiroplectammina* sp.
Quasiendothyra (?) nibelis DURKINA
Loeblichia sp.
Eoparastaffella sp.
Eoparastaffella simplex VDOVENKO
Eostaffella sp.
Mediocris sp.

Kamaena sp.
Issinella sp.

Conodont research:

depth	weight of material dissolved	results
1178 m	± 100 to 150 gr.	no
1183 m	idem	no
1185 m	idem	no
1198 m	idem	no
1198.50 m	idem	no
1202 m	idem	no

Ostracode research:
Ostracodes have been recovered from 1178 m, 1185 m, 1198 m, 1198.50 m and 1202 m. They include Bairdiid, Paraparchitacean, Kirkbyid (*Kummerowia*) and Cypridinacean forms, which are of little stratigraphic value. See chapter 4.3.

3.2. HEIBAART BOREHOLE

The Heibaart borehole (in some publications also named Loenhout borehole) has been drilled in 1962 by Petrofina. The descriptions and the samples are kept at Labofina (Brussels). Coring was discontinuous. Lower Namurian (with a dip of 12 to 15°) underlying Cretaceous was reached at 1052 m (= −1026 m NAL) and the Dinantian at approximately 1138 m (= −1112 m NAL). Sandstones of supposedly Famennian age were reached at 1452 m, whereas true Famennian sandstones were encountered at 1184 m (with a dip of 15°) followed by marine shales of Frasnian age (with a dip of 12°). The borehole penetrated the Silurian subcrop at 1627 m (dip of Silurian: 12°) and was stopped at a total depth of 1631.70 m (after LEGRAND 1968).

An important karstic zone was encountered in the Lower to Middle Visean.

Further information from this borehole is not yet available and will remain classified until the entire resurvey of the Campine Basin has been completed.

However, the following foraminifers from the Heibaart borehole were figured by CONIL & LYS (1964):

Fig. 116 – *Glomospira(?) crassa* CONIL & LYS, holotype.
Fig. 239 – *Tetrataxis paraminimus* var. *paraminimus* VISSARIONOVA.
Fig. 285 – *Archaediscus cornuta* CONIL & LYS.
Fig. 288 – *Archaediscus crux* CONIL & LYS.
Fig. 463 – *Plectogyra* aff. *antiqua* (RAUSER–CHERNOUSSOVA) at 1333 m.
Fig. 558 – *Plectogyra exelikta* var. *exelikta* CONIL & LYS at 1330 m.

3.3. TURNHOUT BOREHOLE

The Turnhout borehole has been drilled between 1953 and 1955 for the "Institut National de l'Industrie Charbonnière" and the "Service Géologique de Belgique". The original unpublished lithological description by GROSJEAN, DELMER, GRAULICH & LEGRAND and the samples are kept at the "Service Géologique de Belgique" under the reference number 17E225 (120).

The Carboniferous was reached at 1050 m (= −1018 m NAL) and top Dinantian at 2162 m (= −2130 m NAL), underlying the E2c zone (2156 to 2162m). The sequence between 2152 and 2175 m consists of ampelitic shales with phthanite beds; there is a calcareous and siliceous level at 2162 m and many little crinoidal limestone beds between 2170 and 2175 m. The sequence continues with 13 m of black dolomitic limestone, becoming a pulverulent dolomite at the base, followed by 7 m of coarse crinoidal and shelly limestone, 17 m of fine grained black limestone with cherts and 7 m of fine black limestone without cherts. A sedimentary breccia level is encountered at 2219 m till 2232 m, followed by 11 m of light fossiliferous limestone. From 2252 to 2276 m, the sequence passes from a limestone with many levels of breccia and microbreccia into grey and white homogeneous limestone (2276 to 2309 m). A thick sequence of grey homogeneous limestone follows till 2435 m, this sequence being oolitic in the upper part and microbrecciated in the lower. From 2435 to 2540 m, the limestone is fine grained and of grey color. From 2540 m to total depth at 2705 m, the limestone is fine grained and algal.

Lithological descriptions have been published by DELMER (1962, 1963). Goniatites from the upper Visean and the Visean and Namurian boundary have been studied by BOUCKAERT (unpublished original description in 1967). The Dinantian biostratigraphy based on foraminifers was briefly studied by CONIL (1964). LEDERER (1973) made a survey of the microfauna between 2168 m and 2699.50 m. This microfauna was studied in detail by LONGERSTAEY (1975) and his biostratigraphic conclusions are followed here.

MORTELMANS (1955) described a new species of *Rhabdopleura* from the Upper Visean. Many microfossils from this borehole have been already figured by CONIL & LYS (1964, 1967, 1968), who published several new species based on type material from Turnhout. The borehole yielded holotypes for the following species of CONIL & LYS (1964): *Girvanella distans* (2414 m), *Earlandinella*(?) *deformis* (2476 m), *Septabrunsiina producta* (2391 m), *Tetrataxis depressus* (2314 m), *Tetrataxis mirus* (2228.50 m), *Tetrataxis pusillus* (2189.50 m), *Tetrataxis rugosus* (2458 m), *Archaediscus triangulus* (2195 m), *Plectogyra compacta* (2445.50 m), *Plectogyra*(?) *exuberans* (2346 m), *Plectogyra laxa* (2457 m), *Plectogyra pseudorotayi* (2290 m).

Fig. 12 gives our biostratigraphical conclusions and the extension of the main guide microfossils. Only those guides and a few other important microfossils will be mentioned here.

Lower Visean (V1a) from 2699.50 to 2324 m has been subdivided in 4 assemblages, all of them (except assemblage I) are based on the first appearance of different organisms. See here the characteristics of these assemblages:

Assemblage I (from 2699.50 to 2624.60 m);
presence of *Girvanella densa* CONIL & LYS and of *Endothyra honesta* CHLYKOVA, cf. *Dainella* sp. and cf. *Eoparastafella* sp.,

Assemblage II (from 2622 to 2545 m);
first appearance of *Brunsia* sp., and presence of: *Girvanella(?) distans* CONIL & LYS, *Endothyra laxa* (CONIL & LYS), *Endospiroplectammina conili* LIPINA,

Assemblage III (from 2541 to 2445.50 m);
first appearance of *Dainella* sp., *Dainella fleronensis* (CONIL & LYS) and *Eostaffella* sp., and presence of *Palaeospiroplectammina mellina* (MALAKHOVA), *Endothyra-campinei* (CONIL & LYS), *E. inflata* LIPINA and *Endospiroplectammina venusta* (VDOVENKO),

Assemblage IV (from 2439 to 2324 m);
first appearance of primitive *Koninckopora* and presence of: *Eotextularia diversa* (N. TCHERNYSHEVA), *Endothyra inflata* LIPINA, *Dainella exuberans* (CONIL & LYS),, *D. cussyensis* (MEUNIER) and *D. elegantula* BRAZHNIKOVA.

The V1b follows from 2322 to 2288 m with the first appearance of *Ammarchaediscus* (*Rectodiscus*) *rotundus* (N. TCHERNYSHEVA). We can mention also the presence of *Endothyra devia* (CONIL & LYS).

The V2a follows from 2282 to 2277.43 m (?). There is only one real V2a level at 2282 m; no fauna was recovered from other samples. We note the first appearance of *Koninckopora tenuiramosa* WOOD, *Archaediscus* (*Archaediscus*) *stilus* GROZDILOVA & LEBEDEVA and *Mediocris* sp.. *Ammarchaediscus* (*Rectodiscus*) *rotundus* (N. TCHERNYSHEVA) is still present.

Upon this lies the breccia and microbreccia sequence from 2272 to 2252 m with a very rich microflora and microfauna. The principal organisms are: *Koninckopora tenuiramosa* WOOD, *Koninckopora inflata* (DE KONINCK), *Wetheredella* sp., *Izhella* sp., *Fasciella kizilia* IVANOVA, *Pseudolituotuba gravata* (CONIL & LYS), *Archaediscus* (*Glomodiscus*) sp., *Archaediscus* (*Archaediscus*) *stilus* GROZDILOVA & LEBEDEVA, *Archaediscus* (*Archaediscus*) *chernoussovensis* MAMET, *Archaediscus* (*Nudarchaediscus*) sp., *Nodosarchaediscus* (*Nodosarchaediscus*) sp., *Nodosarchaediscus* (*Nodasperodiscus*) sp., *Quasiendothyra* (?) *nibelis* DURKINA and *Howchinia bradyana* (HOWCHIN) (only at 2252 m).

Pseudolituotuba gravata (CONIL & LYS) is restricted to this sequense. *Quasiendothyra (?) nibelis* DURKINA is not known below the V2b, and *Fasciella kizilia* IVANOVA and *Howchina bradyana* (HOWCHIN) are not older than V3bγ; while the *Archaediscus* (*Glomodiscus*) sp. encountered is not known higher than V2a. We suggests therefore that this sequence reworks organisms from the V2a to the V3b. This means that the main part of the V2a, the V2b, the V3a and the lower V3b (α and β) are missing or mixed up by the reworking phenomenon.

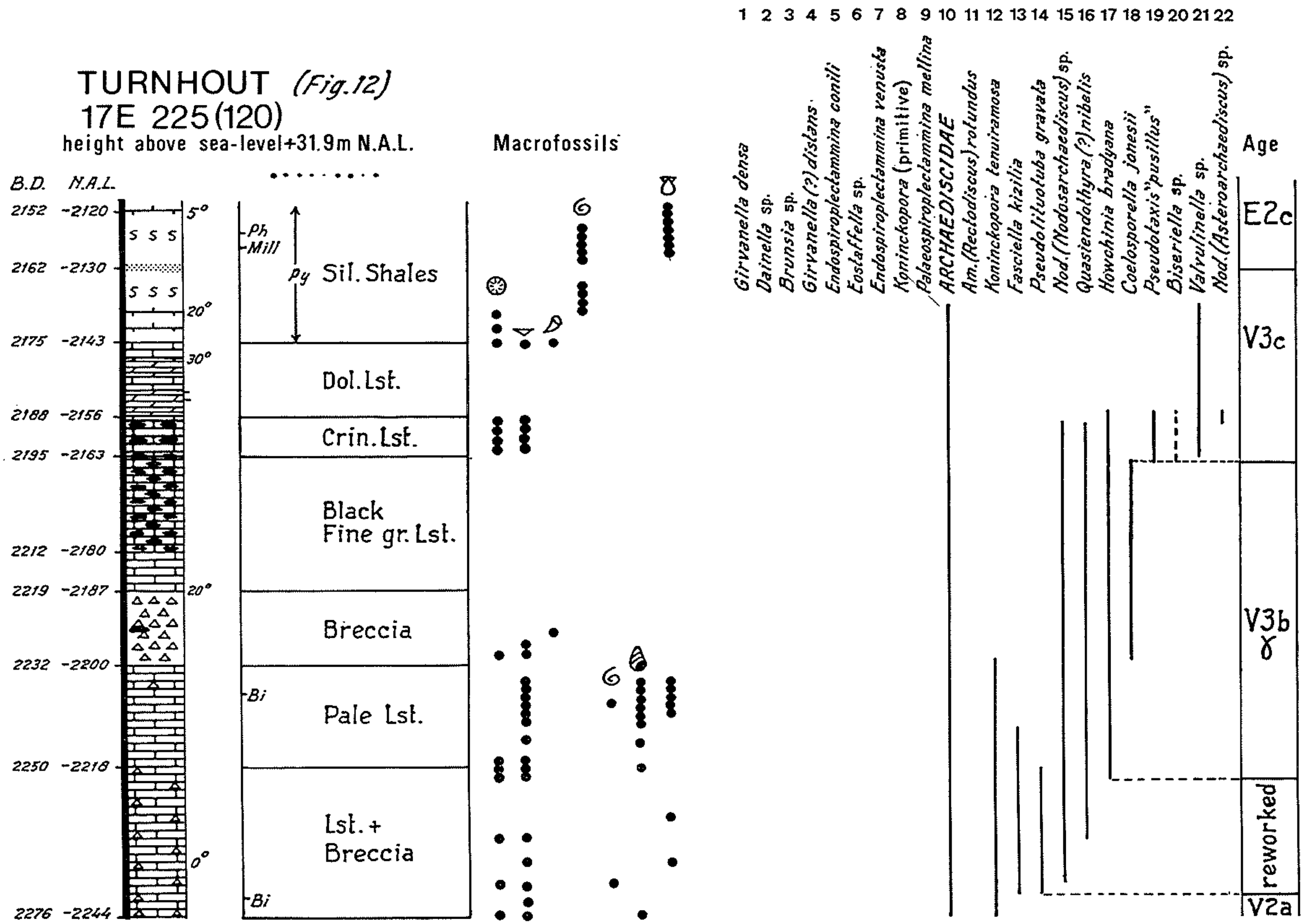
Upon this breccia sequence lies the rest of the V3bγ sequence (from 2249.50 to 2199.22 m) with: *Stacheoides* sp., *Coelosporella jonesii* WOOD, *Valvulinella* sp., *Howchinia bradyana* (HOWCHIN), *Endostaffella* sp., *Endothyra* ex gr. *omphalota* RAUSER & REITLINGER and *Quasiendothyra* (?) *nibelis* DURKINA.

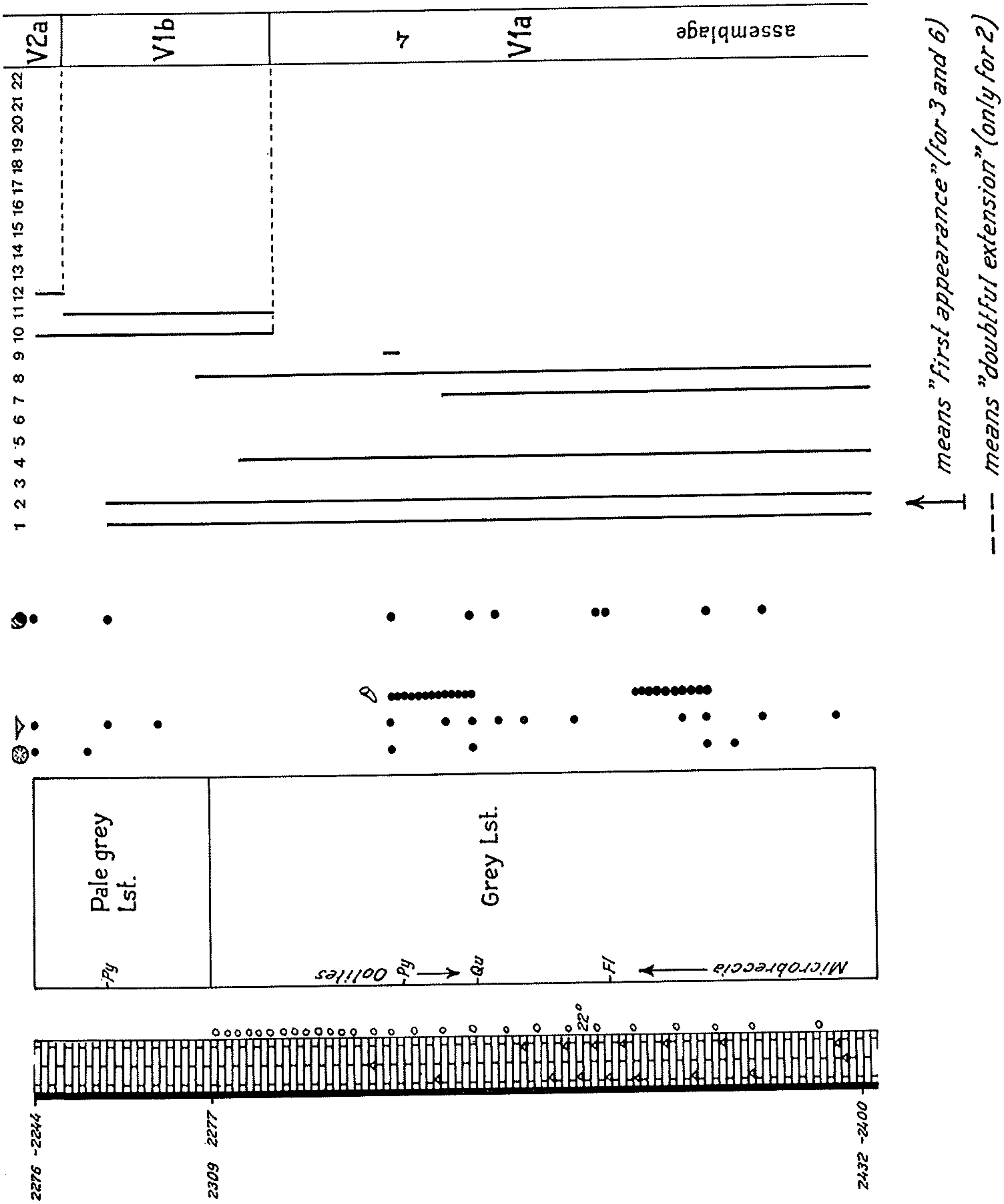
The upper part of the borehole from 2196 m is V3c with the first appearancec of: *Biseriella* sp., *Pseudotaxis "pusillus"* (CONIL & LYS), *Endostaffella* sp. and *Nodosarchaediscus* (*Asteroarchaediscus*) sp. The last foraminifera were encountered at 2168 m.

Conodont research:

depth	weight of material dissolved	results
2170 m	± 200 gr.	no
2175 m	idem	no
2175.50 m	idem	no
2178 m	idem	few specimens

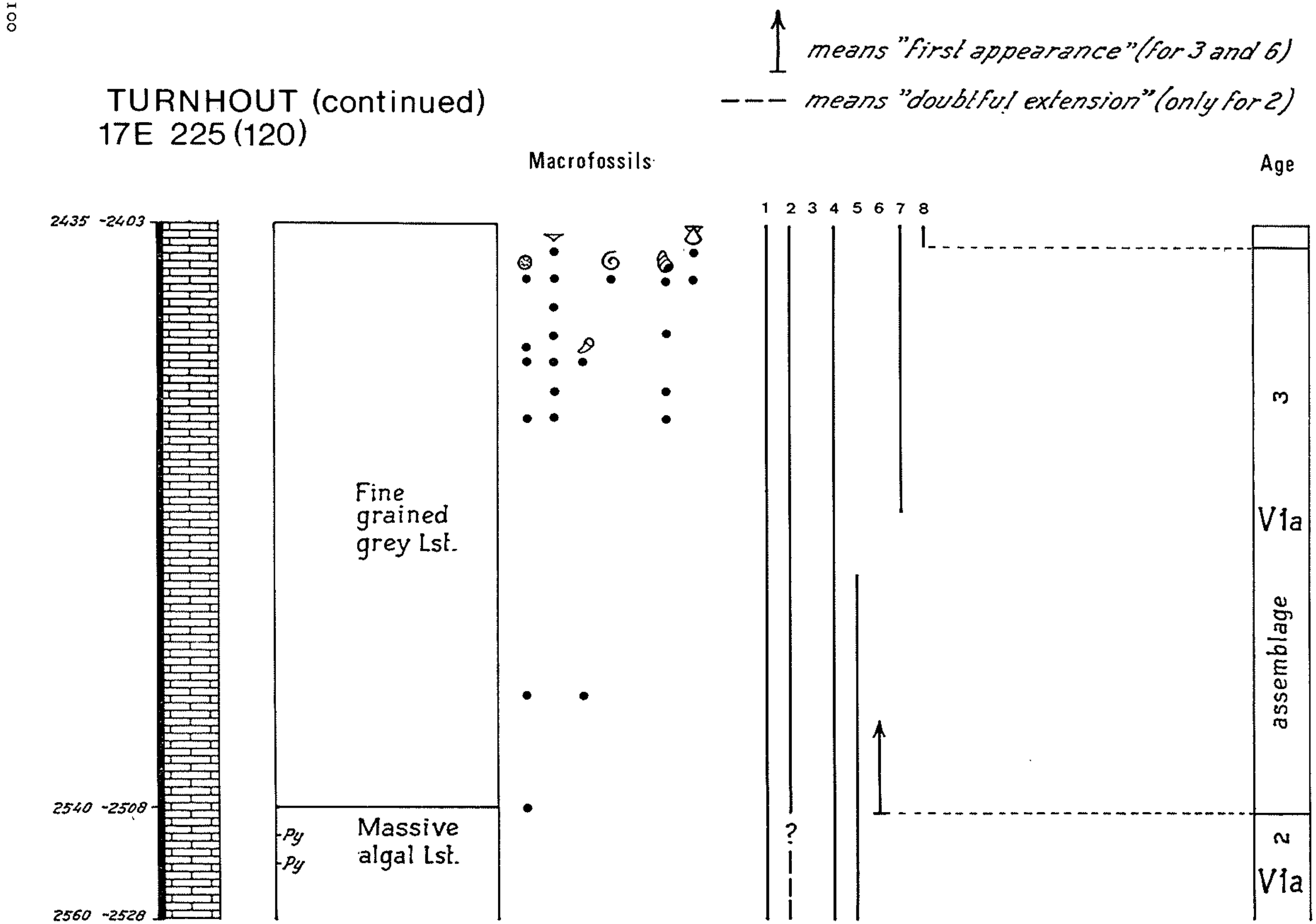
Sample from 2178 m yielded a.o. *Gnathodus commutatus nodosus* and *G. symmutatus symmutatus*, what suggests a V3c age for the sample.

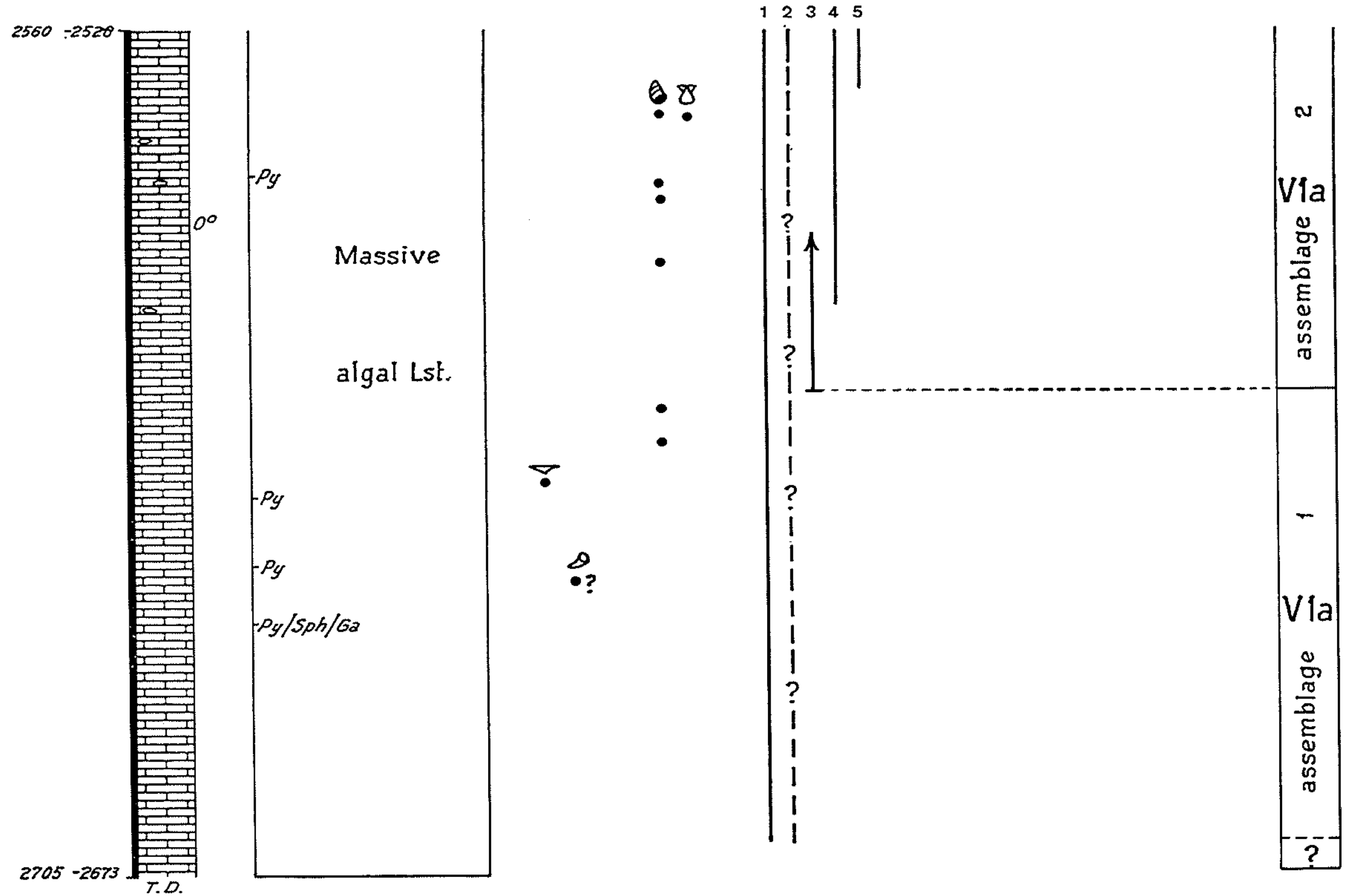

TURNHOUT (Fig.12)
17E 225(120)
height above sea-level+31.9m N.A.L.
Macrofossils
B.D. N.A.L.
2152 -2120
2162 -2130
2175 -2143
2188 -2156
2195 -2163
2212 -2180
2219 -2187
2232 -2200
2250 -2218
2276 -2244
5°
20°
30°
20°
0°
Ph
Mill
Py
Sil. Shales
Dol. Lst.
Crin. Lst.
Black Fine gr. Lst.
Breccia
Bi
Pale Lst.
Lst. + Breccia
Bi
1 Girvanella densa
2 Dainella sp.
3 Brunsia sp.
4 Girvanella (?) distans
5 Endospiroplectammina conili
6 Eostaffella sp.
7 Endospiroplectammina venusta
8 Koninckopora (primitive)
9 Palaeospiroplectammina mellina
10 ARCHAEDISCIDAE
11 Am. (Rectodiscus) rotundus
12 Koninckopora tenuiramosa
13 Fasciella kizilia
14 Pseudolituotuba gravata
15 Nod. (Nodosarchaediscus) sp.
16 Quasiendothyra (?) nibelis
17 Howchinia bradyana
18 Coelosporella jonesii
19 Pseudotaxis "pusillus"
20 Biseriella sp.
21 Valvulinella sp.
22 Nod. (Asteroarchaediscus) sp.
Age
E2c
V3c
V3b
γ
reworked
V2a



V2a
V1b
V1a
assemblage
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
means "first appearance" (for 3 and 6)
means "doubtful extension" (only for 2)
Pale grey Lst.
Grey Lst.
Py
Oolites
Py
Qu
Fl
Microbreccia
22°
2276 -2244
2309 2277
2432 -2400

TURNHOUT (continued)
17E 225 (120)





2560 -2528
2705 -2673
T.D.
0°
Py
Py
Py
Py/Sph/Ga
Massive
algal Lst.
1 2 3 4 5
?
?
?
?
?
VIa assemblage 2
VIa assemblage 1
?

3.4. KESSEL BOREHOLE

The Kessel borehole has been drilled in 1902 for the "Société Anonyme des Charbonnages du Nord de la Belgique". The samples are now kept at the "Service Géologique de Belgique" under the following reference number: 44W11(38), together with the original descriptions.

The Dinantian was reached at 573 m (= −563 m NAL), underlying Cretaceous glauconiferous chalk. The sequence begins with 29 m (573 to 602 m) of grey crystalline limestone, with a doubtful breccia level at 587 m. The sequence between 602 and 622 m was not cored and is reported to be a cherty limestone. Afterwards the borehole encounters a thick sequence of grey-brown limestones alternating with red shaly limestones, with a few red or green sandstone and conglomerate strata. The borehole ended in that sequence at 703.60 m.

Lithological descriptions and stratigraphic interpretations have been published by LOHEST, HABETS & FORIR (1902–1903, pp. 401–405), RENIER (1903, pp. 1031–1041) and VAN ERTBORN (1905, pp. 168–171). The limestone sequence was reported to the Dinantian while the lower part of the borehole (622 to 703 m) was considered to be of Middle and Upper Devonian age. STAINIER (1932) was the first to consider the whole sequence as being of Dinantian age. CONIL (1964) recognized the Lower and Middle Viséan on base of microfossils evidences (algae and foraminifera). DELMER (1963) republished a brief log and LEGRAND (1968) a brief description of this borehole.

Twenty-three microfossils have been previously figured in CONIL & LYS (1964, 1965), including the following holotypes in CONIL & LYS (1964):

Fig. 3 – *Girvanella densa* CONIL & LYS at 658 m.
Fig. 83 – *Diplosphaerina lamproderma* CONIL & LYS at 657 m.
Fig. 547 – *Plectogyra demisa* CONIL & LYS at 664 m.
Fig. 670 – *Plectogyra perundata* CONIL & LYS at 658 m.

Fig. 13 gives our biostratigraphical conclusions and the extension of the main guide microfossils. Only those guides and a few other important microfossils will be mentioned here.

The sequense between 703.60 and 622 m is dated V1 on base of the presence of *Girvanella densa* CONIL & LYS and *Brunsia* sp. We note also the presence of *Endothyra agathis* (CONIL & LYS) and *Endothyra cuneisepta* (CONIL & LYS). We can give no conclusions for the sequence between 622 and 602 m, since it was not cored and there are no cuttings preserved. The upper part of this sequence from 703.60 and 602 m could be of V1b age: the typical V1b *ARCHAEDISCIDAE* are not present but this could have been caused by local ecological conditions.

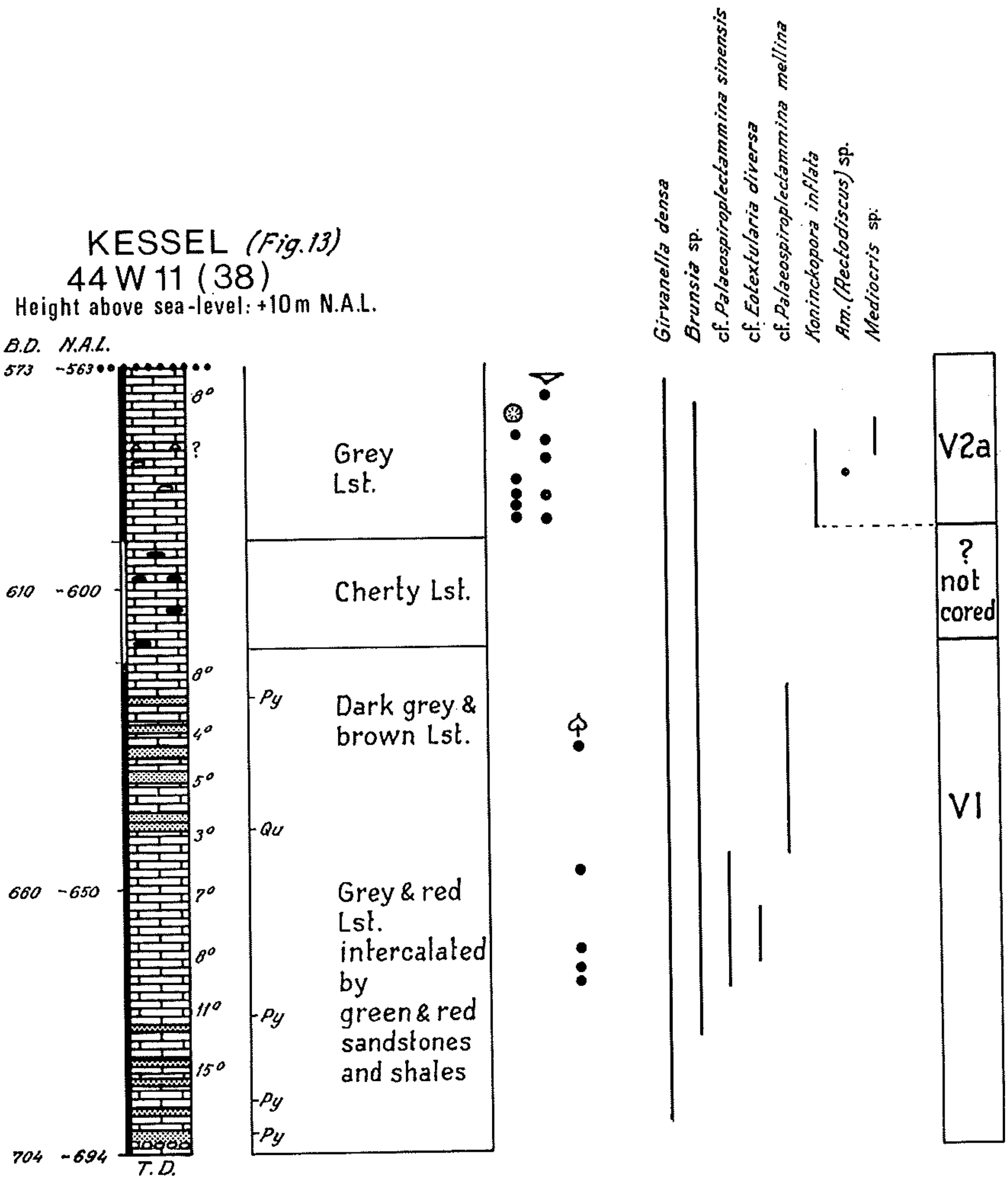
The first appearance of *Koninckopora inflata* (DE KONINCK) at 591 m and the presence of *Mediocris* sp. and *Ammarchaediscus* (*Rectodiscus*) sp. give a V2a age to the sequence from 602 to 573 m. We can note also the presence of *Endothyra nebulosa* MALAKHOVA and *Endothyra saleti* (CONIL & LYS). The Cretaceous rests upon this V2a sequence.

Tetrataxis and *Pseudotaxis*, genera feeling variations of ecological conditions, are not represented in the fauna.

3.5. BOOISCHOT BOREHOLE

The Booischot borehole was drilled in 1963 for the "Service Géologique de Belgique". The original unpublished descriptions by GULINCK, LEGRAND, OVERLAU & FOSTIER and the samples are kept at the "Service Géologique de Belgique" under the following reference number: 59E146(132). The Dinantian was reached at 438.50 m (= −423.50 m NAL) underlying Cretaceous (Campanian). The sequence between 438.50 m and 522 m consists of grained grey limestones which become white and crystalline in the lower part; between 478 m and 487 m, there is a breccia level with black clay, alterated limestone blocks and chalky rocks; there is a 2 m oolitic level at 445 m. From 522 m to 602 m, there is an alternation of limestones, shales, dolomites, sandstones and a few conglomerates with sandstone pebbles; there are a great number of root levels and paleosols. A fault is to be mentioned at 602 m. Underlying are 12 m of dolomites and dolomitized limestones, followed by 10 m of fine-grained black limestones becoming dolomitized at the bottom. From 635.50 to 699.50 m, there is a crystalline and fractured dolomite. From 699.50 to 802 m, we have an alternation of sandstones and quartzites with some shaly levels and a few conglomerates with sandstone pebbles. An alternation (802 m to 867 m) of grey and green shales with a 2 m limestone level at 839 m is followed by a thick limestone level between 867 and 876 m, 12 m of dolomitized shales and 4 m of hematitic oolites in a sandstone matrix. From 892 to 1288 m, we have a thick succession of conglomerates, of green colour till 1085 m and of red colour below. The borehole entered the Silurian at 1288 m and ended at 1330 m.

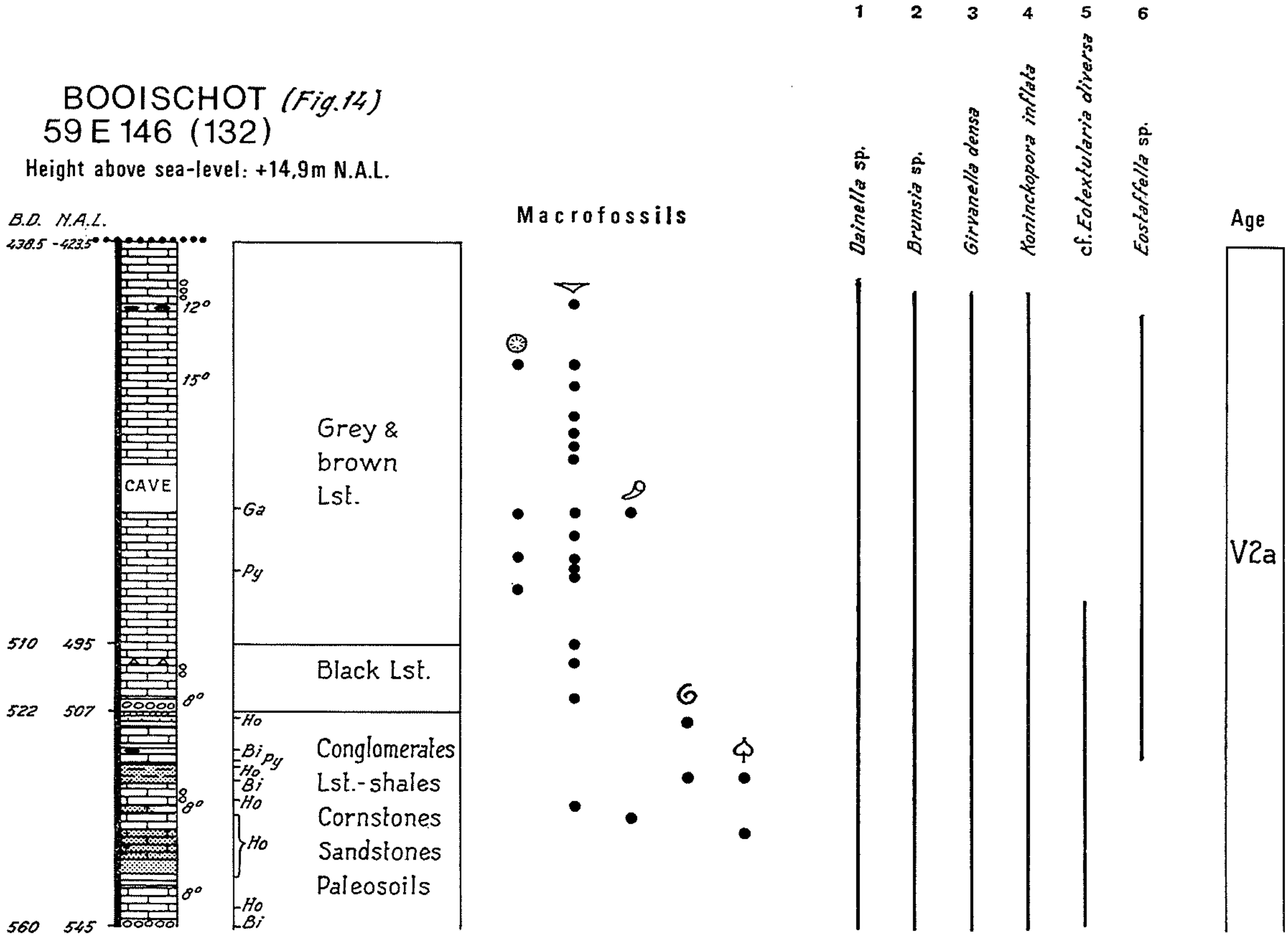
Lithological descriptions together with stratigraphic interpretations were published by LEGRAND (1964a, 1964b). The sequence between 439 and 636 m was attribued to the Lower-Middle Visean while the 64 m dolomitic sequence was considered to be of Tournaisian age. The sandstone series between 699.50 m and 802 m were related to the Upper Famennian (Fa2); between 802 m and 892 m, the sequence passed from the Lower Famennian (Fa1) into a coral facies of Upper Frasnian age and an oolitic level of undetermined Frasnian age. The sequence from 892 to 1085 m is related to the Frasnian (green conglomerates) and from 1085 to 1288 m (red conglomerates) to the Middle Devonian (Gvb). The Silurian was reported to be Lower Ludlow.

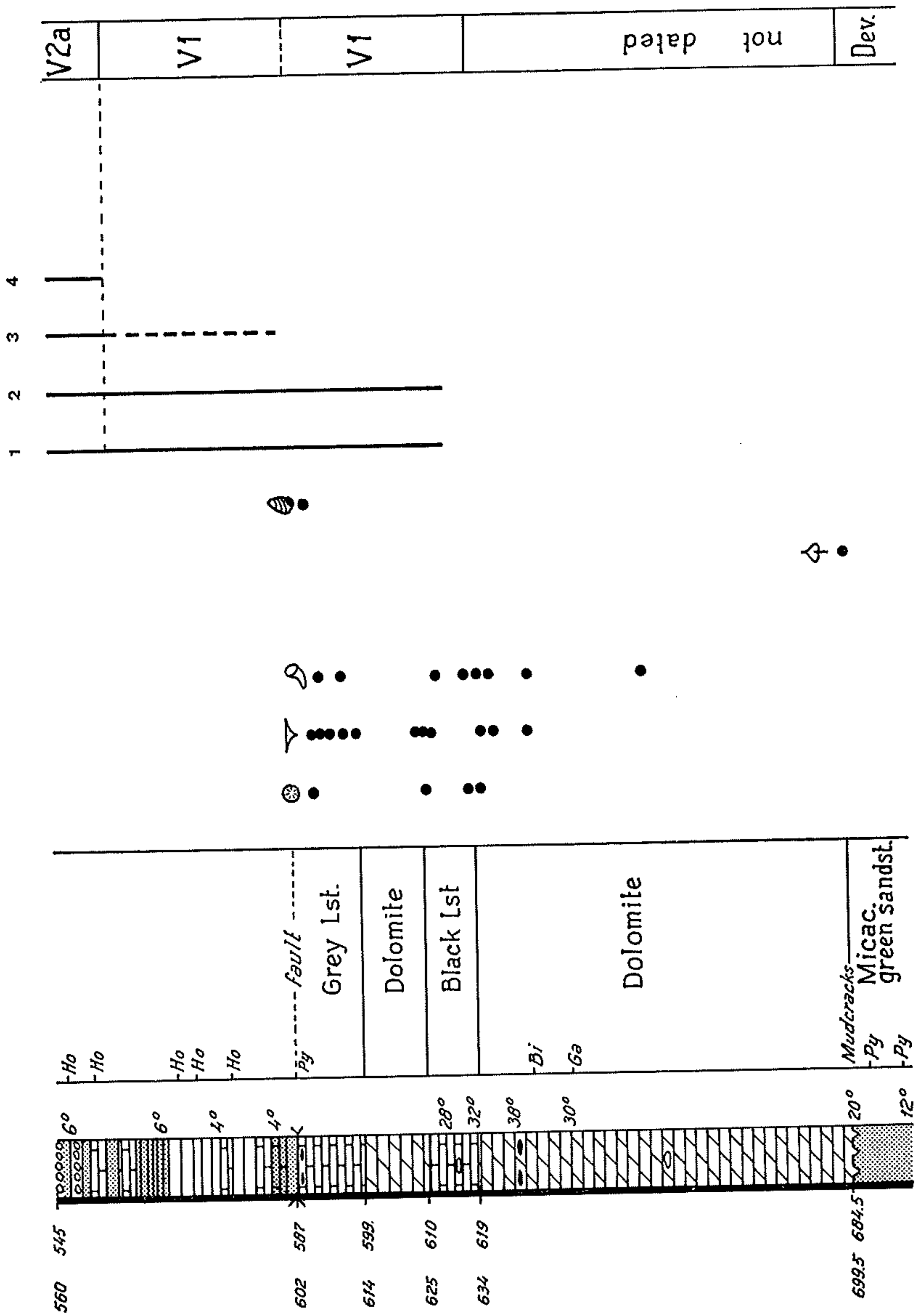


Stockmans & Willière (1964) reported a species of plant at 908.50 m: *Archaeopteris fimbriata* Nathorst and an analogous specimen from 1089.60 m.

Streel (1965, 1972) related the Devonian sequence from 918 m to 1120 m to the Middle Frasnian (F2) on base of miospore evidences.

A limestone level from 803 to 810 m has been recently dated by conodonts as being Lower Famennian (Groessens, unpublished); the 839 m limestone level has been dated Upper Frasnian to Lower Famennian (same); the coral fauna between 867 and 876 m, including *Phillipsastraea* and *Alveolites*,


BOOISCHOT (Fig.14)
59 E 146 (132)
Height above sea-level: +14,9m N.A.L.
B.D. N.A.L.
438.5 -423.5
510 495
522 507
560 545
12°
15°
8°
CAVE
Grey & brown Lst.
Black Lst.
Conglomerates
Lst.-shales
Cornstones
Sandstones
Paleosoils
Ga
Py
Ho
Bi
Macrofossils
1 Dainella sp.
2 Brunsia sp.
3 Girvanella densa
4 Koninckopora inflata
5 cf. Eotextularia diversa
6 Eostaffella sp.
Age
V2a


V2a
V1
V1
not dated
Dev.
1
2
3
4
fault
Grey Lst.
Dolomite
Black Lst.
Dolomite
Mudcracks
Micac. green sandst.
Ho
Ho
Ho
Ho
Ho
Py
Bi
Ga
Py
Py
6°
6°
4°
4°
28°
32°
38°
30°
20°
12°
545
587
599
610
619
684.5
560
602
614
625
634
699.5

has been dated Upper-Middle to Upper Frasnian (same).

Conil (1964) attributed the Dinantian limestone sequence to the V2a and the sequence with paleosols to the Lower Visean.

Voglet (1970), in a more detailed study, came to the same conclusions.

A few attemps were made to give a more precise age to the 64 m dolomite sequence; a first trial of channel samples of approximately 5 kg between 675 m and 680 m has given no results (Groessens, unpublished). A second set of 4 samples gave no more results (after Longerstaey, unpublished).

Eighteen foraminifera have been previously figured in Conil & Lys (1964, 1967), including the following holotypes in Conil & Lys (1964);

Fig. 496 – *Plectogyra bradyi* (Mikhailov) var. *submissa* Conil & Lys, holotype, 629.60 m.

Fig. 504 – *Plectogyra campinei* Conil & Lys, holotype, 629.60 m.

Fig. 14 gives our biostratigraphical conclusions and the extension of the main guide microfossils. Only those guides and a few other important microorganisms will be mentioned here.

The sequence below the fault (from 634 to 602 m) is dated by a rich V1 fauna of *Dainella* sp., *Brunsia* sp., *Tournayella gigantea* Lipina and many species of *Endothyra*, as *E. campinei* (Conil & Lys), *E. recta* Lipina and *E. spinosa* N. Tchernysheva, and *Plectogyranopsis convexa* (Rauser).

The upper part of the V1 sequence (from 602 to 570 m) could be of V1b age. As in Kessel, the *ARCHAEDISCIDAE* are not present but, again, this could have been caused by local ecological conditions.

The sequence from 570 m is dated V2a on base of the first appearance of *Koninckopora inflata* (De Koninck). This appearance and the presence of *Girvanella densa* Conil & Lys and *Dainella* sp. till the top of this sequence gives a V2a age to the whole sequence from 570 to 438.50 m. The fauna of this sequence is relatively poor. As in Kessel, the Cretaceous rests upon the V2a. As in Kessel, *Tetrataxis* and *Pseudotaxis* are absent.

Conodont research (after Longerstaey, unpublished):

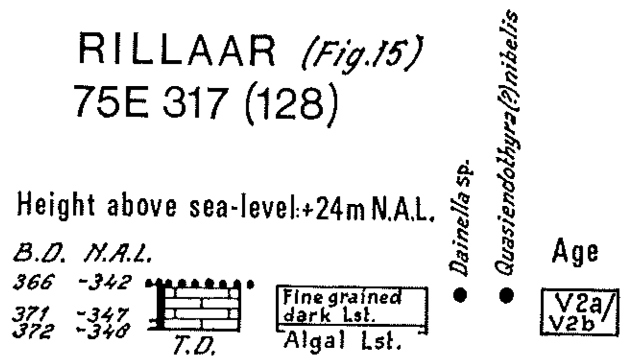
depth	weight of material dissolved	results
641 m	390 gr	no
658 m	450 gr	no
662 m	370 gr	no
697 m	350 gr	no

3.6. RILLAAR BOREHOLE

The Rillaar borehole was drilled in 1961 for the "Service Géologique de Belgique". The original unpublished lithological description by Gulinck and the samples are kept at the "Service Geologique de Belgique" under the following reference number: 75E317(128).

The Dinantian underlying Cretaceous (Campanian) was reached at 365.95 m (= −342 m NAL) and the borehole ended at 371.84 m. The whole sequence is a fine-grained dark limestone with about 1 m of algal limestone at the bottom. This sequence was attributed to the V1b-V2 by Conil (1964).

Four foraminifera have been previously figured by Conil & Lys (1964; figs. 88, 199, 456 and 557).



Here is the microorganisms assemblage recovered from 371.50 to 365 m (only the most important organisms):

Girvanella densa Conil & Lys
Koninckopora tenuiramosa Wood

Archaediscus (Archaediscus) stage *involutus*
Septabrunsiina sp.
Endothyra sp.
Globoendothyra sp.
Endothyranopsis crassa compressa (Rauser)
Quasiendothyra(?) *nibelis* Durkina
Dainella sp.

The simultaneous presence of *Quasiendothyra*(?) *nibelis*, *Endothyranopsis crassa compressa* both typical of V2b, and on the other hand, *Dainella* sp. and primitive *Archaediscus* could suggest two assumptions:

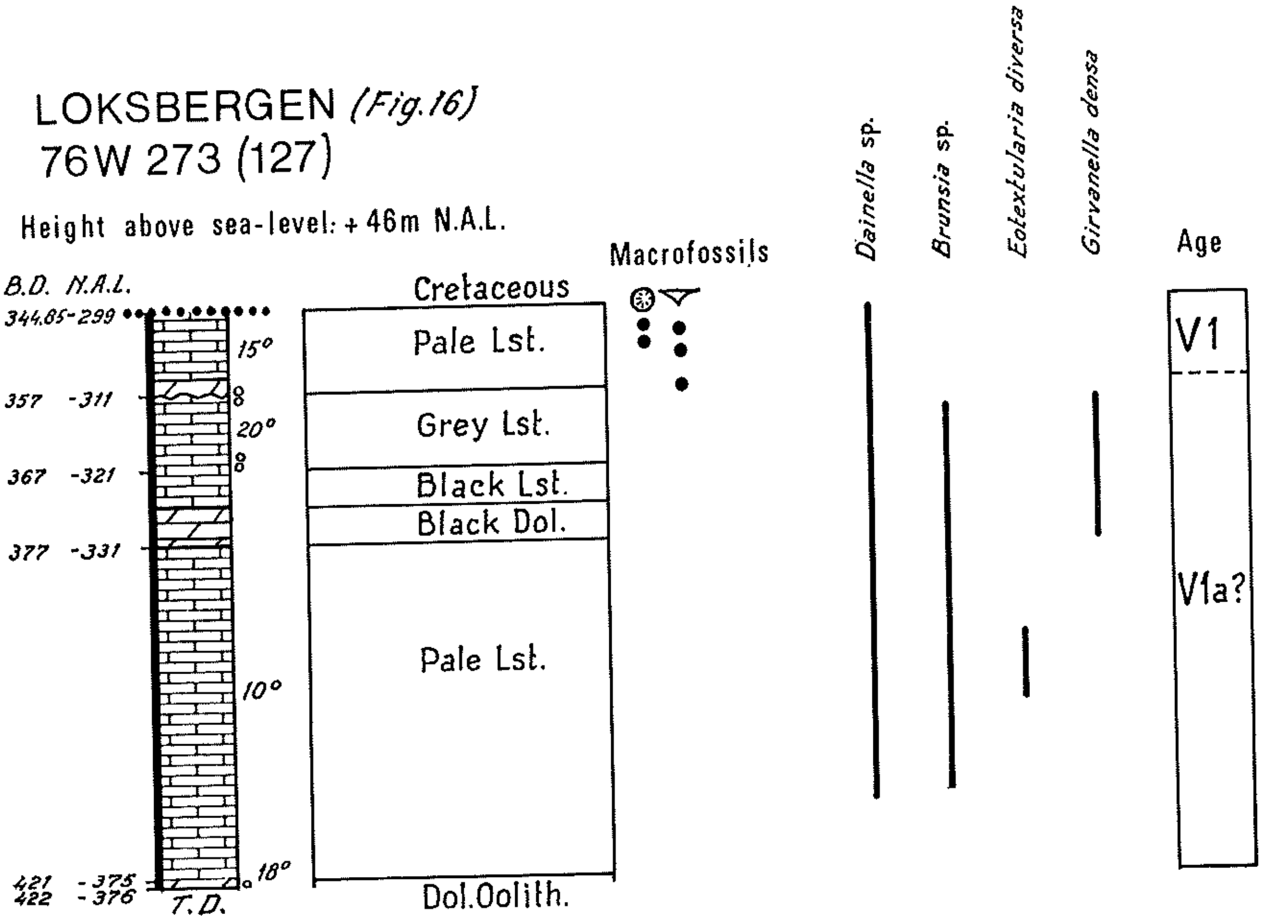
First: a reworked sequense, or

second: transitive assemblage between V2a and V2b, unknown until now in the other Belgian provinces.

3.7. LOKSBERGEN BOREHOLE

The Loksbergen borehole was drilled in 1960 for the "Service Géologique de Belgique". The original unpublished lithological description by Legrand and the samples are kept at the "Service Géologique de Belgique" under the following reference number: 76W273(127).

The Dinantian underlying Cretaceous marl was reached at 344.85 m (= −299 m NAL). From 344.85 to 357.60 m, we have a fine crystalline light-brown limestone, a little dolomitic at the base.



That sequence rests unconformably upon 1 m of oolitic limestone. From 358.85 to 367 m, we have a sequence of grey limestones, being alternately coarse or fine-grained. Six m of black grained limestones are followed by 5.8 m of black crystalline dolomites. The next sequence from 378.80 to 421.50 m is a light crystalline limestone sequence of dolomic aspect. The borehole ended at 422.04 m in an oolitic and dolomitic limestone.

The main part of the Dinantian sequence was attributed to the V2 by CONIL (1964).

Ten microfossils have been previously figured by CONIL & LYS (1964) including 2 holotypes:

Fig. 672 – *Plectogyra prisca* (RAUSER-CERN. & REITL.) var. *denticulata*, 390 m.

Fig. 778 - *Plectogyra(?) versata* 405 m.

Here is the microorganisms assemblage recovered from 420 to 350 m:

Girvanella densa CONIL & LYS
Koninckopora (primitive)

Brunsia sp.
Palaeotextularia ex gr. *consobrina* LIPINA
cf. *Palaeospiroplectammina mellina* (MALAKHOVA)
Eotextularia diversa (N. TCHERNYSHEVA)
Tetraxis sp.
Endothyra laxa (CONIL & LYS)
Dainella sp.

Issinella sp.

This assemblage is typical of V1 age. The absence of *ARCHAEDISCIDAE* suggest a V1a age.

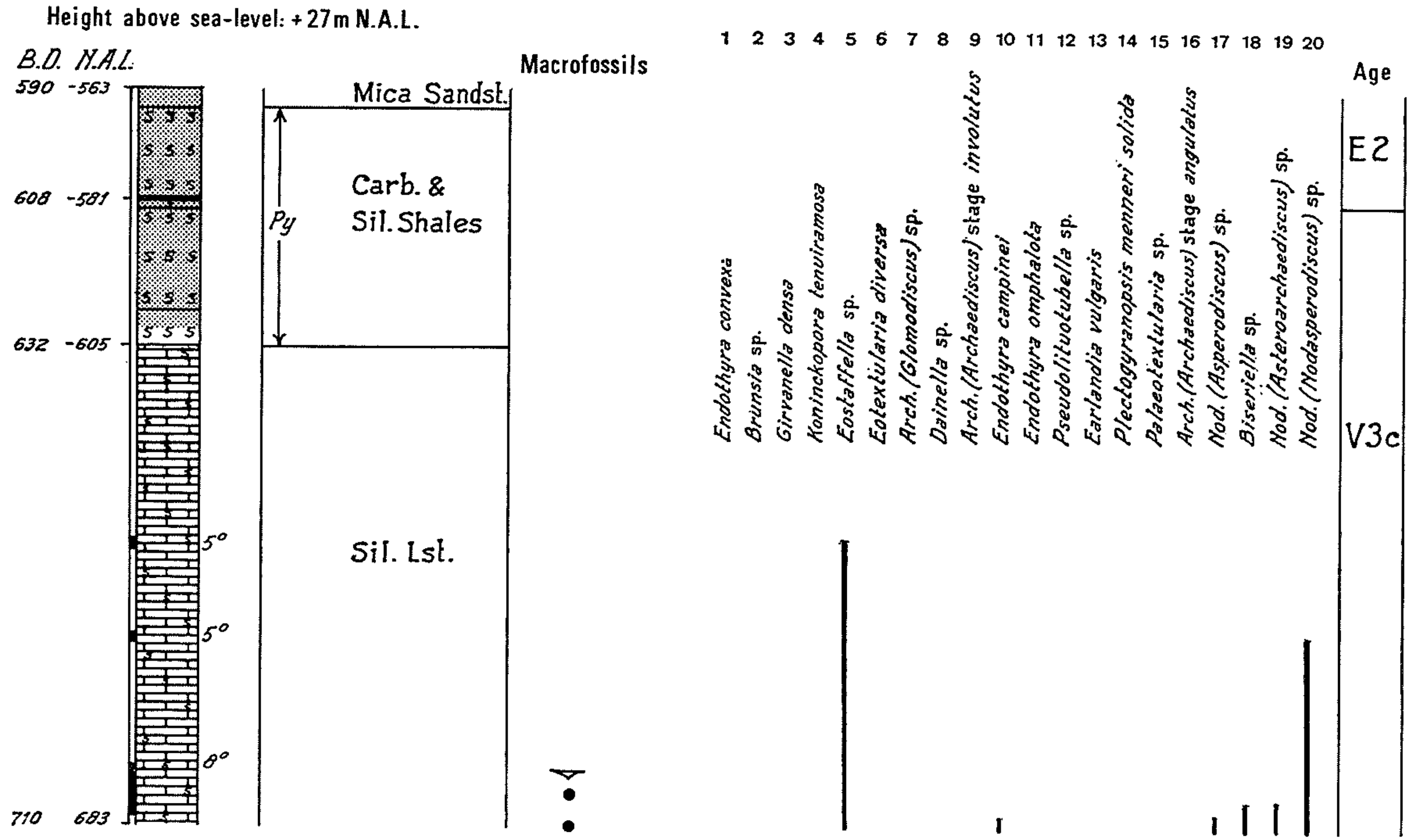
3.8. HALEN BOREHOLE

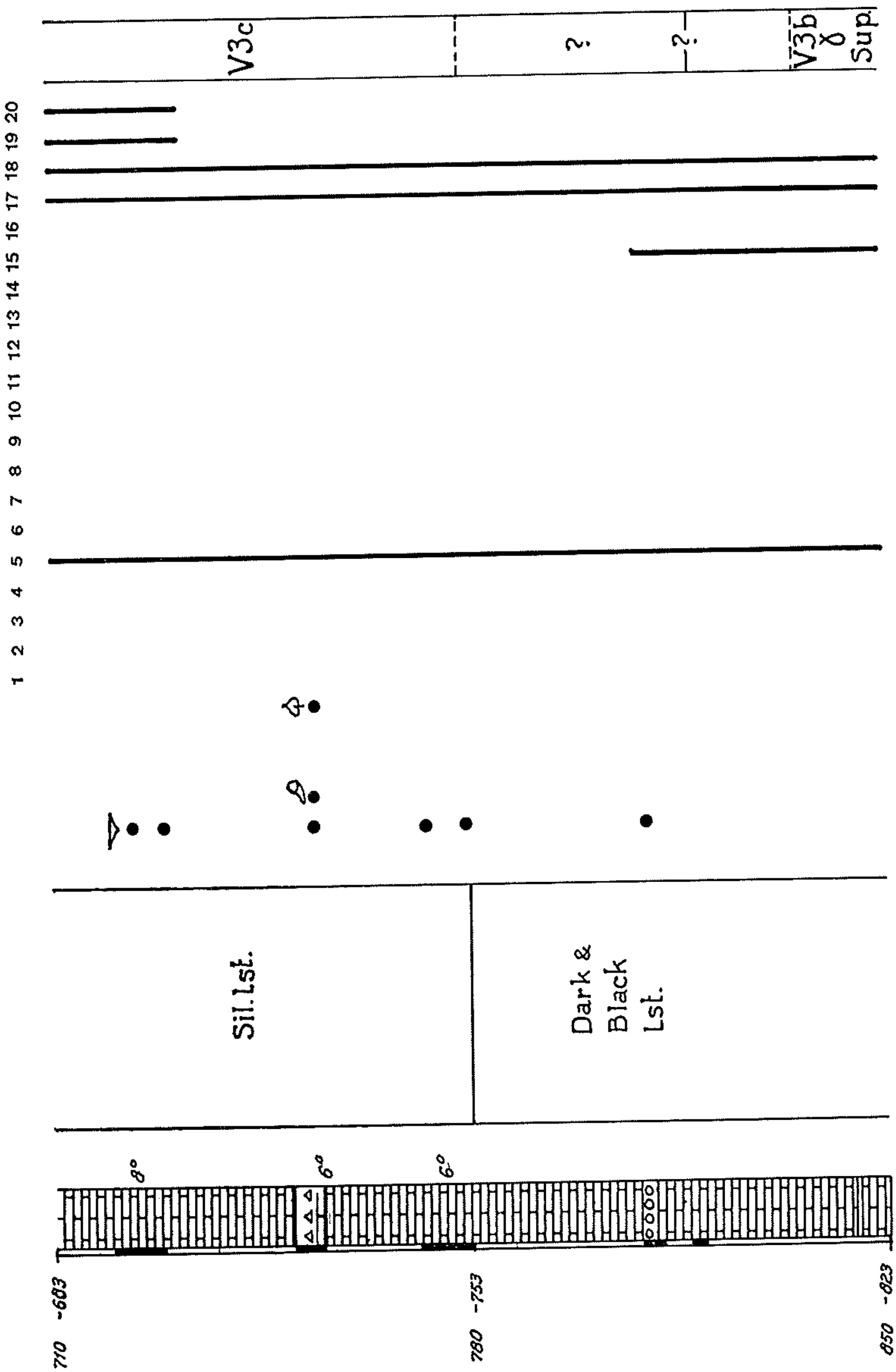
The Halen borehole was drilled between 1962 and 1965 for "La Citrique belge". The original unpublished litological descriptions by BOUCKAERT & LEGRAND and the samples are kept at the "Service Géologique de Belgique" under the following reference number: 76E243(131). The Carboniferous was reached at 349 m (= −322 m NAL) underlying Cretaceous. The Namurian sequence from 349 to 608 m (= −581 m NAL) considered to be the E2 zone, is much to thick and this sequence is probably faulted. The underlying sequence to total depth at 1366 m is of Dinantian age.

Here follows the lithological description; this description till 905 m must be read cautiously because coring was discontinued (only a very few levels were cored) and the description is based mainly on calcimetric data.

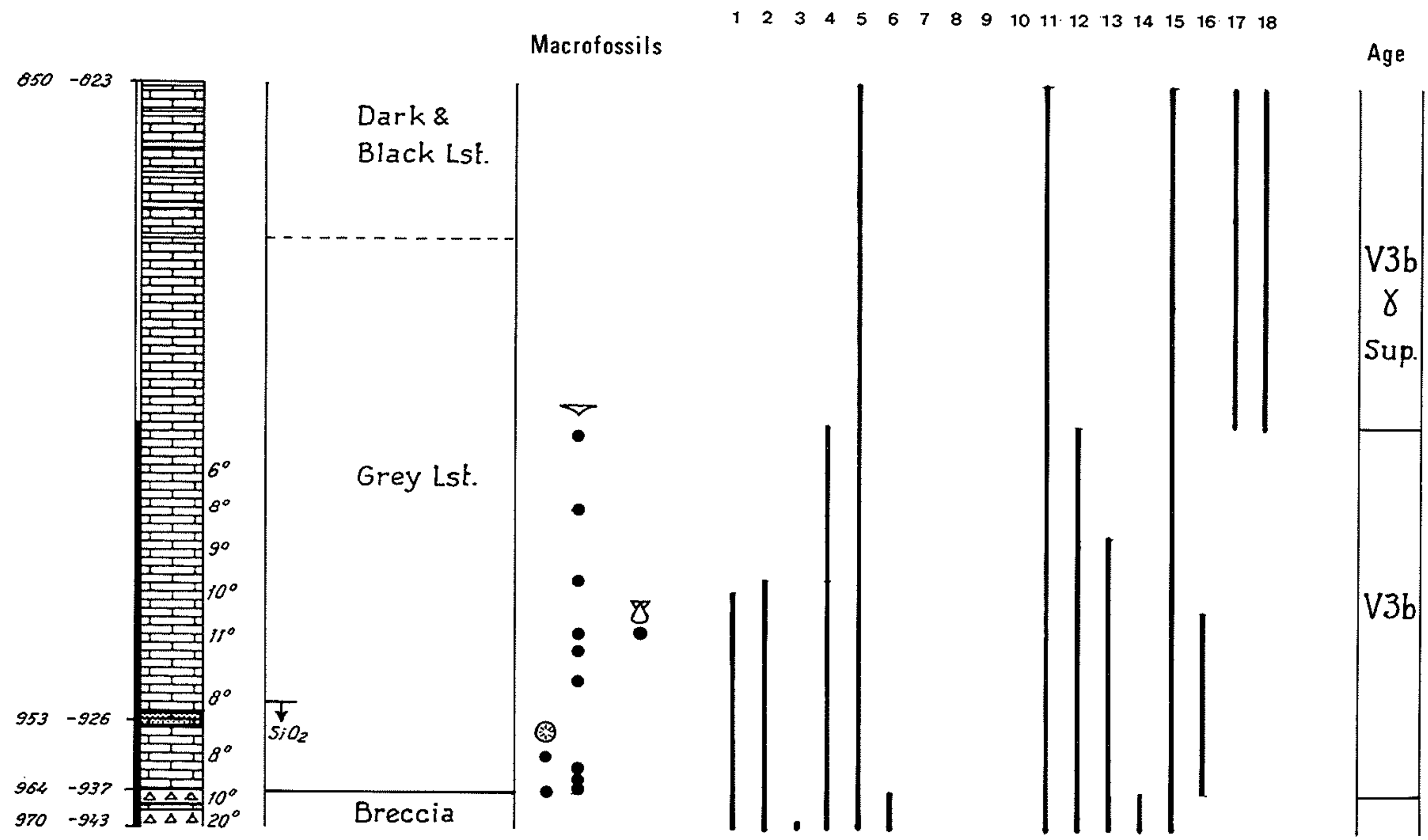
HALEN (Fig.17)

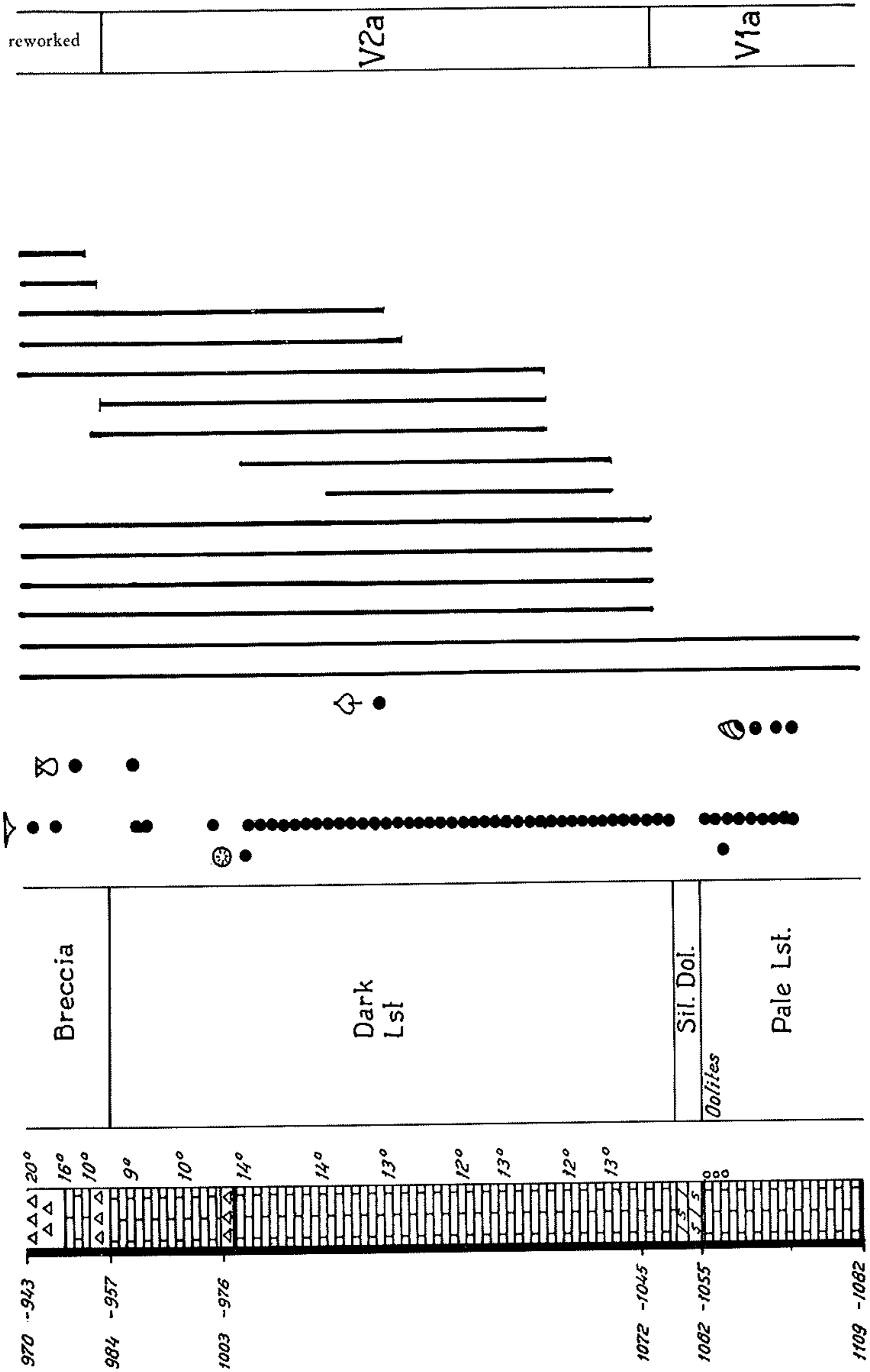
76E 243 (131)




V3c
?
?
V3b & Sup.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Sil. Lst.
Dark & Black Lst.
8°
6°
6°
710 -683
780 -753
850 -823

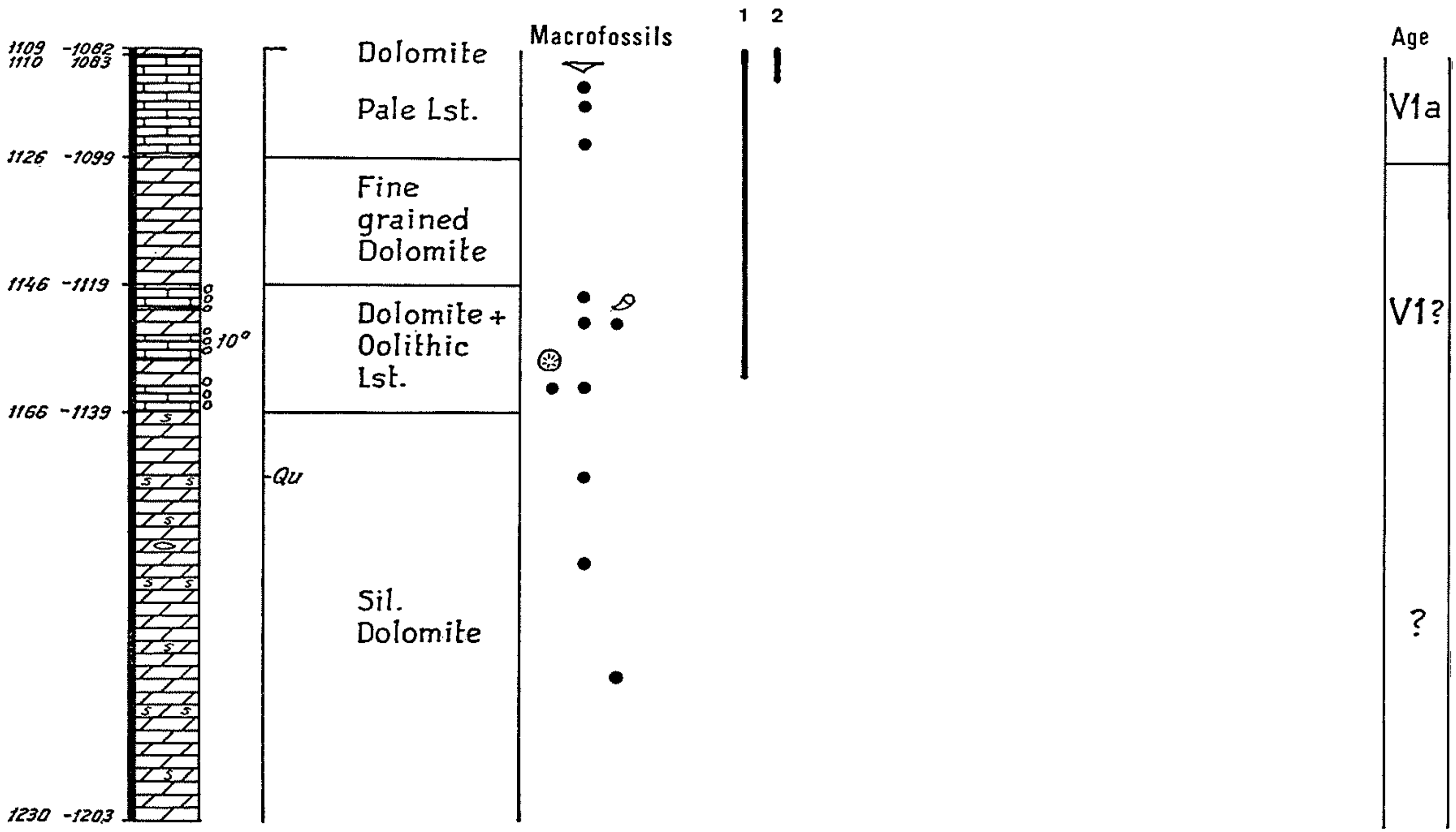
HALEN (continued)
76E 243 (131)

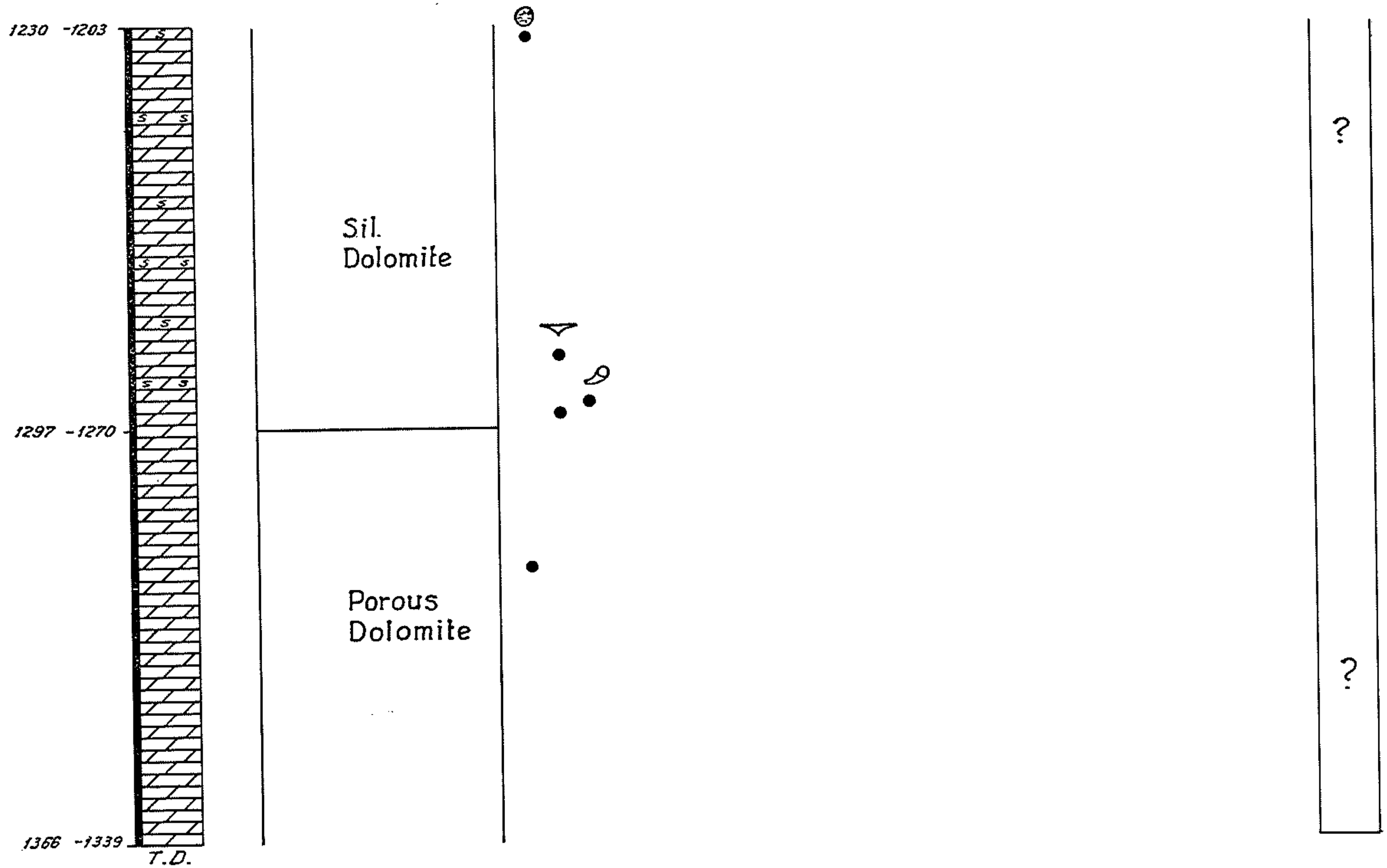




reworked
V2a
V1a
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Breccia
Dark Lsl
Sil. Dol.
Pale Lst.
Oolites
20° 16° 10° 9° 10° 14° 14° 13° 12° 13° 12° 13°
970 -943
984 -957
1003 -976
1072 -1045
1082 -1055
1109 -1082

HALEN (continued) 76E 243 (131)




1230 -1203
1297 -1270
1366 -1339
T.D.
Sil.
Dolomite
Porous
Dolomite
?
?

The sequence between 593 and 632 m, underlying argillaceous sandstones, is made of black siliceous and carbonaceous shales with pyrite. This sequence passes into a siliceous limestone with cherts till 780 m; a 1 m breccia level was encountered at 752 m. The next part of the sequence from 780 m to approximately 875 m is a dark and black limestone, being more siliceous in the upper part and more shaly in the lower; there is a calcareous conglomerate level at 810 m. From 875 to 1078 m, we have a great deal of grey grained limestones with a 2 m sandstone level at 952 m and a discountinuous breccia zone between 964 and 984 m; another 2 m breccia level occurs at 1002 m and a cherty level at 1050 m; the sequence around 1020 to 1040 m shows evidences of possible turbiditic structures. After 4 m of siliceous dolomites (1078 to 1082 m) and a thin oolitic level, the sequence continues with 44 m of grained and crystalline light limestones till 1126 m. At 1126 m, the borehole encounters a dolomitic sequence being an alternation of dolomites and grained oolitic limestones from 1126 to 1166 m, followed by siliceous dolomites till 1300 m with a few fracturation breccia levels. From 1300 m onwards there is a porous crystalline dolomite and the borehole ended in that sequence at 1366 m.

This dolomite sequence from 1166 till 1366 m was considered because of its lithology to be of Tournaisian age.

The upper part of the Dinantian sequence was attributed to the V3c by CONIL (1964). LEDERER (1973) made the first survey of the Dinantian foraminifers between 1125 and 678.80 m. Conodonts were recovered from the Upper Visean by BOUCKAERT (unpublished original description); they were restudied by GROESSENS (this paper). The detailed study of the microfauna was made by BOUZET (1975) and his stratigraphic conclusions are followed here.

A tentative was made to give a more precise age to the thick dolomitic sequence by means of conodonts, but it gave no results. See here the table of the sampled levels (after BOUZET, 1975).

depth	weight of material dissolved	results
1114 m	450 gr	no
1136 m	550 gr	no
1170 m	370 gr	Scolecodonte
1209 m	610 gr	no
1231 m	420 gr	no
1242 m	230 gr	no
1248 m	480 gr	no
1271 m	540 gr	no
1284 m	430 gr	no
1304 m	580 gr	no
1325 m	540 gr	no

One specimen of *Archaediscus suppressus* CHLYKOVA from Halen has been previously figured in CONIL & LYS (1968, fig. 152).

Fig. 17 gives our biostratigraphical conclusions and the extension of the main guide fossils. Only these guides and a few other important microfossils will be mentioned here.

Lower Visean (V1) has been recognized from 1185 to 1081 m, based on a very few foraminifers: *Endothyra convexa*(?), *Endothyra bowmani*. The absence of *ARCHAEDISCIDAE* suggests a V1a age.

The V2a follows from 1075 to 984 m, with a very abundant microfauna and microflora. The principal organisms are: *Koninckopora tenuiramosa* WOOD, *Girvanella densa* CONIL & LYS, *Pseudolituotuba gravata* (CONIL & LYS), *Pseudolituotubella* sp., *Brunsia* sp., *Archaediscus* (*Archaediscus*) stage *involutus*, *Archaediscus* (*Glomodiscus*) sp., *Ammarchaediscus* (*Rectodiscus*) *rotundus inflatus* (CONIL & LYS), *Plectogyranopsis convexa* (RAUSER), *Plectogyranopsis menneri solida* (CONIL & LYS), *Endothyra laxa* (CONIL & LYS) *Endothyra campinei* (CONIL & LYS), *Dainella fleronensis* (CONIL & LYS), *Eostaffella* sp.

Some of these fossils appear generally in Lower Visean, but the ecological conditions in the Halen borehole area, are so bad during V1, that their first appearance comes with Middle Visean.

Like in Turnhout, a reworked sequence lies upon the V2a, from 984 to 964 m, containing a very rich microfauna, which is probably typical of 3 different ages: *Plectogyranopsis menneri solida* (CONIL & LYS) and *Archaediscus* stage *involutus*, both from V2a age; *Koskinotextularia* sp. and *Archaediscus* stage *concavus* which could be typical of V2b–V3 age; *Archaediscus* stage *angulatus* which appears generally in the V3b.

Upon this reworked sequence, lies a V3b sequence (from 963.50 to 907 m) with: *Archaediscus* stage *angulatus*, *Nodosarchaediscus* (*Asperodiscus*) sp., *Endothyra omphalota* RAUSER & REITLINGER, and *Eostaffella* sp. (with compact dark wall).

The overlying sequence (from 906 to 808.90 m) is defined by the appearance of *Nodosarchaediscus* (*Asperodiscus*) sp. and principally by *Biseriella* sp. which appears in the English Central Province at the top of the D1 zone. In according with that biozonation, we suggest a V3bγ age.

The upper part of the borehole is V3c, based especially on the appearance of *Nodosarchaediscus* (*Asteroarchaediscus*) sp. and on his abundance at that level.

Samples between 700 and 810.50 m have yielded conodonts. The following species (all belonging to the genus *Gnathodus*) have been recognized:

Gnathodus commutatis commutatis (703.50 m, 705.45 m., 707 m, 808.50–810.50 m)
Gnathodus commutatus mononodosus (700 m, 700.25 m, 703.50 m)
Gnathodus commutatus nodosus (700 m?, 703.50 m?)
Gnathodus bilineatus bilineatus (808.50–810.50 m)
Gnathodus symmutatus homopunctatus (703.50 m)

Gnathodus symmutatus mermaidus (700 m, 700.25 m, 703.50 m, 705.45 m, 707 m?)
Gnathodus girtyi girtyi (700.25 m, 703.50 m)
Gnathodus girtyi meischneri (703.50 m, 808.50–810.50 m?)
bars only (703 m)

They suggest a V3bγ–V3c age for this interval.

3.9. WIJVENHEIDE BOREHOLE

The Wijvenheide borehole was drilled in 1920 for the "Charbonnages de Helchteren-Zolder". Descriptions and samples are kept at the "Service Géologique de Belgique" under the reference number 77W174(86). Top Dinantian underlying Namurian was reached at 1906.1 m (= −1866 m NAL). The Dinantian sequence to total depth at 1912.2 m consists of dark limestones with ampelitic joints at the top alternating with light grey fine-grained limestones with cherty nodules. This sequence has been attributed to the Upper Visean because of the lithology. Original descriptions were published by STAINIER (1922) and VRANCKEN (1922). The Namurian overlying the Dinantian has been attributed to the E2c cephalopod zone on the base of goniatites (DELMER 1963, BOUCKAERT 1967).

One thin section (pl. 7, fig. 1) was cut from a sample at 1912.19 m, but no microfossils were found.

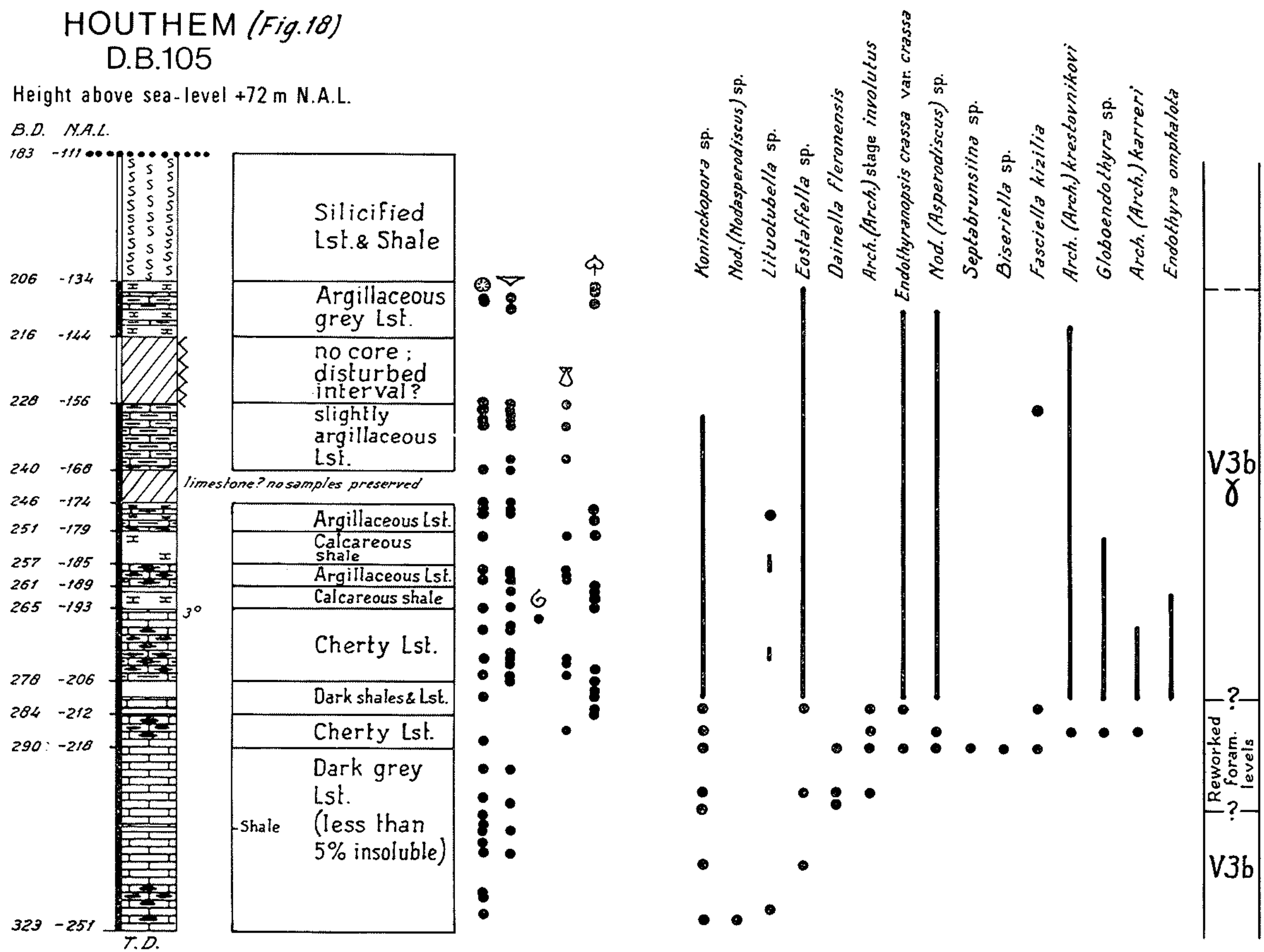
3.10. LANAKEN BOREHOLE

The Lanaken borehole has been drilled in 1898 for M. URBAN and M. PUTSAGE. The original unpublished description by MOURLON is kept at the "Service Géologique de Belgique" under the reference number 93E115(43). No samples have been preserved. A black phtanite was encountered at about 277 m (= −222 m NAL) underlying dark brown sands. The borehole ended in that sequence at about 278 m. DELMER (1963) considers the 272–278 m interval to represent the Namurian-Visean transition beds. Descriptions of this borehole were published by FINEUSE (1899), VAN ERTBORN (1901, 1905), FORIR (1901–1902), RENIER (1903), LEDOUX (1909) and DELMER (1963).

3.11. HOUTHEM BOREHOLE (DB105)

The Houthem borehole (= DB105) has been drilled between 1920 and 1921 for the "Rijksopsporing van Delfstoffen in Nederland". Top Carboniferous was reached at 183 m (= -111 m NAL). The sequence between 183 and 206 m consists of black to dark-grey silicified shales and limestones alternating with decalcified shales and siltstones containing few crinoid fragments. No core could be taken from these apparently weathered friable rocks. No samples from this interval have been preserved. From 206 to 216 m a black, partly argillaceous limestone occurs. From 216 to 228 m no core has been obtained. We suggest that this may have been a tectonically disturbed interval. From 228 m to total depth at 323 m (= −251 m NAL), the sequence consists of limestones which may locally be argillaceous or contain chert levels. Lithological descriptions have been published by TESCH (1924) and JONGMANS (1927b). They suggested that the whole sequence should be assigned to the Dinantian. DÉLÉPINE (1927, 1928) and DORSMAN (1945) described the macrofauna which is predominated by brachiopods. They correlated the fauna with the D3 coral Zone of VAUGHAN (1905) in Great Britain, the *Goniatites crenistria* cephalopod Zone of BISAT (1924) in Great Britain and with the upper part of the *Productus giganteus* brachiopod Zone of DÉLÉPINE (1911) in Belgium, what equals the V3bγ of PIRLET (1967c). A few fragments of macroflora from the interval between 261 and 277 m have been mentioned by JONGMANS (1927b). This author compared a specimen of *Sphenopteridium* (from 264.00 - 270.90 m interval according to JONGMANS 1927b, but from 284 m according to JONGMANS & VAN RUMMELEN 1937) with *S.* cf. *pachyrrhachis*, a species that has been described by HARTUNG & PATTEISKY (1960) from the cephalopod zones *Goniatites intermedius* and *Goniatites striatus falcatus* (topmost V3bγ to lower V3c of DEMANET 1938) in the East Sudetic area and by WALTON (1931) from strata with *Goniatites sphaericostriatus* (V3c) in North Wales and from the Cementstone and Oil Shale Groups in Scotland. The ostracode fauna from the interval between 228 and 238 m has been described by DÉLÉPINE (1927, 1928), DORSMAN (1945) and BECKER & BLESS (1974). They compared this fauna with similar assemblages described by DE KONINCK (1841, 1844), JONES & KIRKBY (1874) and BECKER & BLESS (1974) from the Upper Visean (V3b-c) of Belgium and the Dinantian of Great Britain. DÉLÉPINE (1927) and CONIL & LYS (1964) mentioned the occurrence of a few foraminifers. PATIJN (1963), THIADENS (1963) and LEGRAND (1968) consider the sequence between 183 and 204 m to be of Namurian age according to the geological maps of the Paleozoic abrasion surface published by these authors. THIADENS (1963) followed JONGMANS & VAN RUMMELEN (1930) in their believe that this sequence consists of loose ampelite debris. Neither the radiolarians mentioned by DÉLÉPINE (1928) from the 251 m level, nor the diatoms noticed by ZANON (1938) from 228 m have been recognized again by us.

The whole limestone sequence from 207 to 320 m has been attributed to the upper V3bγ on the base of the rich microfauna and -flora. The sequence starts (in ascending order) from 320 to 300 m with a relatively poor microfauna including notably *Nodosarchaedscus* (*Nodosperodiscus*) sp. which is typical of V3b–V3c age. From 300 to 280 m, a few levels contain a remarkable reworked microfauna. But there is no evidence that this complete interval


HOUTHEM (Fig.18)
D.B.105
Height above sea-level +72 m N.A.L.
B.D.
N.A.L.
183 -111
206 -134
216 -144
228 -156
240 -168
246 -174
251 -179
257 -185
261 -189
265 -193
278 -206
284 -212
290 -218
323 -251
T.D.
3°
limestone? no samples preserved
Silicified Lst.& Shale
Argillaceous grey Lst.
no core; disturbed interval?
slightly argillaceous Lst.
Argillaceous Lst.
Calcareous shale
Argillaceous Lst.
Calcareous shale
Cherty Lst.
Dark shales & Lst.
Cherty Lst.
Dark grey Lst. (less than 5% insoluble)
Shale
Koninckopora sp.
Nod. (Nodasperodiscus) sp.
Lituotubella sp.
Eostaffella sp.
Dainella fleronensis
Arch. (Arch.) stage involutus
Endothyranopsis crassa var. crassa
Nod. (Asperodiscus) sp.
Septabrunsiina sp.
Biseriella sp.
Fasciella kizilia
Arch. (Arch.) krestovnikovi
Globoendothyra sp.
Arch. (Arch.) karreri
Endothyra omphalota
V3b
γ
?
Reworked foram. levels
?
V3b

should contain reworked elements. The five most important levels of this interval and their reworked microfauna are listed below.

297 m: *Koskinobigenerina* sp. (V3b)
Archaediscus (Archaediscus) stage *involutus* (V1b–V2a–(V2b))
Nodosarchaediscus (Nodosarchaediscus) sp. ((V2a)–V2b–V3)
Dainella fleronensis (Conil & Lys) (V1–V2a)
Dainella exuberans (Conil & Lys) (V1–V2a)

290 m: *Septabrunsiina* cf. *bouckaerti* Conil & Lys (Fa2a–Tn1b)
Archaediscus (Archaediscus) convexus Grozdilova & Lebedeva (V2–V3)

289 m: *Septabrunsiina* cf. *kingirica* (Reitlinger) (Fa2d–Tn1b)
Forschiella prisca Mikhailov ((V1b)–V2b–V3)
Palaeotextularia ex gr. *longiseptata* Lipina (V3b–Nm)
Koskinotextularia sp. (V2b–V3)
Archaediscus (Archaediscus) vertens Conil & Lys (V3b)
Archaediscus (Archaediscus) stage *involutus* (V1b–V2a–(V2b))
Nodosarchaediscus (Asperodiscus) sp. (V3b–Nm)
Endothyra agathis (Conil & Lys) (V1–V3)
Endothyranopsis crassa (Brady) (V3b–Nm)
Dainella fleronensis (Conil & Lys) (V1–V2a)
Fasciella kizilia Ivanova (V3bγ–V3c)

286 m: *Archaediscus (Glomodiscus)* sp. (V1b–V2a)
Archaediscus (Archaediscus) stage *involutus* (V1b–V2a–(V2b)
Archaediscus (Archaediscus) stage *concavus* (V2b–V3)
Nodosarchaediscus (Nodosarchaediscus) sp. (V2a–V3)
cf. *Howchinia bradyana* (Howchin) (V3b–Nm)
Vissariotaxis compressa (Brazhnikova) (V3b)
Globoendothyra delmeri Conil & Lys (V2–V3)
cf. *Euxinella sp.* (V3b–V3c)
Millerella sp. (V2–V3)

282 m: *Archaediscus (Archaediscus)* stage *involutus* (V1b–V2a–(V2b))
Archaediscus (Archaediscus) vertens Conil & Lys (V3b)
Endothyranopsis crassa (Brady) (V3b–Nm)
Fasciella kizilia Ivanova (V3bγ–V3c)

Like in Halen and Turnhout, this reworked sequence is of upper V3b age.

Two more levels (273 and 228 m) may contain microbreccias as suggested by thin sections.

The overlying sequence (from 280 to 207 m) is defined by a rich microfossils assemblage, which is typical of V3bγ age.

Koninckopora mortelmansi Mamet
Koninckopora tenuiramosa Wood
Girvanella ducii Wethered
Parathurammina suleimanovi Lipina
Archaesphaera inaequalis (Derville)
Palaeocancellus sp.
Pseudolituotuba gravata (Conil & Lys)
Earlandia vulgaris (Rauser & Reitlinger)
Lituotubella glomospiroides Rauser
Pseudolituotubella sp.
Forschiella prisca Mikhailov
Pseudoammodiscus sp.
Brunsia sp.
Archaediscus (Nudarchaediscus) sp.
Archaediscus (Archaediscus) stage *angulatus*
Archaediscus (Archaediscus) krestovnikovi Rauser
Archaediscus (Archaediscus) karreri Brady
Archaediscus (Archaediscus) aff. *grandiculus* Chlykova
Archaediscus (Archaediscus) aff. *spira* Conil & Lys
Nodosarchaediscus (Nodosarchaediscus) sp.
Nodosarchaediscus (Asperodiscus) sp.
Palaeotextularia ex gr. *longiseptata* Lipina
Climacammina sp.
Cribrostomum sp.
Tetrataxis sp.
Pseudotaxis "*pusillus*" (Conil & Lys)
Valvulinella sp.
Biseriella sp.
Endothyra omphalota minima Rauser & Reitlinger
Plectogyranopsis ampla (Conil & Lys)
Endothyranopsis crassa (Brady)
Globoendothyra sp.
Euxinella aff. *efremovi* (Vdovenko & Rostovceva)
Janischevskina cf. *orbiculata* (Ganelina)
Millerella sp.
Eostaffella sp.
Mediocris sp.
Fasciella kizilia Ivanova

Some 85 samples have been tested for conodonts. Eighteen samples yielded conodonts, whereas four samples yielded scolecodonts. Each sample had a weight of about 100 to 150 gr. Samples at 214.54–216.20 m and 267.50 m contained reworked conodonts.

Gnathodus commutatus commutatus (206.50-207.10 m, 214.54-216.20 m, 258-259 m(?), 267.50 m, 297.63-299.61 m)
Gnathodus bilineatus bilineatus (208.27-208.47 m, 285.65-290.35 m)
Gnathodus symmutatus symmutatus (207.10-208.27 m, 267.50 m, 269.34-270.04 m)
Gnathodus symmutatus homopunctatus (206.50-207.10 m, 208.27-208.47 m, 214.54-216.20 m, 269.34-270.04 m, 289.41-290.35 m)
Gnathodus symmutatus mermaidus (207.10-208.27 m, 214.54-216.20 m)
Gnathodus girtyi girtyi (269.34-270.04 m)
Gnathodus girtyi collinsoni (206.50-207.10 m(?))
Gnathodus girtyi simplex (267.50 m(?))
Gnathodus girtyi meischneri (254 m)
Gnathodus simplicatus (299.61-301.29 m)

Reworked conodonts:
Siphonodella obsoleta (214.54-216.20 m)
Geniculatus glottoides (267.50 m)

Bars only (208.47-210.50 m, 246.30-246.94 m, 246.94-248.70 m, 270.91-272.56 m, 272.56-274.48 m, 288 m)

Scolecodonts (296.42-297.02 m, 305.41-306.15 m, 313.94-314.43 m, 318.89-319.64 m)

The fauna as a whole points to a V3b–V3c age. The reworked *Siphonodella* species characterizes the Tn1b to Tn2c in Belgium. *Geniculatus glottoides* is a rare species only known below the V3b of Germany thus far. It is here presumed to have been reworked.

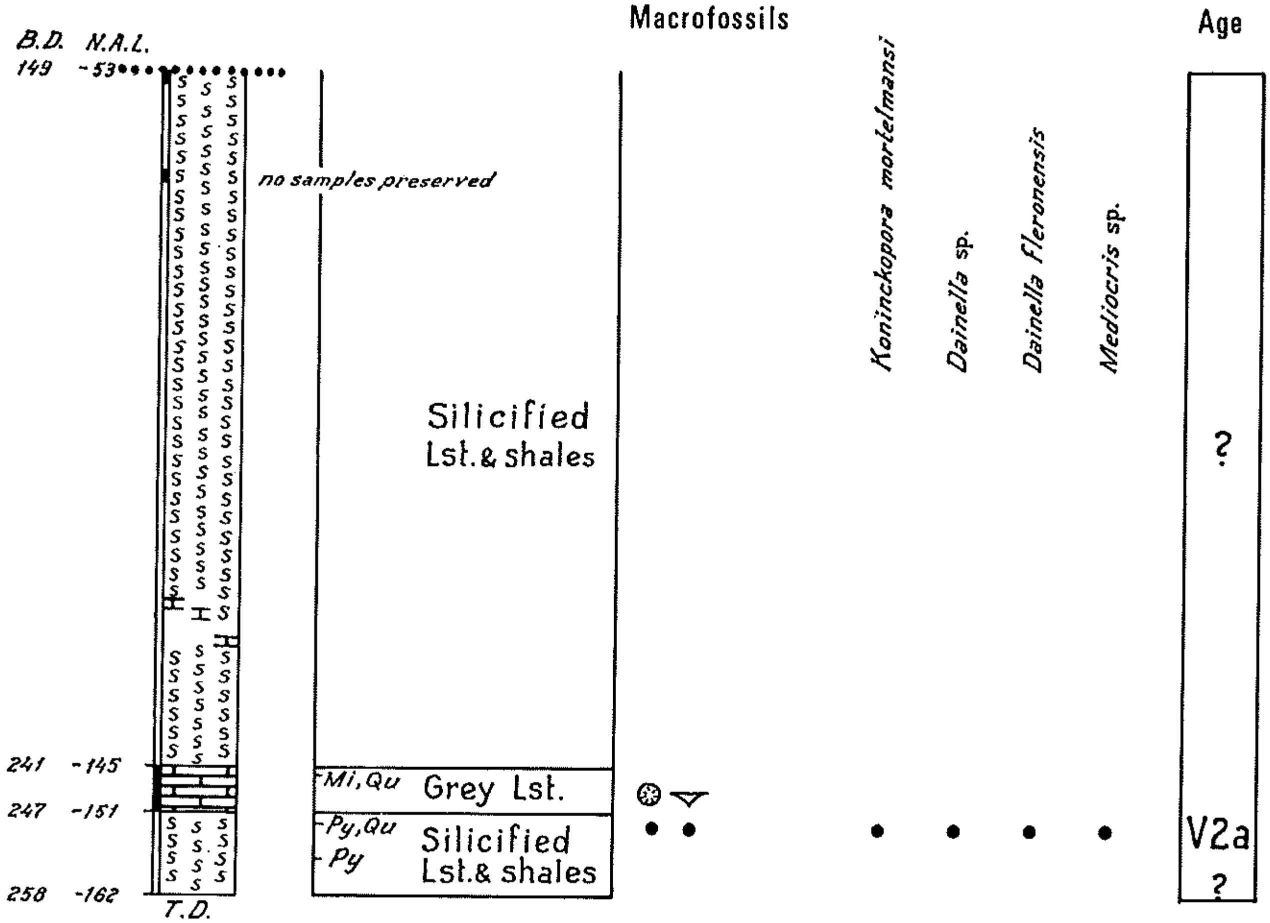
Ostracode research: see chapter 4.3.

3.12. CADIER EN KEER BOREHOLE (DB109)

The Cadier en Keer borehole (= DB109) has been drilled in 1921 for the "Rijksopsporing van Delfstoffen in Nederland". Top Carboniferous

CADIER EN KEER *(Fig. 19)*
D.B.109

Height above sea-level +96.7 m N.A.L.



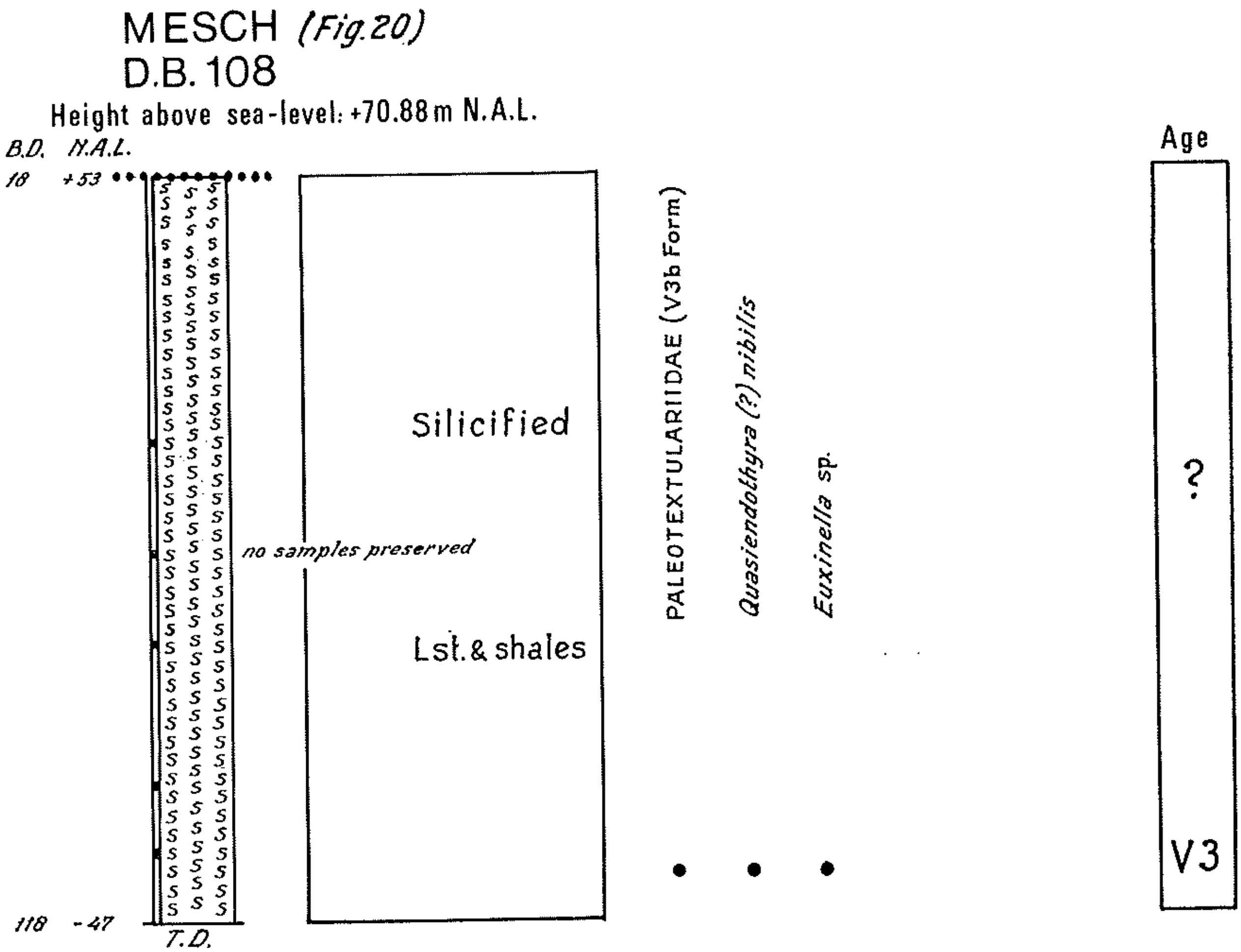
was reached at 149 m (= −53 m NAL). The sequence between 149 and 241 m consists of dark grey to black silicified shales and limestones. From 241 to 247 m, a dark-grey – partly argillaceous – limestone was recognized. From 247 m to total depth at 258 m (= −162 m NAL), partly silicified and subsequently decalcified limestones occur. The lithology has been incompletely described by TESCH (1924). JONGMANS & VAN RUMMELEN (1930) give a complete description. The latter authors changed in 1930 the lithological description of the interval between 149 and 241 m in such a way, that it was suggested that this sequence consists of a loose breccia of ampelites instead of a solid, but rather friable rock. TESCH (1924) and DORSMAN (1945) presumed that the whole sequence should be assigned to the Dinantian. PATIJN (1963), THIADENS (1963) and LEGRAND (1968) placed the sequence between 149 and 241 m in the Namurian

Samples have been stored with the collections of the "Geologisch Bureau" at Heerlen.

The following thin sections from the borehole have been examined: 241.90 m (1 thin section), 249 m (4) and 253.52 m (2). Only the 249 m sample has yielded an important microfossils assemblage.

Koninckopora mortelmansi MAMET

Pachysphaerina pachysphaerica (PRONINA)
Baituganella sp.
Earlandia vulgaris (RAUSER & REITLINGER)
Glomospiranella sp.
Laxoseptabrunsiina (Spinolaxina) pauli (CONIL & LYS)
Pseudolituotubella sp.
Septabrunsiina sp.
Spinochernella sp.
Brunsia sp.
Brunsia spirillinoides (GROZDILOVA & LEBEDEVA)
Archaediscus (Glomodiscus) sp.
PALAEOTEXTULARIIDAE
Endothyra sp.
Endothyra inflata LIPINA forma *maxima*
Endothyra laxa (CONIL & LYS)



Endothyra recta LIPINA
Dainella sp.
Dainella fleronensis (CONIL & LYS)
Dainella magna (VDOVENKO)
Endospiroplectammina cf. *syzranica* (LIPINA)
Plectogyranopsis sp.
Loeblichia (Urbanella) fragilis (LIPINA)
Eostaffella sp.
Mediocris sp.

Issinella sp.

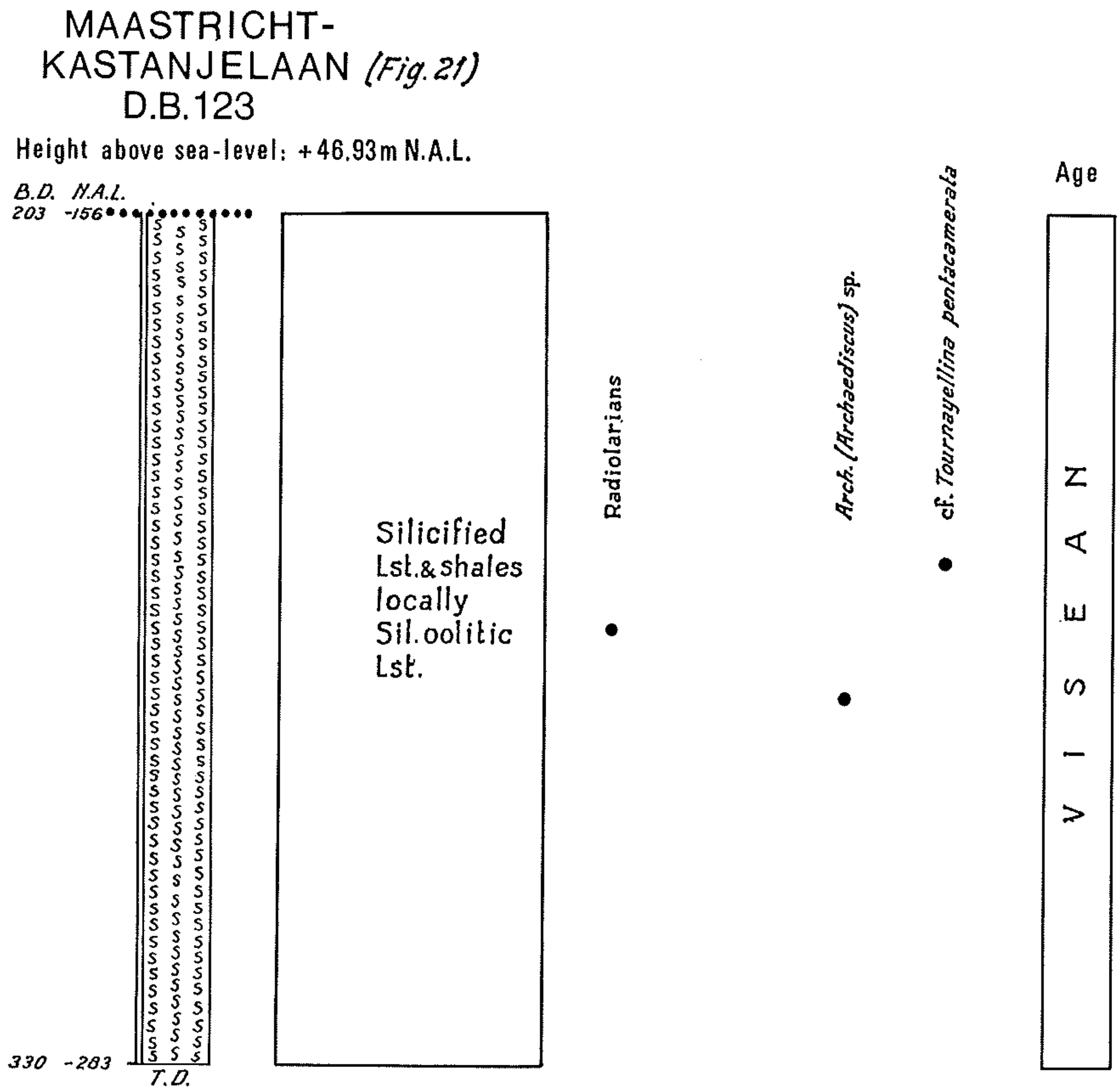
The presence of evolved *Koninckopora* and *Mediocris* together with *Dainella* sp. and *Dainella fleronensis* suggests a V2a age.

Conodont research:

depth	weight of material dissolved	results
241.90 m	± 100 to 150 gr	no
249 m	idem	no
253.52 m	idem	no

3.13. MESCH BOREHOLE (DB108)

The Mesch borehole has been drilled in 1921 for the "Rijksopsporing van Delfstoffen in Nederland" in order to check the eventual occurrence of "terre-houille" (coalmeasures) mentioned by HARZE (1899) and FORIR (1899) from the nearby "fosse no. 2" of HARZE (= DB89). This latter hole penetrated dark rocks, which we now presume to be of Devonian age and comparable to those recognized in the Belgian borehole 108W333. The top Carboniferous in the Mesch borehole was reached at 18 m (= +53 m NAL). The whole sequence to total depth at 118 m (= −47 m NAL) consists of dark grey to black cherts, silicified shales and incompletely silicified (partly decalcified) limestones. Some of the samples contain abundant sponge spicules. The lithology has been described by TESCH (1924), JONGMANS (1927b) and JONGMANS & VAN RUMMELEN (1930), who presumed the interval between 18 and 102 m to be Mesozoic overburden. The latter authors changed moreover the lithological description in such a way, that it was suggested that no solid rock had been found, but only a loose ampelite debris. However, the day reports of the driller mention "hard shale with chert and sandstone" or "hard shale with chert and limestone". The sequence was believed to be Dinantian by TESCH



(1924) and DORSMAN (1945), but Namurian by PATIJN (1963), THIADENS (1963) and LEGRAND (1968).

Samples have been stored with the collection of the "Geologisch Bureau" at Heerlen.

Two thin sections have been cut from the 109–116 m level. They yielded the following microfossils.

Koninckopora sp.

Brunsia sp.
Archaediscus sp.
PALAEOTEXTULARIIDAE (V3b form)

Endothyra sp.
Endothyra ex gr. *omphalota* RAUSER & REITLINGER
Endothyra ex gr. *bowmani* PHILLIPS
cf. *Planoendothyra* sp.
Quasiendothyra(?) nibelis DURKINA
Euxinella sp.

AOUJGALIIDAE

These microfossils are not very well preserved and the silicification prevents us in most cases to give specific names. The assemblage suggests an Upper Visean age (V3).

Two thin sections have been cut from the 36-35 m level, but they did not contain microfossils.

3.14. MAASTRICHT-KASTANJELAAN BOREHOLE (DB123)

The Maastricht-Kastanjelaan borehole (=DB123) has been drilled between 1927 and 1929. Top Carboniferous was reached at 203 m (= –156 m NAL). From 203 m to total depth at 330 m (= –283 m NAL), silicified limestone was found. The lithology has been described by JONGMANS & VAN RUMMELEN (1930) and JONGMANS & DRIESSEN (1932). These authors suggested that the sequence consisted of loose ampelite debris of probably Silesian age. DORSMAN (1945) interpreted the sequence as Cambro-Silurian to Devonian, whereas PATIJN (1963) and THIADENS (1963) believed it to be Cambro-Silurian. VAN LECKWIJCK (1956) and LEGRAND (1968) presumed a Namurian age for the same. Samples are preserved at the Geologisch Bureau at Heerlen.

The following levels have been restudied: 240–250 m (1 thin section), 250–260 m (3), 260–270 m (1) and 270–280 m (1).

We recovered one foraminifer from the 250–260 m level, a Chernyshinellinae similar to *Tournayellina pentacamerata* BOZORGNIA (V1a of Alborz, Iran). The silicification prevents us from defining clearly the wall structure.

The 260–270 m level sample is made of radiolarian skeletons.

A very badly preserved *Archaediscus* (*Archaediscus*) sp. was recovered from the 270–280 m level. This suggests a Visean age (V1b–V3) for the whole sequence.

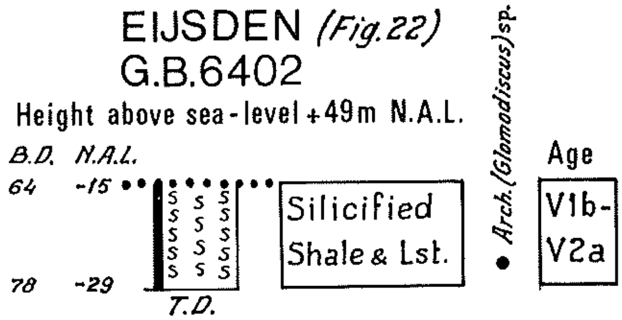
3.15. EIJSDEN BOREHOLE (GB6402)

The Eijsden borehole (= GB6402) has been drilled in 1974. Top Dinantian was reached at 64 m (= –15 m NAL). The sequence to total depth at 78 m (= –29 m NAL) consists of incompletely silicified and subsequently decalcified limestones, locally intercalated by whitish or black weathered clay with brachiopod spines. The silicified limestone is slightly fossiliferous here and there. At other places it looks like a silicified varvoid cryptite. Samples are kept at the Geologisch Bureau at Heerlen.

The following levels have been sampled: 75–76 m (2 thin sections), 73.8–74.5 m (1), 72–73 m (1) and 69–70 m (1). Only the 75–76 m level has yielded microfossils.

Earlandia vulgaris (RAUSER & REITLINGER)
Archaediscus (Glomodiscus) sp.
Endothyra sp.
Eoparastaffella sp.

The presence of *Archaediscus* (*Glomodiscus*) sp. suggests a V1b–V2a age.



3.16. HOUTAIN-ST-SIMÉON BOREHOLE

The Houtain-St-Siméon borehole has been drilled in 1965 for the "Service Géologique de Belgique". The original unpublished lithological description by DELMER & GRAULICH and the samples are kept at the "Service Géologique de Belgique" under the reference number 107E246.

Namurian underlying Cretaceous was reached at 92 m (= +63.7 m NAL), while the Namurian-Visean boundary was reached at 143.80 m (= +12.50 m NAL). The Visean sequence to total depth at 202 m consists mainly of silicified limestones with a phtanitic bed at about 153 m. Between 164 and 171 m, the rock is a calcareous sandstone. Many levels throughout the sequence consist of crinoidal limestone. BOUCKAERT & GRAULICH (1966) published a detailed lithology and dated the limestone interval by means of conodonts. LEGRAND (1968) gives a concise description of the same borehole.

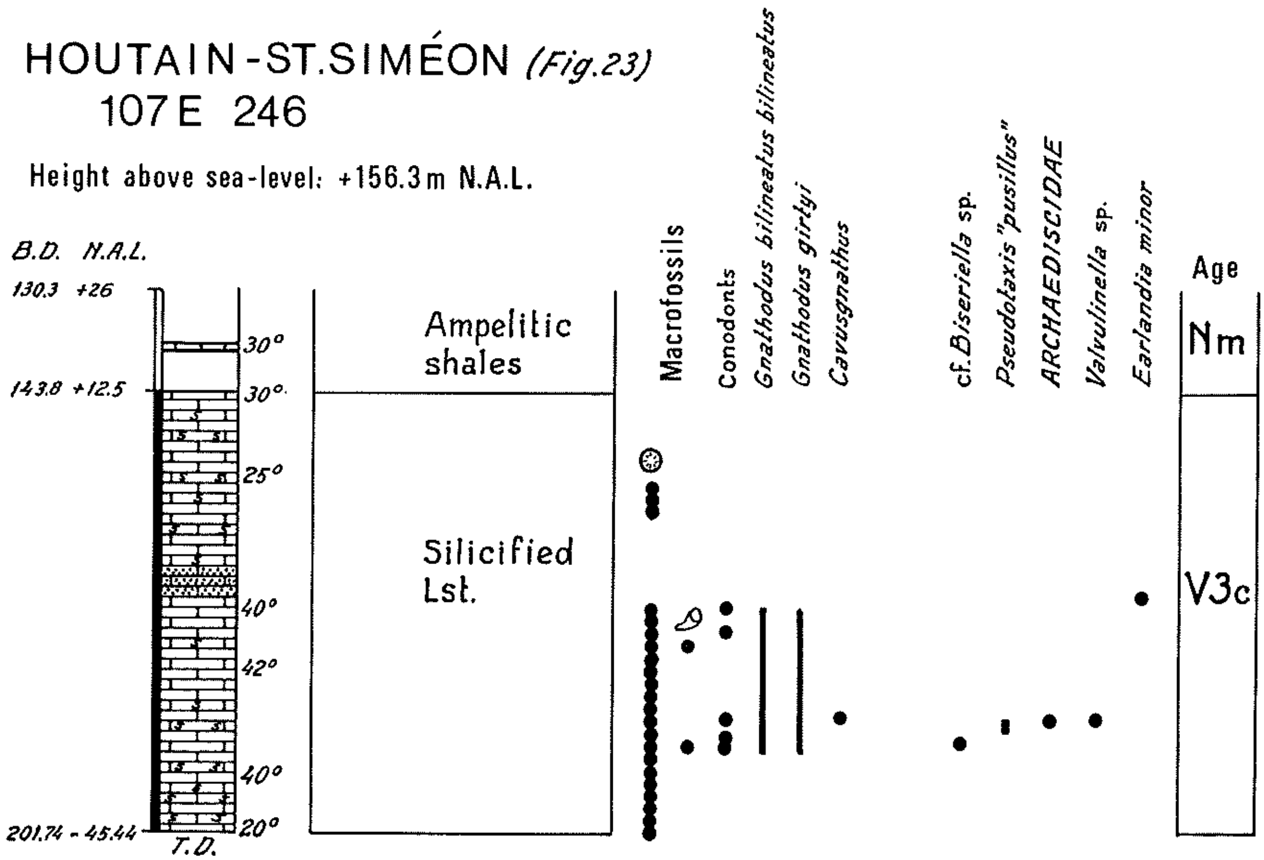
The microfauna recovered from 19 thin sections cut throughout the limestone interval is poor. The following species should be mentioned.

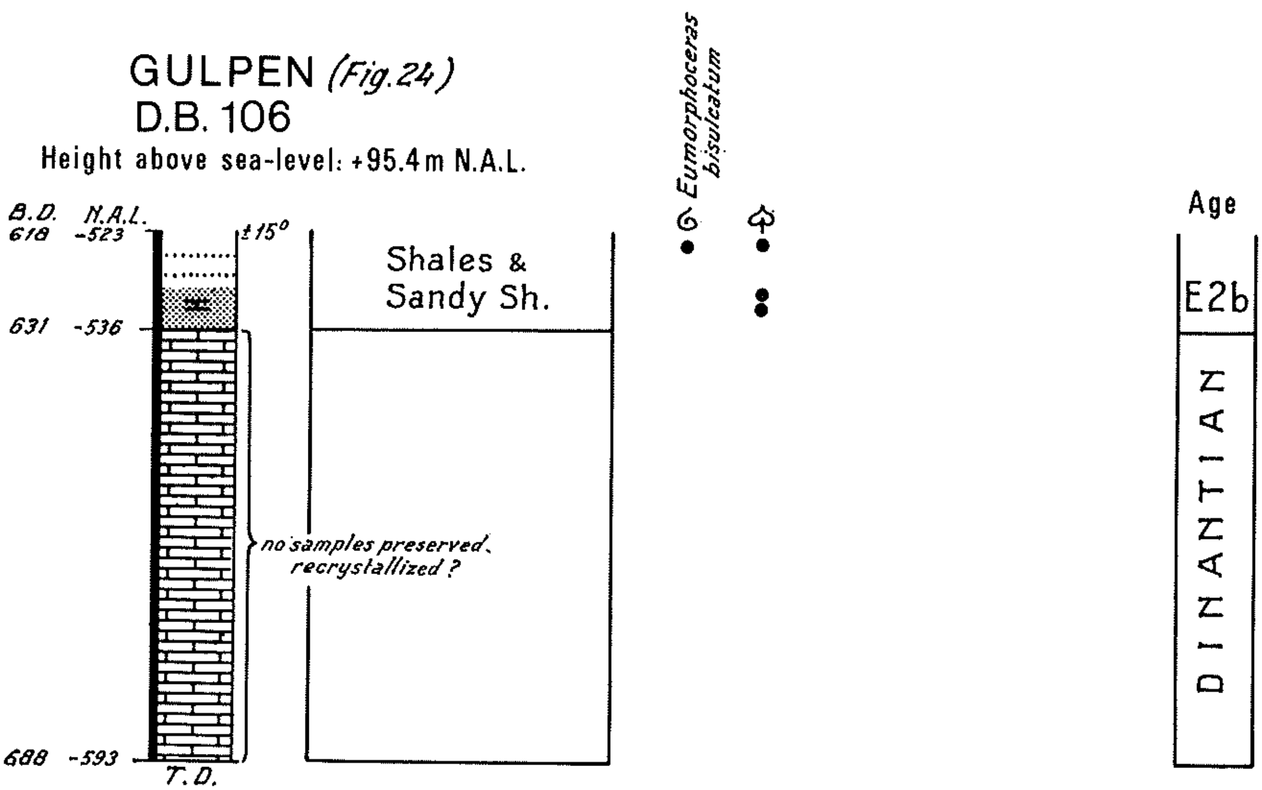
Archaesphaera sp.
Archaesphaera inaequalis (DERVILLE)
Earlandia minor (RAUSER)
Tetrataxis sp.
Pseudotaxis "pusillus" (CONIL & LYS)
cf. *Biseriella* sp.
Valvulinella sp.
Archaediscus (Archaediscus) karreri BRADY
Endothyra sp.

This assemblage suggests a V3bγ–V3c age.

This age has been more precisely determined by the conodont study. A few levels have been sampled between 171 and 190 m (171 m, 175 m, 187 m, 189 m, 190 m) and yielded the following assemblage, which is typical of the V3c.

Gnathodus bilineatus bilineatus (at all levels)
Gnathodus girtyi girtyi (at all levels except 171 m)
Gnathodus girtyi collinsoni (at 171 m)
Gnathodus girtyi turritus (at 175 m)
Gnathodus commutatus commutatus (at 190 m)
Gnathodus commutatus mononodosus (at 187 m and 190 m)
Gnathodus commutatus nodosus (at 187 m, 189 m and 190 m)
Cavusgnathus cristatus (at 187 m)


HOUTAIN-ST.SIMÉON (Fig.23)
107E 246
Height above sea-level: +156.3 m N.A.L.
B.D. N.A.L.
130.3 +26
143.8 +12.5
201.74 - 45.44
T.D.
30°
30°
25°
40°
42°
40°
20°
Ampelitic shales
Silicified Lst.
Macrofossils
Conodonts
Gnathodus bilineatus bilineatus
Gnathodus girtyi
Cavusgnathus
cf. Biseriella sp.
Pseudolaxis "pusillus"
ARCHAEDISCIDAE
Valvulinella sp.
Earlandia minor
Age
Nm
V3c


GULPEN (Fig.24)
D.B. 106
Height above sea-level: +95.4 m N.A.L.
B.D. N.A.L.
618 -523
631 -536
688 -593
T.D.
±15°
Shales & Sandy Sh.
no samples preserved, recrystallized ?
Eumorphoceras bisulcatum
Age
E2b
DINANTIAN

3.17. GULPEN BOREHOLE (DB106)

The Gulpen borehole (= DB106) has been drill- between 1920 and 1921 for the "Rijksopsporing van Delfstoffen in Nederland". Top Carboniferous was reached at 66 m (= +29 m NAL). The sequence between 66 and 631 m consists of an alternation of shales and sandstones containing a rich macroflora and -fauna of Namurian age. The sequence from 631 m (= −536 m NAL) to total depth at 688 m (= −593 m NAL) consists of black, recrystallized(??) limestone. Lithological descriptions of the Carboniferous in this borehole have been published by TESCH (1924) and JONGMANS (1927a). JONGMANS stated that the limestone was completely recrystallized. Unfortunately, no samples of the limestone interval have been preserved. The macrofauna of the Namurian has been described by JONGMANS (1927a) and DORSMAN (1945), who mentioned a goniatite horizon at 618 m at some 13 m above the limestone. The most significant species are *Eumorphoceras bisulcatum* and *Cravenoceratoides* sp. (the latter specimen from 562 m). This suggests an Arnsbergian (E2a-b) age for the shales. The occurrence of the plant *Gulpenia limburgensis* at six meters above the limestone (JONGMANS 1927a) confirms this age. The same species has been recognized by STOCKMANS & WILLIÈRE (1953) and VAN LECKWIJCK, STOCKMANS & WILLIÈRE (1953) in the Arnsbergian of Belgium. If we accept that the limestone is of Dinantian age, we must conclude that the basal Namurian (Pendleian and eventually lowermost Arnsbergian) is either missing or condensed into less than 6 m. THIADENS (1963) stated that a "small unconformity is present in the Gulpen boring" between Namurian and Dinantian. This unconformity is not mentioned by TESCH (1924) and JONGMANS (1927a), but may be deduced indeed from the fossil evidence as shown here.

3.18. WACHTENDONK-1 BOREHOLE

The Wachtendonk-1 borehole was drilled in 1957. The section has been described by ELBERSKIRCH & WOLBURG (1962). Top Dinantian was reached at about 293 m (= −256 m NAL). From 293 m to about 580 m, organogenic and occasionally oolitic limestone occurs with a few macrofossils between 293 and 296 m, amongst which the brachiopod *Productus* (*Linoproductus*) *rhenanus*. This fossil points to a Visean age for the limestone. Between 580 and 587 m, a cave was found with a breccious filling of residual sediment derived from limestone. Micropaleozoological investigation of 210 gr material from this interval (J. INDANS, personal communication) yielded some sedimentary structures, which might be interpreted as the inner moulds of chambers of some post-Carboniferous foraminifers. Palynological research (sample treated with HF, H_2O_2 and $NaBO_3$) yielded a few spores which do not permit any conclusions about the age of the sample (H. GREBE, personal communication). ELBERSKIRCH & WOLBURG (1962) compared the cave-filling with Miocene "Hemmoor Letten".

Below this cave, at about 590 m, a dolomite sequence follows. This sequence without any recognizable fossils continues to about 718 m and overlies quartzitic Famennian sandstones. These sandstones are often micaceous and may contain some diminuted plant debris.

From 579 to 293 m, a microfossils assemblage has been recovered, which suggests a V1 age.

Girvanella densa CONIL & LYS
Koninckopora sp. (primitive form)

Earlandia vulgaris (RAUSER & REITLINGER)
Brunsia sp.
PALAEOTEXTULARIIDAE
Tournayella sp.
Septabrunsiina sp.
Endothyra laxa (CONIL & LYS)
Endothyra cuneisepta (CONIL & LYS)
Endothyra inflata LIPINA
Endothyra sp.
Dainella sp.
Eostaffella sp.

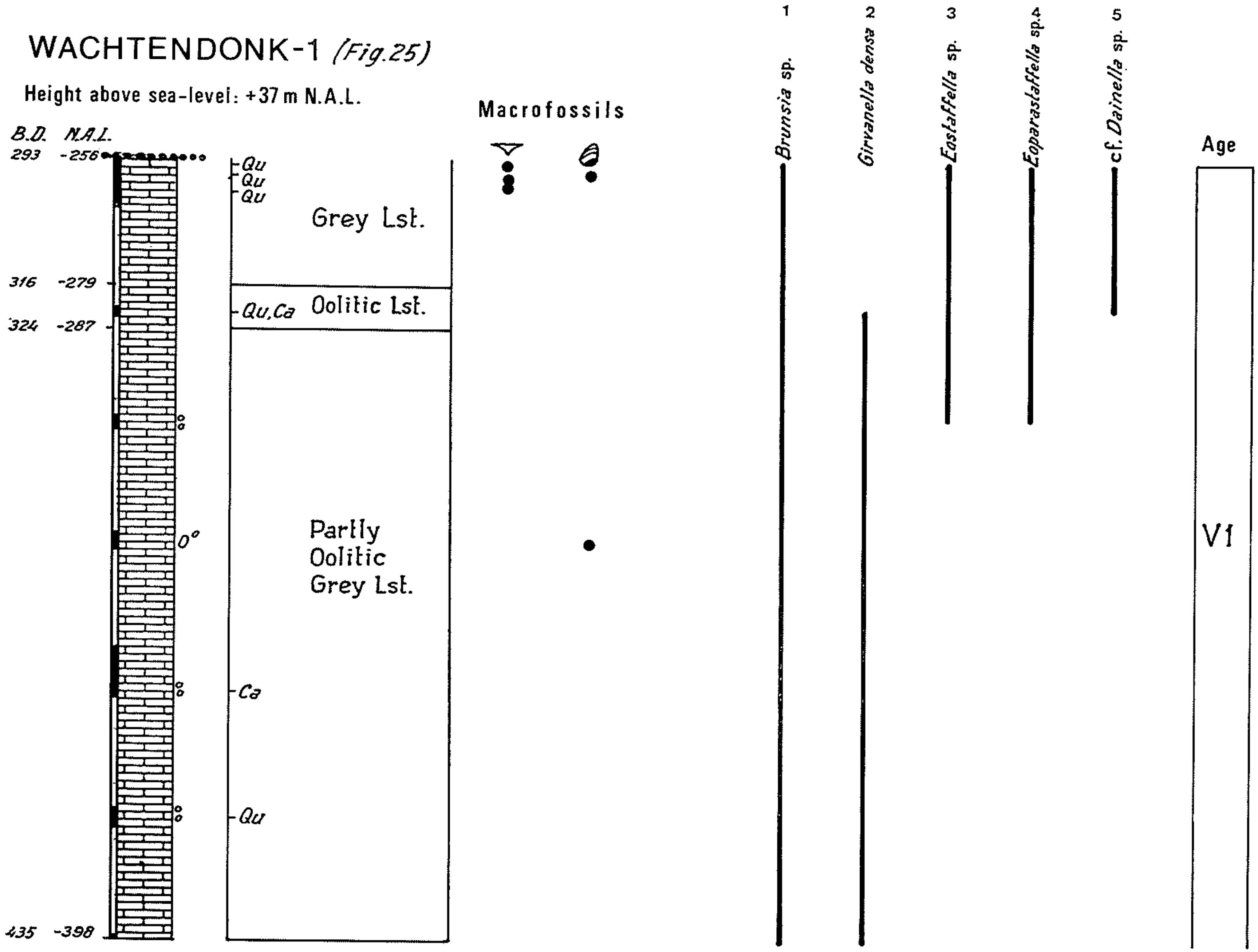
As stated by ELBERSKIRCH & WOLBURG (1962), BÖGER and ZIEGLER have investigated fifteen samples from the limestone and dolomite interval on the eventual occurrence of conodonts. No conodonts have been recovered.

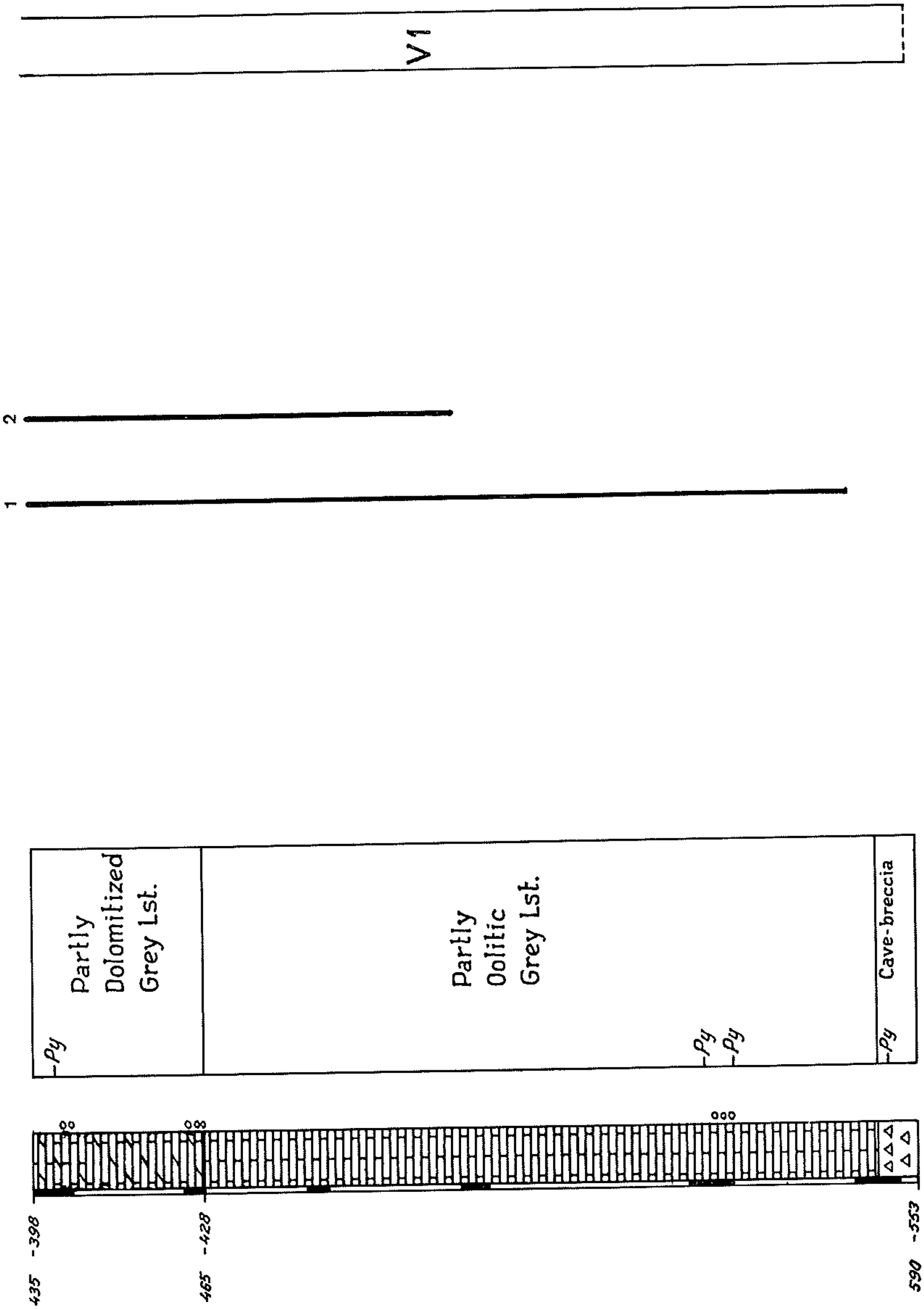
3.19. ISSELBURG-3 BOREHOLE

The Isselburg-3 borehole has been drilled between 1965 and 1966 for the "Gewerkschaft Elwerath". The borehole has not been published in detail as far as the Dinantian is concerned. The Carboniferous (Westphalian A) was reached at 1342 m (= −1322 m NAL). The Westphalian A was described by WOLBURG & WOLF (1971) and TEICHMÜLLER (1971), who recognized the base of the Westphalian A at 2125 m. The Namurian is about 1930 m thick according to FABIAN (1971), so that the top of the Dinantian must be at about 4050 m. From the descriptions by WOLBURG (1970) and FABIAN (1971) we can get a fair idea of the lithology of the Dinantian in this borehole. The sequence should be about 95 m thick (FABIAN 1971), what is slightly more than the thickness found in the Münsterland-1 borehole, but considerably less than the more than 400 m of Dinantian limestones and dolomites of the Wachtendonk-1 borehole only 35 km towards the South-West of Isselburg-3. Evidently, practically no detritus transport from the Campine-Brabant Basin into the Ruhr Basin has taken place because of the intermediate Krefeld High. It is suggested that the lithology can be compared with that of the Münsterland-1 borehole (WOLBURG 1970) and consists of mainly black – partly silicified – shales

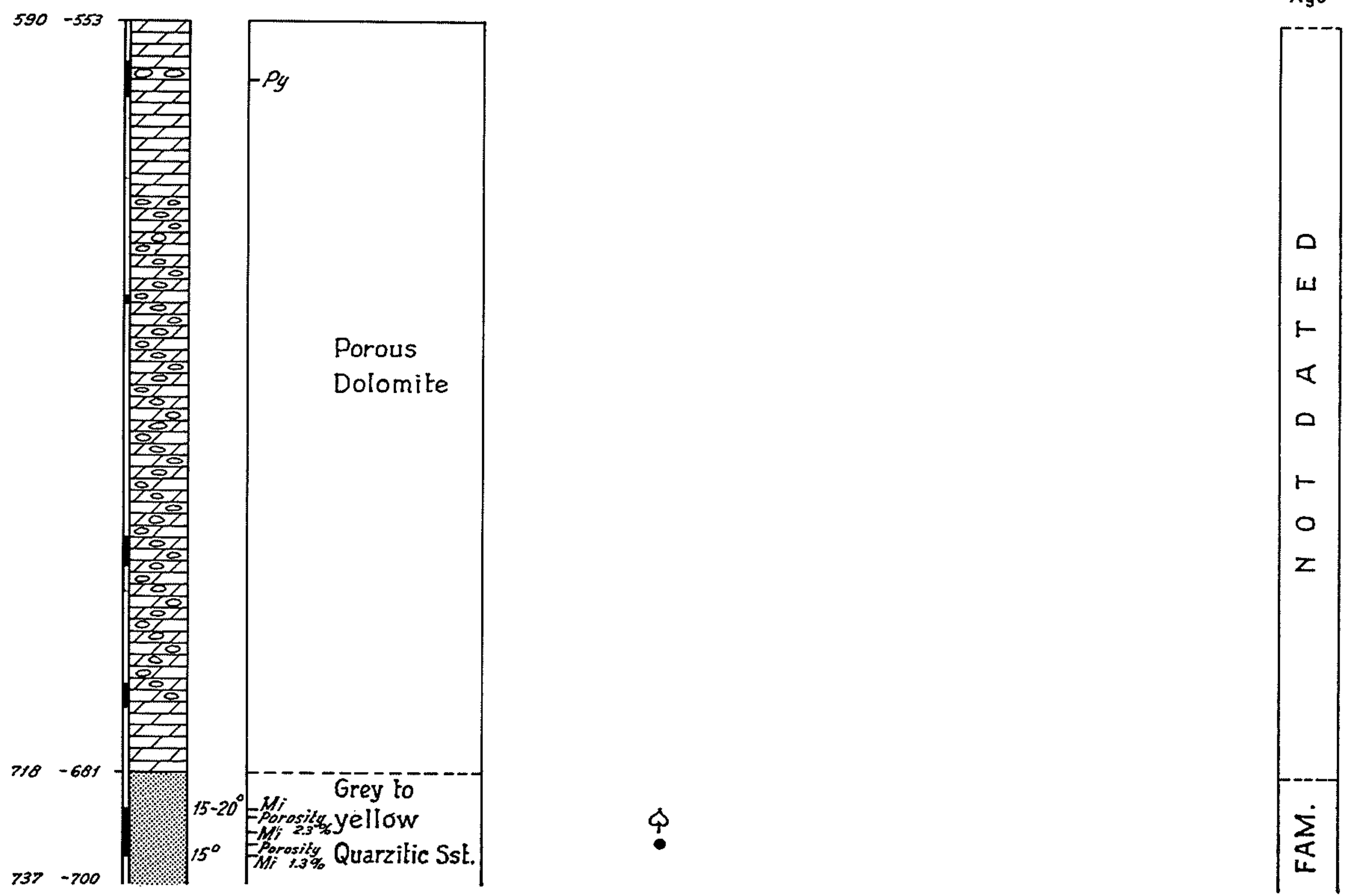
WACHTENDONK-1 *(Fig.25)*

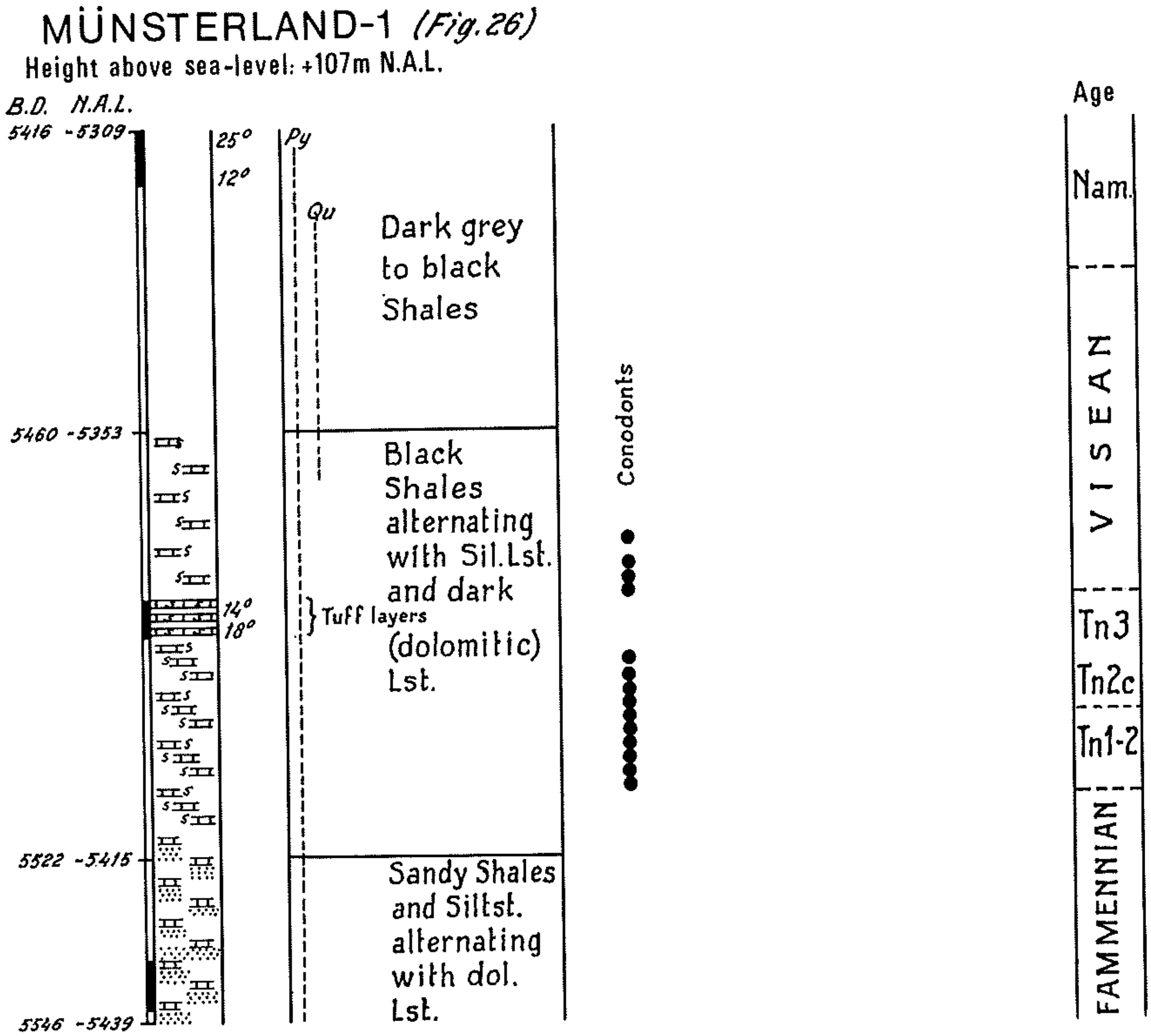
Height above sea-level: +37 m N.A.L.




V1
2
1
Partly Dolomitized Grey Lst.
Partly Oolitic Grey Lst.
Cave-breccia
Py
Py
Py
Py
435 -398
465 -428
590 -553

WACHTENDONK-1 (continued)





alternating with thin beds of partly silicified limestones.

3.20. MÜNSTERLAND-1 BOREHOLE

The Münsterland-1 borehole was drilled between 1961 and 1962 for the Geologisches Landesamt Nordrhein-Westfalen and eigth oil companies in order to investigate o.a. the composition of the rocks underlying the Silesian. The borehole has been published in detail by HESEMANN (ed., 1963) and later by HESEMANN (1965). Top Carboniferous (Westphalian) was reached at 1788 m (= −1681 m NAL). The Dinantian was reached at 5438 m (= −5331 m NAL). Since only one core of about five meters was taken between 5485 and 5490.5 m, the stratigraphic descriptions and determinations depend on few direct data. WOLBURG (1963, see fig. 28) has correlated the Dinantian rocks of this borehole with the better known sequence of the Vingerhoets-93 borehole. The interpretation of the lithology in fig. 26 is based on mainly cuttings and one core (KELCH 1963; FÜCHTBAUER 1963). Some foraminifers, echinoderm debris, lamellibranchs, ostracodes and other fossil remains have been recorded from the cuttings at 5496 m, 5500 m and 5504 m (FÜCHTBAUER 1963). WOLBURG (1963) suggested that this part of the borehole belongs to the Lower Tournaisian (Tn1b) or Upper Hangenberg Beds (*Gattendorfia* goniatite zone). ZIEGLER (1963) described conodonts from the sequence between 5476 and 5512 m.

A sample from 5482 m with *Gnathodus texanus* s.s. and cf. *Gnathodus bilineatus* was interpreted by that author as eventually indicating the *bilineatus* zone or the *anchoralis-bilineatus* interregnum, and might thus indicate a Visean age.

Samples from 5494 to 5498 m contain a.o. the genus *Dollymae, Pseudopolygnathus triangulus triangulus, Polygnathus communis* and *Hindeodella segaformis,* what may be interpreted as an Upper Tournaisian assemblage.

The occurrence of a.o. *Scaliognathus anchoralis* in a sample from 5504 m suggests that the whole interval from 5494 to 5504 m should be assigned to the Upper Tournaisian.

The sample from 5512 m contains a.o. a specimen of *Pseudopolygnathus* cf. *fusiformis* (according to ZIEGLER 1963), what might point to a Lower or Middle Tournaisian age.

This means that the boundary between the Dinantian and Devonian should be placed below 5512 m, say at 5515 m, and not at 5507 m as proposed by KELCH (1963) and WOLBURG (1963). These latter authors determined this boundary by means of Schlumberger diagrams and not on the paleontological evidence.

Seventeen layers of quartz keratophyr tuff have been found in the interval between 5484 and 5492 m (FÜCHTBAUER 1963). Tuffs of this type are common in the middle part of the Dinantian Kulm facies ("Kulm-Kieselschiefer and equivalent beds) of probably upper Middle Tournaisian to lower Upper Visean age (HOSS 1957, 1959). This is in agreement with the age based on conodont evidence.

No study has been made of the coalification of vitrinite in the Dinantian of this borehole. LENSCH (1963) gave the following average values for the overlying and underlying rocks:

± 5100 m (Namurian): ± 5.2% Rm (mean reflectivity)

± 5600 m (Famennian): ± 5.8% Rm corresponding to 8% Rmax (maximum reflectivity).

3.21. VERSMOLD-1 BOREHOLE

The Versmold-1 borehole has been drilled between 1964 and 1965 for the Gewerkschaft Elwerath. The borehole is located at some 10 km North-East of the town Warendorf near the banks of the Ems River. Top Dinantian was reached at some –4700 m NAL (after HOYER, CLAUSEN, LEUTERITZ, TEICHMÜLLER & THOME 1974). The Dinantian should be some 80 m thick (FABIAN 1971). From the descriptions by PORTH (1965), WOLBURG (1970) and HOYER, CLAUSEN, LEUTERITZ, TEICHMÜLLER & THOME (1974) it may be deduced, that the lithology of Dinantian rocks can be compared with that of the boreholes Münsterland-1 and Vingerhoets-93. Also the thickness of the Dinantian in these boreholes is comparable.

The coalification of vitrinite material in the Lower Namurian varies between 5.5 and 7.1% R(max?) (cf. HOYER, CLAUSEN, LEUTERITZ, TEICHMÜLLER & THOME 1974). In Dinantian rocks, it may be slightly higher (between 7 and 8% R(max?)). Evidently, this relatively high coalification rank is due to the heat flow of the Warstein High (compare also fig. 29, chapter 3.23.).

3.22. VINGERHOETS-93 BOREHOLE

The Vingerhoets-93 borehole was drilled between 1936 and 1938. The borehole has been described by O. KÜHNE & W. PAECKELMANN (unpublished manuscript, Preussische Geologische Landesanstalt, Berlin). This description – although never published – has been cited by several authors, a.o. PAPROTH & TEICHMÜLLER (1961), WOLBURG (1963, 1970) and HEDEMANN & TEICHMÜLLER (1971). A copy of the original manuscript is stored in the files of the Geologisches Landesamt Nordrhein-Westfalen at Krefeld. In 1962, P. HOYER (Krefeld) made a "Schichtenverzeichnis" in which he put all the available information on this borehole (HOYER, unpublished manuscript, Geologisches Landesamt Nordrhein-Westfalen, Krefeld).

The position of the stratigraphic boundaries has been determined by KÜHNE & PAECKELMANN and there is no reason to change these. The most important horizons within the Dinantian sequence or inmediately above or below it are:

1572.8 - 1575 m: 0.4 m silicified shale with *Cravenoceratoides edalense*?, Eumorphoceratids and *Posidonia membranacea.* The "*bisulcatum*-Kieselschiefer" is a very distinctive marker horizon of black silicified shales and cherts of less than 0.5 m thick in the eastern part of the Rhenish Massif near the base of the Arnsbergian (E2).

1624.1 - 1627.5 m: Goniatites with spiral ornament belonging to the *Goniatites granosus* Zone (Goγ = upper V3c) or *Neoglyphioceras spirale* Zone (topmost Goβ = upper V3c).

1643 - 1644.7 m: Assemblage with *Nomismoceras* sp. and *Posidonia becheri. Nomismoceras* sp. occurs mainly in the Goα Zone and the lower Goβ Zone (V3bγ - lower V3c), whereas *P. becheri* is known from the *Goniatites crenistria* (Goα) to the upper part (but not the topmost) of the *Goniatites striatus* (Goβ) Zone (V3b - lower V3c).

1680.6 - 1691.0 m: *Imitoceras intermedium.* This species is known from the lower *Gattendorfia* Zone (= Tn1b) of the Rhenish Massif. This interval is correlated with the Upper Hangenberg Beds.

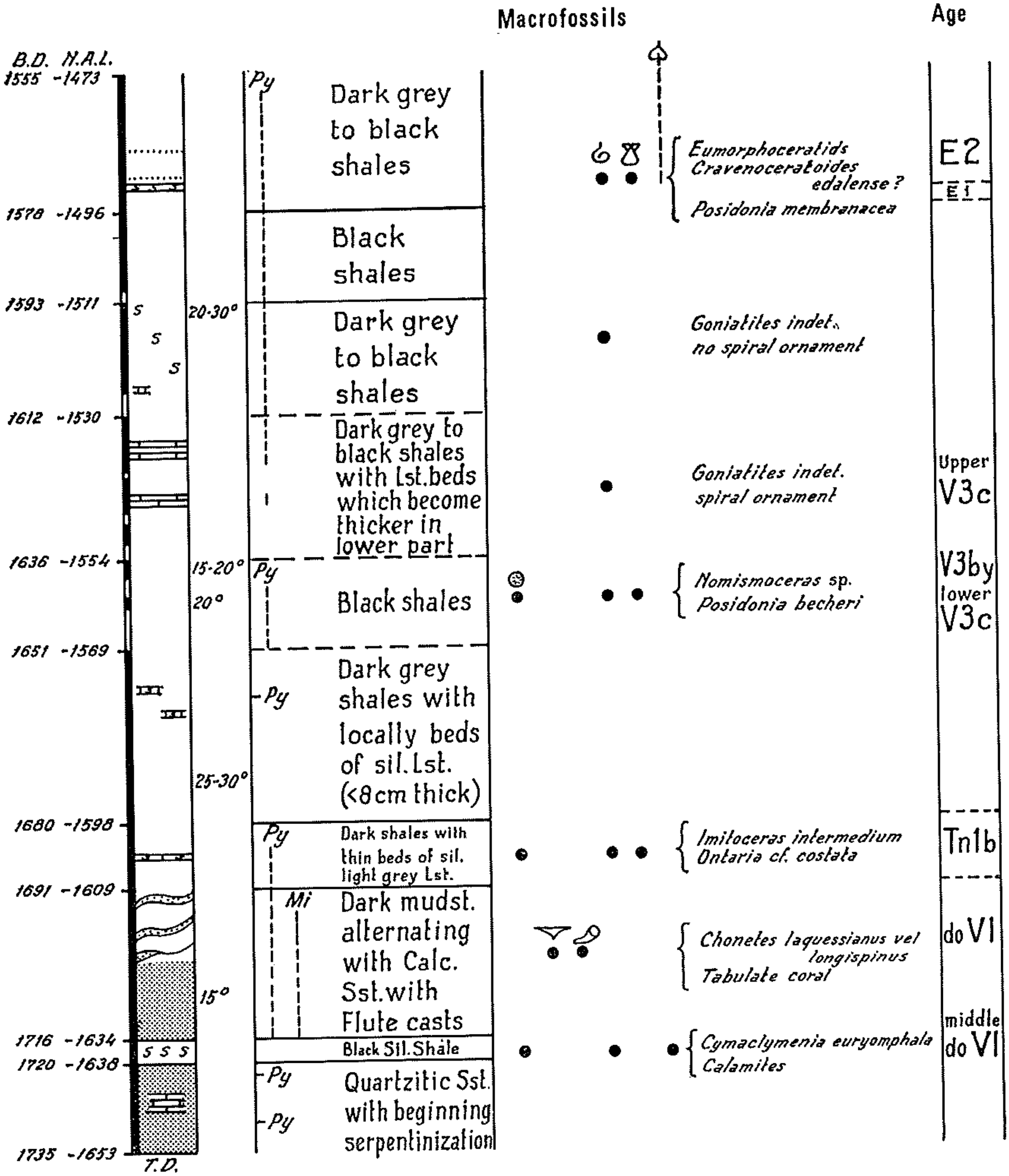
1691 - 1700 m: Dark mudstones intercalated by siltstone beds, calcareous layers and "graphitoid" layers, the latter comparable to cherts (PAECKELMANN, unpublished manuscript). This interval has been correlated with the Lower Hangenberg Beds of the upper part of the *Wocklumeria-Kalloclymenia* Zone.

1719 m: *Cymaclymenia euryomphala.* This species is restricted to the middle part of the *Wocklumeria* Zone (= Tn1a) in the Rhenish Massif.

The top of the Dinantian has been placed at 1578 m (= –1496 m NAL), the base at 1691 m

VINGERHOETS-93 *(Fig.27)*

Height above sea-level: +82 m N.A.L.



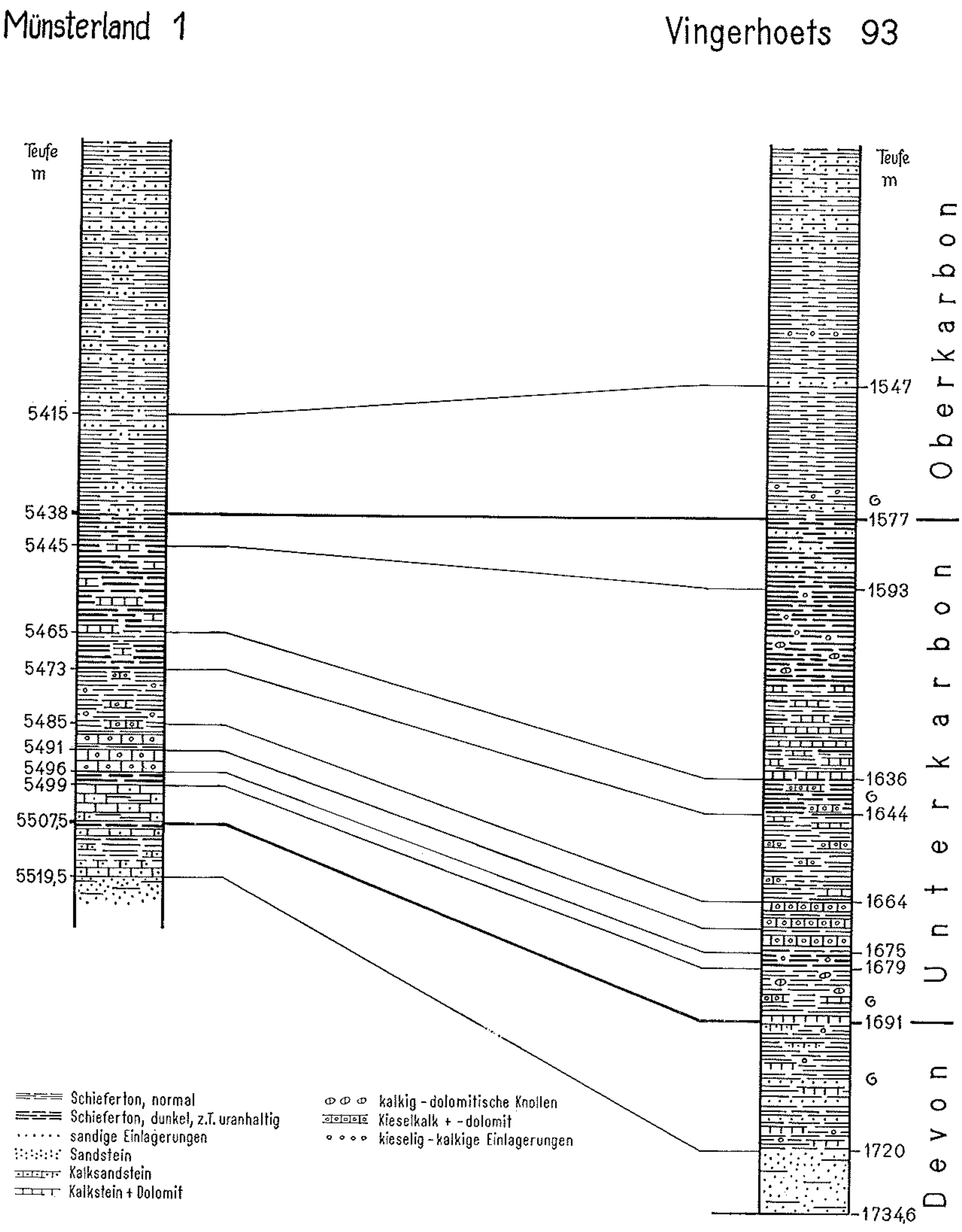


Fig 28 – Correlation between simplified sections of boreholes Münsterland-1 and Vingerhoets-93 after Wolburg (1963)

(= −1609 m NAL). This 113 m thick sequence has to be reduced to true thickness because of the dip of about 20° of the strata. This would be some 107 m, so that a suggested thickness of say 110 m for the Dinantian in this borehole seems reasonable. The uppermost Visean (V3c) is relatively thick (about 50 m), whereas the middle Tournaisian to middle Visean is relatively thin (only some 35 m). The *Gattendorfia* Zone or Tn1b is about 10 m thick. This means, that the greater part of the Dinantian is practically as thin as at its less developed place at the northwestern edge of the Rhenish Massif near the Velbert Anticline. Only with the incoming influence of the greywacke fan from the South, thickness increases during the topmost Visean.

The limestone layers in this borehole normally consist of very fine-grained detritus and appear to be comparable to the type of limestones recognized in the Münsterland-1 borehole (see chapter 3.20.). The occurrence of the 0.4 m thick "*bisulcatum*-Kieselschiefer" in the Lower Namurian and the thin bed of black silicified shale with *Cymaclymenia euryomphala* in the topmost Devonian prove that this area formed part of the Kulm Basin.

The deepest core was incomplete. The cored interval between 1720 and 1734.6 m (= 14.6) yielded only 6.4 m of core. Paeckelmann describes the inte-r val as quartzitic calcareous sandstone (at 1728.5 m) and quartzite containing some heavily silicified mudstone lumps. He also mentions a beginning serpentinization. This evident metamorphosis is easily explained if we take into account that this borehole is situated on top of the Warstein High (see 3.23.). As far as known, this is the northwesternmost extension of this ridge and at the same time the most heavily affected by the post-Namurian pluton.

3.23. COALIFICATION

Data on the degree of coalification of the organic material in Dinantian rocks are still scarce. Paproth & Wolf (1973) discussed the isoapostilbes (lines of equal reflectance) in the Rhenish Massif, where they had investigated the outcropping Devonian and Carboniferous sediments. Since then, new data have become available. Teichmüller (in: Hoyer, Clausen, Leuteritz, Teichmüller & Thome 1974) studied the coalification in Namurian rocks of the boreholes Versmold-1 and Lippspringe, whereas Wolf (1975) investigated the coalification rank in probably Givetian sediments of the boreholes Soest-Erwitte-1/1a and Sassendorf. For the present paper, some boreholes in the Netherlands (Woensdrecht, Houthem and Cadier en Keer) and Belgium (108W 334) have also been investigated on the coalification (Table II) in Namurian (Woensdrecht and 108W 334) and Dinantian rocks (Houthem and Cadier en Keer). These data allow us to complete the isoapostilbes pattern around the Rhenish Massif and notably towards the North (fig. 29).

Two main features can now be distinguished: the Warstein High and the Ruhr Depression.

The Warstein High must have been produced by the heat flow of a post-Namurian pluton (Paproth & Wolf 1973). This heat flow is also indicated by the beginning metamorphosis of topmost Devonian sediments in the Vingerhoets-93 borehole (see chapter 3.22.). This is in contrast to the heat flow recognized by the high coalification rank in the troughs of the Rhenish Massif (e.g. the "Ostsauerländer Quer-Trog"), which was produced in inversion structures sensu Dvorak (1973) and Paproth (in press).

The isoapostilbes in the underground of the southern Ruhr Basin seem to form a depression, the Ruhr Depression. Its eastern border is formed by the Warstein High and its western border by the Zandvoort-Maasbommel-Krefeld High.

The low coalification rank (relatively low to the rank of sediments of the same thickness in inversion structures sensu Dvorak) may be a diagnostic character of this (and eventually all) foredeeps: a great geothermic depth associated with a low coalification gradient.

4. BIOSTRATIGRAPHY

4.1. BIOSTRATIGRAPHICAL RANGE CHART OF THE TYPE DINANTIAN

The actual state of knowledge of biostratigraphical zonation of the type Dinantian (Namur-Dinant Basin South of Brabant Massif) by means of foraminifers and conodonts is graphically represented in

Table II – Reflectance of some borehole samples North and East of the Brabant Massif. Note the different values found in the same sample of the Cadier en Keer (DB109) borehole! It is suggested that this is due to influx of reworked material.

borehole	depth	n	s	Rmax %	(% VM)	
DB17	1167 m	25	0.23	2.52	10	few sclerotioid grains
DB105	304.7-305.4 m	20	0.27	4.57	4	abundant sclerotioid grains
DB109	241.9 m	—	—	± 3.5-4.0	5-4.5	bituminous limestone;
		30	0.43	6.20	3.5	reworked material??
108W334	10.6-10.7 m	9	0.24	3.47	5	sapropelitic shale with many oxidized fragments

n = number of analysis realized; s = standard deviation
Maximal reflectance compared with percentage volatile matter (VM.) (after Wolf 1972)

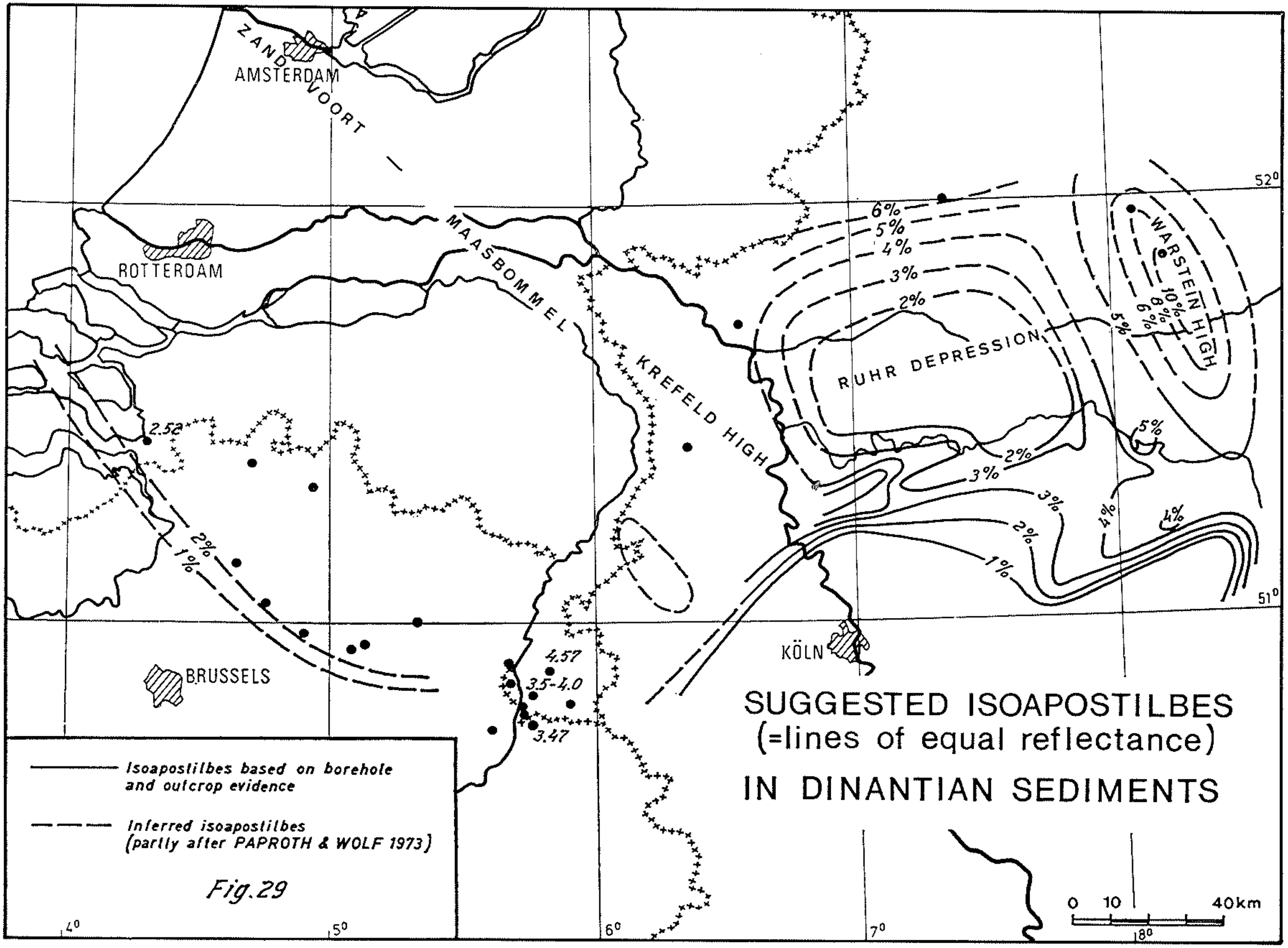

SUGGESTED ISOAPOSTILBES
(=lines of equal reflectance)
IN DINANTIAN SEDIMENTS
Isoapostilbes based on borehole and outcrop evidence
Inferred isoapostilbes (partly after PAPROTH & WOLF 1973)
ZANDVOORT
AMSTERDAM
ROTTERDAM
BRUSSELS
KÖLN
MAASBOMMEL
KREFELD HIGH
RUHR DEPRESSION
WARSTEIN HIGH
10%
8%
6%
5%
4%
3%
2%
1%
2.52
4.57
3.5-4.0
3.47
52°
51°
4°
5°
6°
7°
8°
0 10 40km

Fig.29

enclosure 2. This range chart can be compared without problems with the results of the foraminifer and conodont studies presented in this report for the Campine-Brabant Basin North of the Brabant Massif.

This range chart should be used also in combination with the "International Correlation of Dinantian Strata" presented by CONIL *et al.* as an appendix to this report (enclosure 3). The following remarks should be made here in order to make enclosure 3 better readable.

a: No correlation lines have been drawn between the successions of the different areas. These correlations are only suggested by the relative position of these successions according to the present state of our knowledge. This chart completes the two charts of CONIL, LYS, PAPROTH, RAMSBOTTOM & SEVASTOPULO (in press).

b: The traditional subdivision of the Belgian Dinantian (Tn1 - V3) is mentioned together with the formation names to whom they have been often assigned. This juxtaposition allows to avoid ambiguity with the literature. In recent publications of the authors of this report, most of these symbols (Tn1 - V3) have received biostratigraphical value.

c: The main epeirogenic movements in the Belgian type sequence are indicated. They are reflected in the lithostratigraphic and in the biostratigraphical succession. Most of them seem to have had a wide stratigraphic geographic influence and coincide with important faunal migrations ("colonisations") and thus with paleogeographic changes. In this sense, they are interpreted as successive trans- and regressions. These can be only followed in areas with shallow and regular sedimentation within the time-span discussed here.

d: For further information about this international correlation of Dinantian strata and about the biostratigraphical range chart (enclosures 3 and 2 respectively), the reader is refered to CONIL, GROESSENS & PIRLET (in press).

4.2. CONODONTS

Despite intensive research, only the upper part of the Belgian Visean has yielded significant conodont faunas thus far. These have been described by HIGGINS & BOUCKAERT (1968), BOUCKAERT & HIGGINS (1971), BOUCKAERT & GRAULICH (1966), PIRLET (1968b) and GROESSENS (1974). The results of their work are summarized in enclosure 2.

New investigations on and revision of old collections from four boreholes (Turnhout, Halen, Houthem and Houtain-St-Siméon) have yielded promising results which encourage further study. Several rich conodont faunas have been observed. Most of the specimens recovered belong to the genus *Gnathodus* or *Paragnathodus.*

Gnathodus commutatus occurs from the V1b onwards in Belgium. In the boreholes Halen and Houtain-St-Siméon, the subspecies *nodosus* and *monondosus* have been only found in V3c rocks (age based on foraminifers).

Gnathodus bilineatus bilineatus has been recovered from V3b-V3c levels of the boreholes Houthem, Halen and Houtain-St-Siméon.

Gnathodus symmutatus homopunctatus, a species already present at the base of the Visean elsewhere in Belgium, has been found together with *Gnathodus symmutatus mermaidus* in the boreholes Houthem and Halen. Most of the specimens show an ornamentation intermediate between the subspecies *homopunctatus* and *mermaidus.*

Specimens related to the several subspecies of *Gnathodus girtyi* have been found in the boreholes Halen, Houthem and Houtain-St-Siméon.

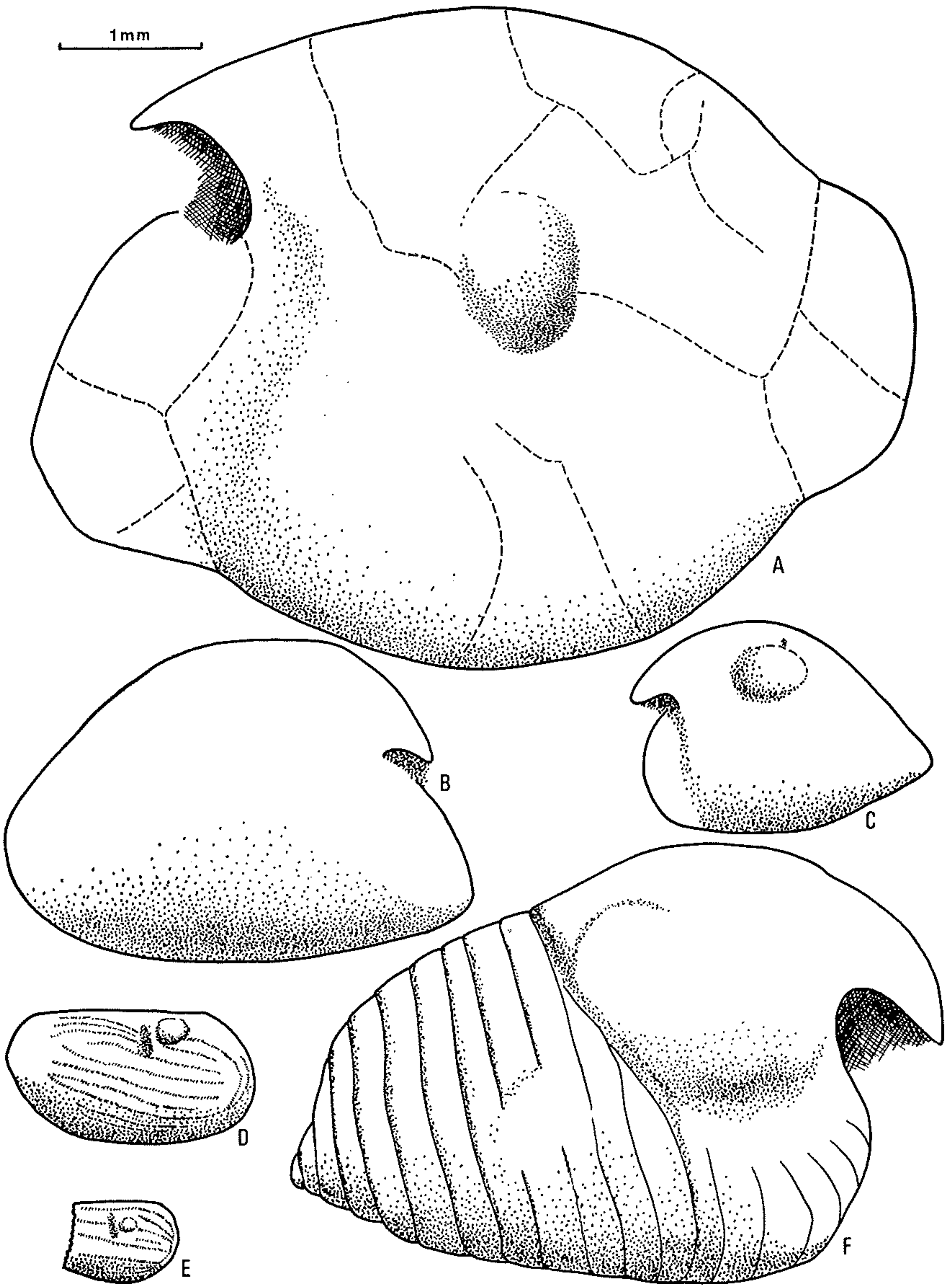
Only one specimen of *Cavusgnathus* (*C. cristatus*) has been recovered from a sample at 187 m of the Houtain-St-Siméon borehole. *Cavusgnathus bipluti*, which has been found in the V3c of Richelle near Visé, was not found in the samples of the boreholes.

Special attention should be paid to the possible occurrence of reworked conodonts. The conodont faunas described by ZIEGLER (1963) from the Upper Tournaisian or Lower Visean of the Münsterland-1 borehole suggest that they may have been reworked. In the Houthem borehole, a specimen of *Siphonodella obsoleta* has been recovered from the 214.54–216.20 m level. This species is restricted in Belgium to the Tn1b–Tn2. The same borehole yielded a specimen of *Geniculatus glottoides* (267.50 m level). This species was described by VOGES (1959) from the base of the *Anchoralis* conodont zone (= Tn3c) of Germany, whereas PAPROTH, STOPPEL & CONIL (1976) recognized this species in the V2a–V2b of Sondern and possibly also in the V2-V3 (below upper V3b) of Zippenhaus in the northwestern part of the Rhenish Massif (Velbert area). It is here presumed that also *Geniculatus glottoides* from the V3bγ of the Houthem borehole may represent a reworked element.

4.3. OSTRACODES

Ostracodes are amongst the most common and widespread microfossils in Dinantian limestones. The problem is that they cannot be specifically identified in thin sections like foraminifers. And only silicified or mineralized specimens can be extracted from limestone by means of some acid like conodonts. Mechanical crushing of the limestone yields often only smooth-shelled forms of little biostratigraphic value. The use of vibratory needles may be successful for the preparation of a single specimen, but this time-consuming method can hardly find general application. A further problem is the fact that practically no recent systematic study on Dinantian ostracodes in Northwestern Europe exists, sothat we know little or nothing about the vertical and lateral distribution of these microfossils if we do find them in a borehole.

Ostracodes have been noticed thus far in Dinantian rocks of the boreholes Houthem (DÉLÉPINE 1927, 1928; DORSMAN 1945; BECKER & BLESS 1974), Münsterland-1, Turnhout (DELMER 1962) and Woensdrecht.


1mm
A
B
C
D
E
F

The ostracodes in the Münsterland-1 borehole have been only recognized in thin sections of cutting material and cannot be identified. They occur near the base of the Dinantian.

The ostracodes of the boreholes Houthem and Woensdrecht have been revised for the present paper, whereas also some spot samples of Turnhout have been studied on their ostracode contents. Three different assemblages can be recognized. The first is characterized by a relatively large number of giant nectonic Cypridinacean ostracodes, which may be more than 5 mm long. This assemblage has been described. Ostracodes belonging to this assemblages have been described by DE KONINCK (1841), JONES & KIRKBY (1874) and BECKER & BLESS (1974) from the Visean of Visé (Belgium) and from several Dinantian rocks of Ireland and Great Britain. The widespread occurrence of this otherwise very rare group of Cypridinacean ostracodes in the Dinantian limestone facies is most probably facies rather than age-controlled. Smooth-shelled Paraparchitacean and Bairdiacean, and ornamented Kirkbyacean and Hollinacean ostracodes are also common in this assemblage. This assemblage has been recognized in the Houthem borehole between 228 and 240 m (V3bγ - V3c) and in the Turnhout borehole between 2234 and 2241 m (V3bγ). Interesting is to observe the occurrence of the very characteristic species *Cyprella chrysalidea* in both intervals. This species is also known from the Upper Visean of Richelle near Visé in Belgium and from Dinantian rocks at Hainault (France), Little Island (Cork, Ireland), Settle, Isle of Man, Longnor and Bathgate (Great Britain), and may be important for correlations within Northwestern Europe.

The second assemblage consists of very small (juvenile??) silicified specimens of mainly Bairdiacean and Kirkbyacean ostracodes with some isolated specimens of *Roundyella*. This assemblage has been found in the Houthem borehole between 245 and 315 m. Comparable assemblages have been described from rocks of different ages (cf. German Zechstein microfossil assemblages described by JORDAN 1968). They should be characteristic of "near-shore" environments.

The third assemblage is predominated by Bairdiacean and Paraparchitacean (including *Shishaella*) ostracodes with rare Cypridinacean and Kirkbyacean specimens. On the generic level this assemblage can be compared with ostracode faunas of Dinantian age from Belgium (BECKER & BLESS 1974; BECKER, BLESS, STREEL & THOREZ 1974), Germany (KUMMEROW 1939), Scotland (LATHAM 1932) and the U.S.S.R. (BUSHMINA 1968, 1970). This assemblage was found in the Woensdrecht borehole between 1178 and 1202 m and in the Turnhout borehole at 2367 m.

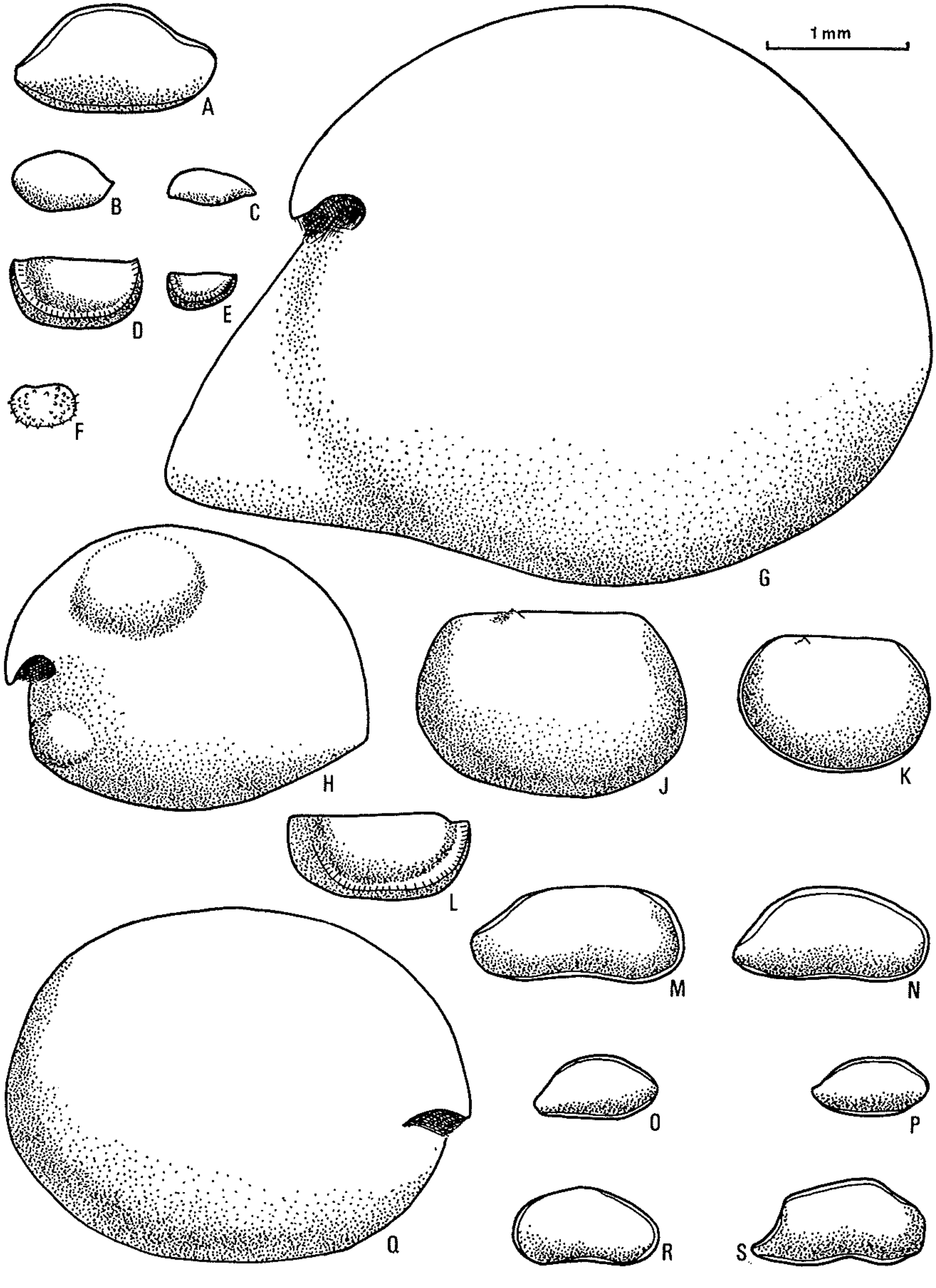
The above assemblages cannot be compared with those described from the Hiddensee and Rügen area (German Democratic Republic) by BLUMENSTENGEL (1975) and GRÜNDEL (1975). These latter faunas contain abundant Healdeacean and Quasillitacean or Kloedenellacean elements, which have not been observed in the Campine-Brabant Basin thus far. Although no identifiable ostracodes have been reported from the Dinantian of the Ruhr Basin boreholes, it may be expected that ostracode faunas within the Kulm facies will be comparable to those described by GRÜNDEL (1963) and SANCHEZ DE POSADA & BLESS (1974) from the Visean of the Ruhr Basin. These faunas contain o.a. Entomozoacean ostracodes, which are associated with a wide variety of other forms.

4.4. SCLEROTIOID GRAINS

Samples between 206.5 and 307.0 m of the Houthem borehole have yielded abundant black grains of about half a millimeter. They can be observed on the rock surface of the samples and prepared by a needle or by mechanical crushing of the sediment. They can also be prepared by means of HF or HCl, but are etched and subsequently dissolved in warm HNO_3. They occur in black marine shales, dark – often argillaceous – limestones and were even observed in silicified limestone. Because they had never been observed before in other boreholes, the question arised of what nature these grains might be.

Stereoscan microscopy (pl. 15 and 16) revaeled, that the shape of the grains varies from spheric to irregularly elongate, the latter often with one or two pointed ends. The surface may be smooth or bear a coarse ornament of low regular annular ribs. The micro-ornamentation consist in a smooth or rarely vermiculate surface. Often, the whole grain is covered by crater-like pits of variable size which occasionally seem to connect with the interior. Grooves and fissures occur in many grains, as if this had been teared open. Cross-sections show a massive outer rim surrounding a porous or spongeous center. Polished sections (pl. 17) may also show this spongeous center with a more compact outer rim with characteristic fissures, or they show a completely homogeneous mass with one or more fissures and cracks. It is not impossible that this second type merely represents peripheral sections of the first type of grains. The reflectance of the grains is always higher than that of the associated vitrinite.

Fig 30 – Ostracodes from Houthem borehole A: Diagenetically deformed specimen of *Cypridellina* sp., 228-232 m; B: *Cypridinella* sp., 228 m; C: *Cypridelliforma* sp., 238 m; D: *Glyptopleura* aff. *costata* (McCOY 1844), 228-232 m; E: *Glyptopleura* sp., 228-232 m; F: *Cyprella chrysalidea* DE KONINCK 1841, 228-232 m.


1 mm
A
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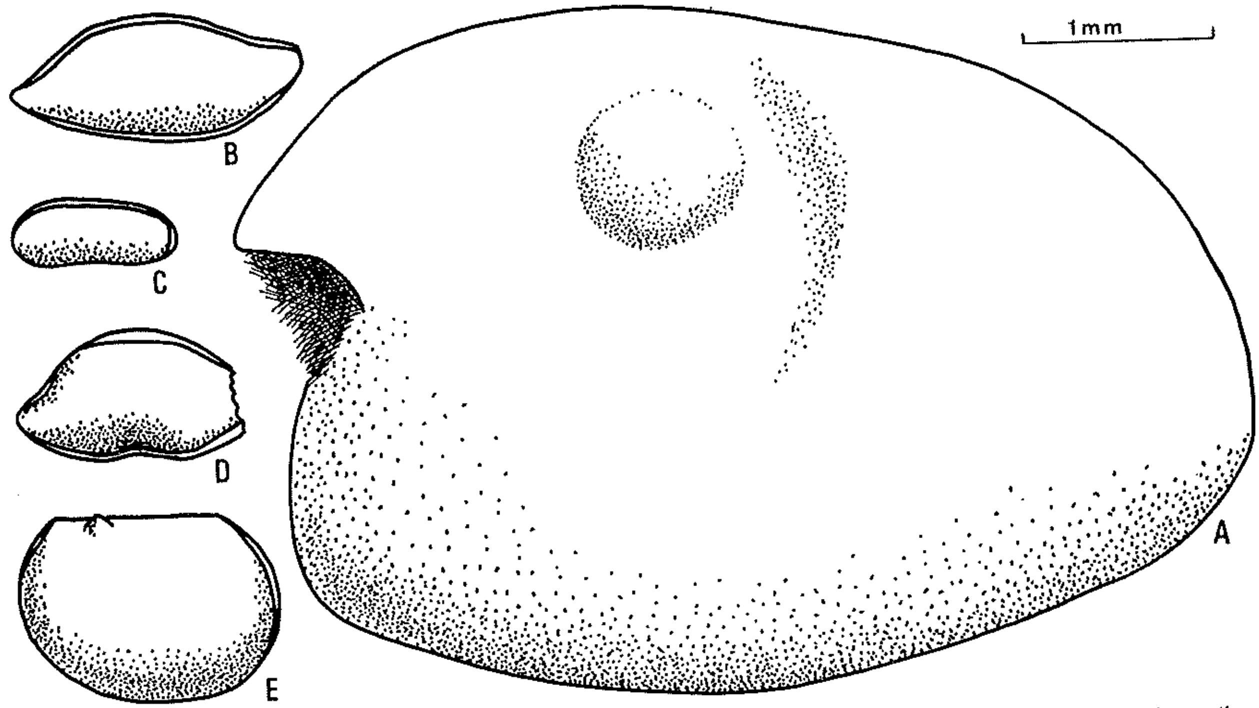


Fig 32 – Ostracodes from Turnhout borehole A: cf. *Cypridella* sp., 2234 m; B: *Bairdia* sp., 2367 m; C: *Bairdiacypris* sp. (juvenile?), 2367 m; D: *Bairdia* sp., 2367 m; E: *Shishaella* sp., 2367 m.

The spongeous center may contain randomly distributed quartz, calcite and clay minerals, the latter being concentrated in the outer part of the spongeous center. It is unknown whether these minerals formed part of the original grain or if they entered it secondarily. It finally was shown, that they are non-magnetic and can be easily burned. The carbon content is 65 % (colormetric titration apparatus; weight of the sample was 1 mg). Microprobe analysis (pl. 18-19) showed a remarkable high sulphur content (pl. 18, fig. 3; pl. 19, fig. 3). Inorganic constituents are quartz (Si), clay minerals (Si, Al, K) and calcite (Ca).

Similar black grains are well known to coal petrologists. In the coal petrology nomenclature, they are included in the maceral sclerotinite. This indicates that most coal petrographers did believe that these grains are fungal sclerotia.

Hacquebard (1952) observed some 2600 "sclerotinite" grains per square inch in the Seam No. 5 Coal of the Saint Rose and Chimney Corner Coalfield (Westphalian A) of Nova Scotia. He concluded that these numerous grains never could be true sclerotia. Therefore, he named them sclerotioid grains. Benes & Kraussova (1964) published similar objects from the Silesian of Czechoslovakia. They also doubted that these objects might be sclerotia. Stach & Pickhardt (1964) were the first who stated that their grain (*op.cit.*, pl. 7, fig. 2) of Silesian age is no sclerotium but eventually a highly polymerized resin.

From the results of the chemical and microprobe analysis, we may deduce that these may be either resinite or corpovitrinite grains. As already argumented above, these are certainly no sclerotia.

Resins are composed of carbon, hydrogen and oxygen with sulphur and nitrogen as subordinated elements (Soos 1964). Within coal, the resins often contain small pyrite crystals which are explained as the remains of sulphur bacteria. This suggests that some resins are able to absorb sulphur in a subfossil or fresh stage, which is subsequently used by these sulphur bacteria for their metabolism. If this is true, the sclerotioid grains may be strongly oxidized (polymerized) resins. This is the opinion of Stach & Pickhardt (1964). Stach (1964, 1966) published a series of pictures in order to show the transition from fresh resins to our sclerotioid grains.

Another possibility is that these are corpohuminite or corpovitrinite grains. In origin, these bodies should have been secretions similar to recent caoutchouc. Within an environment with reducing con-

Fig 31 – A-H: Ostracodes from Houthem borehole A: *Bairdia* sp., 246-247; B: *Bairdia* sp., 269-270 m; C: *Acratia* sp., 269-270 m; D: cf. *Kummerowia* sp., 247-249 m; E: cf. *Kummerowia* sp., 269-270 m; F: *Roundyella* sp., 269-270 m; G: *Cypridinella* sp., 238 m; H: cf. *Cypridella* sp., 238 m.

J-S: Ostracodes from Woensdrecht borehole J: *Shishaella* vel *Shivaella* sp., 1202 m; K: *Shishaella* sp., 1178 m; L: cf. *Kummerowia* sp., deformed specimen, 1202 m; M: *Bairdia* sp., 1185 m; N: *Bairdia* sp., 1178 m; O: *Bairdia* sp., 1185 m; P: *Bairdia* sp., 1178 m; Q: "*Cypridina*" sp., 1185 m; R: *Bairdiacypris* sp., 1185 m; S: *Bairdia* sp., 1178 m.

Location	Sediment	Age	Coalification (Rmax %)	Remarks
GERMANY				
Quarry South of Scharfenberg	dark shale	Goα1	4.4	
Geitenberg near Wennemen	dark limestone	limit (Goα-Goβ)	3.3	abundant grains
Quarry Oese	black calcareous shale	Goα4	3.4	
Affeler Mühle	black shale	Goα1	3.4	
Henninghausen	black shale	Goα	—	
Brom-Berg near Medebach	black shale	base Goα3	—	
idem	black shale	Goα3	4.5	only one specimen
idem	black shale	Goβ	4.5	
Quarry Wachenfeld	dark fine-grained greywacke	Goβspi	3.7	only massive type recognized
Quarry Zippenhaus	black shale	V3b	3.6	
NETHERLANDS				
Woensdrecht (DB17)	black shale	H2	2.5	few grains (absent in V2a-V3a)
Houthem (DB105)	black shales and limestones	V3bγ	4.6	abundant in all samples
CZECHOSLOVAKIA				
Teplice BJ101 borehole	black siltstone	top Goβ	7.1	one characteristic specimen

Table III – Oldest occurrences of sclerotioid grains in Germany, the Netherlands and Czechoslovakia.

ditions and containing sulphides, this "caoutchouc" was "vulcanized" and got the necessary solidity to survive decay, transport and sedimentation. This vulcanizing process should have played the same role as the oxidizing process of the resins.

Certain is at least that these are secretion products of some plant or plants. In order to find out what group of plants may have produced these grains, analysis was made of the stratigraphic distribution of the same. Investigation of over 150 polished blocks of shales, dark siltstones and marls from Dinantian and Upper Devonian outcrops along the northern and northeastern flank of the Rhenish Massif and the Attendorn-Elsper Syncline (± 70 km East of Köln) showed that these grains only start in Upper Visean (Go = V3b) rocks (Table III). This agrees with the V3b - V3c age of the grains in the Houthem borehole and the Goβ-age (= V3c) of a Czechoslovakian grain. This type of sclerotioid grains occurs further throughout the Silesian (Alportian of Woensdrecht borehole; Namurian and Westphalian of Ruhr Basin; Westphalian A of Nova Scotia; Silesian of Czechoslovakia; Silesian of Karaganda Basin in the U.S.S.R., cf. Kusnezova *et al.* 1976) and into the Gondwana (Stach 1966). They persist into coals of possibly Triassic age (Gondwana facies). But no younger occurrences of these grains are known to us.

These sclerotioid grains seem thus to be related to a plant or group of plants that occurs throughout the paralic to non-marine "coal measures" belts of the world. At least in part they seem to represent resinous casts from canals and/or cells. But others may have been secreted as suggested by the annular ornament of some grains.

Most resins in Cretaceous and Tertiary lignites have been derived from coniferous trees (White 1914). But the oldest true conifers are known from much higher strata than the Dinantian (Scott 1974). It seems not unreasonable however to believe that our sclerotioid grains may have been derived by some gymnosperm plant(s).

4.5. MICROFOSSILS OF DIFFERENT AFFINITIES

Although the aim of this paper is not a systematic description of organisms, we have to mention briefly some uncommon organisms from boreholes of the Campine-Brabant Basin.

Izhella sp. (pl. 12, fig. 23)

A Renalcid organism (algae or foraminifera) was recovered at 2271.50 m from the reworked sequence in the Turnhout borehole. It is a sedimentary microbreccia in a microsparitic matrix with micrite intraclasts. Organisms include *Wetheredella* sp., *Koninckopora* sp., many species of foraminifers (including the encrusting *Pseudolituotuba gravata*), crinoid debris and bryozoans. This sedimentary microbreccia might be the evidence for a perirecifal environment.

Although we cannot see any clefts in the wall, the thick walls and few chambers of our organism suggest *Izhella* Antropov rather than *Renalcis* (R. Riding, personal communication). The specimen is not very well preserved and since we were not able to recover more than one specimen in spite of all our efforts we prefer not to assign a specific name to it.

As far as we know, this is only the second Renalcid from the Dinantian. Vachard (1974) figured two specimens of *Renalcis turbitus* Wray from the Upper Visean of the Montagne Noir (France) in a comparable facies.

Fasciella kizilia IVANOVA (pl. 12, figs. 21, 22)

This species (algae or sponge) has been found in the Turnhout borehole at the same depth as *Izhella* sp. (2271.50 m) and also at a few other depths between 2272 and 2252 m. This organism occurs also in the Houthem borehole in the same stratigraphic interval (V3bγ). It has been noted also in the Upper D1 and D2 zones of Great Britain (CONIL, PAPROTH, RAMSBOTTOM & SEVASTOPULO, 1975; LONGERSTAEY 1975). This organism is unknown from the southern part of Belgium (Namur-Dinant Basin) and seems to be restricted to the basins North of the Wales-Brabant Massif.

AOUJGALIIDAE (pl. 20, fig. 11)

Two specimens have been recovered from 285.65 - 286.46 m in the Houthem borehole. This organism closely ressembles other genera of the family *AOUJGALIIDAE*, such as *Stacheoides*. It is difficult to assign a precise name to our specimens since all members of this family have been described from thin sections. But it seems to be closely related to *Stacheoides*.

Ribbon-like organism of unknow affinity (pl. 20, figs. 1-10).

Three specimens have been recovered from a black shale at 304.66 - 305.41 m in the Houthem borehole. They consist of several partly intermingling cylindrical tubes running parallel together and forming a definitely bilateral structure of about 0.20 to 0.25 mm wide. Its margins are serrate, the teeth being irregularly spaced at intervals varying from 0.2 to 0.3 mm. The total length of the ribbon is unknown, but fragments are slightly over 1 mm. The axial mid-region of the organism is thickened (pl. 20, fig. 5). Whether this is due to the fact that more tubes are concentrated or if more organic matter has been preserved in that part is unknown. The number of tubes is difficult to determine, since they are intermingling, occasionally seem to bifurcate (pl. 20, fig. 10) and considerably change their diameter even within the preserved length of a single tube. No definite transverse end walls have been noted in the tubes.

After HF and Schulze's treatments, most of the tubes are empty (pl. 20, figs. 5, 6). No cellular internal structure could be found. Bulges and more or less regularly distributed raised bosses on the tubes (pl. 20, figs. 3, 4, 5, 10) resulted to be framboidal pyrite bodies (pl. 20, fig. 8), which are easily dissolved by Schulze's reagent (pl. 20, fig. 7). These artefacts have nothing to do with original ornamentation of the tube walls. These walls appear to be smooth both internally and externally when they are well preserved (pl. 20, fig. 9).

The lateral teeth are all pointing into the direction of the presumed apex of the organism. Their tips are broken off (pl. 20, fig. 2) and therefore the full length of any one of these teeth cannot be determined. Apparently, these teeth are broadened tips of marginal tubes which depart from the bilateral structure at an angle of about 45° (pl. 20, figs. 3, 4).

For the time being we will not formally describe these ribbon-like organism because of incomplete data.

4.6. SPORES

Each effort to find spores in Dinantian rocks of boreholes North and East of the Brabant Massif and in several regions of the Sauerland (Germany) has been negative thus far. Also stereo-scan microscope search has not yielded any spores. This is the more remarkable since underlying rocks of Devonian and basal Tournaisian age commonly yield rich microflora. The investigated samples do contain sometimes a rather abundant diminuted plant debris as in the Houthem borehole. The samples are listed below.

Campine-Brabant Basin
Booischot borehole Visean at 525 m, 529 m, 539 m, 539.5 m, 547 m, 557 m, 562 m, 572 m, 582 m, 591 m, 595 m, 599 m.
Halen borehole Visean at 810.6 m, 810.75 m.
Houthem borehole Visean at 249.05-251.35 m, 304.66-305.41 m.
's Gravenvoeren borehole (108W334) Namurian at 54-56 m.

Sauerland area
Dill region Tournaisian of Dillenburg: 9 samples
Brillon region Visean: 2 samples; Tournaisian: 5 samples
Kellerwald Liegende Alaunschiefer: 10 samples
Grimminghausen Liegende Alaunschiefer: 10 samples
Melebach region (Leilbach-Rhena section) Visean: 2 samples

4.7. MACROFLORA

Macrofloral elements are extremely rare within the Dinantian of the Campine-Brabant Basin. They have not been recorded thus far from the Dinantian in boreholes in the Ruhr Basin. The V3bγ of the Houthem borehole has yielded the best preserved specimen: *Sphenopteridium pachyrrhachis*. Other identifiable fragments from the same borehole are assigned to the genus *Calamites* sp. Unidentified diminuted plant debris of Dinantian age occurs also in the boreholes Turnhout (above 2167.1 m), Kessel (632-675 m interval) and Halen (at 1025 m). The occurrence of this debris is only interesting inasfar as it may be used as an argument that the Brabant Massif should have been in part emergent during late Dinantian time.

The lowermost Namurian flora along the eastern spur is also known as "Gulpen" flora because it has been first described from the Gulpen borehole (JONGMANS 1927a). Its most characteristic representatives are *Gulpenia limburgensis* and *Sphenopteris gulpeniana*. Both species seem to have a limited

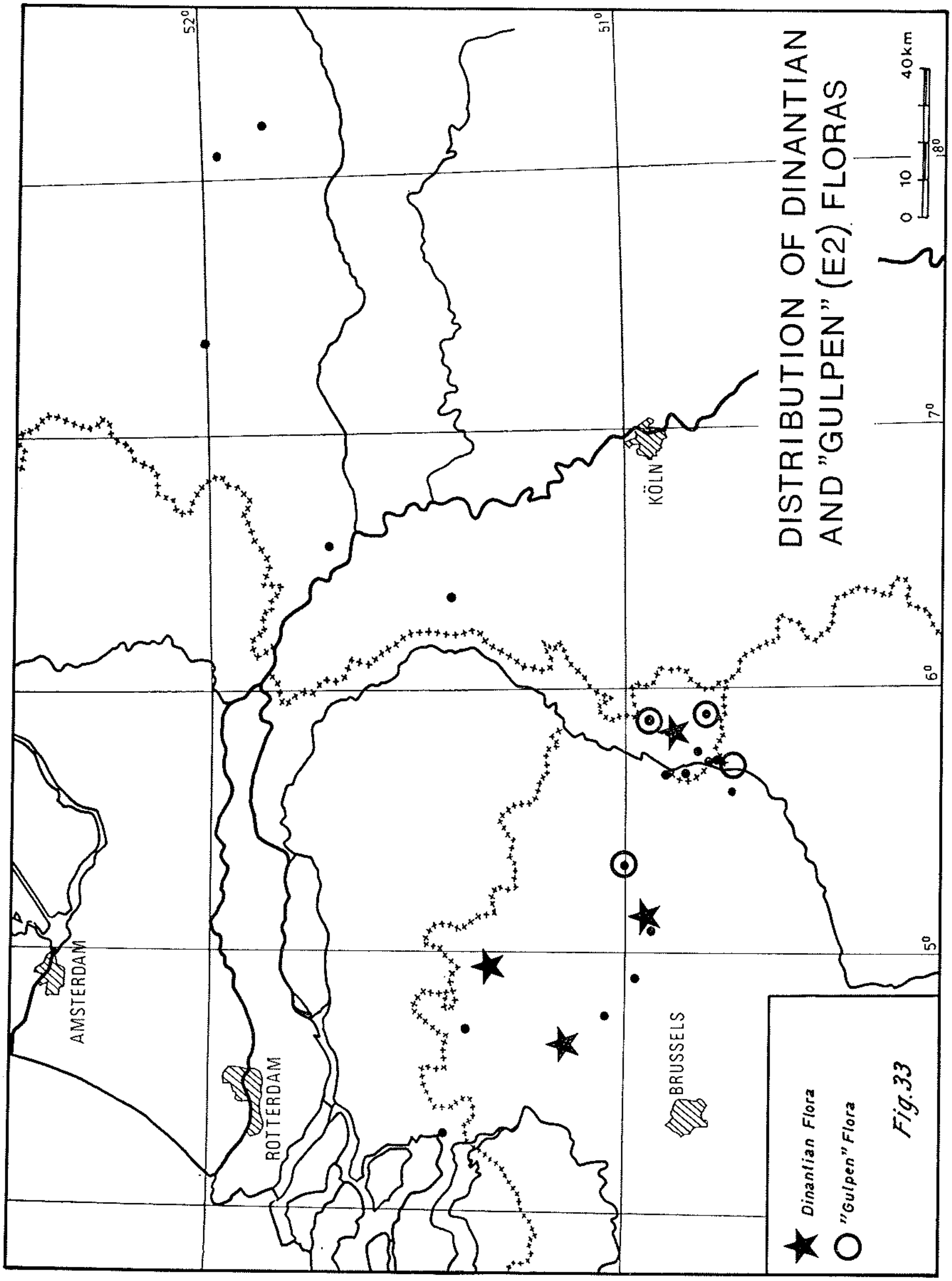

DISTRIBUTION OF DINANTIAN
AND "GULPEN" (E2) FLORAS
0 10 20 40km
52°
51°
5°
6°
7°
AMSTERDAM
ROTTERDAM
BRUSSELS
KÖLN
Dinantian Flora
"Gulpen" Flora

Fig. 33

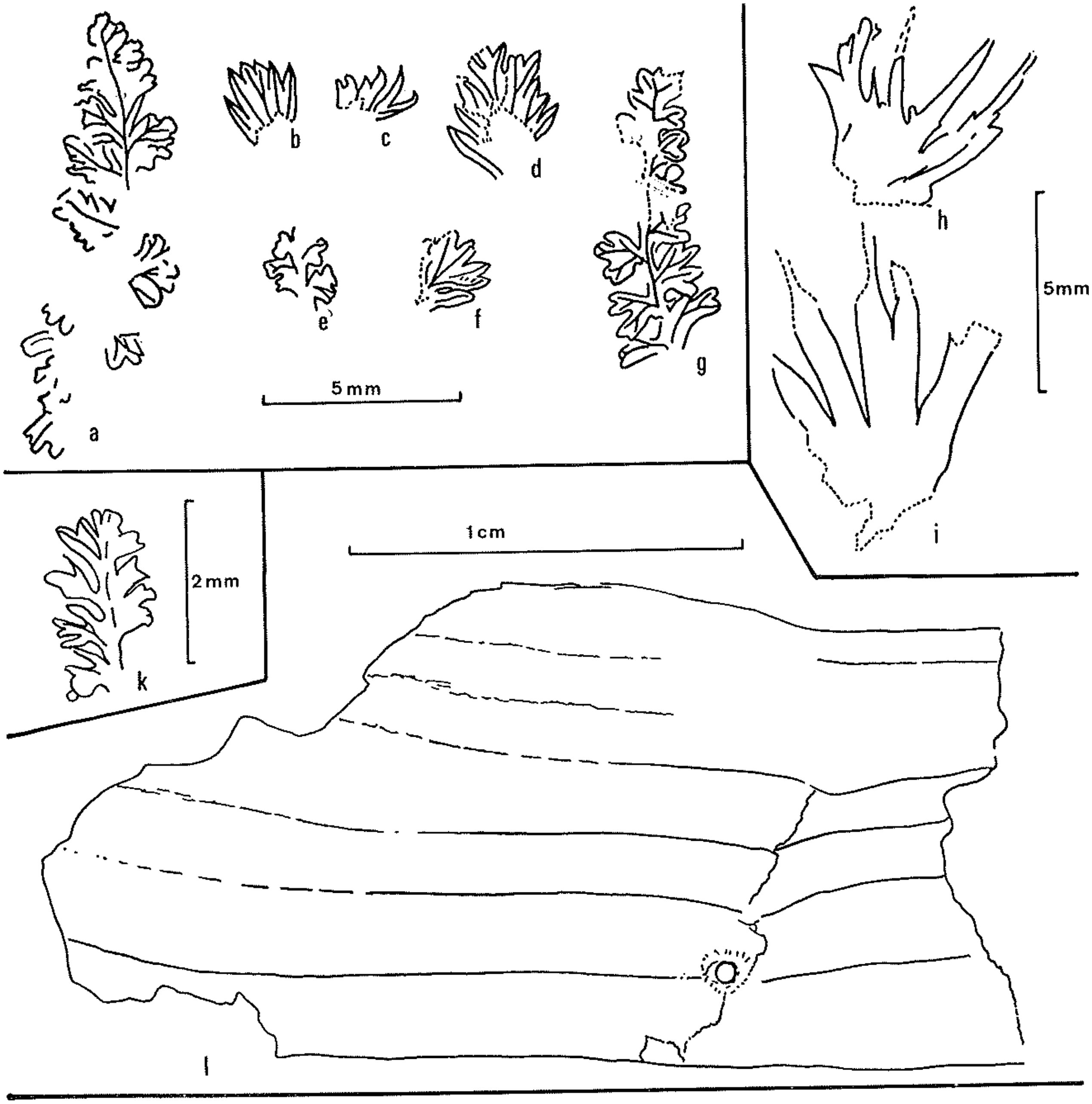


Fig. 34 – A-G: *Sphenopteris gulpeniana* GOTHAN & JONGMANS 1927. A-F: Gulpen borehole, 618 m; G: Gulpen borehole, 614 m. H-I: *Gulpenia limburgensis* GOTHAN & JONGMANS 1927. H: Gulpen borehole, 614 m; I: Gulpen borehole. 625 m. K: *Sphenopteris gulpeniana* GOTHAN & JONGMANS 1927, Wijvenheide borehole, 1894-1896 m. L: *Calamites* sp., Houthem borehole, 274-277 m.

lateral and vertical distribution, since they have been mentioned thus far only from the area around the eastern spur of the Brabant Massif, where it characterizes the Arnsbergian (E2). It should be noted that this "Gulpen" flora does not occur in strata of about the same age further to the West neither South of the Brabant Massif in northern France nor North of this massif in the Turnhout borehole (fig. 33), where a different floral assemblage occurs.

The above mentioned plants are briefly commented below.

Calamites sp. (fig. 34 l)

Several poorly preserved fragments from the Houthem borehole are assigned to this genus. In some cases we cannot distinguish between the axe of some pteridophyl and *Calamites*. Specimens have been recovered from 207.10–208.27 m (?), 246.00–247.00 m (?), 261.35–264.98 m (?) and 274.00–277.00 m.

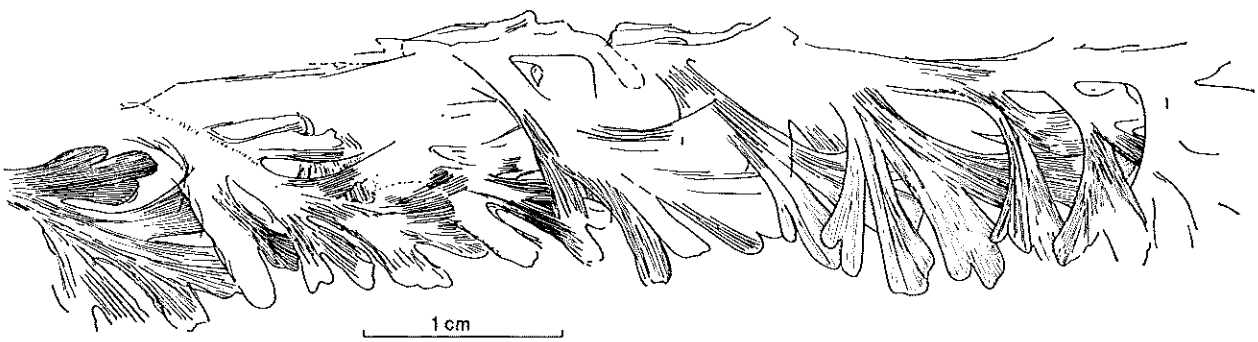


Fig 35 – *Sphenopteridium pachyrrhachis* (GOEPPERT) SCHIMPER 1852. Houthem borehole, 264-270.90 m or 284 m.

Sphenopteridium pachyrrhachis (GOEPPERT) SCHIMPER (fig. 35)

One specimen from dark shale at 264.00–270.90 m or 284 m level (see also chapter 3.11.). Rachis longitudinally weakly striated. Pinna partly folded so that exact outline of pinnulae is difficult to determine.

Species occurs thoughout the Dinantian in Great Britain, Czechoslovakia, Germany and France. PURKYNOVÁ (1970) quoted it also from the Petrkovice-Schichten, lowermost Arnsbergian (E2) of Czechoslovakia.

Gulpenia limburgensis GOTHAN & JONGMANS (fig. 34 h-i)

For full description of this species the reader is referred to STOCKMANS & WILLIÈRE (1953). The species is restricted to the Gulpen borehole (625.00–449.00 m interval and at 244.50 m) and some locations and boreholes near Argenteau (South of Visé in Belgium) of Arnsbergian (E2) age.

Sphenopteris gulpeniana GOTHAN & JONGMANS (fig. 34 a-g, k)

For full description the reader is referred to STOCKMANS & WLLIÈRE (1953). Species restricted to boreholes Gulpen (614–521 m interval), Schimmert (DBLVIII at 398.50 m) and Wijvenheide (1894–1896 m interval) and to some locations and boreholes near Argenteau (South of Visé in Belgium) of Arnsbergian (E2) age.

5. PALEOTECTONICS

5.1. INFLUENCE OF EPEIROGENIC MOVEMENTS ON SEDIMENTATION

Several epeirogenic movements have influenced the sedimentation pattern North and South of the Brabant Massif during Dinantian time. This can be deduced from the frequent occurrence of stratigraphic gaps, unconformities, breccias and reworked microfossil assemblages. None of the boreholes North of the Brabant Massif has yielded a complete

Age	Visé area (after PIRLET 1968)	Campine
V3c	unconformity between upper V3c silicified limestones and underlying dolomite; unconformity between upper V3c dolomite and lower V3c limestone	absent in Woensdrecht
V3b	breccias	absent in Woensdrecht; reworked sequences and breccias in Houthem, Halen and Turnhout
V3a	breccias	absent in Halen and Turnhout; probably present in Woensdrecht
V2b	absent in Richelle; present in La Folie	absent in Halen; present in Rillaar
V2a	absent in Richelle and La Folie	extremely reduced in Turnhout; normal development in Halen and Booischot; conglomerates in Booischot
V1b	several uncorformities and breccias	absent in Halen; present in Booischot and Turnhout
V1a		microbreccias in Turnhout
Tn	late Tournaisian movements in La Folie; absent in Richelle	?

Table IV – Influence of epeirogenic movements on sedimentation during Dinantian.

uninterrupted sequence of Dinantian rocks thus far. The same is true for the Visé area along the eastern spur of the massif. It may be expected that only in the central parts of the Campine-Brabant Basin continuous deposition of Dinantian sediments has occurred. Table IV shows the influence of epeirogenic movements on the Dinantian sedimentation in the Visé and Campine areas. The same movements have been also recognized along the southern flank of the Brabant Massif in the Namur Basin (PIRLET 1964, 1967b, 1970, in press).

5.2. FOLDING ALONG EASTERN SPUR OF BRABANT MASSIF

The following anticlinal structures are known along the eastern spur of the Brabant Massif: the Visé-Puth Anticline in the West, the Booze-Le Val Dieu Anticline in the South-East and in between several other anticlines, of which the Waubach Anticline is the best well described thus far (Enclosure 1).

The Visé-Puth Anticline has been a high since the Lower Dinantian as proven by PIRLET (1967a). The core of this anticline consists in the Visé area of Frasnian rocks, unconformably overlain by an extremely reduced Tournaisian (less than 1 m) at La Folie, which is absent at Richelle. These rocks are overlain by incomplete sequences of Viséan strata with breccias and intraformational unconformities. BLESS (1973) demonstrated that the same structure has also influenced the sedimentation pattern in South Limburg during Lower Westphalian time. This means that this anticline has been a synsedimentary ridge from at least Dinantian to Lower Westphalian time and was at least intermittently active during short episodes corresponding to the above (see 5.1.) epeirogenic movements during the Dinantian, eventually during the Namurian (but nobody has thus far looked for any evidence because of the few boreholes penetrating the badly dated Namurian in this area) and during the Westphalian A-B.

The Booze-Le Val Dieu Anticline is fractured by several longitudinal thrust-faults (o.a. Aguesses-Asse Overthrust) into several nappe-like structures (cf. GRAULICH 1955, 1964) as shown by the outcropping Famennian on the Booze-Le Val Dieu Ridge (ANCION, VAN LECKWIJCK & UBAGHS 1943) and the Bolland borehole (GRAULICH 1975). This anticline dips in eastnortheastern direction under the Dinantian and Namurian of the Sippenaeken area as shown by the depth contour lines of the top Dinantian (Enclosure 1). This structure must have been a synsedimentary ridge during the Dinantian and lowermost Namurian, because the Dinantian occurring all around this structure is absent on top of it, where the Upper Arnsbergian (E2c) unconformably overlies the Famennian (see the several "nappes" occurring in the Bolland borehole described by

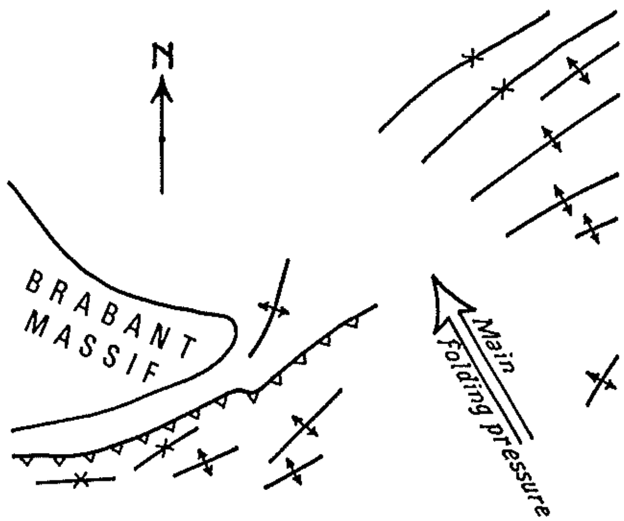


Fig 36 – Deviation of folding axes around eastern spur of Brabant Massif.

GRAULICH 1975). Since the Namurian-Dinantian rocks in the Sippenaeken area form an anticlinal structure, this folding process must have continued after the deposition of Upper Namurian strata. This means that also this structure has been formed since the Dinantian and may have been active into Lower Westphalian time as a positive element.

In between these two anticlinal structures of Visé-Puth and Booze-Le Val Dieu, several more anticlines occur of which the Waubach and Hamm (East of the considered area) are the best well known. These structures have been proven to have influenced the Lower Westphalian sedimentation pattern in South Limburg (BLESS 1973). No information exists whether they were also active during Dinantian and Namurian time, nor if they continue in southwestern direction.

Summarizing, we may conclude that these structures have been all synsedimentary formed by the different Variscan Carboniferous movements, beginning with at least late Bretonnic (pre-Sudetic) phases and continuing untill at least early Malvernian movements. Of course, this does not exclude that these structures have been accentuated by later folding. This conclusion reinforces the hypothesis that in particular circumstances some anticlinal and synclinal structures may already have started to be formed at the time of sedimentation.

The North-South direction of the Visé-Puth Anticline is here considered as a natural deviation of the generally East-West oriented structures in the Ardennan and Rhenish-Ruhr areas, caused by a different resistivity of the cratonic Brabant Massif and the area immediately East of it. We do not believe that this deviation of the fold axes implies also deviation of the general direction of the main folding pressure (fig. 36).

6. PALEOGEOGRAPHY

6.1. FAMENNIAN

Famennian rocks are practically unknown in the Campine with the exception of Heibaart and Booischot (BOUCKAERT & GROESSENS, unpublished data on conodont-biozonation).

THOREZ (in: BECKER, BLESS, STREEL & THOREZ 1974) has convincingly shown that the southeastern border of the Brabant Massif is delineated by a sandy near-shore facies, currently known as "Condroz Sandstone". Farther to the South, this facies is replaced by a more open marine environment.

A similar situation can be observed in the Ruhr area. In the boreholes Wachtendonk-1, Münsterland-1 and Vingerhoets-93, the Famennian consists of a non-turbiditic, sandy sequence which is rather similar to the "Condroz Sandstone" facies of Belgium. It is presumed that a comparable rock facies occurs in Isselburg-3 and Versmold-1. The same environment is found also in the Velbert area near the junction of Rhine and Ruhr. East of this latter area, Famennian turbidites occur, which doubtlessly have been derived from the North (cf. PAPROTH & WOLF 1973). The shoal Rhenish Massif has locally supplied some conglomerates into the basin along its northeastern border (PLESSMANN 1962). The distribution pattern of "Condroz" facies in the North and turbidites in the South within the Ruhr Basin points to a Famennian erosive high at some distance North of the Münsterland-1 borehole.

6.2. DINANTIAN

6.2.1. Ruhr Basin

In the boreholes Isselburg-3, Münsterland-1 and Versmold-1, a rather condensed Dinantian interval of less than 100 m of Kulm facies occurs (WOLBURG 1963, 1970; FABIAN 1971). In the Vingerhoets-93 borehole, this Kulm sequence reaches a thickness of about 100 m. Further towards the South, the thickness of Kulm facies-type rocks increases along the northern and eastern slopes of the Rhenish Massif to values of well over 200 m. Only locally along the northwestern slope of this massif, a thickness of only 35 m occurs. South in the Kulm facies area and East of the Rhenish Massif, a Greywacke fan – derived from the Middle German High in the South – occurs. It is suggested that most Kulm sediments (with exception of the Flaggy Limestone and Hellefeld Limestone s.l.) North and East of the Rhenish Massif have been derived from this Middle German High. The decrease of thickness of the sediments towards the North and the simultaneous decrease of the overall grain size in the same direction suggest that no sediment supply came from the North.

As pointed out above, there are indications that a high existed somewhere North of the Münsterland-1 borehole in Famennian and in Namurian time. It is presumed here, that this high was existent also during the Dinantian as a non-erosive shoal with no or practically no sedimentation on it.

6.2.2. Zandvoort-Maasbommel-Krefeld Ridge

There are several indications that it is not impossible that a shoal existed on the place of the actual Zandvoort-Maasbommel-Krefeld Ridge. This may or may not have been a continuous structure.

This area formed part of the pre-Hercynian consolidated Old Red Continent, which was faulted and broken into smaller blocks as – for example – the Wales-Brabant Massif in the South and the Alston Block in northern England. Several of such massifs or blocks will have served at least temporarily as shoals separating subsiding areas. Such vertical block movements are reflected in the regional sedimentation pattern (cf. HOFFMANN, LINDERT, WEYER & ILLERS, 1975). From the Lower into the Upper Devonian, there was a transgression covering gradually high positive blocks of this faulted craton from say South to North. It is suggested that also the shoal North of the Münsterland-1 borehole in figs. 37 and 38 was such a block.

The following arguments have brought us to believe that the Zandvoort-Maasbommel-Krefeld Ridge or at least parts of it has at least intermittently acted as a shoal from the Middle Devonian onwards:

a – The Givetian Schwarzbachtal Conglomerate North of Düsseldorf can only have been derived from a nearby high in the North, because towards the South and South-East contemporaneous marine sediments occur (PAPROTH & WOLF 1974).

b – The limit between the thick limestone facies in the Campine-Brabant Basin and the thin Kulm facies in the Ruhr Basin during the Dinantian is parallel to the Krefeld High (WOLBURG 1970). The Upper Visean Flaggy Limestones within the Ruhr Basin must have been derived also from the Krefeld High s.l.

c – The isopachs of the Namurian Ruhr Basin suggest that this basin was limited in the South by the Rhenish Massif, in the West by the Krefeld High and in the North by a not yet delimited shoal (cf. HEDEMANN & TEICHMULLER 1971).

d – The reduced Westphalian B-C in the boreholes Hardenberg-2 and Tubbergen-8 at the southwestern edge of the later Ems Low favours also the existence of a positive area along the Zandvoort-Maasbommel-Krefeld Ridge (cf. VAN WIJHE & BLESS 1974; BLESS & STREEL 1976)

e – Before the Stephanian sedimentation took place, either erosion or non-deposition of Upper Westphalian sediments must have occurred at least along the western edge of the later Ems Low (HEDEMANN & TEICHMULLER 1971).

The intermittent existence of such a shoal along this line during Devonian to Silesian time might be proven by a borehole somewhere on this structure as shown in fig. 41. In this case one should expect to find pre-Hercynian rocks inmediately underlying the Silesian, eventually separated from these by a very condensed and incomplete sequence of Devono-Dinantian. This structure might also be deduced from the eventual occurrence of reworked material (heavy minerals, spores) in boreholes around it in strata of the above-said ages.

6.2.3. Campine-Brabant Basin

In contrast to the thin sequences of Kulm facies in the Ruhr Basin, thick carbonate sequences mark the Dinantian in the Campine-Brabant Basin (figs. 39-40).

The lower part of the Dinantian in the boreholes Booischot, Halen and Wachtendonk and in outcrops of the Aachen area consists mainly of dolomites. These dolomites show a remarkably constant thickness and character in the Aachen area. We presume these occurrences to belong to a dolomitic belt along the eastern border of a lagoon, which made up the bulk of the Campine-Brabant Basin (fig. 31). This basin was closed in lower Dinantian times to the South by the Brabant Massif, to the East by the Rhenish Massif and to the North by the Zandvoort-Maasbommel-Krefeld Shoal. Most probably, there was no open contact to the Dinant-Namur Basin. The shallow lagoon was in contact with the open sea in the North-West, where eventually reef belts may have existed parallel to the shoals on the edge between subtidal and infratidal environments. The lagoon itself will have been chararterized by the deposition of dark calcilutites and by a poor fauna.

The upper part of the Dinantian in the boreholes Woensdrecht, Turnhout, Kessel, Booischot, Rillaar, Loksbergen, Halen, Wijvenheide, Houthem and Wachtendonk and in outcrops of the Aachen and Velbert areas consists of limestones (fig. 40). In the Halen borehole, a turbiditic(?) sequence of V2a age is found. V3b-V3bγ breccias occur at Turnhout and Halen.

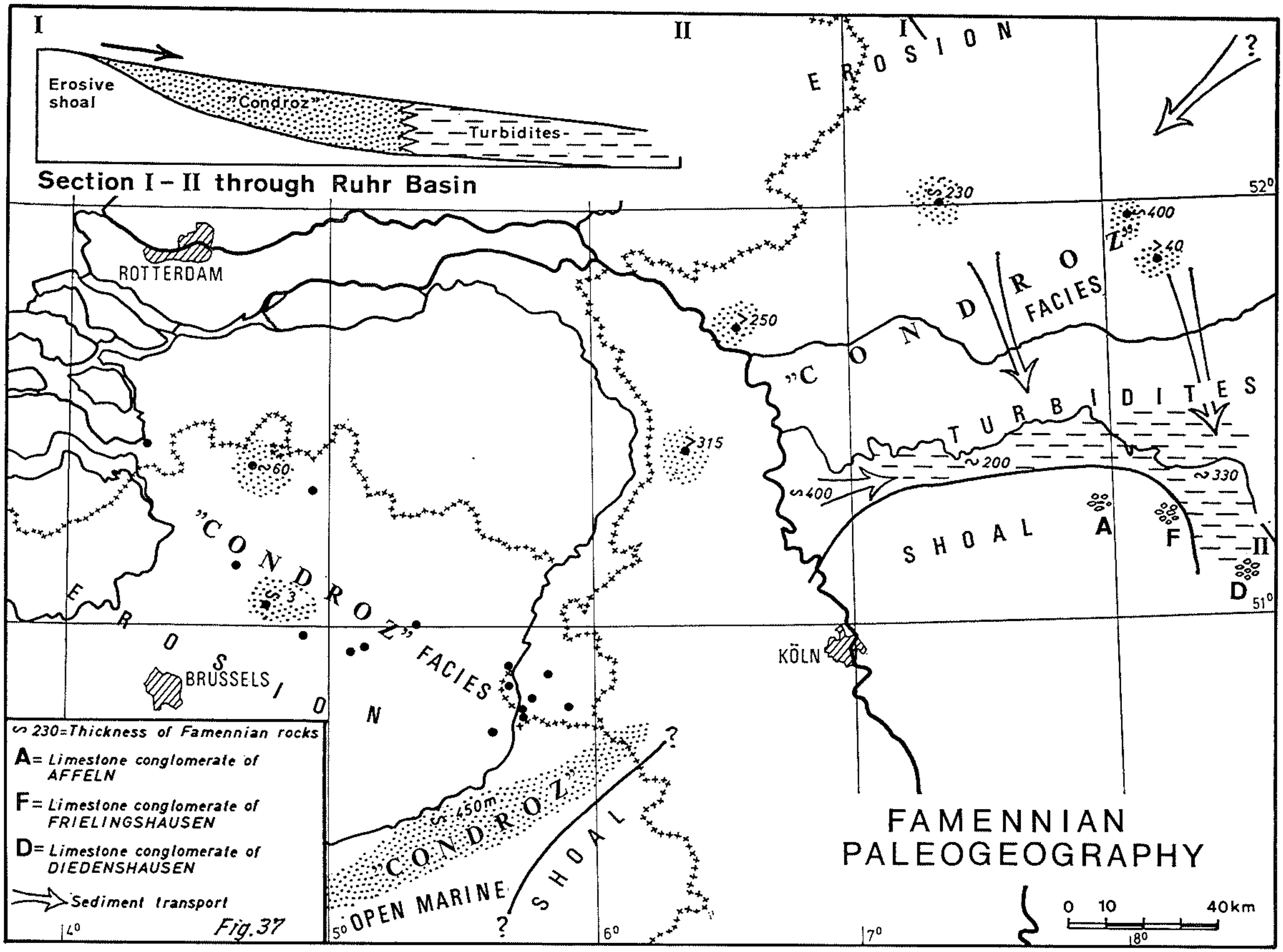
A worldwide transgression marks the base of the upper part of the Dinantian. This transgression is characterized by deposition of thick, fossiliferous limestones. In the Campine-Brabant Basin and in the Dinant-Namur Basin, this transgression is marked by a rather quick change in the sedimentation pattern. A more open contact of the Campine-Brabant Basin to the British basins must have existed. This open sea facies covered and passed the Zandvoort-Maasbommel-Krefeld Shoal in the Velbert area as testified by the imbricated limestone detritus in that region (Franke, Eder & Engel 1975). A subtidal to infratidal, thick limestone facies may be expected to occur throughout the Campine-Brabant Basin.

In late Visean time, uplift of the Brabant Massif South-West of the Woensdrecht borehole caused non-deposition and/or erosion of at least Upper Visean rocks. It is not impossible, that further westwards even Middle and Lower Visean may have been eroded. This uplift is reflected also in Middle to Upper Visean carbonate breccias at Halen and Turnhout and Middle to basal Upper Visean possible turbidites in the Halen area, what suggests local movements at the Brabant Massif in that area.

6.3. CONCLUSIONS

Of course, the above paleogeographical pictures are to be considered highly tentative, since they cover a large area without any factual information. Still, it is believed that they may serve as a base for further discussion. In order to clarify into some detail the interpretation of paleogeographic development of this area during the Carboniferous, four sites or areas have been selected for which a rough outlook of what kind of Carboniferous rocks may be expected at relatively low depth is given (fig. 41). They are briefly commented below.

I. The Zandvoort-Maasbommel-Krefeld Shoal. Although we are aware, that this lineament is an essentially Mesozoic structure, it is suggested that parts of it may have been existent already in the Paleozoic. This believe is based on indirect arguments (see 6.2.2.). Of course the proof, that a shoal existed here at least intermittently during the Paleozoic, can only be found by drilling or by geophysical methods. This shoal (or shoals) would divide the Dutch Carboniferous in at least two basins: the Campine-Brabant Basin in the South and a basin in the North, that comprises a.o. the thick Lower Westphalian A of the Steenwijkerwold-1 borehole (cf. Van Wijhe & Bless 1974). This structure may not have been active during the Lower Westphalian since no reduction of Westphalian A sediments could be recognized in the Oostzaan-1 borehole (Thiadens 1963). Therefore, a normal thickness development of Westphalian A-B may be expected. As suggested above (see 2.4.), the Namurian may be less than 1000 m thick. This means, that the base of the Namurian or top of Dinantian is to be found at about –4000 m NAL. As argumented above (see 6.2.2.), we expect – following our paleogeographical concept – that the Devono-Dinantian on this shoal will be very condensed and incomplete. Therefore, the pre-Hercynian basement should be found well above –5000 m NAL. Our suggestion of a structure that acted as a shoal during Dinantian, Namurian and Upper Westphalian and on the contrary subsided during the Lower Westphalian is not a mere artifice to explain the observed normal thickness of Lower Westphalian strata and


I
II
Erosive shoal
"Condroz"
Turbidites
Section I – II through Ruhr Basin
EROSION
ROTTERDAM
BRUSSELS
KÖLN
"CONDROZ" FACIES
"CONDROZ" FACIES
TURBIDITES
SHOAL
A
F
D
"CONDROZ"
OPEN MARINE
SHOAL
~230
~400
>40
>250
>315
~60
~3
~200
~330
~400
~450m
52°
51°
4°
5°
6°
7°
8°
0 10 40km
~ 230=Thickness of Famennian rocks
A= Limestone conglomerate of AFFELN
F= Limestone conglomerate of FRIELINGSHAUSEN
D= Limestone conglomerate of DIEDENSHAUSEN
Sediment transport
FAMENNIAN PALEOGEOGRAPHY
Fig. 37

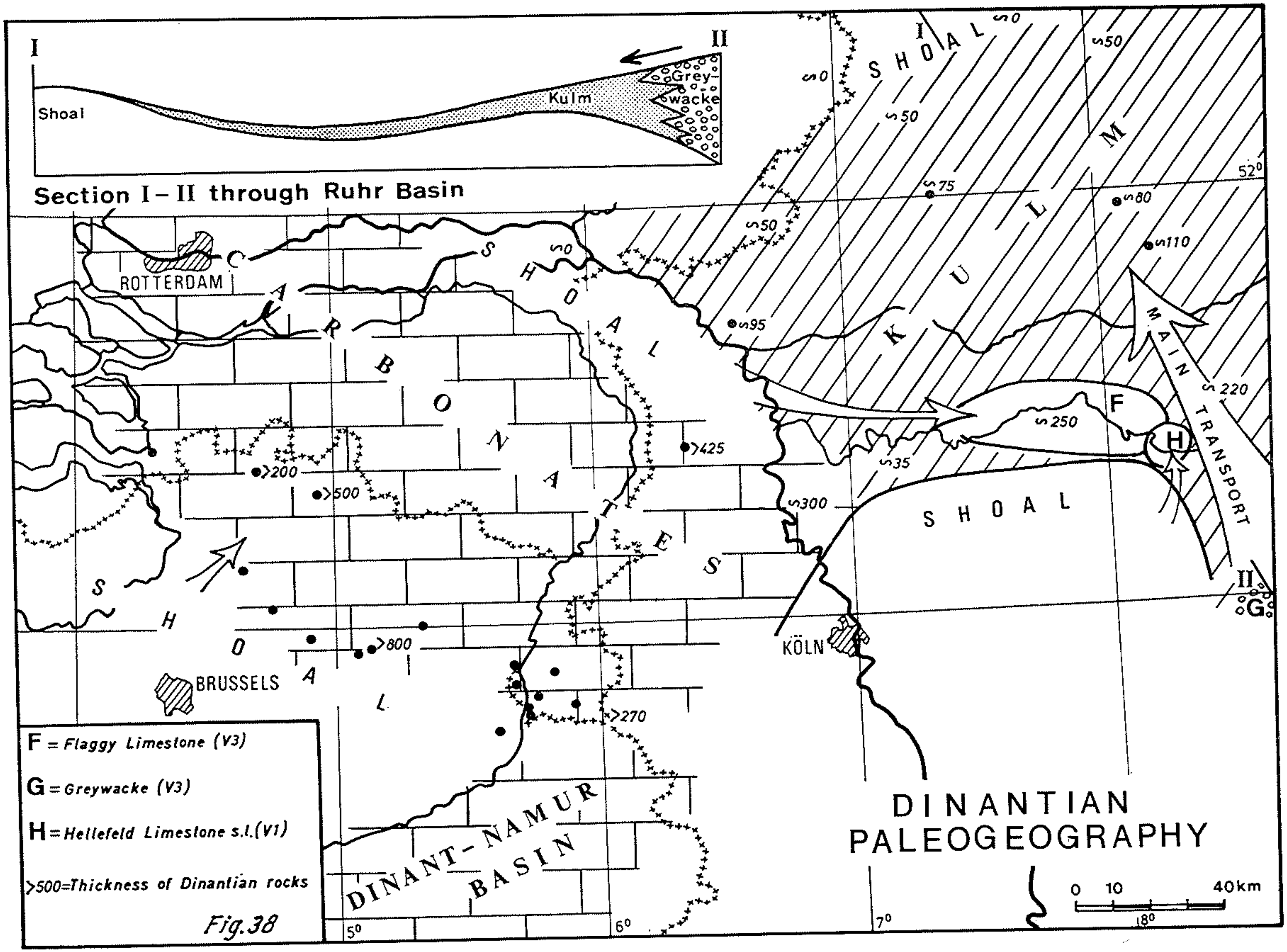
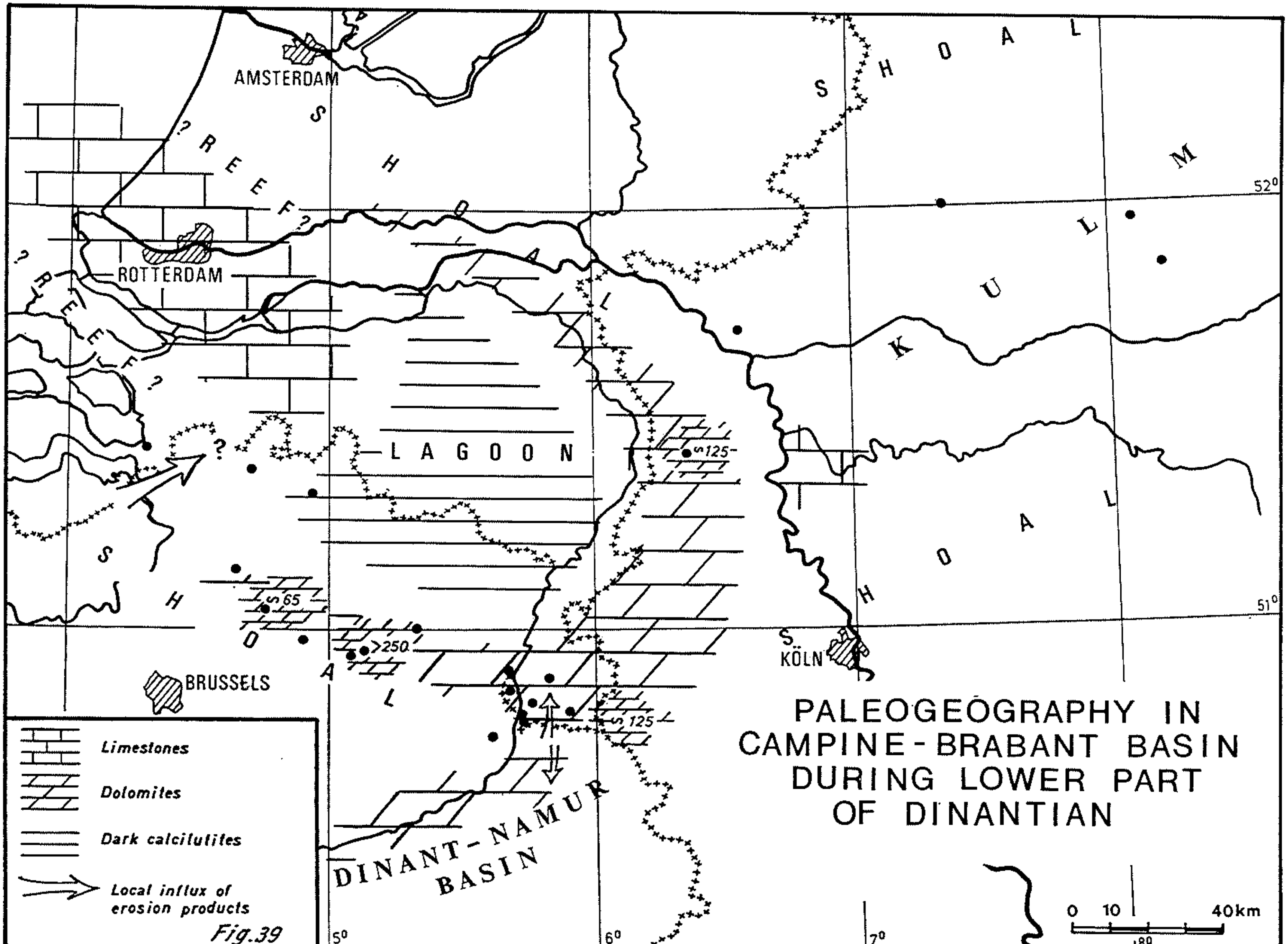

Section I – II through Ruhr Basin
I
II
Shoal
Kulm
Grey-
wacke
SHOAL
KULM
MAIN TRANSPORT
CARBONATES
SHOAL
DINANT-NAMUR
BASIN
DINANTIAN
PALEOGEOGRAPHY
ROTTERDAM
BRUSSELS
KÖLN
F
H
G
0
50
75
80
110
95
220
250
35
300
>425
>200
>500
>800
>270
5°
6°
7°
18°
52°
0 10 40km
F = Flaggy Limestone (V3)
G = Greywacke (V3)
H = Hellefeld Limestone s.l.(V1)
>500=Thickness of Dinantian rocks

Fig.38



PALEOGEOGRAPHY IN
CAMPINE - BRABANT BASIN
DURING LOWER PART
OF DINANTIAN
AMSTERDAM
ROTTERDAM
BRUSSELS
KÖLN
? REEF ?
? REEF ?
SHOAL
SHOAL
SHOAL
KULM
LAGOON
DINANT-NAMUR BASIN
≤125
≤125
≤65
>250
5°
6°
7°
51°
52°
0 10 40km
18°
Limestones
Dolomites
Dark calcilutites
Local influx of erosion products

Fig.39

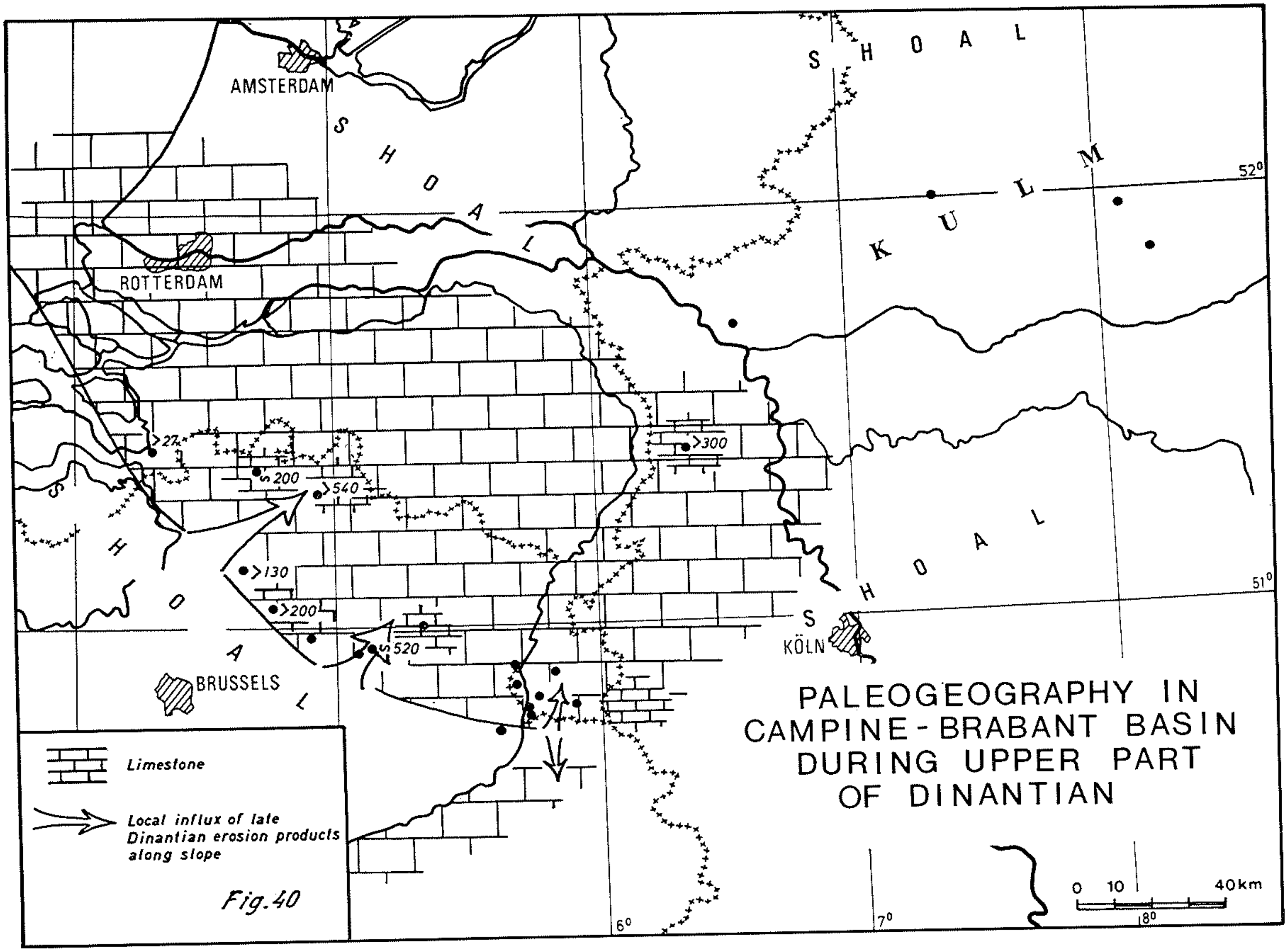
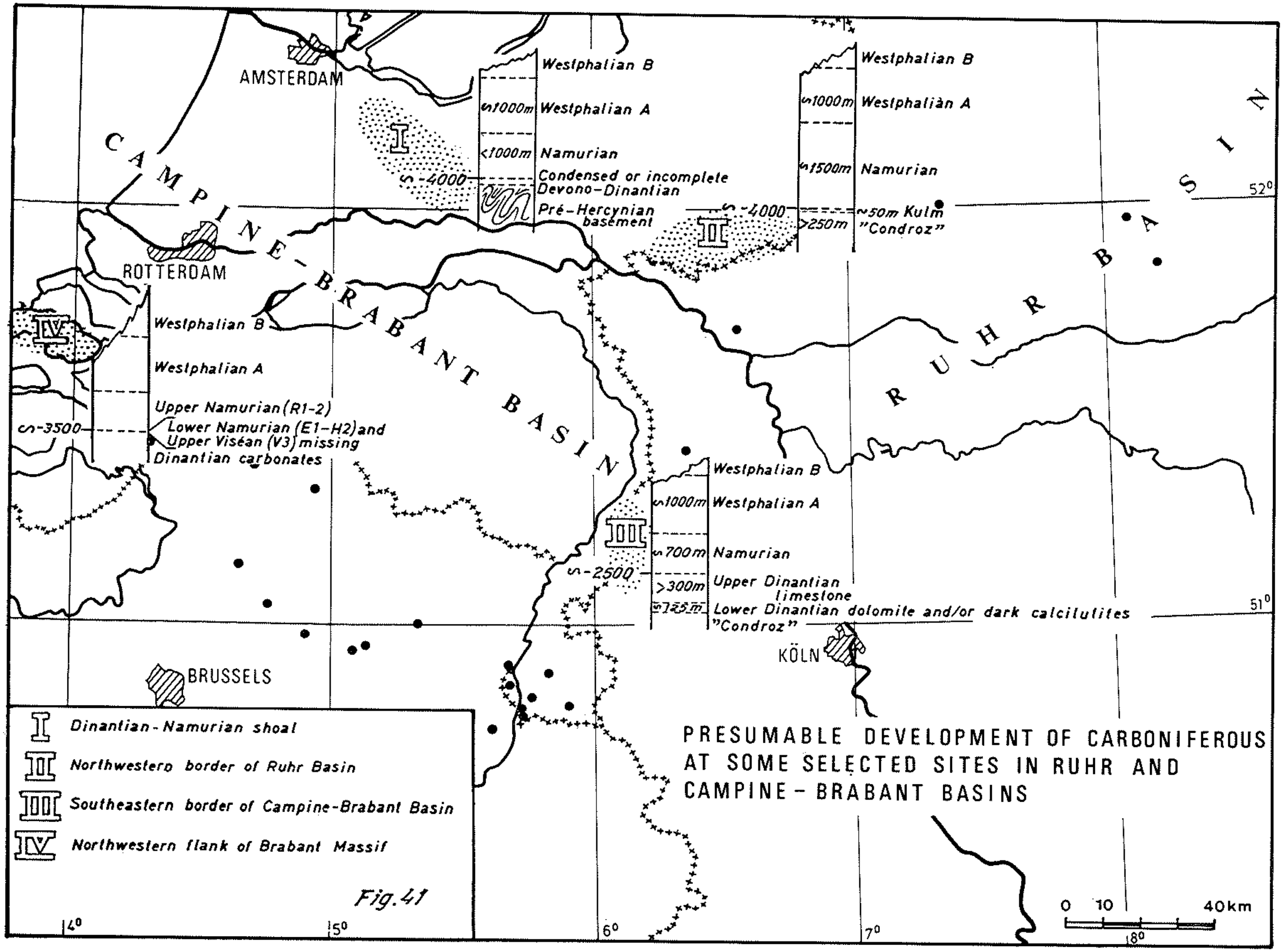

PALEOGEOGRAPHY IN
CAMPINE - BRABANT BASIN
DURING UPPER PART
OF DINANTIAN
SHOAL
SHOAL
SHOAL
SHOAL
KULM
AMSTERDAM
ROTTERDAM
BRUSSELS
KÖLN
>27
200
>540
>130
>200
520
>300
52°
51°
6°
7°
0 10 40km
Limestone
Local influx of late Dinantian erosion products along slope

Fig. 40



PRESUMABLE DEVELOPMENT OF CARBONIFEROUS AT SOME SELECTED SITES IN RUHR AND CAMPINE - BRABANT BASINS

Fig. 41

still bet on a non-deposited Upper Westphalian and Dinantian and Namurian in that area. The incomplete Dinantian and Namurian in e.g. the Woensdrecht borehole, and the "normal" thickness of Lower Westphalian overlain by a quite reduced Upper Westphalian in the Rijsbergen borehole (VAN WIJHE & BLESS 1974), both situated along the northern flank of the Brabant Massif, are in favour of such a hypothesis.

II. The northwestern border of the Ruhr Basin. The thickness of the Lower Westphalian strata in this area is relatively well documented by notably the Corle and Zeddam-1 boreholes (THIADENS 1963). The base of the Westphalian will be at about –2000 m NAL or even slightly higher. The Namurian will be somewhere between 1000 and 2000 m thick (cf. HEDEMANN & TEICHMULLER 1971), so that the Dinantian should be reached at a maximum depth of say –4000 m NAL. We presume that the Dinantian will consist of only some 50 m of Kulm sediments. In our opinion, the limestone facies of the Orslev-1 borehole in Denmark (MICHELSEN 1971) and of the islands Rügen and Hiddensee in the German Democratic Republic (HOFFMANN, LINDERT, WEYER & ILLERS 1975) has been deposited in a different basin in the North. This basin was separated from the Ruhr Basin by a shoal somewhere North of the Münsterland-1 borehole. It was also separated from the Campine-Brabant Basin as suggested above. It is beyond the scope of this paper to discuss whether such a northern basin was again subdivided into smaller sedimentation areas. Underlying the Dinantian, a thick sequence of Famennian "Condroz" sediments may be expected, analogous to those found in the boreholes Münsterland-1 and Wachtendonk-1.

This may be a key-area for investigating whether there really existed a Kulm basin separated from more or less independent limestone basins as presumed here, or if there was rather a gradual transition from Kulm into limestone facies similar to the situation in Wales and South-West England (cf. GEORGE 1969). It should be noted however that also in this latter area, a shoal may have separated the Kulm and Limestone environments. This possibility can be deduced at least from RAMSBOTTOM's (1969) suggestion, that a landmass might be inferred between South Wales and South-West England in Namurian times because of a similar abrupt change in Namurian sedimentary facies. RAMSBOTTOM argued that some of the (Namurian) sediments in South-West England are probably northerly derived, whereas some of the Namurian sandstones in South Wales appear to have been derived from the South. He further stated, that "there is ample evidence of thrusting from the South in Devon and Cornwall, and restoration of this region to its original Carboniferous position would make room for a substantial landmass between South Wales and South-West England."

III. The southeastern border of the Campine-Brabant Basin. The base of the Westphalian is situated between –1000 m and –2000 m NAL (KIMPE 1973). The Namurian may be between some 600 and 800 m thick. Therefore, the Dinantian should be reached somewhere between –2000 m and –3000 m NAL. A more or less complete sequence from Visean into Namurian rocks may be expected to exist, since this area is far enough from the surrounding shoals (Krefeld High, Rhenish Massif, Brabant Massif). There are no arguments to believe that the upper part of the Dinantian is not developed in a limestone facies. The lower part of the Dinantian may consist of dolomites, similer to those found in the Wachtendonk-1 borehole and in the Aachen area and in some borehole along the northeastern flank of the Brabant Massif. But it is also possible, that one finds dark calcilutites of the lagoonal facies. As explained under 6.2.3., we do believe, that the Campine-Brabant Basin was more or less isolated from the Dinant-Namur Basin in the South, the Ruhr Basin in the East and the "northern" basin by several shoals, which locally may have been emergent and even erosive as for example in the area around Visé and Booze-Val Dieu (cf. fig. 5; PIRLET 1967a). In such a more or less closed basin with only a possible opening towards the North-West, a poorly aerated and quiet environment, unsuited for a prolific fauna, can be expected. Only the shallow water facies of its borders will have known a rich fauna and flora. A similar situation is found in the Central Province of England in lower Dinantian times (cf. GEORGE 1969).

IV. The northwestern flank of the Brabant Massif. The base of the Westphalian may be somewhere between –2000 m and –3000 m NAL. Only the higher parts of the Namurian may be expected to occur (cf. also 2.2., fig. 4). At least the Upper Visean will not be found. In fact, this would be comparable to the Woensdrecht borehole, the hiatus between Dinantian and Silesian rocks being only larger. A probably incomplete Dinantian may be found below, consisting of carbonates intercalated by terrigenes derived from the Brabant Massif during short irregular uplifts. We do not exclude the possibility that further North a reefal facies developed parallel to the edge of the Brabant Massif in lower Dinantian time.

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PLATES AND EXPLANATIONS

The photographs of plates 13 to 16 and 20 have been made with the Cambridge Stereoscan S2 at the University of Liège.

PLATE 1

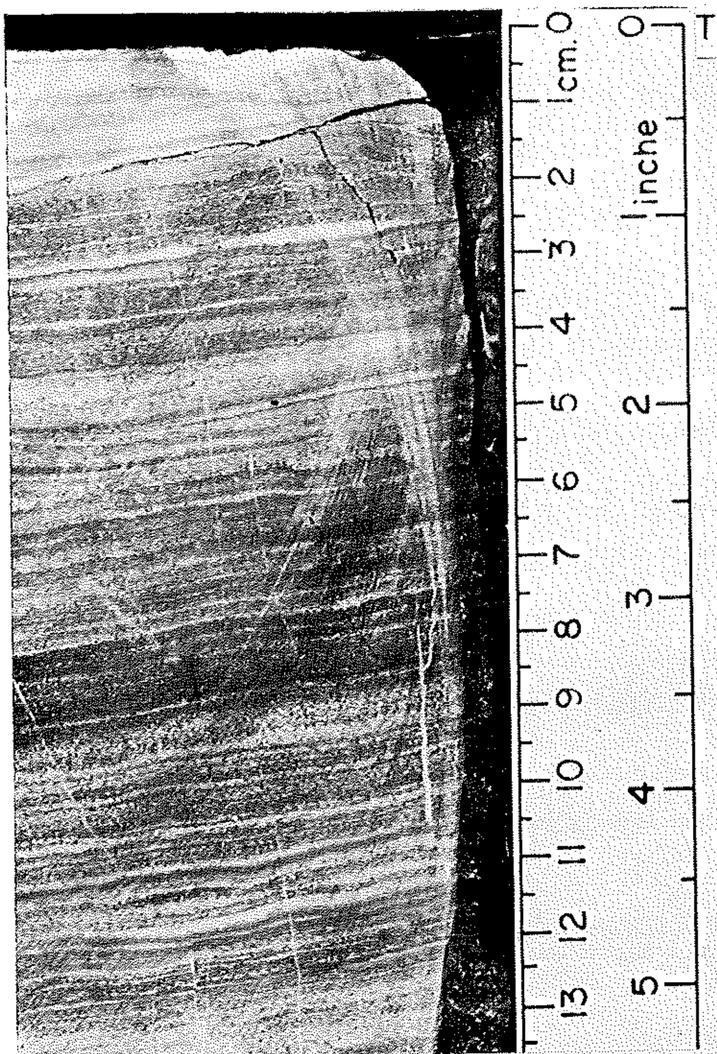
1 Dry sample
Turnhout borehole, 2216.83-2220.98 m; black silicified shale or microcrystalline shaly limestone with lighter slightly undulating or lenticular laminations which consist of non-silicified bioclastic trails. At the top (between 0 and 1 cm), irregular eroded surface filled with finely laminated argillaceous limestone (not silicified).

2 Polished sample
Woensdrecht borehole, 1183 m; middle grey pseudo-oolitic (biointraclastic) calcarenite with sparite cement (grainstone). Bioclasts are mainly crinoids, shell debris, ostracodes, *Koninckopora* and foraminifers. Large rounded intraclasts (darker) are made of the same sediment of finer granulometry (from 4 to 7.5 cm and 12 to 15 cm). Some are lined by small stylolites. Voids and fractures are filled with calcite.

3 Dry sample
Turnhout borehole, 2187 m;

From 7 to 3 cm: recrystallized calcirudite, extremely porous in lower left, with numerous thin vertical fractures filled with calcite. The darker oblique trail is made of finer-grained and more cemented material. The upper right is a recrystallized calcarenite with muddy matrix (packstone) and some argillaceous peels (reworked laminations). The lighter uppermost part of this zone shows a calcitic filling of voids (geodes) with incorporated large peels of black argillite. Porosity and voids seem to be the result of dissolution phenomena.

From 3 to 0 cm: large angular intraclast of laminated black calcareous shale (indurated marl) with regular or lenticular laminations of limestone (recrystallized calcirudite).



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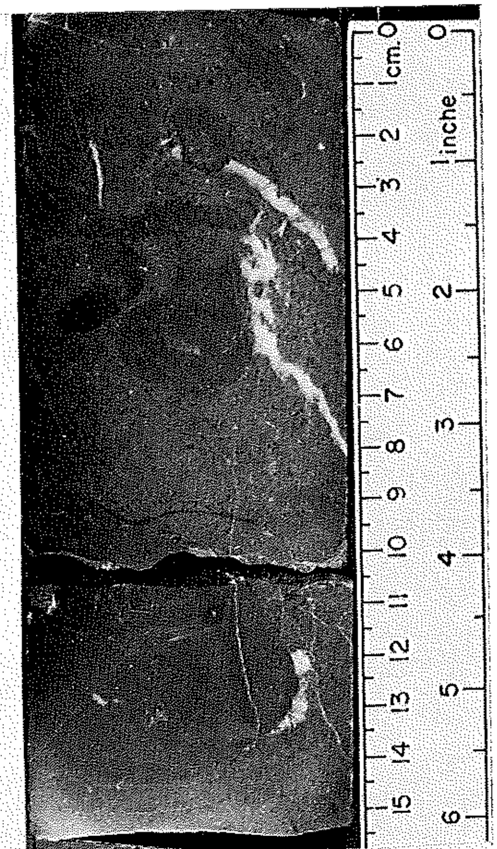

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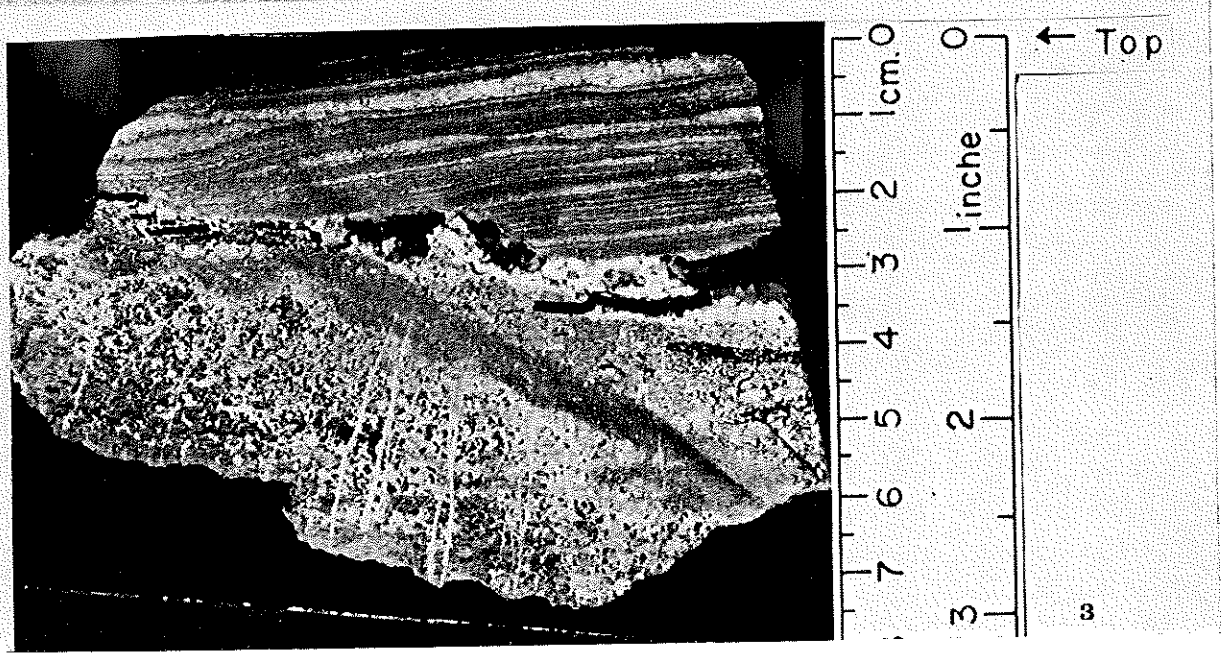

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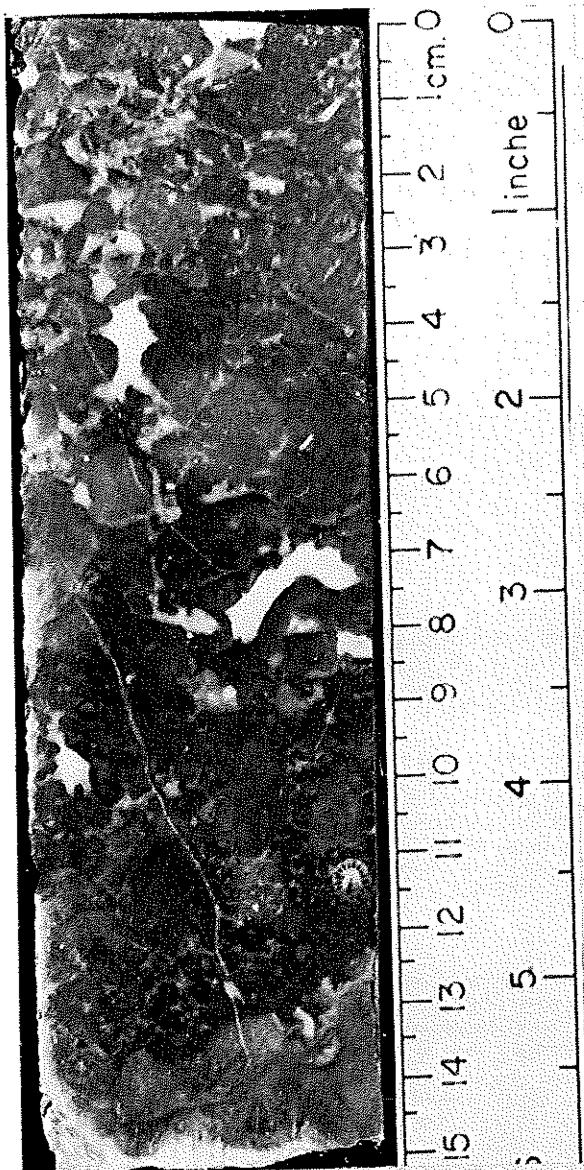
PLATE 2

1 Wet sample
Turnhout borehole, 2271.50 m; infraformational breccia composed of an accumulation of heterogeneous intraclasts of micritic and bioclastic limestone. Matrix is both micritic and sparitic. Some larger fragments of crinoids and corals are visible.

2 Same sample, but dry.

3 Wet sample
Turnhout borehole, 2182 m; middle grey laminated microcrystalline dolomite with slump structure. Slumping took place in coherent sediment. Voids are filled with crystalline dolomite.

Calcimetry:	30″	60″	15′	30′
	15	29	92	92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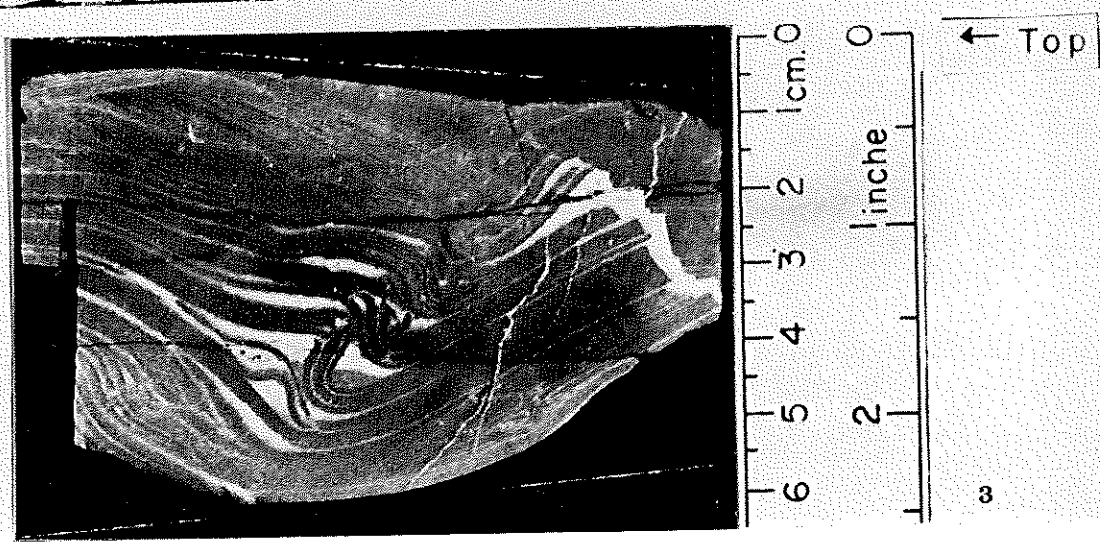
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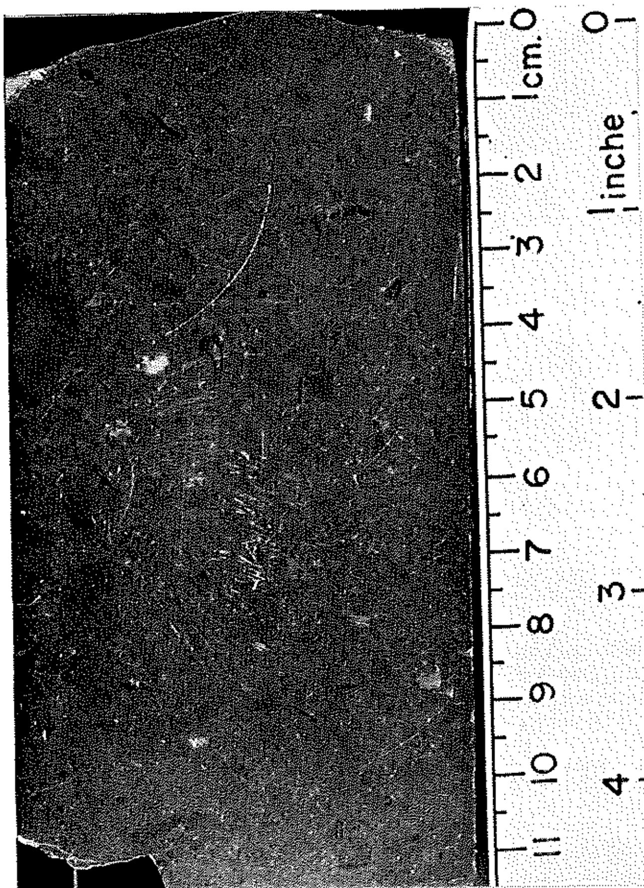
PLATE 3

1 Polished sample
Woensdrecht borehole, 1182.50 m; middle grey pseudo-oolitic (biointraclastic) calcarenite with sparite cement. Comparable to sample from 1183 m (pl. 1, fig. 2), but richer in shell debris and large crinoid debris. Soft pebbles of finer granulometry than sample from 1183 m of which one has a coarser-grained nucleus (between 3 and 5 cm on left side of core).

2 Polished sample
Woensdrecht borehole, 1185 m (B); light grey pseudo-oolitic (biointraclastic) calcarenite with sparite cement (grainstone). Bioclasts are mainly crinoids, shell debris, ostracodes, *Koninckopora* and foraminifers. Some indistinct laminations are visible in the lower part of the sample. They are made of alternating layers of coarser and finer sediment. These laminations are disturbed by bioturbation between 8 and 10 cm.

3 Polished sample
Turnhout borehole, 2651 m; algal limestone (micrite) showing a typical fenestrate fabric filled with sparry calcite. Some of these algal layers have been fractured and reworked, especially in the uppermost part. The upper surface has been eroded and filled with calcarenite. The vertical structure may be a dissication crack or a trace of water expulsion.

N.B.: This kind of facies is commonly called "calcaire fleuri" in descriptions of this borehole.



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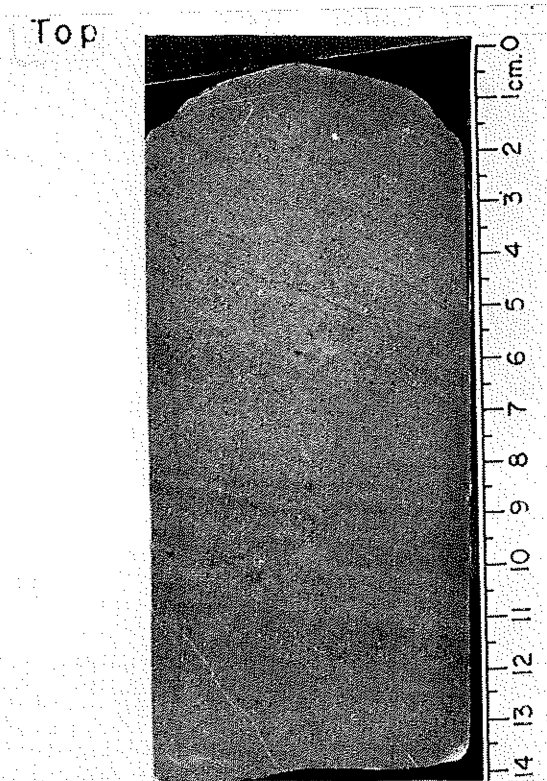

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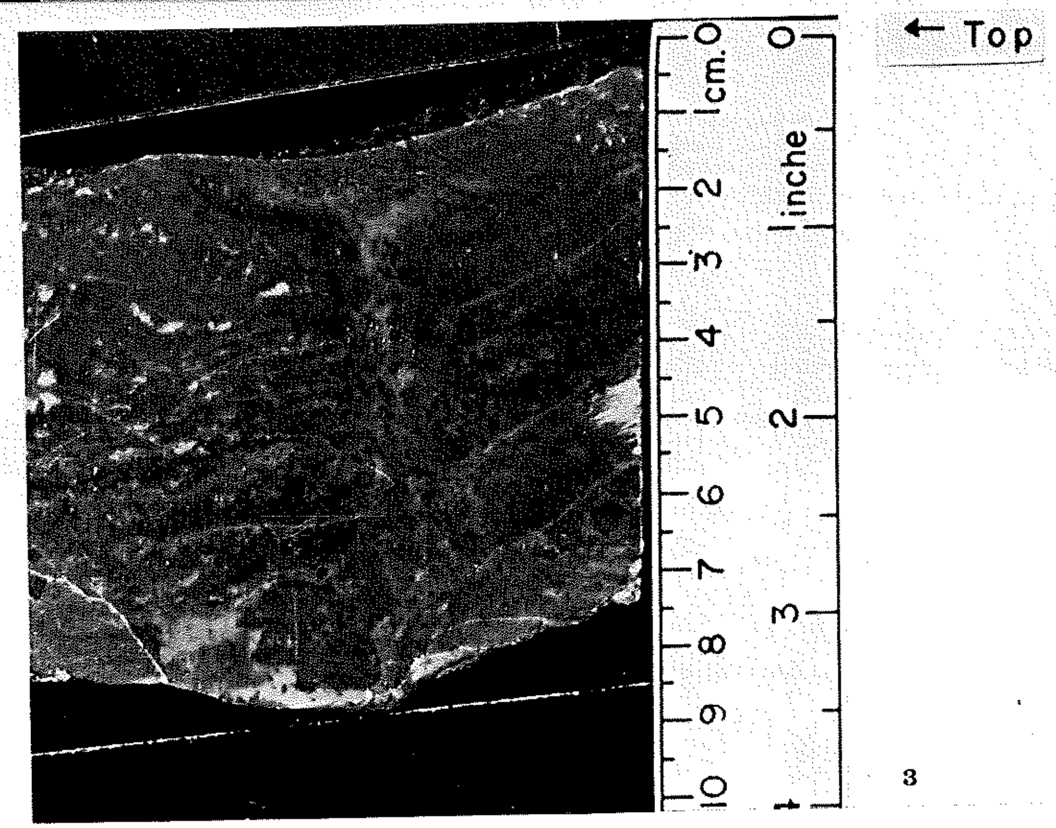


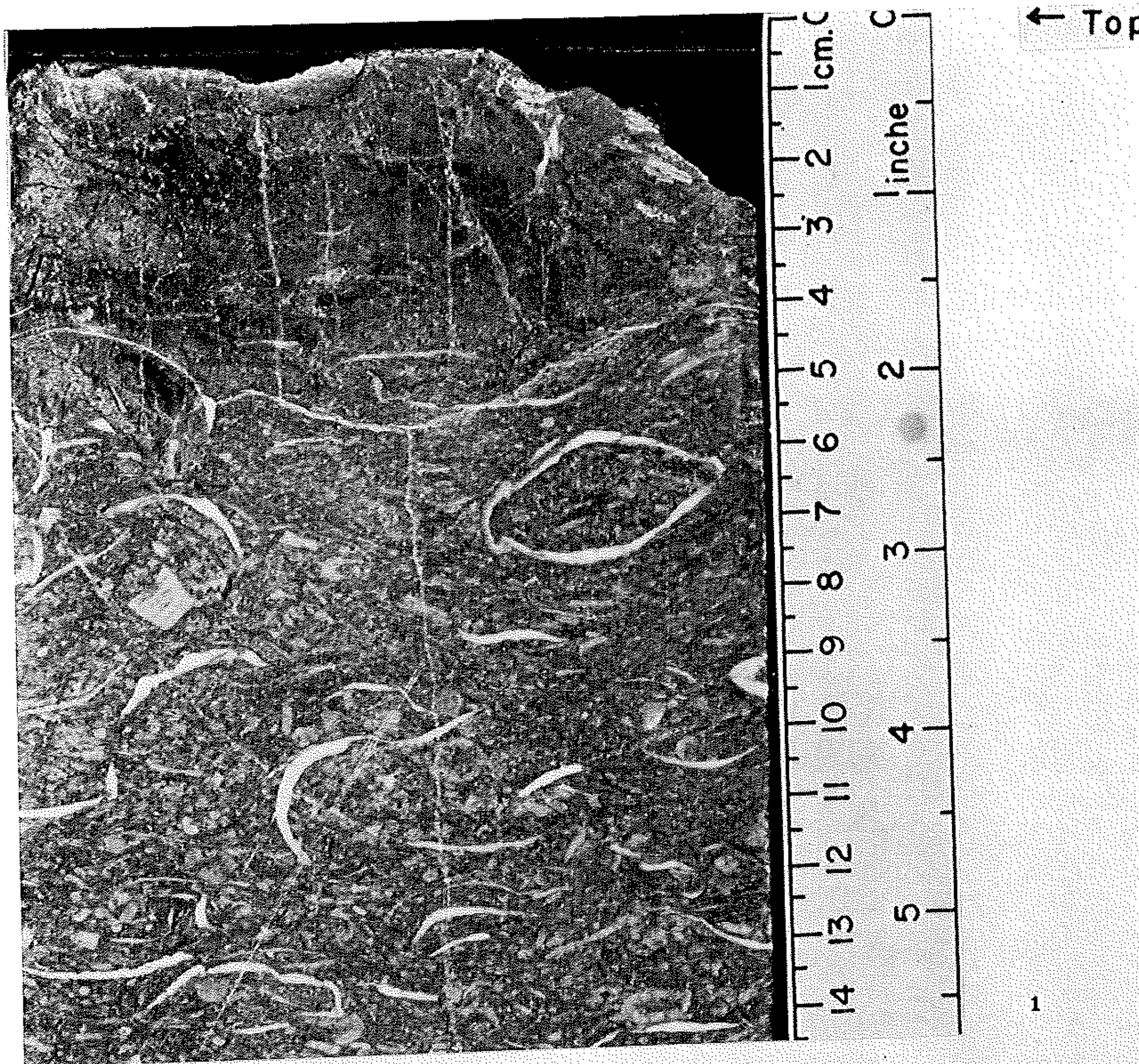
3

PLATE 4

1 Dry sample
Turnhout borehole, 2194.22 m; middle grey to beige very poorly sorted shelly and crinoidal debris in muddy matrix (floatstone?) Most shell fragments are rather large and show different orientations (of which the horizontal is the most common). One shell is undissociated (between 6 and 8 cm) and filled with the same sediment as surrounding this shell. From 0.5 to 5 cm, a large darker irregular intraclast lined by small stylolites consists of silicified calcarenite showing a network of thin fractures filled with calcite.

2 Polished sample
Woensdrecht borehole, 1185 m (A; cf. also B on pl. 3, fig. 2); Pseudo-oolitic calcarenite (biointraclastic) in sparite matrix (grainstone), of light grey-beige color. Bioclasts are mainly crinoid and shell debris, *Koninckopora*, foraminifers and ostracodes. One can see many white fragments of *Issinella* (algae or sponge) loose in the mass or assembled in balls trapping a finer-grained and darker sediment (between 1 and 2 cm).

3 Polished sample
Woensdrecht borehole, 1182 m; pseudo-oolitic (biointraclastic) calcarenite in sparite matrix (grainstone) of middle grey color; poorly sorted (grain-size varying between 40 and 1000 μ).



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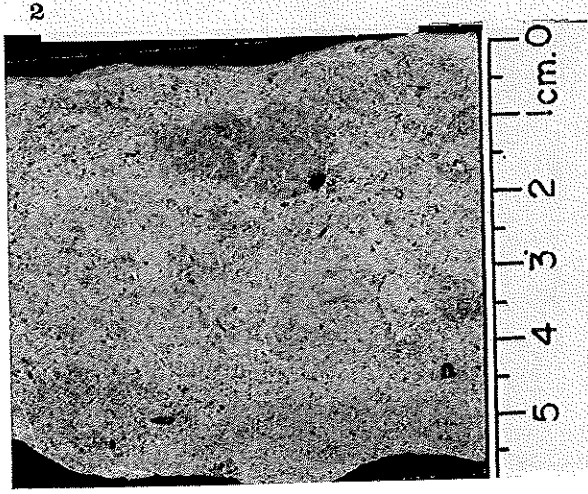

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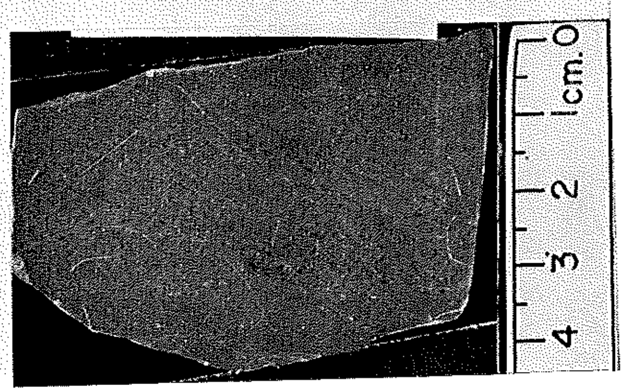


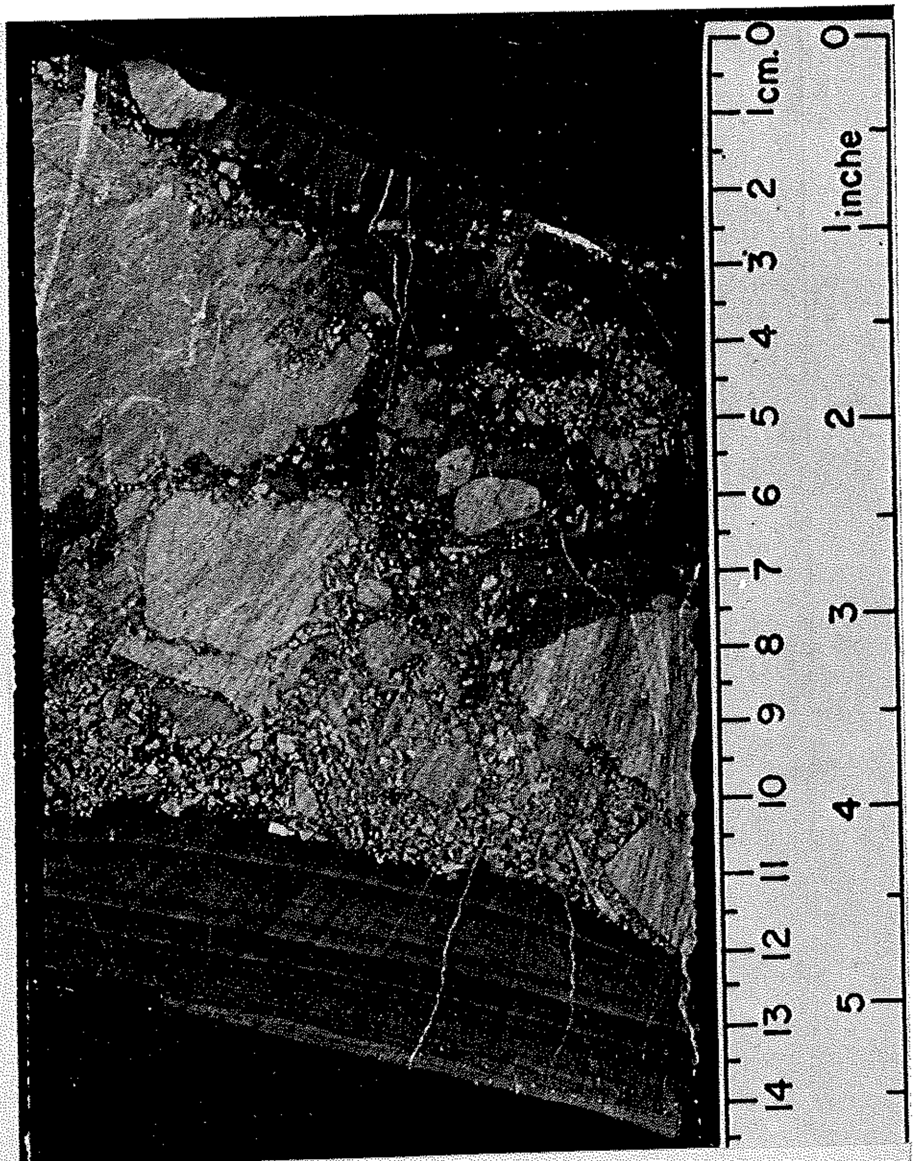
PLATE 5

1 Halen borehole, 1004 m;

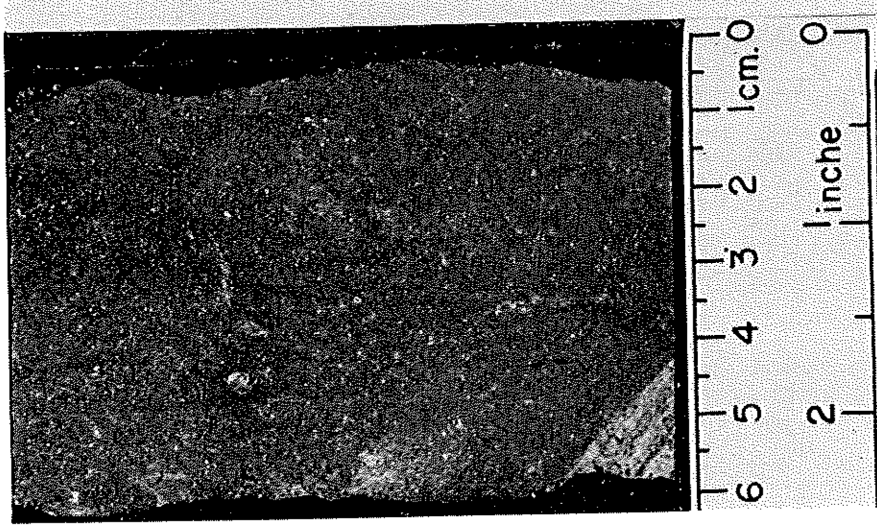
From 14.5 to 12 cm: finely laminated argillaceous microcrystalline limestone. The top has been eroded.

From 12 to 0 cm: infraformational breccia consisting of irregular patches of heterogeneous biomicrite. Some intraclasts are angular whereas others are rounded. Matrix consists of different masses and trails of more or less biointraclastic calcareous shale deformed by infrasedimentary movements and compaction.

2 Halen borehole, 1359.50 m; fine-grained to normal-grained slightly porous dolomite, showing some obscure traces of recrystallized bioclasts. This is a dolomitized calcarenite or bioclastic micrite. Porosity seems to be partly caused by dissolution of bioclasts. The high density of the sample and the occurrence of numerous limonitized specks suggest that this dolomite may be mineralized.



1



2

PLATE 6

1-2 Silicified black shales with layers of light colored detrital limestone from core at 5485-5490 m of Münsterland-1 borehole. Polished samples.
1: sample from about 5485 m (KAR2349)
2: sample from 5489.5 m (KAR2350)
Specimens stored with the geological collections of the "Geologisches Landesamt Nordrhein-Westfalen" at Krefeld.

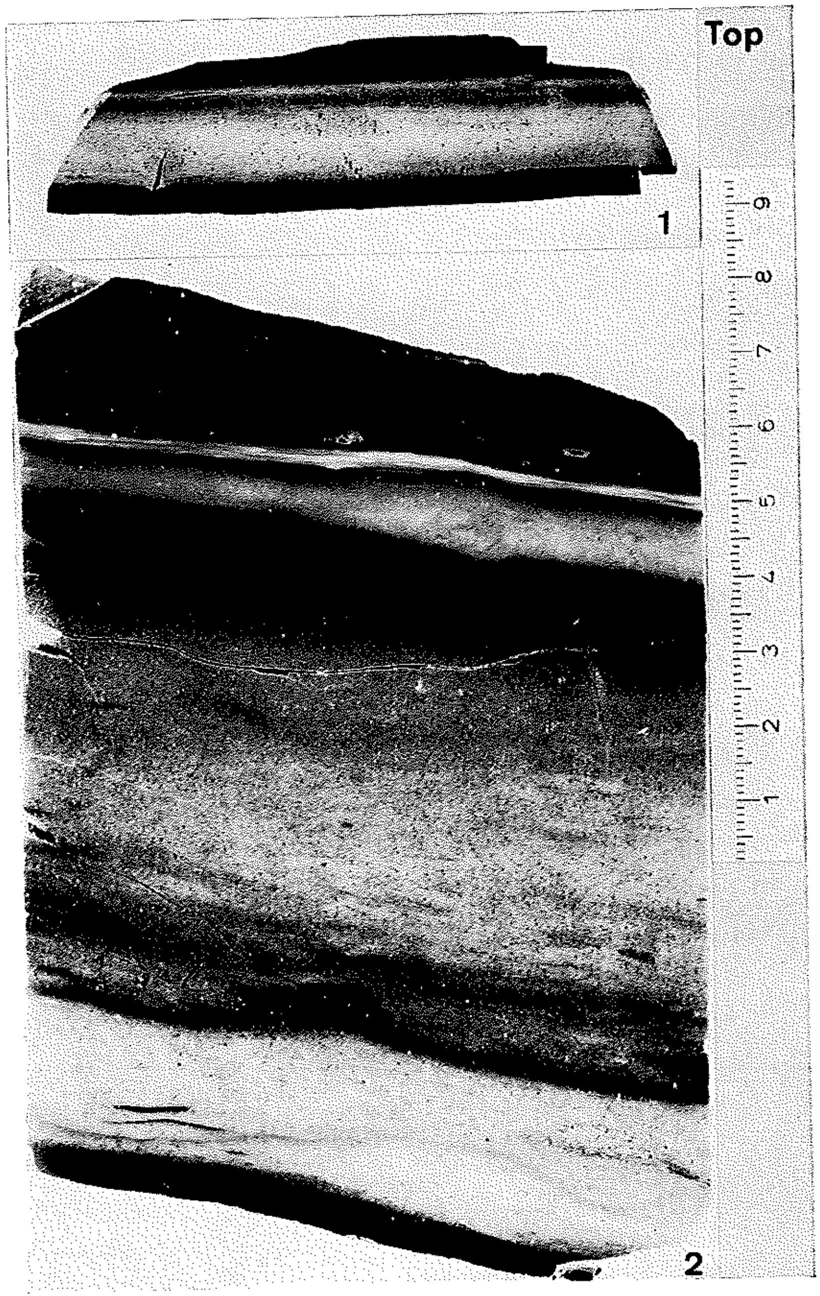

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PLATE 7

1 Wijvenheide borehole, 1912.19 m (RC12.536, negative of thin section, × 8). Carbonaceous silty shale with few pyrite grains and secondary silicification. Obscure traces of silicified shells and of possible radiolarians.

2 Halen borehole, 1160.50 m (RC10.666, negative of thin section, × 8). Dolomitized micritic limestone with phantoms of pebbles and bioclasts. Algal structure still visible.

3 Cadier en Keer borehole, 249 m (RC12.382, negative of thin section, × 8). Bioclastic limestone with small pebbles and foraminifers, which are partly very finely recrystallized (microcrystalline). Phantoms of slightly silicified bivalves are visible.

4 Mesch borehole, 109-116.32 m (RC12.568, negative of thin section, × 8). Bioclastic, almost completely silicified limestone with small pebbles and foraminifers.

5 Maastricht-Kastanjelaan borehole, 250-260 m (RC12.488, negative of thin section, × 8). Almost completely silicified pseudo-oolitic limestone.

6 Maastricht-Kastanjelaan borehole, 260-270 m (RC12.569, negative of thin section, × 8). Radiolarite.

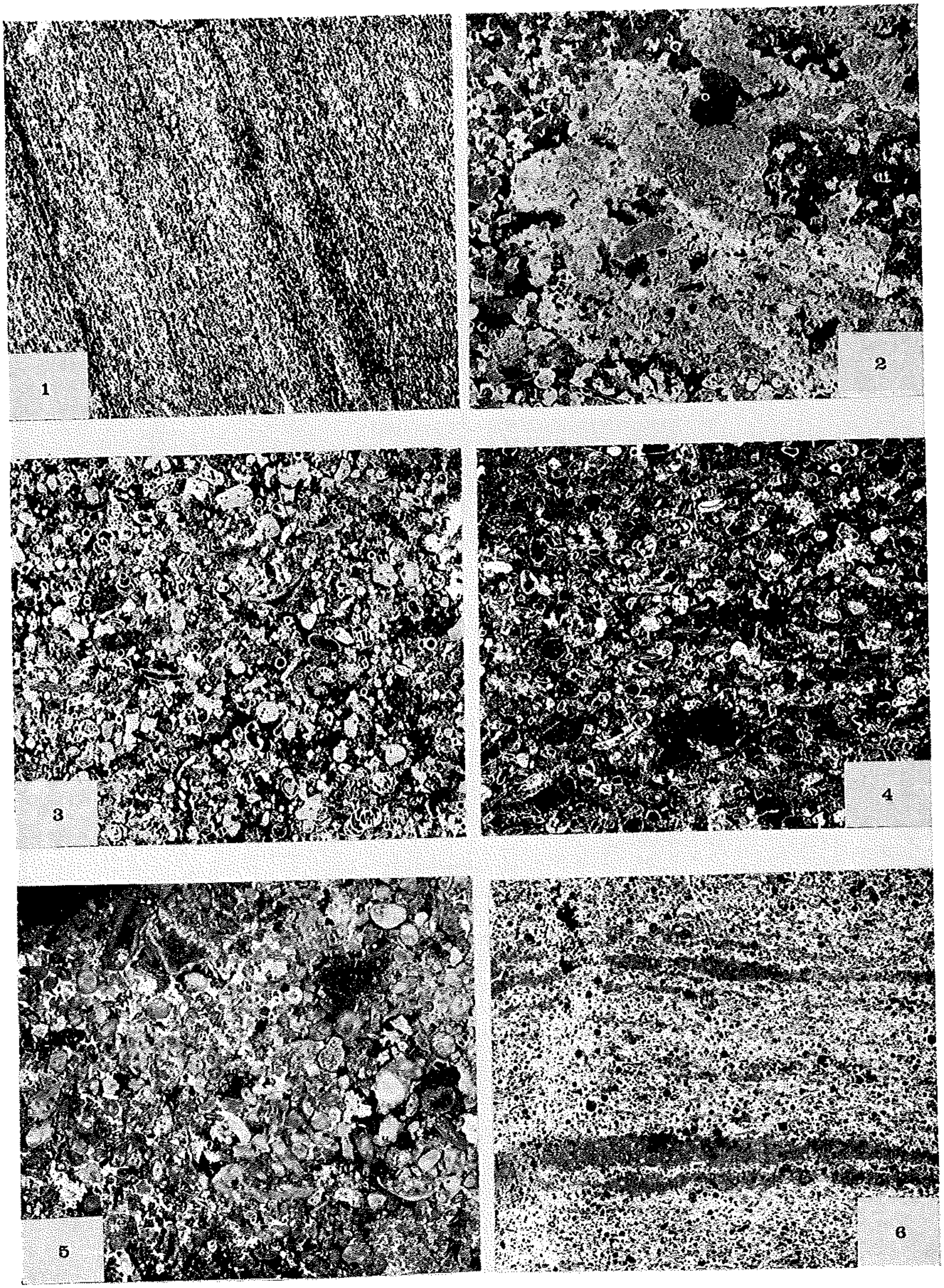
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PLATE 8

1-18 Foraminifers from Woensdrecht borehole.

1: *PALAEOTEXTULARIIDAE*
V2b-V3a, 1185 m, RC12.293 (12.949), × 75.

2: *Endothyra* sp.
V2b-V3a, 1185 m, RC12.288 (12.951), × 75.

3: *LITUOTUBELLINAE*
V2b-V3a, 1182.5 m, RC12.281 (12.944), × 75.

4: *Plectogyranopsis* sp.
V2b-V3a, 1182.5 m, RC12.278 (12.939), × 75.

5: *Plectogyranopsis ampla* (CONIL & LYS 1964)
V2b-V3a, 1182.5 m, RC12.278 (12.940), × 75.

6: *Plectogyranopsis dendrei* (CONIL & LYS 1964)
V2a, 1202 m, RC12.302 (12.931), × 75.

7: *Endothyranopsis* sp.
V2b-V3a, 1183 m, RC12.285 (12.936), × 75.

8: ?*Dainella* sp.
V2b-V3a, 1185 m, RC12.293 (12.950), × 75.

9: *Mstiniella orientalis* (N. TCHERNYSHEVA 1953)
V2a, 1202 m, RC12.302 (12.932), × 75.

10: *Endothyra* sp.
V2b-V3a, 1182.5 m, RC12.281 (12.945), × 75.

11: *Pseudolituotubella* sp.
V2a, 1202 m, RC12.302 (12.930), × 50.

12: *Pseudolituotuba gravata* (CONIL & LYS 1964)
V2b-V3a, 1182.5 m. RC12.278 (12.938), × 50.

13: *Loeblichia* sp.
V2b-V3a, 1185 m, RC12.291 (12.948), × 75.

14: *Loeblichia* sp.
V2b-V3a, 1185 m, RC12.291 (12.947), × 75.

15: *Palaeotextularia* aff. *lipinae* CONIL & LYS 1964
V2b-V3a, 1182 m, RC12.277 (12.933), × 75.

16: *Eoparastaffella simplex* VDOVENKO 1953
V2b-V3a, 1183 m, RC12.285 (12.935), × 75.

17: *Nodosarchaediscus (Nodosarchaediscus)* aff. *exiguus* BOZORGNIA 1973
V2b-V3a, 1183 m, RC12.282 (13.001), × 140.

18: *Nodosarchaediscus (Nodosarchaediscus)* cf. *demaneti* (CONIL & LYS 1964)
V2b-V3a, 1182.5 m, RC12.278 (13.000), × 140.


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PLATE 9

1-2 Foraminifers from Woensdrecht borehole.

1: *Archaediscus (Archaediscus?)* sp.
V2a, 1196 m, RC12.296 (13.041), × 140.

2: *Archaediscus (Archaediscus) chernoussovensis* MAMET 1966
V2a, 1190 m, RC12.294 (13.002), × 140.

3-23 Foraminifers from Cadier en Keer borehole.

3: *Glomospiranella* sp.
V2a, 249 m, RC12.491 (12.953), × 75.

4: *Dainella* sp.
V2a, 249 m, RC12.534 (12.958), × 75.

5: *FORSCHIELLINAE*
V2a, 249 m, RC12.534 (12.959), × 75.

6: *Dainella fleronensis* (CONIL & LYS 1964)
V2a, 249 m, RC12.491 (12.962), × 75.

7: *Dainella fleronensis* (CONIL & LYS 1964)
V2a, 249 m, RC12.382 (12.903), × 75.

8: *Spinochernella* sp.
V2a, 249 m, RC12.491 (12.954), × 75.

9: *TOURNAYELLIDAE*
V2a, 249 m, RC12.535 (12.975), × 75.

10: *Brunsia* sp.
V2a, 249 m, RC12.491 (12.963), × 75.

11: *Septabrunsiina* sp.
V2a, 249 m, RC12.491 (12.952), × 75.

12: *Endothyra recta* LIPINA 1955
V2a, 249 m, RC12.491 (12.956), × 75.

13: *Endothyra* aff. *inflata* LIPINA 1955
V2a, 249 m. RC12.382 (12.901), × 75.

14: *Endothyra* sp.
V2a, 249 m, RC12.535 (12.973), × 75.

15: *Dainella magna* (VDOVENKO 1954)
V2a, 249 m, RC12.491 (12.955), × 75.

16: *Endothyra* aff. *inflata* LIPINA 1955
V2a, 249 m, RC12.491 (12.966), × 75.

17: *Endothyra* sp.
V2a, 249 m, RC12.491 (12.964), × 75.

18: *Palaeotextularia* ex gr. *consobrina* LIPINA 1948 (primitive form)
V2a, 249 m, RC12.491 (12.965), × 75.

19: cf. *Dainella* sp.
V2a, 249 m, RC12.382 (12.793), × 75.

20: *Loeblichia (Urbanella) fragilis* (LIPINA 1951)
V2a, 249 m, RC12.382 (12.792), × 75.

21: *Laxoseptabrunsiina (Spinolaxina) pauli* (CONIL & LYS 1964)
V2a, 249 m, RC12.382 (12.904), × 75.

22: *Laxoseptabrunsiina (Spinolaxina) pauli* (CONIL & LYS 1964)
V2a, 249 m, RC12.535 (12.974), × 75.

23: cf. *Dainella* sp.
V2a, 249 m, RC12.534 (12.961), × 75.

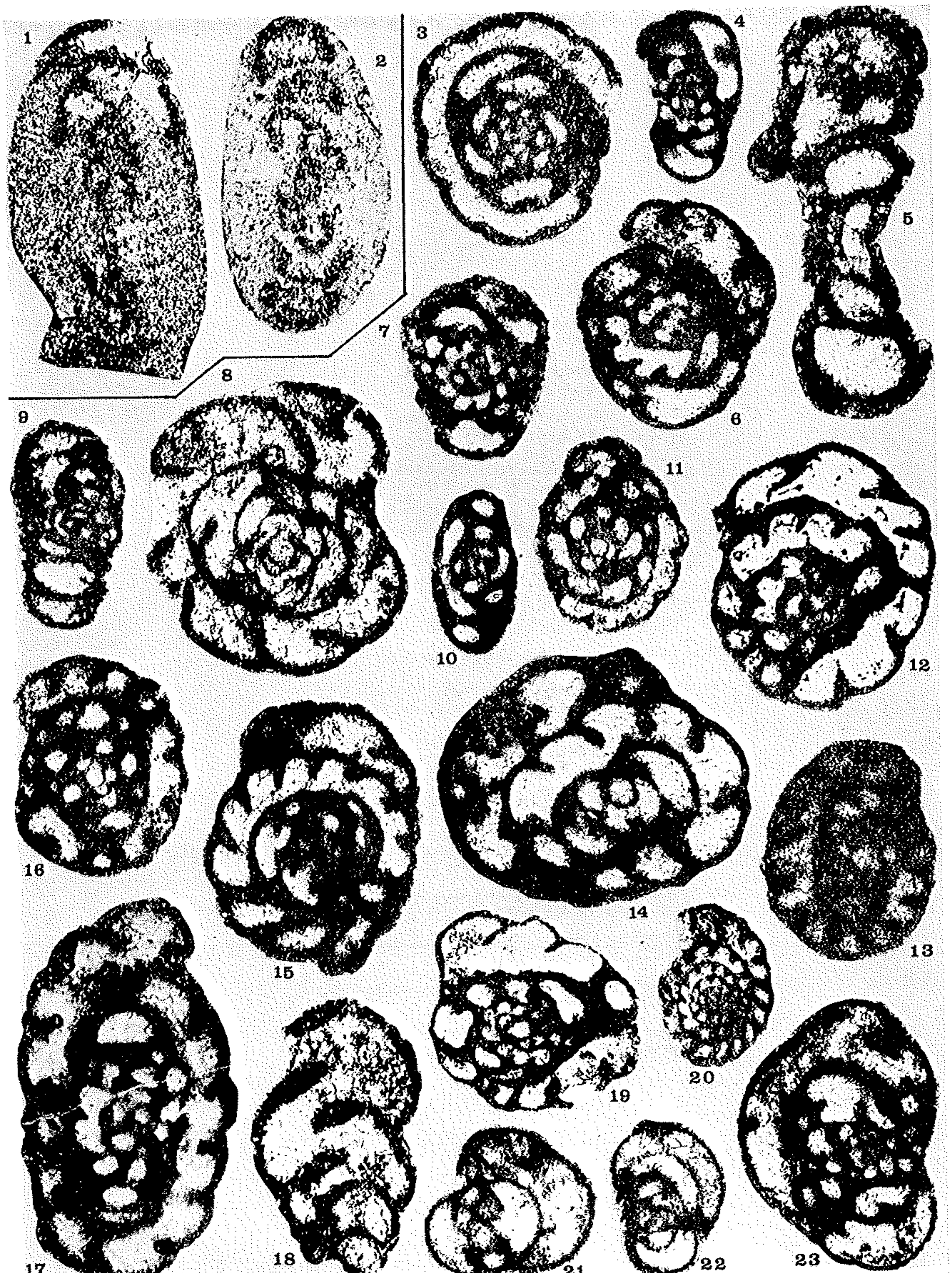
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PLATE 10

1-7 Algae and foraminifers from Cadier en Keer borehole.

1: *Koninckopora mortelmansi* MAMET 1973
V2a, 249 m, RC12.535 (12.795), × 75.

2: *Dainella fleronensis* (CONIL & LYS 1964)
V2a, 249 m, RC12.535 (12.972), × 75.

3: *Dainella fleronensis* (CONIL & LYS 1964)
V2a, 249 m, RC12.535 (12.976), × 75.

4: *Dainella fleronensis* (CONIL & LYS 1964)
V2a, 249 m, RC12.535 (12.794), × 75.

5: *?Dainella* sp.
V2a, 249 m, RC12.535 (12.794), × 75.

6: *LITUOTUBELLINAE*
V2a, 249 m, RC12.535 (12.791), × 75.

7: *Brunsia* sp.
V2a, 249 m, RC12.535 (12.960), × 75.

8-15 Algae and foraminifers from Houthem borehole.

8: *Koninckopora minuta* WEYER 1968
Reworked sequence, 297 m, RC12.386 (12.494), × 75.

9: *Koninckopora inflata* (DE KONINCK 1842) (a) and
Koninckopora tenuiramosa WOOD 1943 (b)
V3bγ, 238 m, RC873 (12.993), × 50.

10: *Ammarchaediscus (Rectodiscus) rotundus* (N. TCHERNYSHEVA 1948)
Reworked sequence, 286 m, RC8.872 (12.599), × 140.

11: *Nodosarchaediscus (Nodosarchaediscus)* cf. *demaneti* (CONIL & LYS 1964)
Reworked sequence, 286 m, RC865 (13.075), × 140.

12: *Archaediscus (Archaediscus) chernoussovensis* MAMET 1966
V3bγ, 251 m, RC863 (12.995), × 140.

13: *Archaediscus (Archaediscus)* aff. *grandiculus* CHLYKOVA 1951
V3bγ, 253 m, RC902 (13.036), × 140.

14: *Archaediscus (Archaediscus) spira* CONIL & LYS 1964
V3bγ, 253 m, RC863 (12.977), × 140.

15: *Nodosarchaediscus (Nodosarchaediscus)* sp.
Reworked sequence, 282 m, RC901 (12.600), × 140.

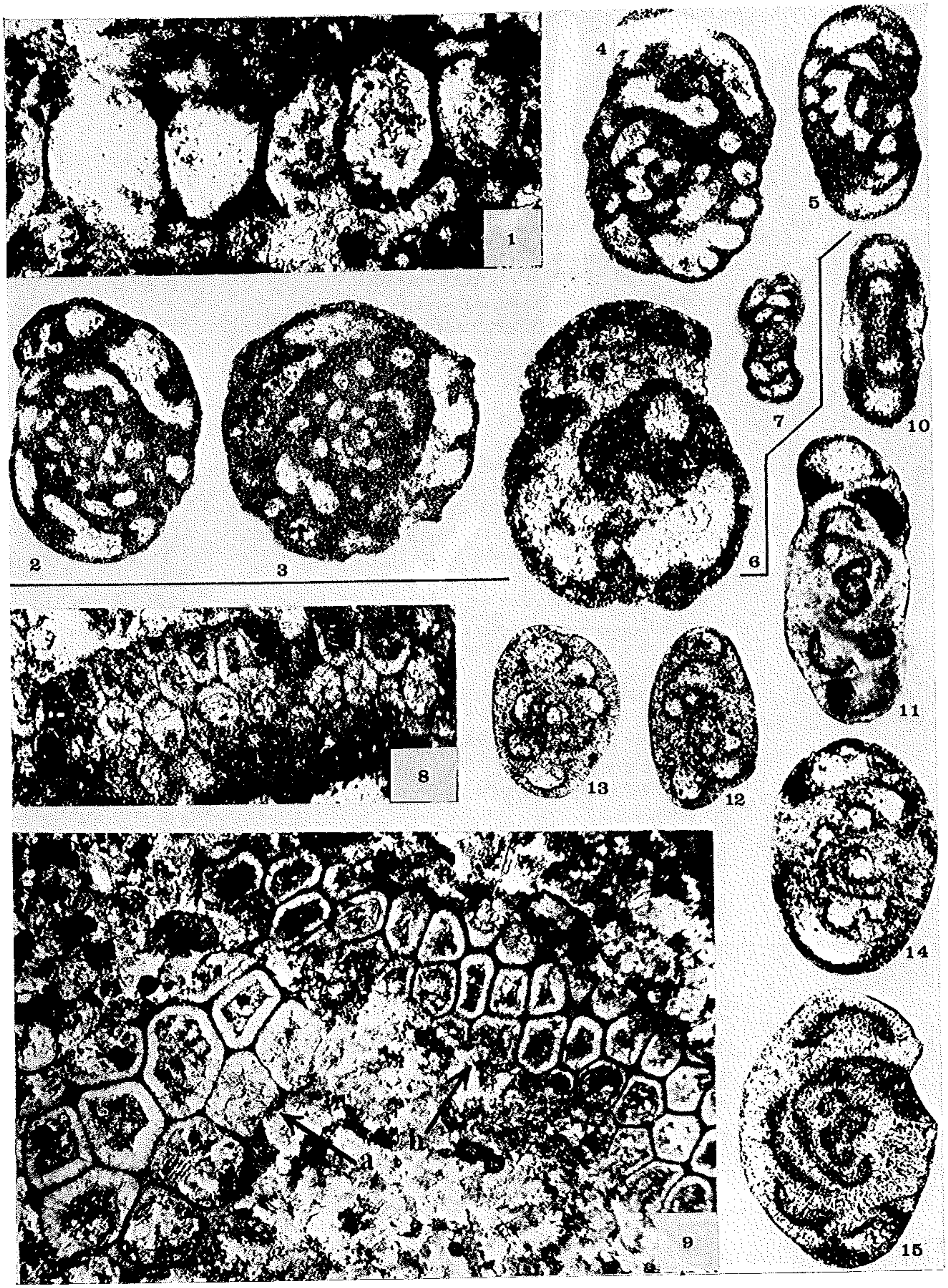
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PLATE 11

1-18 Foraminifers from Houthem borehole.

1: *Dainella fleronensis* (CONIL & LYS 1964)
Reworked sequence, 297 m, RC868 (13.011), × 75.

2: *Dainella exuberans* (CONIL & LYS 1964)
Reworked sequence, 297 m, FKJ (9.395), × 75.

3: *Endothyranopsis crassa* (BRADY 1876)
Reworked sequence, 282 m, RC901 (12.990), × 75.

4: *Planoendothyra* sp.
Reworked sequence, 289 m, RC12.384 (13.018), × 75.

5: *Endothyra* sp.
Reworked sequence, 289 m, RC12.384 (12.492), × 75.

6: ?*Planoendothyra* sp. (*LOEBLICHIIDAE*)
Reworked sequence, 297 m, RC868 (13.013), × 75.

7: *Euxinella* sp.
V3bγ, 251 m, RC863 (12.996), × 75.

8: Gen.nov.?
Reworked sequence, 288 m, RC12.383 (12.541), × 75.

9: *Endothyra omphalota minima* RAUSER & REITLINGER 1936
Reworked sequence, 277-281.51 m, RC12.387 (12.788), × 75.

10: *Septabrunsiina* cf. *bouckaerti* (CONIL & LYS 1970)
Reworked sequence, 290 m, RC12.385 (12.540), × 75.

11: *LITUOTUBELLINAE*
V3b, 319.64-320.68 m, RC12.389 (12.918), × 75.

12: *LITUOTUBELLINAE*
Reworked sequence, 289 m, RC866 (12.988), × 75.

13: *Lituotubella* sp.
Reworked sequence, 289 m, RC888 (12.983), × 50.

14: *Forschiella prisca* MIKHAILOV 1939
Reworked sequence, 289 m, RC888 (12.985), × 75.

15: *Tetrataxis* sp.
Reworked sequence, 289 m, RC888 (12.978), × 75.

16: *Archaediscus (Archaediscus) convexus* GROZDILOVA & LEBEDEVA 1953
Reworked sequence, 290 m. RC12.402 (12.598), × 140.

17: cf. *Haplophragmella* sp.
Reworked sequence, 289 m, RC888 (12.977), × 75.

18: *Millerella* sp.
Reworked sequence, 286 m, RC8.872 (13.019), × 75.

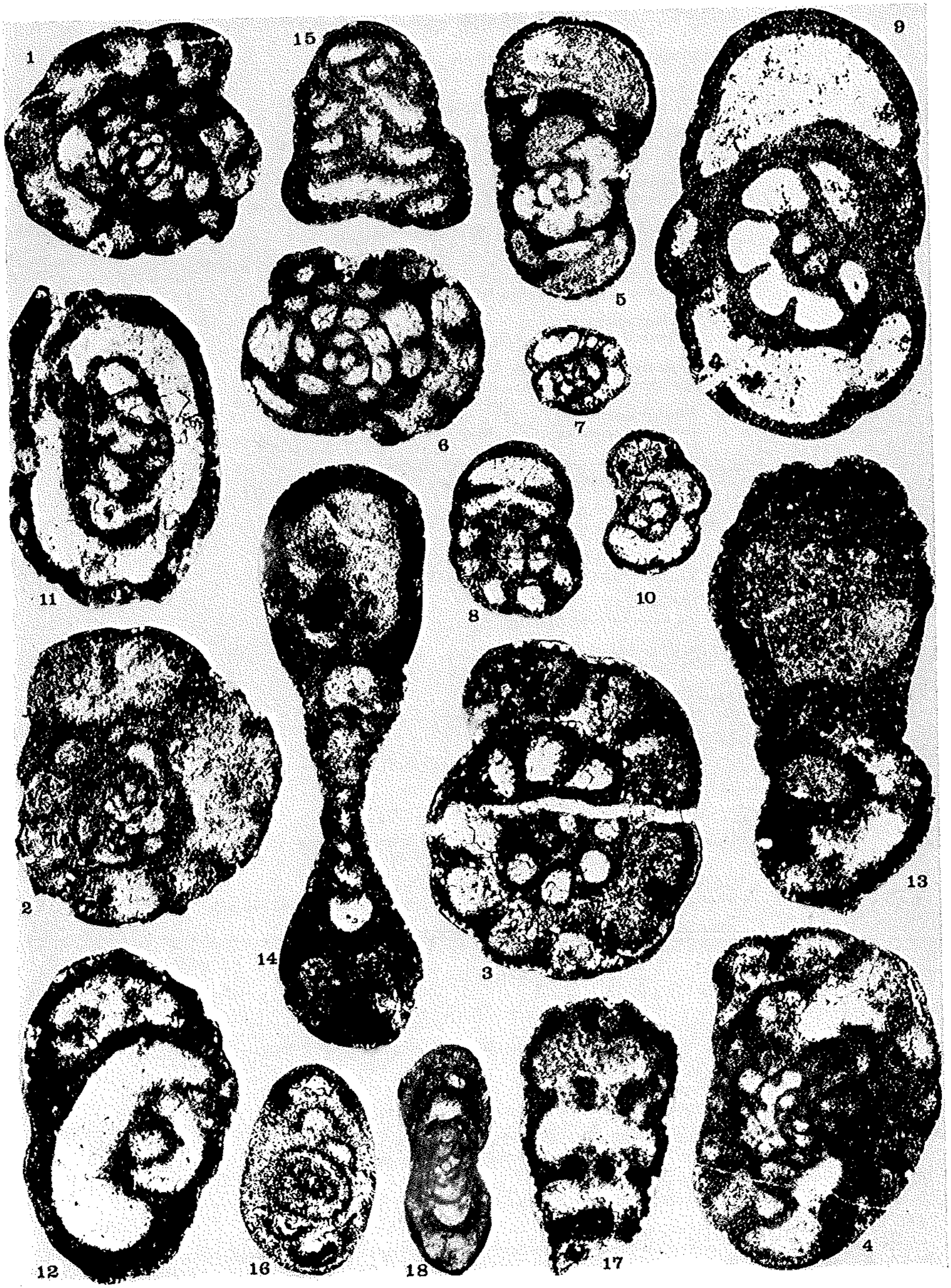
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PLATE 12

1-9 Foraminifers from Houthem borehole.

1: *Howchinia* sp.
Reworked sequence, 286 m, RC8.872 (13.021), × 75.

2: *Euxinella* aff. *efremovi* (VDOVENKO & ROSTOVCEVA 1964)
V3bγ, 253 m, RC902 (12.991), × 75.

3: cf. *Euxinella* sp.
Reworked sequence, 286 m, RC8.872 (13.020), × 75.

4: *Septabrunsiina* cf. *kingirica* (REITLINGER 1961)
Reworked sequence, 289 m, RC12.388 (12.493), × 75.

5: cf. *Palaeotextularia* sp.
Reworked sequence, 289 m, RC888 (12.984), × 75.

6: cf. *Eoendothyranopsis* sp.
Reworked sequence, 284-285.3 m, RC12.437 (12.917), × 75.

7: *Endothyra agathis* (CONIL & LYS 1964)
Reworked sequence, 289 m, RC 888 (12.981), × 75.

8: ?*Septabrunsiina* sp.
Reworked sequence, 297 m, RC868 (13.012), × 75.

9: *Septabrunsiina submissa* (CONIL & LYS 1964)
Reworked sequence, 290.35-293.67 m, RC12.391 (12.916), × 75.

10-16 Foraminifers from Mesch borehole.

10: *PALAEOTEXTULARIIDAE* (type V3b)
V3, 109-116.32 m, RC12.486 (13.026), × 75.

11: ?*Euxinella* sp.
V3, 109-116.32 m, RC12.486 (13.025), × 75.

12: cf. *Planoendothyra* sp.
V3, 109-116.32 m, RC12.487 (13.023), × 75.

13: cf. *Planoendothyra* sp.
V3, 109-116.32 m, RC12.586 (12.929), × 75.

14: cf. *Planoendothyra* sp.
V3, 109-116.32 m, RC12.487 (13.022), × 75.

15: *Euxinella* sp.
V3, 109-116.32 m, RC12.486 (12.027), × 75.

16: *Endothyra* ex gr. *omphalota* RAUSER & REITLINGER 1936
V3, 109-116.32 m, RC12.487 (13.024), × 75.

17 cf. *Tournayellina pentacamerata* BOZORGNIA 1973
Maastricht-Kastanjelaan borehole, Visean, 250-260 m, RC12.381 (12.790), × 75.

18 *Archaediscus (Glomodiscus) oblongus* (CONIL & LYS 1964)
Eijsden borehole, V1b-V2a, 75-76 m, RC12.380 (12.833), × 75.

19-23 Varia

19: *Moravammina* sp.
Houthem borehole, reworked sequence, 284.01-285.38 m, RC12.437 (12.789), × 75.

20: *Pseudokomia* sp.
Houthem borehole, reworked sequence, 289 m, RC888 (12.982), × 75.

21: *Fasciella kizilia* IVANOVA 1973
Houthem borehole, reworked sequence, 289 m, RC901 (12.491), × 50.

22: *Fasciella kizilia* IVANOVA 1973
Turnhout borehole, reworked sequence, 2252 m, RC8.620 (11.491), × 50.

23: *Izhella* sp.
Turnhout borehole, reworked sequence, 2271.5 m, RC8.624 (9.222), × 50.

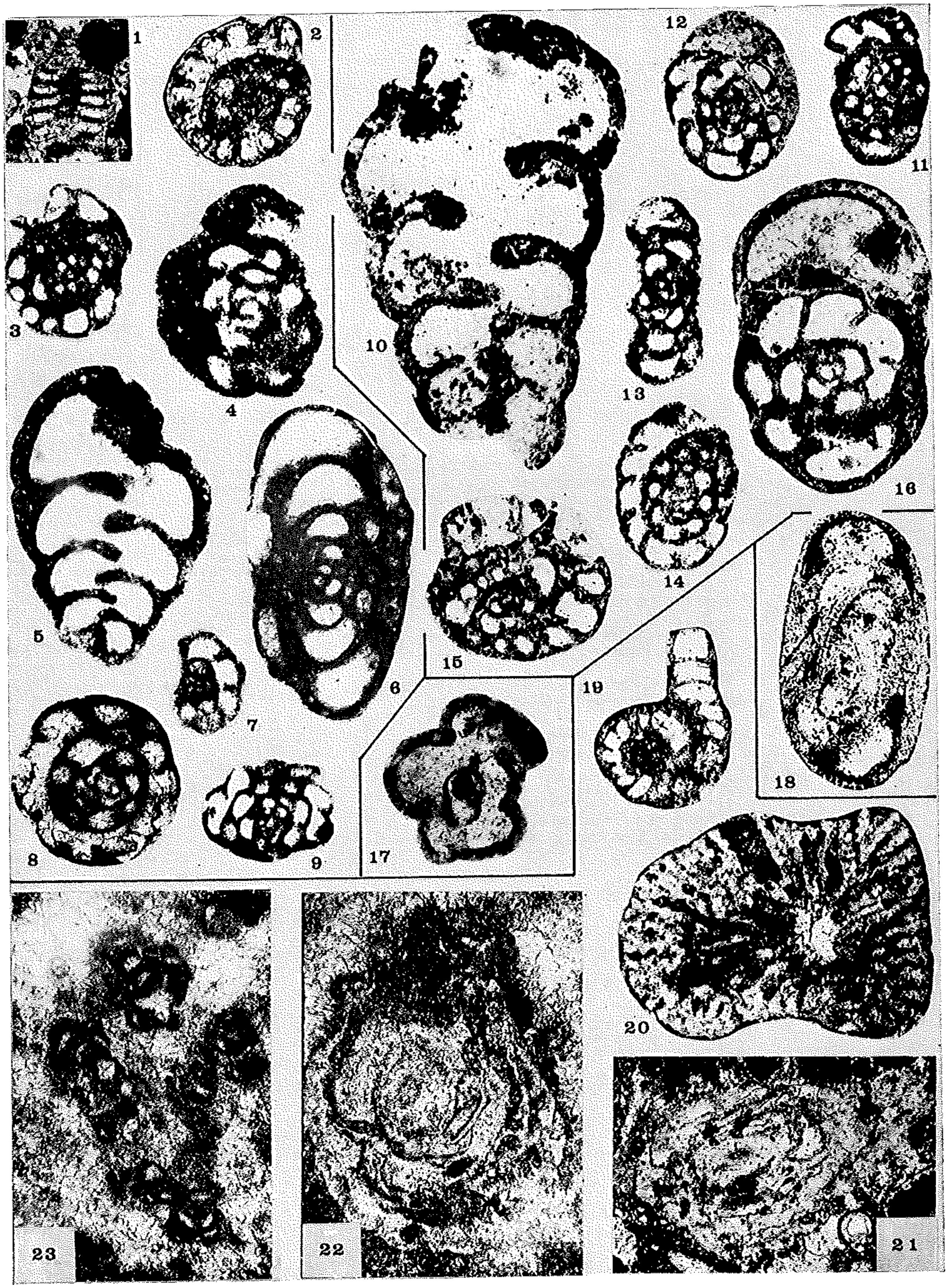
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PLATE 13

1-3	*Gnathodus commutatus commutatus* (BRANSON & MEHL) 1: oral view, Halen borehole, 703.50 m, × 50. 2: oral view, Houtain-Saint Siméon borehole, 190 m, × 50. 3: lateral view, Houthem borehole, 214 m, × 50.
4-6	*Gnathodus commutatus mononodosus* (RHODES, AUSTIN & DRUCE) 4: oral view, Halen borehole, 703.50 m, × 50. 5: oral view, Halen borehole, 700 m, × 50. 6: oral view, Houtain-Saint-Siméon borehole, 187 m, × 50.
7-8	*Gnathodus commutatus nodosus* (BISCHOFF) Oral view, Houtain-Saint Siméon borehole, 187 m, × 50.
9	*Gnathodus girtyi collinsoni* RHODES, AUSTIN & DRUCE Oral view, Houthem borehole, 206.5 m, × 50.
10	*Gnathodus girtyi meischneri* AUSTIN & HUSRI Oral view, Halen borehole, 703.50 m, × 50.
11-15	*Gnathodus girtyi girtyi* HASS 11: oral view, Halen borehole, 703.50 m, × 50. 12: oral view, Houthem borehole, 269 m, × 50. 13-15: oral view, Houtain-Saint Siméon borehole, 175 m; 13-14: × 50; 15: × 25.

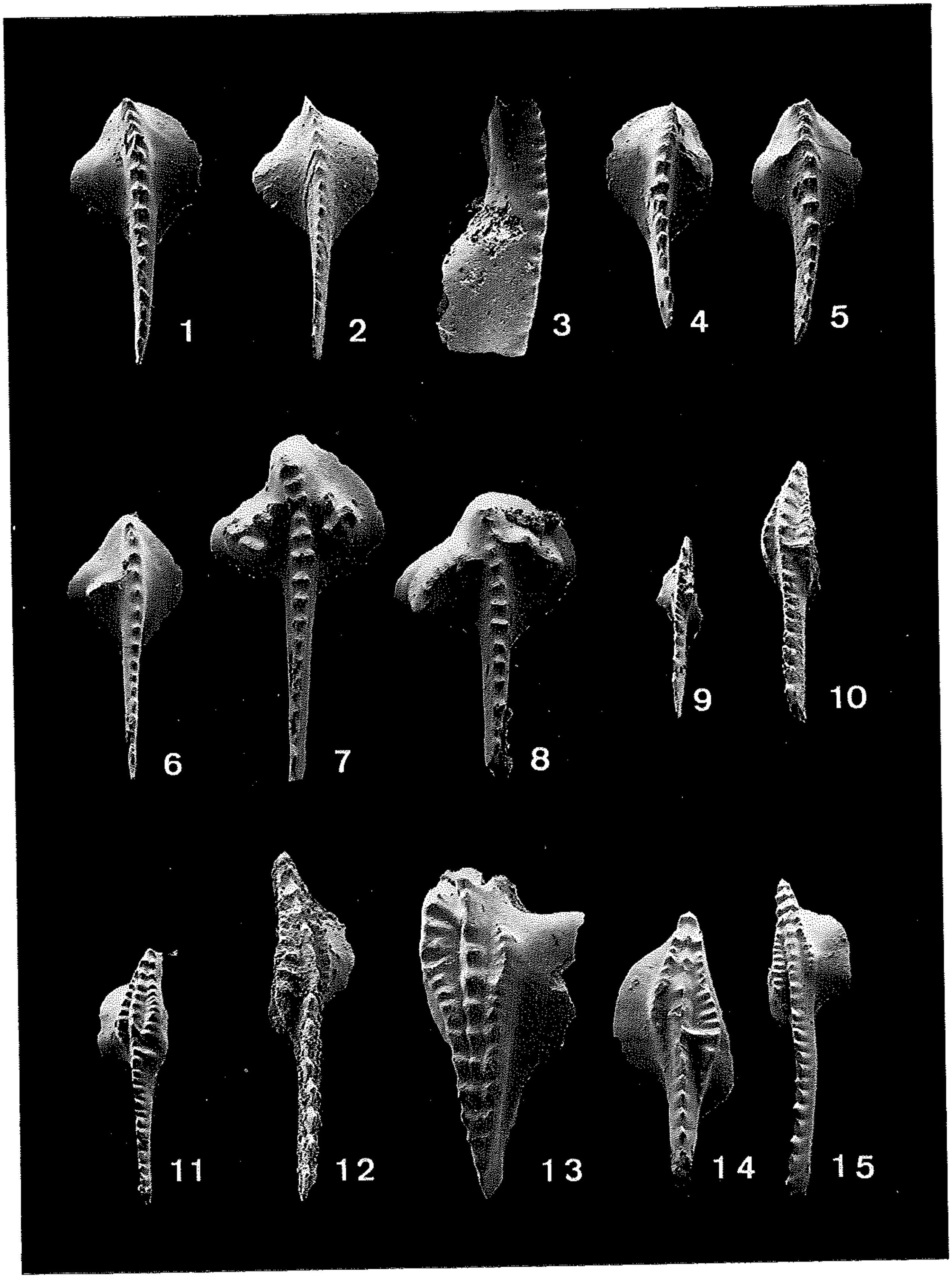
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PLATE 14

1-5 *Gnathodus bilineatus bilineatus* ROUNDY
1: oral view, Houtain-Saint Siméon borehole, 190 m, × 50.
2: oral view, Houthem borehole, 208.27 m, × 50.
3: oral view, Houtain-Saint Siméon borehole, 171 m, × 50.
4: oral view, Houthem borehole, 285 m, × 50.
5: aboral view, Houtain-Saint Siméon borehole, 190 m, × 50.

6 *Gnathodus symmutatus homopunctatus* (ZIEGLER)
Oral view, Houthem borehole, 214 m, × 50.

7 *Cavusgnathus cristatus* BRANSON & MEHL
Oral view, Houtain-Saint Siméon borehole, 175 m, × 50.

8-10 *Gnathodus symmutatus homopunctatus* (ZIEGLER)
8: oral view, Houthem borehole, 269.34-270.04 m, × 50.
9: oral view, Houthem borehole, 208.27 m, × 50.
10: oral view, Houthem borehole, 214 m, × 50.

11 *Gnathodus symmutatus* cf. *mermaidus* AUSTIN & HUSRI
Oral view, Houthem borehole, 207.10 m, × 50.

12 *Siphonodella obsoleta* HASS
Oral view, Houthem borehole, 214.54-216.20 m, × 50.

13 *Geniculatus glottoides* VOGES
Oral view, Houthem borehole, 267.50 m, × 25.

14 *Mestognathus bipluti* HIGGINS
Oral view, abandoned limestone quarry at Richelle near Visé, Upper V3c, × 25

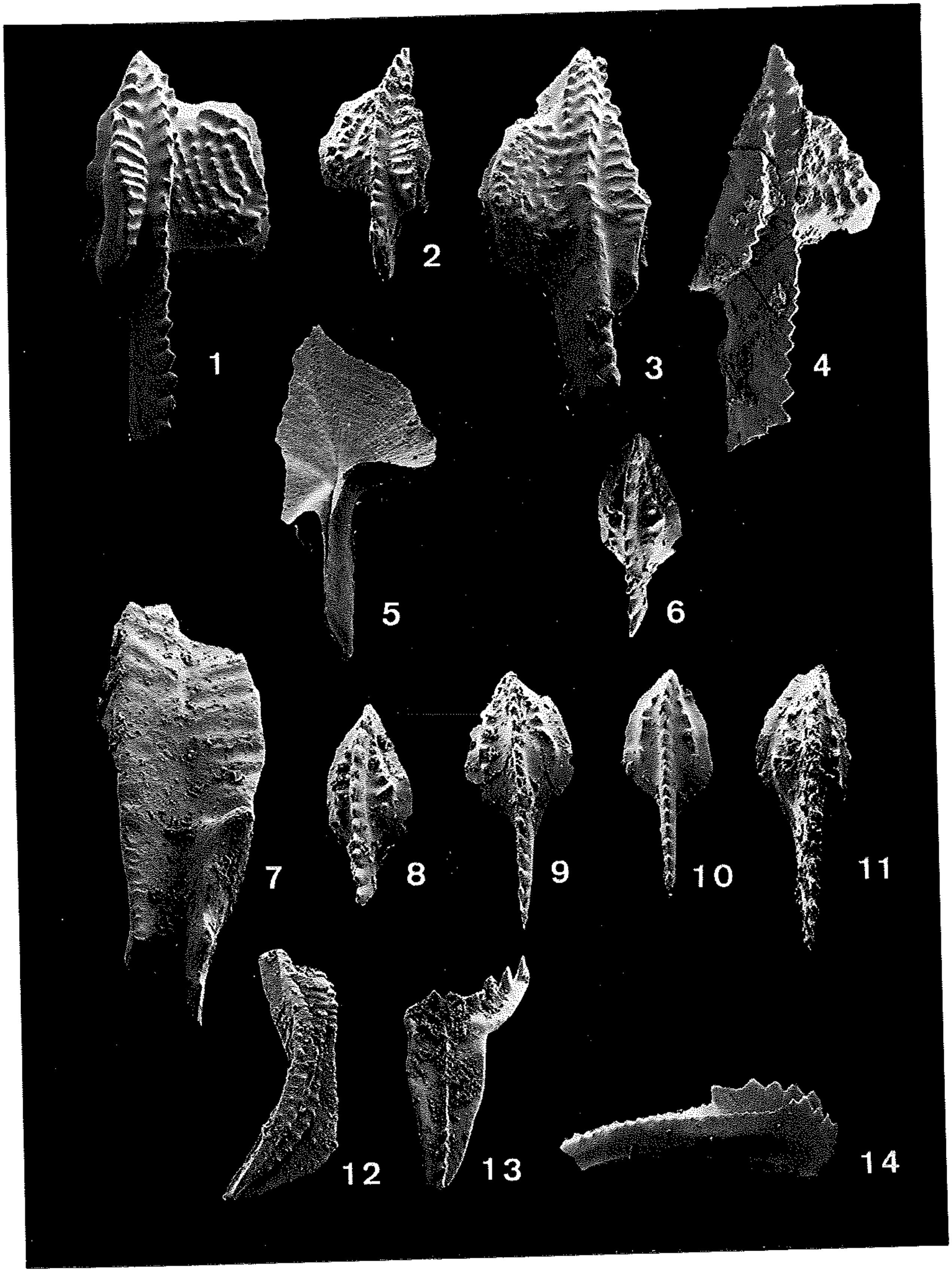
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PLATE 15

Sclerotioid grains from V3bγ of Houthem borehole. All specimens have been stored with the collections of the Geologisch Bureau at Heerlen. All specimens from 249 to 267.5 m interval.

1 Specimen with weakly developed annular ornament and vermiculate surface.
1a: × 100; 1 b: × 500; 1c: × 1000.

2 Specimen with network ornament of irregular ribs.
2a: × 100; 2b: × 500.

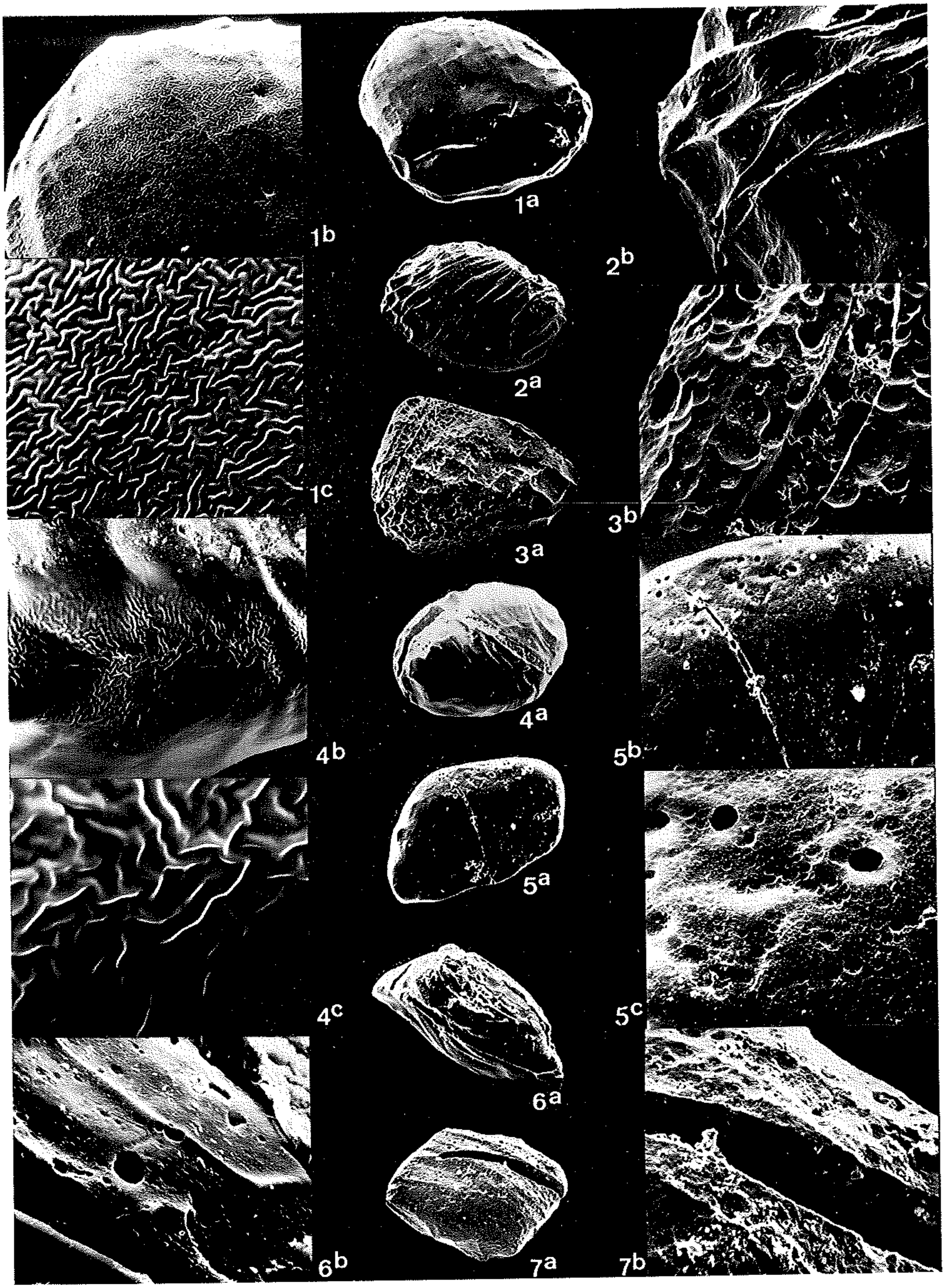
3 Specimen with crater-like pits aligned in rows at one end
3a: × 100; 3b: × 500.

4 Specimen with open fissures and partly vermiculate surface.
4a: × 100; 4b: × 500; 4c: × 2500.

5 Specimen with fissure and surface covered with crater-like pits, some of them apparently connecting with interior.
5a: × 100; 5b: × 500; 5c: × 1000.

6 Specimen with fissures and isolated pits connecting with interior.
6a: × 100; 6b: × 500.

7 Specimen with open fissure showing thickness of massive outer wall and crater-like pits on surface. Weak annular ornament visible.
7a: × 100; 7b: × 500.


1b
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7a
7b

PLATE 16

Sclerotioid grains from V3bγ of Houthem borehole. All specimens have been stored with the collections of the Geologisch Bureau at Heerlen. All specimens from 249 to 267.5 m interval.

1	Broken specimen showing spongeous center with massive outer layer. 1a: × 100; 1b: × 500.
2	Broken specimen showing spongeous center and massive outer wall. × 100.
3	Broken specimen showing spongeous interior and massive outer wall. 3a: × 100; 3b: × 250.
4	Rod-like specimen with two pointed ends and weak annular ornament, showing spongeous interior and massive outer wall perforated by small channels which connect spongeous center with exterior.
5-6	Rod-like specimens with fissures. × 100.
7-8	Rod-like specimens with annular ornament and pointed ends. Surface covered with crater-like pits. × 100.
9-10	Rod-like specimens. × 100.
11	One-end pointed specimen with annular ornament and surface covered with crater-like pits. × 100.
12	One-end pointed specimen with fissures and surface covered with crater-like pits. × 100.
13-14	Rod-like specimens with one concave side. × 100.
15-16	One-end pointed specimens with longitudinal fissures. × 100.
17-21	More or less spheric specimens with smooth surface and fissures. In specimens 20 and 21, large irregular holes connect with the interior. × 100.

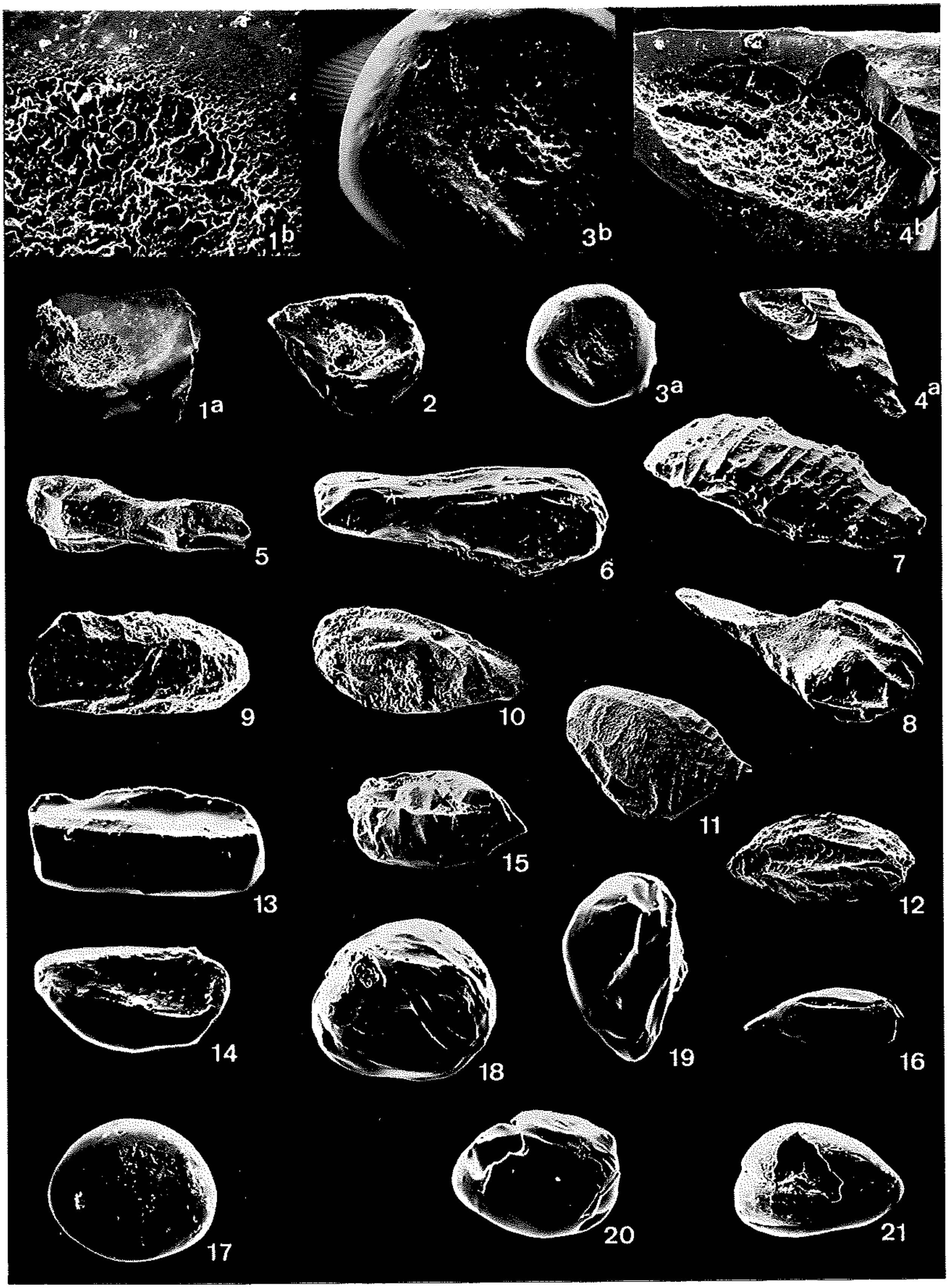
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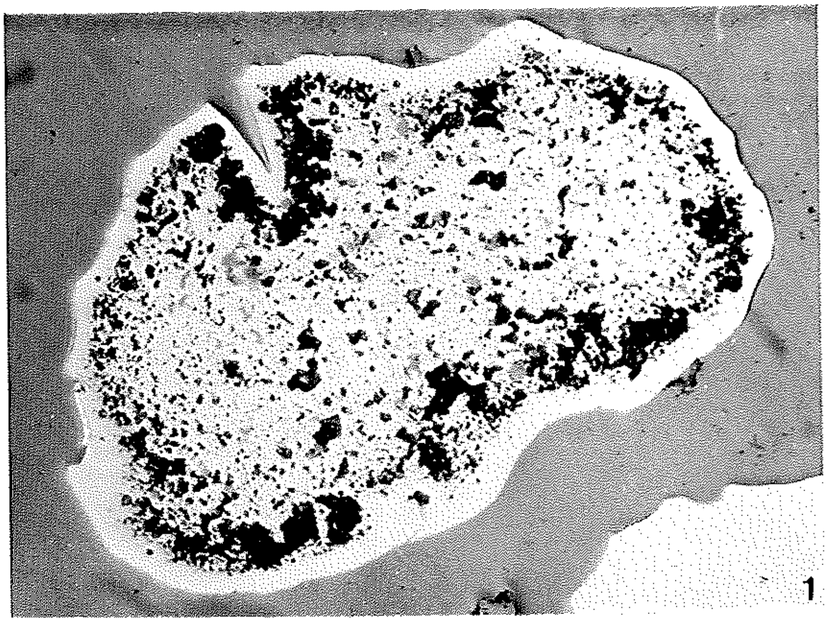
PLATE 17

1-3 Polished sections through sclerotioid grains from V3bγ of Houthem borehole, 249.05 - 251.35 m sample. × 250.
Dry optic objective 16.5, normal reflected light photographs.
Note massive outer wall and spongeous center. Clay minerals (black) are concentrated in peripheral part of center, whereas quartz (light grey) appears to be randomly distributed. Note also that the massive outer wall largely follows the fissures in the grain surface. This suggests that these fissures have been formed before this outer wall was formed.
Microprobe analysis of specimen on figure 3 on next plate.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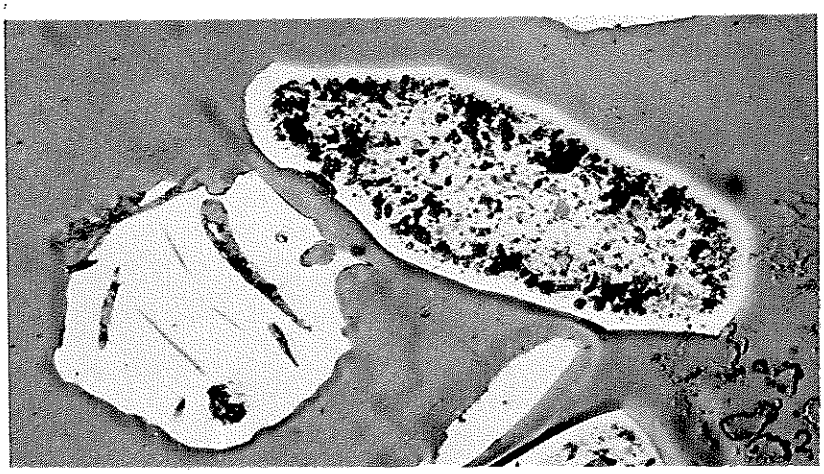
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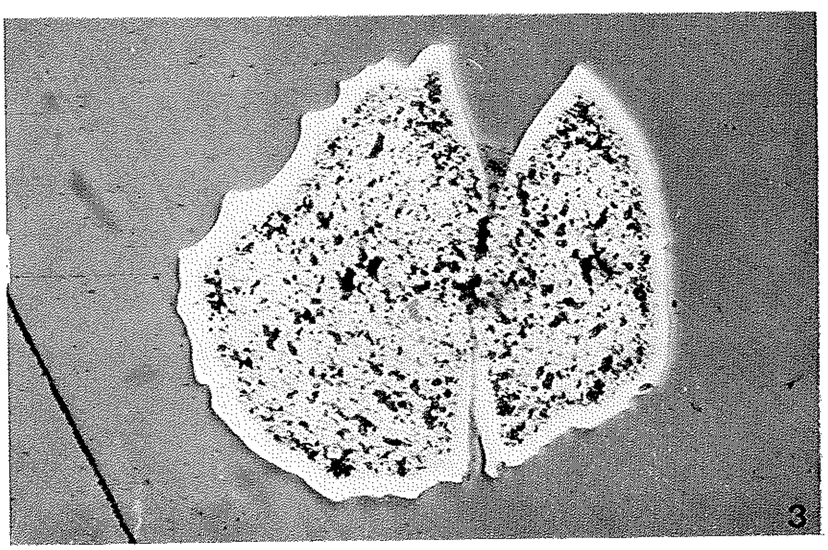
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PLATE 18

1-6 Microprobe analysis of sclerotioid grain from V3bγ of Houthem borehole, 249.05 - 251.35 m sample. Specimen figured in normal reflected light on plate 17. fig. 3. All photographs × 250.

1: ae^+ (positive polarity, 15kV/10nA)

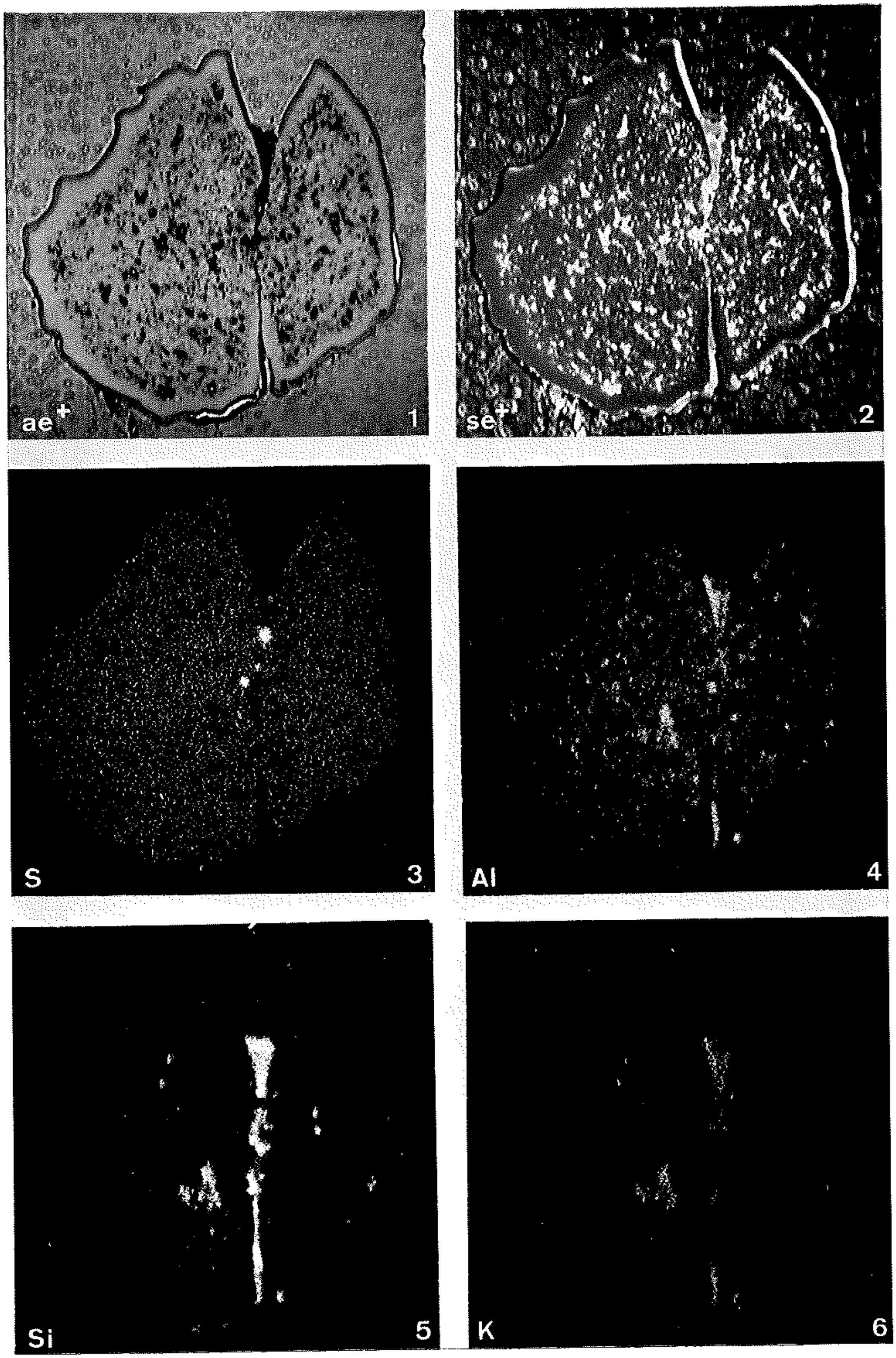
2: se^+ (backscattered and secondary electrons)

3: $S_{K\alpha}$, PET Crystal

4: $Al_{K\alpha}$, KAP Crystal

5: $Si_{K\alpha}$, KAP Crystal

6: $K_{K\alpha}$, PET Crystal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Al
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Si
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K
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PLATE 19

1-6 Microprobe analysis of sclerotioid grain from V3bγ of Houthem borehole, 249.05 - 251.35 m sample. × 250.

1: Dry optic objective 16.5, normal reflected light
2: ac^{+} (positive polarity, 15kV/3nA)
3: $S_{K\alpha}$, PET Crystal
4: $Si_{K\alpha}$, KAP Crystal
5: $Al_{K\alpha}$, KAP Crystal
6: $Ca_{K\alpha}$, PET Crystal

7-11 Polished sections through sclerotioid grains from limestone at Goα-Goβ boundary (= V3bγ–V3c) of Geitenberg near Wennemen, northern flank of Rhenish Massif.

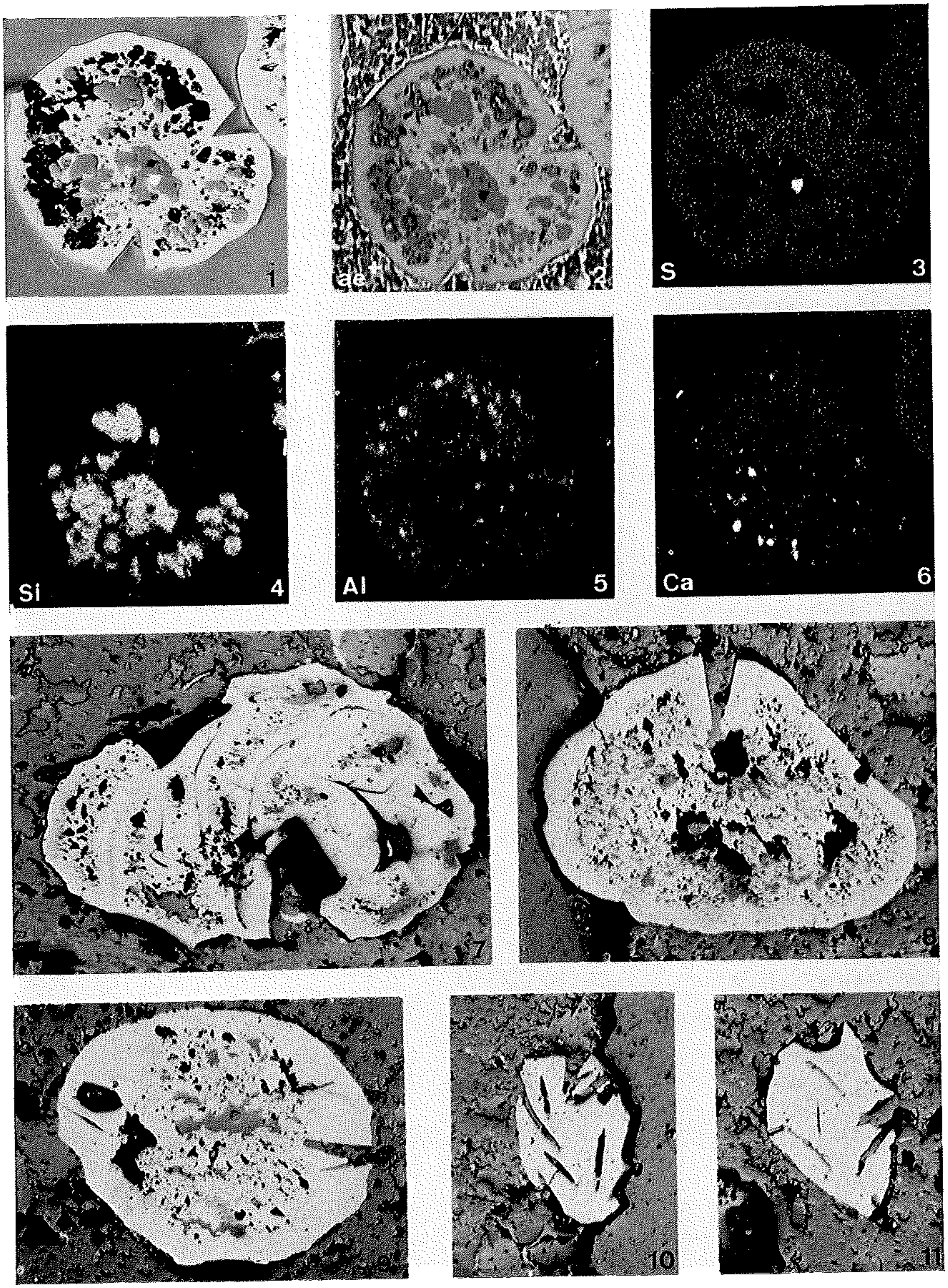
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PLATE 20

1-10 Ribbon-like organism of unknown affinities, Houthem borehole, 304.66-305.41 m.

1: Fragment, × 50. Specimen kept at "Geologisch Bureau" at Heerlen.

2: Detail of 1, showing lateral tooth with broken tip, × 250.

3: Fragment of specimen that has been destroyed during posterior maceration, × 100.

4: Detail of 3, showing tooth-like broadened tip of a marginal tube departing from the bilateral structure (only the base of this tooth has been preserved). Note also regularly distributed raised bosses on the tubes, which are due to the development of framboidal pyrite bodies. × 250.

5: Detail of 3, showing transverse section of organism with thickened axial mid-region, × 500.

6: Detail of 5, showing empty tubes after HF and Schulze's treatments, × 1000.

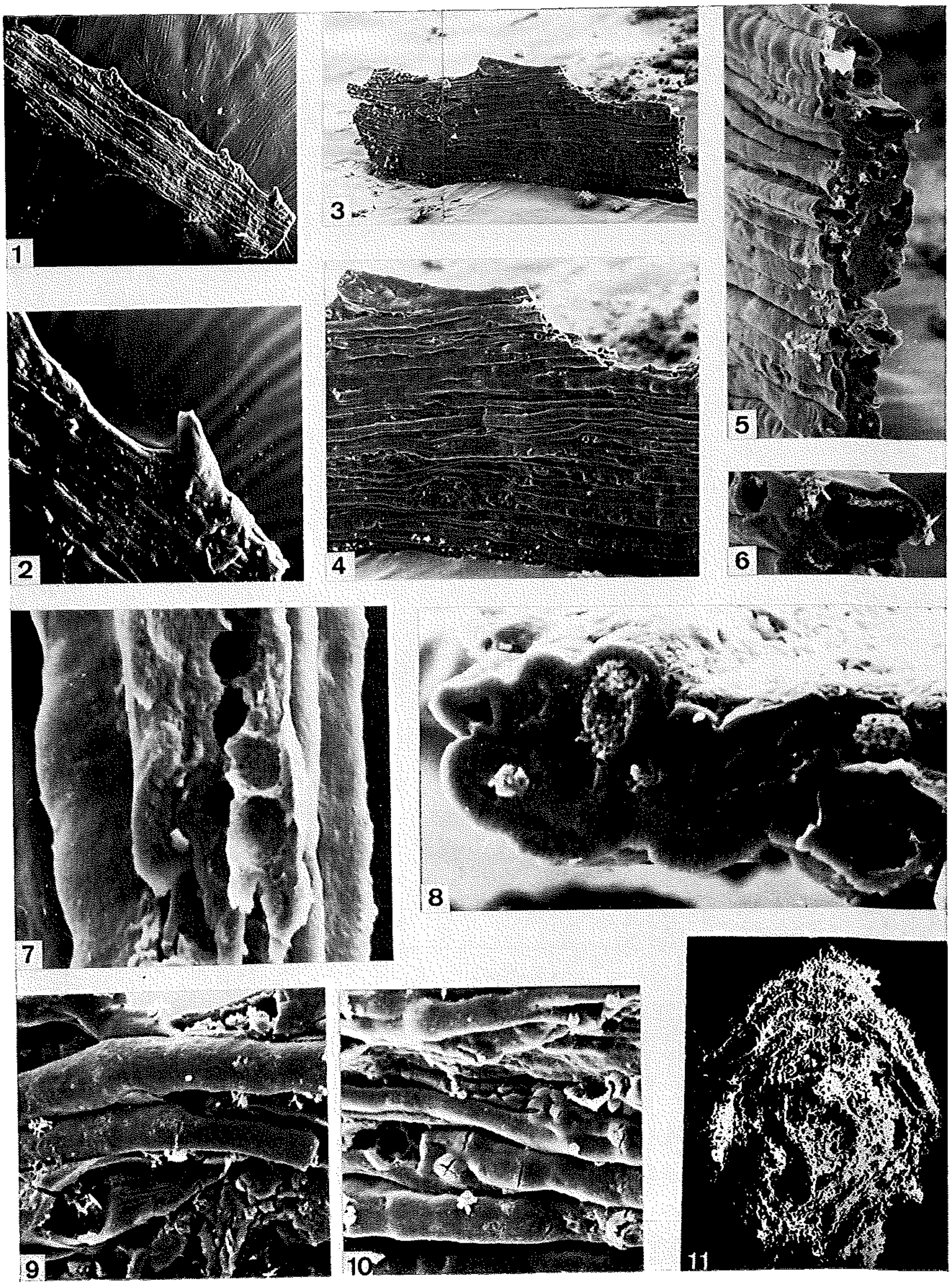
7: Detail, showing casts of framboidal pyrite bodies inside the tubes (obliquely sectioned tubes in top right part of 4) after HF and Schulze's treatments, × 2000.

8: Detail of 3, showing transverse section of organism with framboidal pyrite bodies inside some of the tubes before HF and Schulze's treatments, compare also with 5 and 7, × 2000.

9: Detail of some tubes, showing smooth internal and external walls, × 1000.

10: Detail, showing furcation of tubes, × 1000.

11 *AOUJGALIIDAE* (cf. *Stacheoides*)
Houthem borehole, 285.65-286.46 m, × 100.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