MEDED. RIJKS GEOL. DIENST, 30-2, p. 37-103 (published 1-8-1978)

Paleozoic deposits East of the Brabant Massif in Belgium and the Netherlands

W. F. M. Kimpe[1], M. J. M. Bless[1], J. Bouckaert[2,3], R. Conil[4], E. Groessens[2], J. P. M. Th. Meessen[1], E. Poty[5], M. Streel[6], J. Thorez[7] and M. Vanguestaine[6]

1 Geological Survey of the Netherlands, Geological Bureau, P.B. 126, 6400 AC Heerlen, The Netherlands
2 Service Géologique de Belgique, Rue Jenner 13, B-1040 Brussels, Belgium
3 Department of Micropaleontology, Katholieke Universiteit van Leuven, Redingenstraat 16bis, B-3000 Leuven, Belgium
4 Department of Micropaleontology, Université Catholique de Louvain, 3 Place L. Pasteur, B-1348 Louvain-La-Neuve, Belgium
5 Department of Paleozoology, Université de Liège, 7, Place du Vingt-Août, B-4000 Liège, Belgium
6. Department of Paleobotany and Paleopalynology, Université de Liège, 7, Place du Vingt-Août, B-4000 Liège, Belgium
7 Department of Clays, Université de Liège, 7, Place du Vingt-Août, B-4000 Liège, Belgium

PREFACE

The coïncidence of the date appearance of this publication with the date of retirement of Dr. W. F. M. KIMPE as chief of the Geological Bureau of the Geological Survey of the Netherlands is clearly on purpose.

This issue of ''Mededelingen van de Rijks Geologische Dienst'' in many ways symbolizes the many-sidedness of Dr. KIMPE.

But not only this many-sidedness is characteristic of Dr. KIMPE. Also his open mind for new approaches and conceptions stimulated the work of the Geological Bureau as a whole. In this respect he has continued an illustrious tradition.

Dr. KIMPE has extended his activities beyond the circle of his direct collaborators and always pursued international cooperation of specialists of many geological disciplines. The multidisciplinary studies realized by these teams commonly lead to results in a relatively short period of time.

The paper clearly reflects the above qualities of Dr. KIMPE thus being a clear specimen of his abilities and an hommage to his work.

Ir. B. P. HAGEMAN
Director, Geol. Survey of the Netherlands

12 figures, 5 tables, 16 plates, 7 enclosures

CONTENTS

ABSTRACT

The area of the Brabant Massif and North of the Booze-Le Val Dieu Ridge has formed part of the Campine-Brabant Basin from the Middle Devonian until the end of the Westphalian. Deposition of sediments occurred on the Caledonian folded Cambro-Silurian basement. Our knowledge of these deposits is rather complete in so as far as the productive, coal-bearing Westphalian A-C and the Namurian are concerned. The data on the Devono-Dinantian are mainly confined to the Visé area and to a few boreholes on the Visé-Puth Anticline which have only explored the strata immediately below the Paleozoic abrasion surface. Only the basal part of the Westphalian D has been investigated by three boreholes near Neeroeteren.

Except for a strip West of the line Oupeye-Maastricht-Lanaken which borders the Brabant Massif, a relatively accurate reconstruction of the Paleozoic abrasion surface is possible from the now available data.

Within the area investigated, some four horst-like uplifts have been recognized, namely the Visé-Puth, Waubach and Ham Anticlines and the Eys-Wittem High. Oscillating movements of these structures until the Tertiary have been deduced from the abnormal sedimentation-erosion phenomena occurring from the Lower Westphalian until the Oligocene. Moreover, the Visé-Puth Anticline coincides with a negative gravity anomaly and with a relatively high chloride contents of the water in the Carboniferous rocks. The Waubach Anticline matches the area with most of the lead-zinc mineralizations in the Silesian of South Limburg, with a relatively very high cloride contents of the water in the Carboniferous rocks (including some thermomineral springs - "brines") and with a relatively high rock-temperature.

Presumably, both the oscillating movements of these structures and the above named phenomena are to be attributed to a common origin. The presently known geological history of this area (for the Devono-Dinantian period only known from the Visé region) has not yet yielded the clue to this origin. The hypothesis that the occurrence of evaporites in the pre-Silesian subsurface might explain the above observations can only be verified by further multidisciplinary investigations which imply boreholes.

RÉSUMÉ

La région à l'Est du Massif de Brabant et au Nord de la Ride Booze-Le Val Dieu faisait partie du Bassin de Campine-Brabant à partir du Dévonien moyen jusqu'à la fin du Westphalien. Les dépôts de sédiments ont commencé sur le socle Cambro-Silurien plissé pendent la phase calédonienne. En ce qui concerne le Westphalian A-C productif et le Namurien, les connaissances sur ces sédiments sont assez complètes. Les données sur le Dévono-Dinantien sont limitées principalement à la région de Visé et à quelques sondages dans l'Anticlinal de Visé-Puth qui ont pénétré seulement les couches situées immédiatement en-dessous de la surface d'abrasion du Paléozoïque. Seule la partie basale du Westphalien D a été rencontrée par trois sondages près de Neeroeteren.

Une reconstruction relativement précise de la surface d'abrasion du Paléozoïque est possible à partir des données actuelles, sauf en ce qui concerne une aire à l'Ouest de la ligne Oupeye-Maastricht-Lanaken qui borde le Massif de Brabant.

Dans les limites de l'aire étudiée, quelque quatre surélévations de type "horst" ont été reconnues. Ce sont les anticlinaux de Visé-Puth, Waubach et Ham et la Culmination d'Eys-Wittem. Des oscillations de ces structures jusqu'au Tertiaire ont été déduites de phénomènes anormaux de sédimentation ou d'érosion apparus entre le Westphalien inférieur et l'Oligocène. De plus, l'Anticlinal de Visé-Puth coïncide avec une anomalie négative de la gravité et des teneurs en chlorure relativement importantes de l'eau des roches carbonifères. L'Anticlinal de Waubach se superpose à la plupart des mineralisations Plomb-Zinc dans le Silésien du Sud-Limburg, à des teneurs en chlorure très importantes de l'eau des roches carbonifères (y compris quelques sources thermominérales - "brines") et à des températures de roche relativement élevées.

Probablement, une même cause est-elle à l'origine à la fois des oscillations de ces structures et des phénomènes rappelés ci-dessus. Les connaissances actuelles de l'histoire géologique de cette région (connue seulement dans les environs de Visé en ce qui concerne le Dévono-Dinantien) n'en ont pas encore livré l'explication. La présence d'évaporites dans le sous-sol pré-Silésien pourrait expliquer les observations ci-dessus. Cette hypothèse pourra seulement être vérifiée par d'autres recherches multidisciplinaires qui impliquent des sondages.

SAMENVATTING

Het gebied ten Oosten van het Massief van Brabant en ten Noorden van het Booze-Le Val Dieu Hoog heeft vanaf het Midden Devoon tot aan het einde van het Westphalien deel uitgemaakt van het Kempen-Brabant Bekken. Afzetting van sedimenten vond plaats op de Caledonisch geplooide Cambro-Silurische ondergrond. Onze kennis over deze afzettingen is vrij groot, voorzover het het produktieve, kolenvoerende Westphalien A-C en het Namurien betreft. De gegevens over het Devoon en Dinantien komen in hoofdzaak uit het gebied rond Visé en uit enkele boringen in de Visé-Puth Antiklinaal, die slechts de onmiddellijk onder het paleozoïsch abrasie-oppervlak liggende gesteenten verkend hebben. Slechts de basis van het Westphalien D is verkend door een drietal diepboringen bij Neeroeteren.

Het paleozoïsch abrasie-oppervlak kan aan de hand van de thans beschikbare gegevens vrij nauwkeurig gereconstrueerd worden met uitzondering van een strook ten Westen van de lijn Oupeye-Maastricht-Lanaken, welke grenst aan het Brabant Massief.

Binnen het bestudeerde gebied zijn een viertal horst-achtige opwelvingen herkend, namelijk de Antiklinalen van Visé-Puth, Waubach en Ham en het Eys-Wittem Hoog. Oscillerende bewegingen van deze strukturen tot in het Tertiair zijn aannemelijk te maken aan de hand van abnormale sedimentatie-erosie verschijnselen die optreden vanaf het Onder Westphalien tot in het Oligoceen. Bovendien komt de Antiklinaal van Visé-Puth overeen met een negatieve gravimetrische anomalie en met een relatief hoog chloride gehalte van het in het Carboon aangetroffen water. De Antiklinaal van Waubach valt samen met het gebied waarin de meest lood-zink mineralisaties zijn waargenomen, met het relatief zeer hoog chloride gehalte van het in het Carboon aangetroffen water (waaronder verschillende thermominerale bronnen - "brines") en met een relatief hoge gesteente-temperatuur.

Zowel de oscillerende bewegingen van deze strukturen alsook de hiermee geassocieerde verschijnselen zijn vermoedelijk tot een gemeenschappelijke oorzaak terug te voeren. Deze oorzaak kan uit de thans bekende geologische ontwikkeling van dit gebied (welke voor wat het Devoon en Dinantien betreft slechts bekend is uit het gebied rond Visé) niet zonder meer afgeleid worden. De hypothese, dat het voorkomen van indampingsgesteenten in de pre-Silesien ondergrond de hierboven beschreven waarnemingen zou kunnen verklaren, kan alleen geverifieerd worden door verder multidisciplinair onderzoek, waarbij boringen noodzakelijk zijn.

1. INTRODUCTION

Although the Paleozoic in the area East of the Brabant Massif (Fig. 1) has been intensively explored in hundreds of boreholes, in countless exposures in coalmines and in a large number of outcrops, its geological history and even its nature have remained obscure in so far as the Devono-Dinantian and late Westphalian are concerned. Also our knowledge of the influence of movements of the Paleozoic basement on the Mesozoic-Cenozoic sedimentation pat-

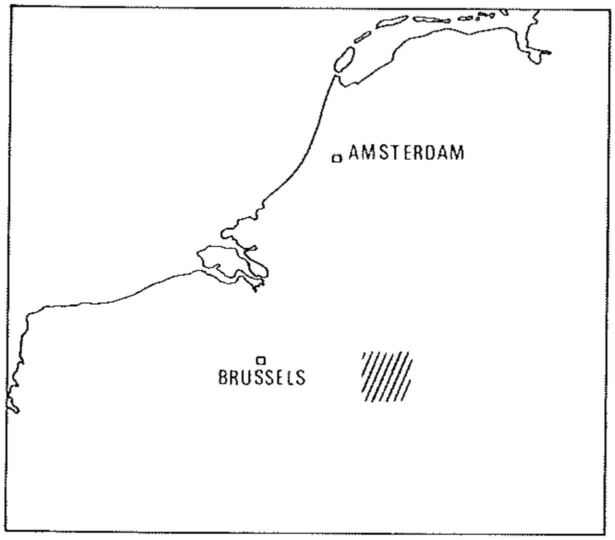


Fig. 1 — General position of the area East of the Brabant Massif

tern is surprisingly incomplete.

An updated inventory of the numberless data in the form of maps of the Paleozoic abrasion surface and its immediate cover should serve as a starting point for further investigations. The principal questions to be solved are the location of the eastern border of the Brabant Massif, the nature, thickness and distribution of Devono-Dinantian and late Westphalian sediments and the origin and tectonic evolution of the anticlinal structures of Visé-Puth, Waubach and Ham.

1.1. HISTORY OF GEOLOGIC MAPS

One of the first geological maps of the Paleozoic abrasion surface East of the Brabant Massif was published in 1902 by FOURMARIER, who limited himself to the complex tectonic structure of the Visé Massif. A revision of the eastern part of this map was made by the same author in 1923, when he described the Berwinne Fault. Later studies by a.o. PIRLET (1967a, 1967b, 1968) yielded additional data on the geological history of the Visé Massif, but did not virtually alter the concept of FOURMARIER.

All later maps of the Paleozoic along the eastern border of the Brabant Massif may be subdivided into detailed maps of the Westphalian strata in the coal mining areas of Liège, South Limburg and the Campine on the one hand, and more general compilation maps of the whole area - usually as part of a much vaster regional geological setting - on the other.

The Liège Coalfield at the —200 m sealevel was figured on a 1:40.000 map by LEDOUBLE in 1905. A general revision was given by HUMBLET in 1941, who published a 1:20.000 map of the same area, but excluded the poorly known region around the village of Oupeye, where LEDOUBLE had indicated the existence of Lower Westphalian coalseams recognized by a shaft (Pieter Shaft) and two boreholes (121E-13 and 121E-14).

The geology of individual mining concessions was subsequently revised by various authors. But their work has not resulted in substantial changes of HUMBLET's map.

A subcrop map of the Carboniferous in the South Limburg Coalfield (scale 1:30.000) was published by SAX in 1946 and revised by PATIJN & KIMPE in 1961 on a 1:25.000 map. Re-interpretation of the data used by these authors and new information that became available from the coal exploitation between 1961 and 1975 (in that year the last coalmine in South Limburg hab been abandoned) have resulted in an updated version of the Carboniferous subcrop map. This new version is here included in the 1:50.000 map of the Paleozoic abrasion surface.

The Carboniferous subcrop map (shale 1:50.000) of the Campine by DELMER (1963) was restricted to the actively worked mining concessions which are partly separated by reserved areas of which no subcrop map was composed.

In between these relatively well known coalfields and the easternmost boreholes 93W-560 (Martenslinde) and 121W-216 (Villers) which penetrated the Caledonian folded Cambro-Silurian rocks of the Brabant Massif below the Mesozoic/Cenozoic cover, an area remains varying in width between 5 and 20 km which has been subject of quite different interpretations as far as the Paleozoic abrasion surface is concerned. This is not in the last place due to insufficient biostratigraphic control of the boreholes and even outcrops within this region.

VAN WATERSCHOOT VAN DER GRACHT (1909, 1912, 1918 and 1938) believed that the eastern border of the Brabant Massif is surrounded by Devono-Dinantian rocks in the area around Maastricht. This hypothesis was also accepted in later compilations by e.g. SAX (1946) and PATIJN (1963). A key-borehole in this interpretation is DB123 in Maastricht, drilled between 1927 and 1929. The Paleozoic strata recognized in this borehole are interpreted as Cambro-Silurian by SAX and PATIJN, but as Silesian by JONGMANS & VAN RUMMELEN (1930), VAN LECKWIJCK (1956) and LEGRAND (1968). Consequently, VAN LECKWIJCK (1956) and LEGRAND (1968) placed the eastern border of the Brabant Massif slightly West of Maastricht. Microfossil analysis of the 127 m thick Paleozoic sequence of the DB 123 borehole proved the Dinantian (Visean) age of these strata (BLESS et al. 1976). It was therefore suggested that the eastern border of the Brabant Massif might be further to the West than formerly was believed. These latter authors als argued that the Visé Massif extends further to the North and merges into the Puth Anticline of the South Limburg Coalfield. This structure was named by them the Visé-Puth Anticline.

As a result of the investigations up to now, the following structural elements can be distinguished on the Paleozoic abrasion surface.

a - The Brabant Massif with its eastern border yet to be defined
b - The Variscan folded and thrust-faulted structures with an overall WSW-ENE strike, which predominate in the southeastern part of the area

c - The overall NW-SE striking normal faults, which become more prominent in the northeastern half of the area and affect the post-Paleozoic cover
d - The Ham Anticline with a N-S strike of its only 2 km long axis, which plunges to the S and to the N
e - The Waubach Anticline with a SW-NE striking axis, which reaches its culmination near the Dutch-German frontier
f - The Visé-Puth Anticline (including the Krawinkel Anticline) with a SSW-NNE striking axis and with its western border yet to be defined

The principal question which remains to be solved is the border and the nature of the same (fault contact?) between the Brabant Massif and the Visé-Puth Anticline.

1.2. CONCEPTS OF ORIGIN OF STRUCTURAL ELEMENTS

The origin of these tectonic structures has been discussed by various authors.

The Caledonian folded Brabant Massif must have been a high during the Devonian because of the thin and incomplete sequence of Devonian strata along its southern flank in the Namur Synclinorium as compared to the thicker and more complete development in the Dinant Synclinorium (FOURMARIER 1954; TSIEN 1974). According to a.o. DELMER & ANCION (1954) and PATIJN (1963), the Brabant Massif formed part of the sedimentary basin during the Silesian. BLESS (1973) and BLESS et al. (1977) suggested however that it continued to be a positive element during the Carboniferous because of the fact that the Carboniferous strata along its flanks are thinner, more incomplete and sometimes less marine than those at some distance from it in southern, eastern and northern directions.

The Variscan origin of the thrust-faulted and folded structures with an overall WSW-ENE strike in the Liège Coalfield and the southeastern part of the South Limburg Coalfield is accepted by all authors. This fault-pattern has not affected the post-Carboniferous cover.

The NW-SE striking normal faults - of which the most important are named on the map of Enclosure II - form the southwestern flank of the Central Graben or Roer Valley Graben. This graben most probably originated as a subsiding segment of the Old Red Continent somewhere during the Middle Devonian (MICHOT 1976). Several inverse movements must have taken place during the Mesozoic and Cenozoic as can be deduced from a cross-section through the graben by PATIJN (1963, Beilage 3). It is unknown whether this Paleozoic basin - the "Fosse Campinoise" (MICHOT 1976) or "Campine-Brabant Basin" (BLESS et al. 1976) - was bordered by the same fault system or not. And if so, whether these faults were mainly restricted to the Caledonian folded basement or affected the still unconsolidated Devonian and/or Carboniferous sediments. Personally, we are inclined to accept the idea that this fault-pattern originated at the same time as the Campine-Brabant Basin - this is during the Middle Devonian - and that it became rejuvenated in post-Variscan times.

The slightly asymmetrical Ham Anticline with its remarkably short N-S striking axis is a quite isolated phenomenon, which may be compared with the northern part of the Visé-Puth Anticline. Neither SAX (1946) nor PATIJN (1963) have forwarded any tectonic explanation of this feature.

The WSW-ENE striking Waubach Anticline parallels the strike of the Variscan structures. Consequently, PATIJN (1963) has interpreted this anticline as formed by the Variscan orogenesis. Both SAX (1946) and PATIJN (1963) reject the hypothesis that the Waubach Anticline might be located on an eastern spur of the Brabant Massif. They argue that the WSW plunging axis does not support this idea. SAX compared the Waubach Anticline with the "Horst" of Visé and apparently believed this structure to be the result of block-faulting.

The Visé Massif and the Puth Flexure have long been regarded as two separate structures. FOURMARIER (1902, 1923), HUMBLET & ANCION (1949) and LEGRAND (1968) presented the Visé Massif as an isolated - strongly faulted - anticline of Dinantian rocks with a core of Devonian strata and surrounded and discordantly overlain by Namurian sediments. LOHEST (1911) supposed that the Visé Massif is an overthrusted structure, comparable to the Theux Massif and the Herve Massif.

The Puth Flexure was interpreted by DIKKERS (1945), SAX (1946) and PATIJN (1963) as a "compression flexure" formed by Variscan and post-Variscan movements of the Brabant Massif.

Revision of boreholes North of the Visé Massif has proven the northward extension of the Dinantian at the Paleozoic abrasion surface until the boreholes Lanaken and Houthem (BLESS et al. 1976, 1978). A depth contour map of the Dinantian in this area made clear that the Visé Massif and the Puth Flexure should no longer be treated as two independent structures. They rather from the two ends of one anticlinal structure, the Visé-Puth Anticline.

BLESS et al. (1978) suggested that this anticline was formed under influence of halokinesis of evaporites underneath. They based their hypothesis on a.o. the following arguments.

- The Visé-Puth Anticline coincides with a negative gravity anomaly of 6 to 8 milligals.

This is in contrast with the positive gravity anomaly observed in the eastern part of the Brabant Massif and also in contradiction with the image of an anticline built up of Devono-Dinantian carbonates and surrounded by quartz-rich Silesian deposits. Negative gravity anomalies with similar amplitudes are known to occur over salt structures.

- Oscillating movements of the Visé-Puth area since the Late Devonian until the Cenozoic.
- The aberrant N-S directed axis of the Visé-Puth Anticline, which is matched by the N-S directed axis of the Ham Anticline. This direction differs considerably from the WSW-ENE trend of the Variscan folding and thrust-faulting pattern and also from the NW-SE trend of the normal faults bordering the Roer Valley Graben.
- The occurrence of ground water with an increased chloride contents in the Carboniferous deposits in and around the Visé-Puth and Waubach

Anticlines. This fact has been observed by KIMPE (1963) for the mining water and a.o. by JONGMANS & DRIESSEN (1932) and JONGMANS, KRUL & VOS (1941) for groundwater from Carboniferous origin in boreholes and wells in the Eysden-Maastricht region.

1.3. STRATIGRAPHIC FRAMEWORK

The bio- and lithostratigraphic framework as a basis for the study of the Paleozoic in the area East of the Brabant Massif is further completed in this report.

Correlation of the Westphalian strata is based on widespread marine marker bands, non-marine fossil horizons, tonsteins and coal seams. For detailed correlation charts, the reader is referred to HUMBLET (1941) for the Liège Coalfield, PATIJN & KIMPE (1961) for the South Limburg Coalfield and DELMER (1963) for the Campine. DELMER (1963) and KIMPE (1969) published correlation charts for the mining areas of northern France, Belgium, the Netherlands and the Ruhr district of Germany.

Correlation of the Namurian deposits is based on goniatite assemblages occurring in relatively thin and widespread marine bands which can be followed throughout NW Europe. We may refer to CHALARD (1960) for northern France, BOUCKAERT (1971) for Belgium, PAPROTH (1971) for the Ruhr and Aachen areas of the Federal Republic of Germany and RAMSBOTTOM (1969) for Great Britain. A revision of the Namurian stratigraphy in South Limburg is presented in this report.

The age of Devono-Dinantian strate explored by boreholes in South Limburg and the Visé area has been the subject of several recent papers (CONIL 1964, GROESSENS 1974, GRAULICH 1975a, BLESS et al. 1976, 1978). This information is supplemented in this paper by a revision of some biostratigraphic data on the outcropping Devono-Dinantian in the Visé area.

1.4. ACKNOWLEDGEMENTS

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 on this report and use data from the Service Géologique de Belgique. We acknowledge the stimulating discussions with many of our colleagues, notably Ir. J. M. GRAULICH (Service Géologique de Belgique), Dr. D. MASSA (Compagnie Française des Pétroles, Paris), Dr. E. PAPROTH (Geologisches Landesamt Nordrhein-Westfalen, Krefeld) and Dr. H. PIRLET (Université de Liège). E. POTY is happy to record his gratitude for the loan of coral specimens provided by Dr. P. SARTENAER, Institut Royal des Sciences Naturelles de Belgique (Brussels). We are also greatly indebted to Messrs. H. J. G. BAGGEN, H. F. J. BISSCHOFF, H. J. KEULEN and W. RITZERFELD (Geological Bureau, Heerlen) for their enthusiastic assistance in preparing the geological maps. We extend our thanks also to Messrs. PH. BERTRAND, L. R. FUNCKEN, G. M. A. GEERAEDTS, J. H. L. JANSEN, H. J. KASTERMANS, M. LHODE and H. M. J. RUYTERS for the excellent quality of the illustrations, to Dr. A. N. MOURAVIEFF (Université Catholique de Louvain, Louvain-La-Neuve) for technical help in working with the stereoscanning microscope, to Mr. J. GEELEN for preparing many of the thin sections, and to Mr. A. J. SCHAAF for typing the manuscript.

2. PALEOZOIC ABRASION SURFACE

This map (enclosure I) has been compiled from partly updated published information about the Paleozoic in South Limburg and the adjacent area of Belgium.

2.1. WESTPHALIAN

2.1.1. Campine

The Carboniferous subcrop map of the Campine by DELMER (1963) was restricted to the private mining concessions and excluded the state concession of the Campine as well as the reserved areas. We have followed DELMER's interpretation of the easternmost private concession (Sainte Barbe et Guillaume Lambert) and extended this to the reserved area C1.

The Midi Fault - recognized by DELMER in the Winterslag-Genk-Sutendael Concession - presumably continues into the Sainte Barbe et Guillaume Lambert Concession as has been deduced from DELMER's section VI through the shafts of the Limbourg-Meuse Colliery and the 51 Borehole (= 79W-4 Borehole in LEGRAND 1968).

The existence of the Westphalian D in the Neeroeteren-Rotem Concession (North of the Sainte Barbe et Guillaume Lambert Concession) has been established by the recognition of the plant fossil *Neuroperis ovata* in the 117 Borehole (STOCKMANS & WILLIÈRE 1975). The subcrop of the base of the Westphalian D (marked by the first occurrence of *N. ovata*) can be extrapolated from the data yielded by the boreholes 110, 113 and 117 in the Neeroeteren-Rotem Concession and can be followed into the northern part of the South Limburg Coalfield.

The (Lower) Westphalian D of the Campine is characterized by massive sandstones with a relatively high porosity. These sandstones originated from the Ardenno-Rhenish Massif and its northern borderlands which had become uplifted during the Variscan orogenesis. It is therefore believed that these sandstones are thickest in the southeastern part of the Campine-Brabant Basin and become less important to the West. Further exploration is needed in order to determine if the porosity of the sandstones is a general feature in the area (potential hydrocarbon reservoir rock?) and if the sandstone facies of the Lower Westphalian D is succeeded by a more shaly sequence in the Upper Westphalian D (impermeable cover?).

2.1.2. South Limburg Coalfield

An updated version of the Carboniferous subcrop map of

PATIJN & KIMPE (1961) is presented.

The subcrop of the base of the Westphalian D has been extrapolated from the data yielded by notably the boreholes 84, XL, and XLV. These have been correlated with the Campine boreholes 110, 113 and 117.

Revision of the biostratigraphy of the Namurian in the southeastern region has established the existence of several overthrusts in the area West of Benzenrade Fault. Similar overthrusts had been known already from the Willem Sophia and Dominiale Collieries in the area South of the Willem Fault. They belong to the northern thrust front of the Variscan deformation. Presumably, they continue towards the WSW in the overthrusts of the Liège Coalfield.

2.1.3. Liège Coalfield

The base of the Westphalian, the Sarnsbank Marine Band, outcrops at three locations near Dalhem, St. Remy and South of Argenteau.The subcrop of this marine band on the western bank of the Meuse can be extrapolated from the section F-F'. These data as well as the maps of the Liège Coalfield (HUMBLET 1941) and of the concessions Cheratte and Argenteau-Trembleur (CHAUDOIR 1953) permit reconstruction of the outcrop of the Sarnsbank Marine Band at the Paleozoic abrasion surface. West of the N-S striking fault along the line Vivegnis-Oupeye, the Lower Westphalian A has been recognized in two boreholes (121E-13 = Oupeye 1 and 121E-14 = Oupeye 2; STAINIER 1941) and in the Pieter Shaft (121E -123; LEDOUBLE 1905). According to LEDOUBLE (1905), Lower Westphalian A coalseams had been exploited in the area North of Oupeye in the past century (also cf. HUMBLET 1941, p. 17). The northward extension of the Lower Westphalian A in that area rests enigmatic. Two or three boreholes of less than 100 m might resolve this problem.

2.2. NAMURIAN

The Namurian is known from several outcrops in the Meuse and Berwinne Valleys near Visé (a.o. LAMBRECHT & CHARLIER 1956) and in the Geul Valley South of Epen. (a.o. BOUCKAERT 1960). Incomplete Namurian sequences have been recognized in several boreholes in the eastern Campine, (DELMER 1963) South Limburg (Enclosure VII), the Sippenaeken area (DELMER & GRAULICH 1959) and the Visé area (a.o. DELMER & GRAULICH 1955, GRAULICH 1975a, LAMBRECHT & BOUCKAERT 1973). The only borehole that explored a complete succession of Namurian strata is the Chertal (= 121E-15) Borehole (DELMER & GRAULICH 1955).

The Namurian strata recognized in the area North of Hallembaye may extend northwards between the eastern edge of the Brabant Massif and the Visé-Puth Anticline. They may merge with the Namurian deposits of the Campine. This enigma can only be resolved by one or more boreholes in the area West of the line Eben-Emael-Maastricht.

2.3. DINANTIAN

The Dinantian outcrops at several places in the Visé area. The best known locations are the "F"-"L" Quarries North of Richelle, the La Folie Quarry South of Berneau and the railway cutting West of Berneau. Other outcrops have been described by a.o. HORION & GOSSELET (1892) and FOURMARIER (1902). The biostratigraphic age of some locations is revised in this paper. A number of boreholes has penetrated the Dinantian subcrop. Four of these (93E-115 at Lanaken, DB106 at Gulpen, 121E-15 at Chertal and 122W-258 at Hermalle-sous-Argenteau) recognized the Dinantian below Namurian strata. All the remaining boreholes penetrated the Dinantian immediately below the post-Paleozoic cover. The silicified - often decalcified - limestones at the top of the Dinantian (so-called phthanites) have frequently been considered as basal Namurian strata. Recent studies (a.o. PIRLET 1967b, BLESS et al. 1976) have established their Visean age. These phthanites are of Upper V3c age at Richelle, Souvré, Mesch and Houthem, of V1b/V2a and V3b age in the Eysden area and of V1(?) age at Maastricht. Silicification is post-sedimentary and may have originated during or after erosion of the Triassic deposits in this area in a rather arid climate before deposition of late Cretaceous sediments.

The Dinantian is unconformably overlain by the Namurian (LOHEST 1911). The unconformity is marked by a karstified erosion level (GRAULICH 1962, 1975a).

The only two boreholes that have explored the Namurian-Dinantian-Upper Devonian succession are Chertal and Hermalle-sous-Argenteau. Unfortunately the Dinantian section of Chertal (only basal Tournaisian below Namurian) and Hermalle-sous-Argenteau (Upper Visean strata directly overlying Frasnian carbonates) are not representative for the Dinantian in this area. A more complete succession of Tournaisian and Visean strata is expected further northwards between Eysden and Houthem. The thickness or the exact nature of these beds are unknown since all the boreholes in that area have only explored the very top of the Dinantian rocks.

2.4. UPPER DEVONIAN

Upper Devonian (Frasnian) rocks outcrop in the "M"-"N" Quarries North of Richelle, in the Souvré Valley South of Visé and in the Berwinne Valley. In the La Folie Quarry South of Berneau, Frasnian shales and carbonates occur at several places below the Dinantian rocks.

Subcrops of presumably Frasnian strata at the Paleozoic abrasion surface have been recognized by a few boreholes between Eysden and Berneau.

The Frasnian is unconformably overlain by the Dinantian. The unconformity is marked by a karstified erosion level, that originated during the Famennian or early Tournaisian.

Upper Famennian rocks have only recognized in the Chertal Borehole where they underlie basal Tournaisian and Namurian deposits. They have been reported from some outcrops in the Meuse and Berwinne Valleys. However, these outcrops have not been recognized by later authors.

2.5. FAULTS

Our knowledge of normal faults and thrust faults is practically limited to the exploited mining areas.

Presumably, the WSW-ENE striking thrust faults (upthrusts and overthrusts) of the Liège Coalfield continue into the thrust faults of the South Limburg Coalfield. This means that the Namurian strata in the Geul Valley South of Epen are allochthonous overthrusted deposits.

We do not exclude the possibility that several "en échelon" faults connect the Berwinne Fault in the SW with the Leut Fault in the NW.

We have deliberately omitted the SW-NE striking faults in the Oupeye-Visé area, which have been depicted on the maps of FOURMARIER (1902) and LEDOUBLE (1905). The existence of these faults in the Oupeye-Haccourt area should be established by further exploration. The faults in the Argenteau-Richelle area had been drawn at discordant contacts of Frasnian and Visean carbonates and between Visean organoclastic limestones and Visean breccias containing reworked Frasnian rocks. These contacts are now interpreted as Visean overlying a paleokarst of Frasnian strata (cf. chapter 7.1.3.) and as Lower Visean wash-outs filled by younger Visean deposits.

The faults recognized in the post-Paleozoic cover of South Limburg such as the Klauwpijp, Schin op Geul and Geulle Faults (cf. PATIJN 1966; Geologische Overzichtkaart van Zuid-Limburg, KUYL, 1971) have not been included on our map. The extension and even the existence of several of these faults is still under discussion. This holds for a.o. the Eckelrade-Rothem Fault, the Geulle Fault, Bellet Fault and Selzerbeek Fault (PATIJN 1966).

2.6. ANTICLINES

The Visé-Puth, Waubach and Ham Anticlines have not been formed by lateral compression. The term "anticline" is therefore misleading. The cross-sections on Enclosure III show that these are uplifted, horst-like structures. The Puth Flexure (PATIJN & KIMPE 1961) with its steep eastern flank must be draped over a discountinuity in the basement below.

These anticlines have originated on tectonic hinge lines in the pre-Westphalian basement, which have influenced the sedimentation pattern of Lower Westphalian deposits (compare also Enclosures V and VI).

The depth contour map of the top of the Dinantian (fig. 2) reveals the existence of a fourth structural high in the Eys-Wittem area. This structure is here named the Eys-Wittem High. It is masked by the overlying - insufficiently explored - Namurian strata. As will be shown in chapter 3, oscillating movements of this structure have influenced the Upper Cretaceous deposits in the area. The exact extension of the Eys-Wittem High is as yet unknown.

As stated in chapter 1, the Visé-Puth and Waubach Anticlines coincide with increased chloride contents of the ground and mining water (KIMPE 1963; BLESS et al. 1978). The Waubach Anticline matches the area of maximum concentration of relatively high-thermal Pb-Zn-Cu mineralizations (cf. chapter 4. and Exclosure IV). The subcrop of the Devono-Dinantian carbonates of the Visé-Puth Anticline is nearly identical with a significant negative gravity anomaly (fig. 3). This leads to the supposition that the density of the pre-Silesian rock-sequence (consisting of predominantly Devono-Dinantian carbonates and subordinate shale-sandstone intercalations overlying rhyolitic Cambro-Silurian rocks in the Visé area) is lower than the density of the Silesian rocks!

Similar structures have been described from Kansas and are referred to as "plains-type folds". MERRIAM (1963) reviewed the several hypotheses concerning the origin of the same.

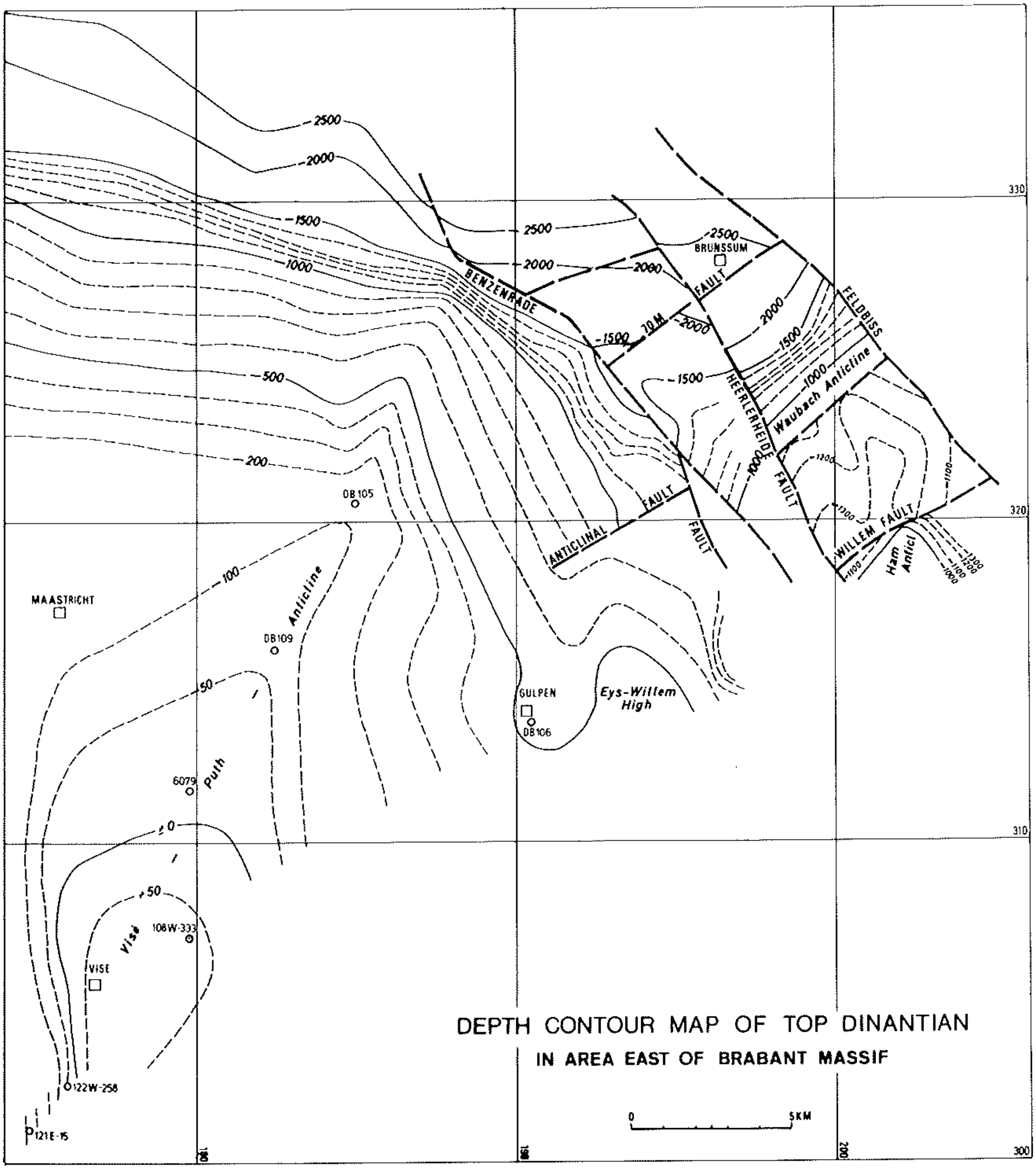


Fig. 2 — Depth contour map of the top Dinantian in area East of Brabant Massif.

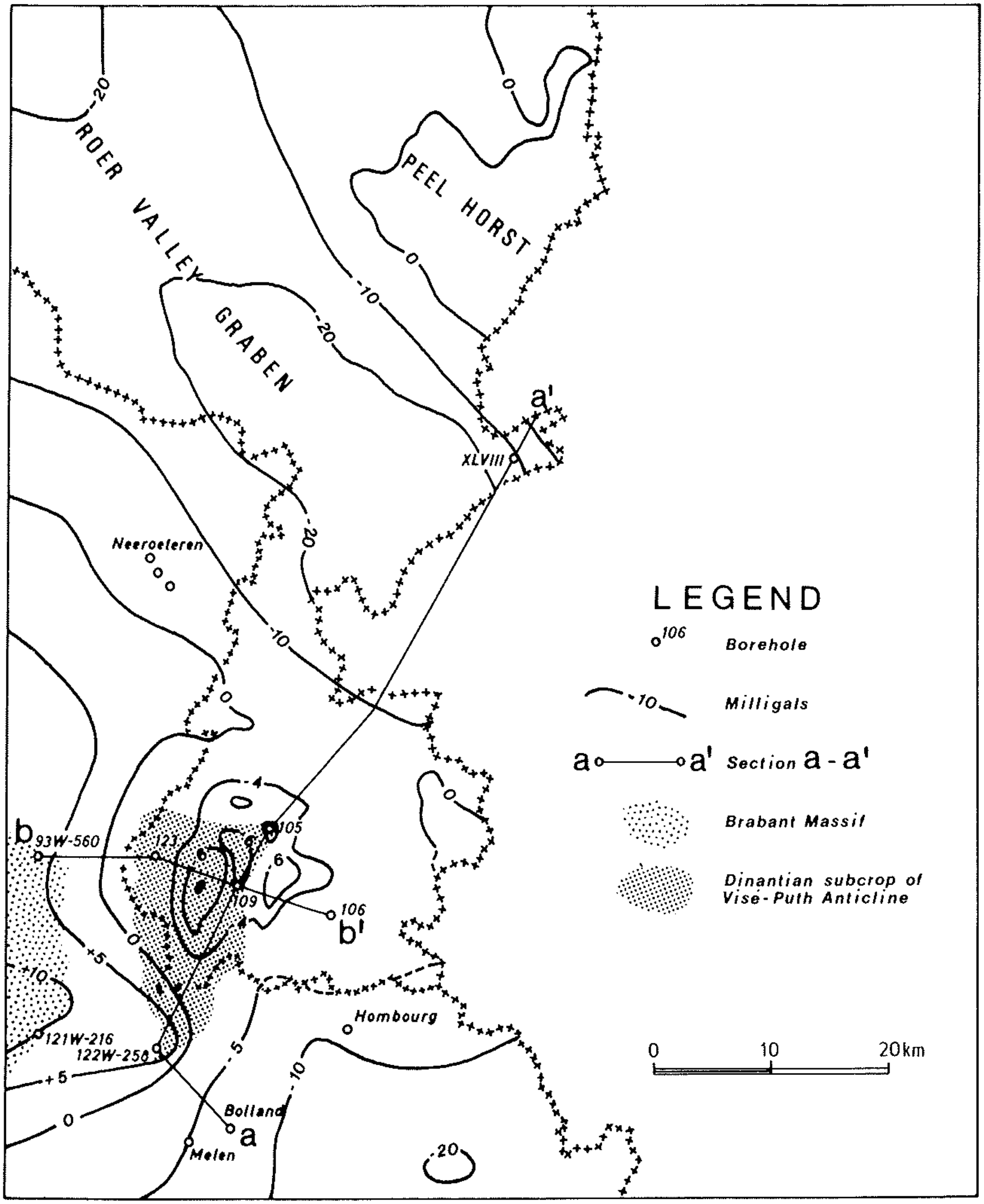
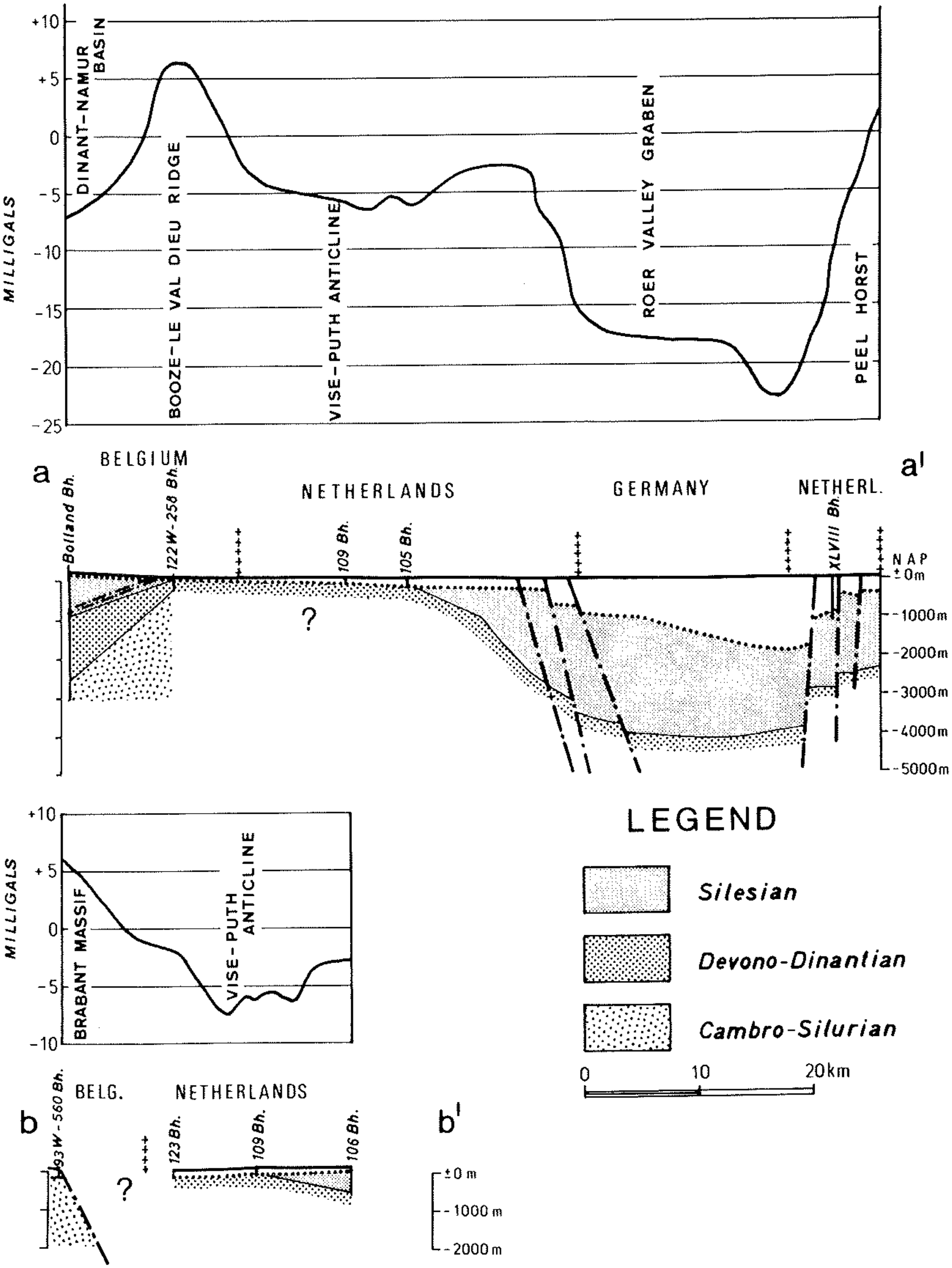


Fig. 3 — Map and geological sections showing relation between gravity anomalies and major tectonic features in the southeastern Netherlands and adyacent parts of Belgium. The negative anomaly coinciding with the Devono-Dinantian subcrop of the Visé-Puth Anticline suggests a lower density of the Devono-Dinantian than of the Silesian rocks.



MILLIGALS
+10
+5
0
-5
-10
-15
-20
-25
DINANT-NAMUR BASIN
BOOZE-LE VAL DIEU RIDGE
VISE-PUTH ANTICLINE
ROER VALLEY GRABEN
PEEL HORST
a
a'
BELGIUM
NETHERLANDS
GERMANY
NETHERL.
Bolland Bh.
122W-258 Bh.
109 Bh.
105 Bh.
XLVIII Bh.
?
NAP
±0m
-1000m
-2000m
-3000m
-4000m
-5000m
BRABANT MASSIF
VISE-PUTH ANTICLINE
b
b'
BELG.
93W-560 Bh.
123 Bh.
106 Bh.
±0 m
-1000 m
-2000 m
LEGEND
Silesian
Devono-Dinantian
Cambro-Silurian
0
10
20km

3. BASAL POST-CARBONIFEROUS DEPOSITS OF PALEOZOIC ABRASION SURFACE

Except for small areas in the Meuse and Geul Valleys and south of Kerkrade, the Paleozoic abrasion surface in South Limburg is mantled by a mosaic of Triassic, Upper Cretaceous and Tertiary deposits (Enclosure II). The distribution pattern of these strata reflects the complicate history of oscillating blocks in this region.

The basal post-Carboniferous strata have been recognized in a few outcrops and in a large number of boreholes and upward borings in the coalmines. The post-Carboniferous deposits have only rarely been cored and identification of strata therefore largely depends on cutting analysis. A short description of the bio- and lithostratigraphic characteristics of the different formations as recognized in cuttings is given below.

3.1. TRIASSIC DEPOSITS

3.1.1. Bunter Sandstone

Reddish-brown or white porous sandstones alternating with thin shales. A thin basal conglomerate sometimes occurs.

3.2. UPPER CRETACEOUS DEPOSITS

3.2.1. Aachen Formation

White-greyish silty sands and silty clays, frequently with rich microflora consisting of megaspores, seeds and cuticulae. The yellow-brown colour of the megaspores distinghuishes them from the black-coloured Carboniferous megaspores (DIJKSTRA 1949). The presence of these microfossils has proven to be the only practical criterion to distinguish Aachen sands and clays from weathered Carboniferous shales and sandstones. Rootlet beds occurring in cored Aachen deposits can easily be misinterpreted as rootlet horizons in weathered Carboniferous rocks. Also in these cases, the yellow-brown plant microfossils are reliable markers of the Aachen Formation.

3.2.2. Vaals Formation

Glauconite-bearing green-greyish silty sands with a foraminifer assemblage characteristic of the Foraminifer Zone A' of ROMEIN (1962). This foraminifer assemblage distinguishes the Vaals Formation from glauconitic bands of the overlying Gulpen Formation.

3.2.3. Gulpen Formation

Grey-white chalk (calcilutites) with glauconite-bearing horizons in the lower and flint-bearing horizons in the upper part. Foraminifer assemblages of this formation characterize the Foraminifer Zones A-F of HOFKER (1966). Important is the foraminifera-gens *Bolivinoides decorata-australis-gigantea*, that displays a gradual evolution of the number of pustules on the last chamber from 3.0 at the base of zone A thru 4.0 at the base of zone B, 5.0 at the base of zone C, 6.0 in zone D to 7.0 at the base of zone F (HOFKER 1966). The orthogenesis of the mean number of pustules also provides reliable marker horizons within these zones. A second marker species is *Bolivinoides draco*. Originally, HOFKER (1966) and MEESSEN (1976) supposed that *B. draco* is confined to zone D. Consequently, specimens occurring in borehole samples belonging to Zone C were considered as contamination from higher levels. Re-examination of a large number of boreholes has proven that *B. draco* systematically occurs in one horizon within Zone C, where the mean number of pustules on the last chamber of *B. australis* is 5.3-5.4. This observation was also made in areas where Zone D had been removed by erosion and contamination of borehole material was impossible. The "5.3-5.4" horizon is now one of the most widespread reliable markers in the lower part of the Gulpen Formation.

3.2.4. Maastricht Formation

Yellow-white chalk (calcarenites and calcirudites) with glauconitic horizons near the base. Flint horizons are confined to the Maastricht Chalk s.s. in the southwestern part of South Limburg. The Maastricht Chalk interfingers in northeastern direction between Valkenburg and Kunrade with the Kunrade Chalk s.s. Only the Kunrade Chalk locally rests immediately on the Carboniferous abrasion surface. The Maastricht Chalk is characterized by the foraminifer assemblages G-I and K-N, of HOFKER (1966), whereas the Kunrade Chalk contains the assemblages G, J and O. Assemblage G is dominated by reworked foraminifer specimens from the Vaals and Gulpen Formations and rare reworked megaspores from the Aachen Formation.

3.3. TERTIARY DEPOSITS

3.3.1. Houthem Formation

Yellow-grey chalk with foraminifer assemblages belonging to the Foraminifer Zones P-R of HOFKER (1966). This formation nowhere rests directly on the Paleozoic abrasion surface.

3.3.2. Tongeren Formation

More or less clayey to loamy sands and quicksands which may be micaceous. The Tongeren Formation is the youngest Tertiary deposit that locally rests immediately on the Carboniferous abrasion surface.

3.4. FAULT PATTERN

Only those faults are indicated in Enclosure II which show a throw at the Paleozoic abrasion surface. They exhibit an overall NW-SE strike. Some NW-SE striking faults as the Geulle, Klauwpijp and Schin op Geul Faults are only known from field observations. These may have a throw at the Paleozoic abrasion surface, but are not indicated here.

3.5. DISTRIBUTION OF SEDIMENTS

3.5.1. Bunter Sandstone

Confined to the northwestern part of blocks North of the Heerlerheide Fault. Presumably, the Bunter Sandstone has been laid down throughout the area. This is deduced from the occurrence of supposed Triassic rocks in the Villers-E4 (= 121W-217) Borehole in Belgium at the southeastern edge of the Brabant Massif (LEGRAND 1968). This suggests post-Triassic - pre-Campanian uplift of the area South of the Heerlerheide Fault and tilting of the southeastern part of the blocks North of the Heerlerheide Fault.

3.5.2. Aachen Formation

The Aachen Formation rests on the Paleozoic abrasion surface in a large area South of the Heerlerheide Fault. In between the Heerlerheide Fault and Feldbiss, it locally occurs as a thin deposit South of the Waubach and North of the Ham Anticline. Presumably, the Aachen Formation had been deposited throughout the area. Before the deposition of the Vaals Formation, it was eroded from the southern and northern parts of the Visé-Puth Anticline and in the southwestern part of the Waubach Anticline (between the Benzenrade and Heerlerheide Faults). Before the deposition of the Gulpen Formation it was eroded from the Eys-Wittem High. Before the deposition of the Tongeren Formation it was eroded from the blocks North of the Heerlerheide Fault with the exception of a small area between the Waubach and Ham Anticlines. This suggests that erosion of the Aachen Formation was not only influenced by block movements along the NW-SE striking fault pattern but also by uplift of at least parts of the Visé-Puth, Waubach and Ham Anticlines as well as the Eys-Wittem High.

3.5.3. Vaals Formation

The distribution of the Vaals Formation largely matches that of the Aachen Formation. Presumably, also the Vaals Formation had been deposited throughout the area. Before the deposition of the Gulpen Formation, it was eroded from the southern part of the Visé-Puth Anticline and from the Eys-Wittem High. Before the deposition of the Maastricht Formation, it was eroded from the northern part of the Visé-Puth Anticline, from the south-western part of the Waubach Anticline (between the Benzenrade and Heerlerheide Faults) and from the area North of the Heerlerheide Fault with the exception of some small portions between the Waubach and Ham Anticlines. This suggests that erosion of the Vaals Formation was not only influenced by block movements along the NW-SE striking fault pattern but also by uplift of at least parts of the Visé-Puth, Waubach and Ham Anticlines as well as the Eys-Wittem High.

3.5.4. Gulpen Formation

The Gulpen Formation is confined to the southern part of South Limburg. It consists of five members, characterized by the foraminifer assemblages A-F of HOFKER (1966). Each member onlaps or oversteps the lower deposits towards the North or North-East. The members characterized by the foraminifer assemblages A and B have been eroded from the southern part of the Visé-Puth Anticline and from the Eys-Wittem High before deposition of the member characterized by assemblages C, D and lower E. Erosion of these lower members may have been simultaneous with the erosion of underlying Aachen and Vaals deposits.

The member characterized by assemblages C, D and lower E was subsequently eroded in the area North of the Eys-Wittem High. This is deduced from the overstep of deposits with assemblages E-F over truncated strata with assemblage C-D in section G-G' on Enclosure III.

Erosion of the lower members is confined to areas on structural highs of Devono-Dinantian rocks. Erosion of the higher member with assemblages C-lower E may be the result of block tilting towards the South-West.

Erosion of the highest members of the Gulpen Formation (with assemblages E-F) occurred before deposition of the Maastricht Formation. This is shown by the overstep of basal Maastrichtian deposits over truncated Gulpen beds in section G-G' on Enclosure III. Also this erosion is related to block tilting to the South-West.

3.5.5. Maastricht Formation

Presumably, the Maastricht Formation has been deposited throughout South Limburg. Erosion in the southern part of the area is due to differential uplift of that region. The Maastricht Formation has been largely eroded from the northwestern part of the blocks North of the Heerlerheide Fault before the deposition of the Houthem Formation. Presumably, this erosion was due to tilting to the South-West of these blocks. Before deposition of the Tongeren Formation, it has also been eroded from the area on the Waubach and Ham Anticlines with the exception of the southwestern part of the Waubach Anticline between the Benzenrade and Heerlerheide Faults. The Maastricht Formation rests directly on the Carboniferous abrasion surface in the southwestern part of the Waubach and the northern part of the Visé-Puth Anticlines.

3.5.6. Houthem Formation

The Houthem Formation rests nowhere directly on the Paleozoic abrasion surface. Houthem deposits are confined to the northwestern area of South Limburg. It is unknown whether they have been sedimented throughout the region or were eroded from the southeastern part before deposition of the Tongeren Formation. In both cases we presume tilting of the area towards the North-West during deposition of the Houthem sediments.

3.5.7. Tongeren Formation

In the area North-East of the Heerlerheide Fault, the Tongeren Formation rests immediately on the Carboniferous except for some locations between the Waubach and Ham Anticlines where it overlies residual Aachen and Vaals deposits. The Tongeren Formation has been eroded from the southern part of South Limburg before the deposition of Pleistocene strata.

3.6. INFLUENCE OF ANTICLINAL STRUCTURES ON EROSION

Erosion of Triassic to Tertiary deposits in the region North and East of the Heerlerheide Fault was related to oscillating block movements along to the NW-SE striking faults. However, differential movements of the anticlinal structures of Visé-Puth, Waubach and Ham must also have influenced the distribution of residual Aachen and Vaals deposits between the Waubach and Ham Anticlines and of Maastricht deposits between the Visé-Puth and Waubach Anticlines.

Erosion of Upper Cretaceous strata in the region South and West of the Heerlerheide Fault was practically confined to the northern and southern parts of the Visé-Puth Anticline, to the southwestern part of the Waubach Anticline and to the Eys-Wittem High. This erosion is here attributed to oscillating movements of these structures. This hypothesis seems to be contradicted by the observation that the Gulpen or Maastricht deposits in these erosion areas display a concave base as if they had been laid down in depressions or erosion channels rather than on a flattened erosion surface (Enclosure III, sections F-F', G-G' and I-I'; Fig. 4).

However, one should remember that the height of the sections F-F', G-G' and I-I' on Enclosure III and of Fig. 4 is ten times exaggerated in comparison to the horizontal scale. These depressions are in fact extremely flat and barely perceptible features.

In the second place, it should be noticed that not only the base of the Gulpen or Maastricht deposits overlying the erosion planes is depressed. The individual horizons within the Gulpen Formation (e.g. the "5.3-5.4" horizon in foraminifer zone C and the "6.0" horizon of foraminifer zone D) show the same depression. Also the base of the Tongeren Formation matches the depression of the base of the Maastricht Formation.

If these depressions had represented original erosion channels, they would have been filled by the younger deposits in such a way that the greatest thickness of these deposits had occurred within the erosion channels.

It is therefore concluded that these depressions are post-sedimentary (post-Gulpen and Post-Tongeren) structures.

4. Pb-Zn-Cu MINERALIZATION

47 out of the 53 known Pb-Zn-Cu mineralization occurrences (or almost 90%) in the Silesian of South Limburg are confined to the Westphalian A on the edges of the Waubach Anticline in the eastern area (Enclosure IV). These are concentrated in and along the main NW-SE striking faults (notably the Feldbiss and the Gangway Seam VI Fault) and their satellites. Within these faulted areas, these minerals have been recognized almost ex-

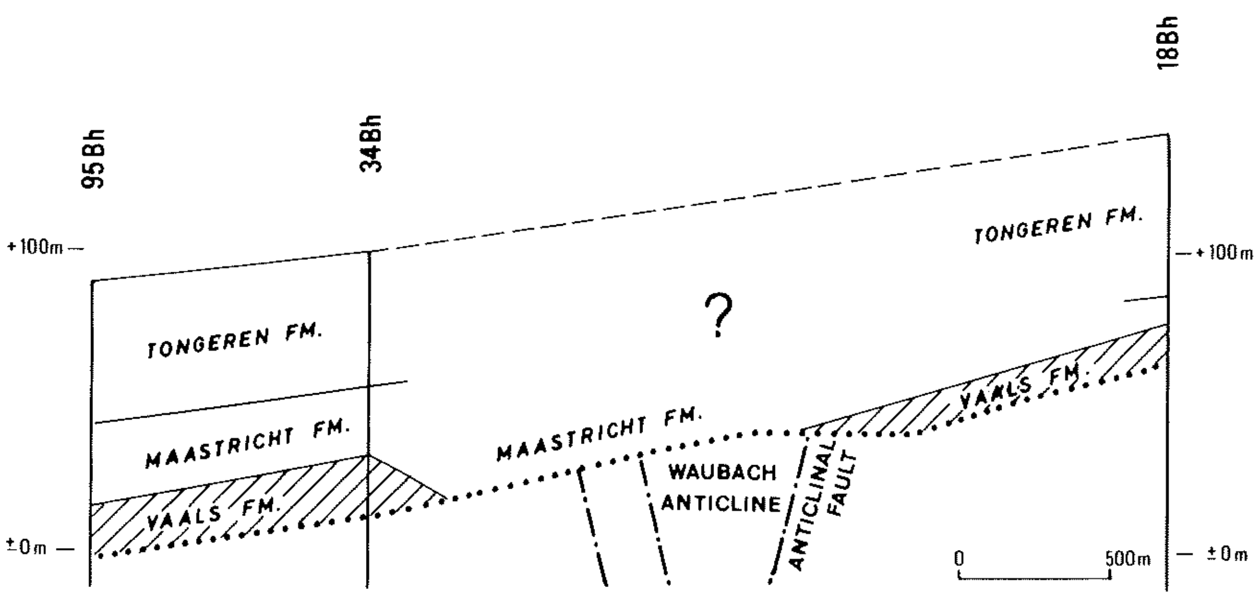


Fig. 4 — NW-SE cross-section through post-Paleozoic deposits on the Waubach Anticline.

clusively within fissures and joints in sandstones and quartzites.

A detailed description of several of these occurrences was published in 1949 by DE WIJKERSLOOTH. This author mentioned galena, sphalerite and chalcopyrite along with quartz, calcite, dolomite, pyrite and some tetrahedrite and

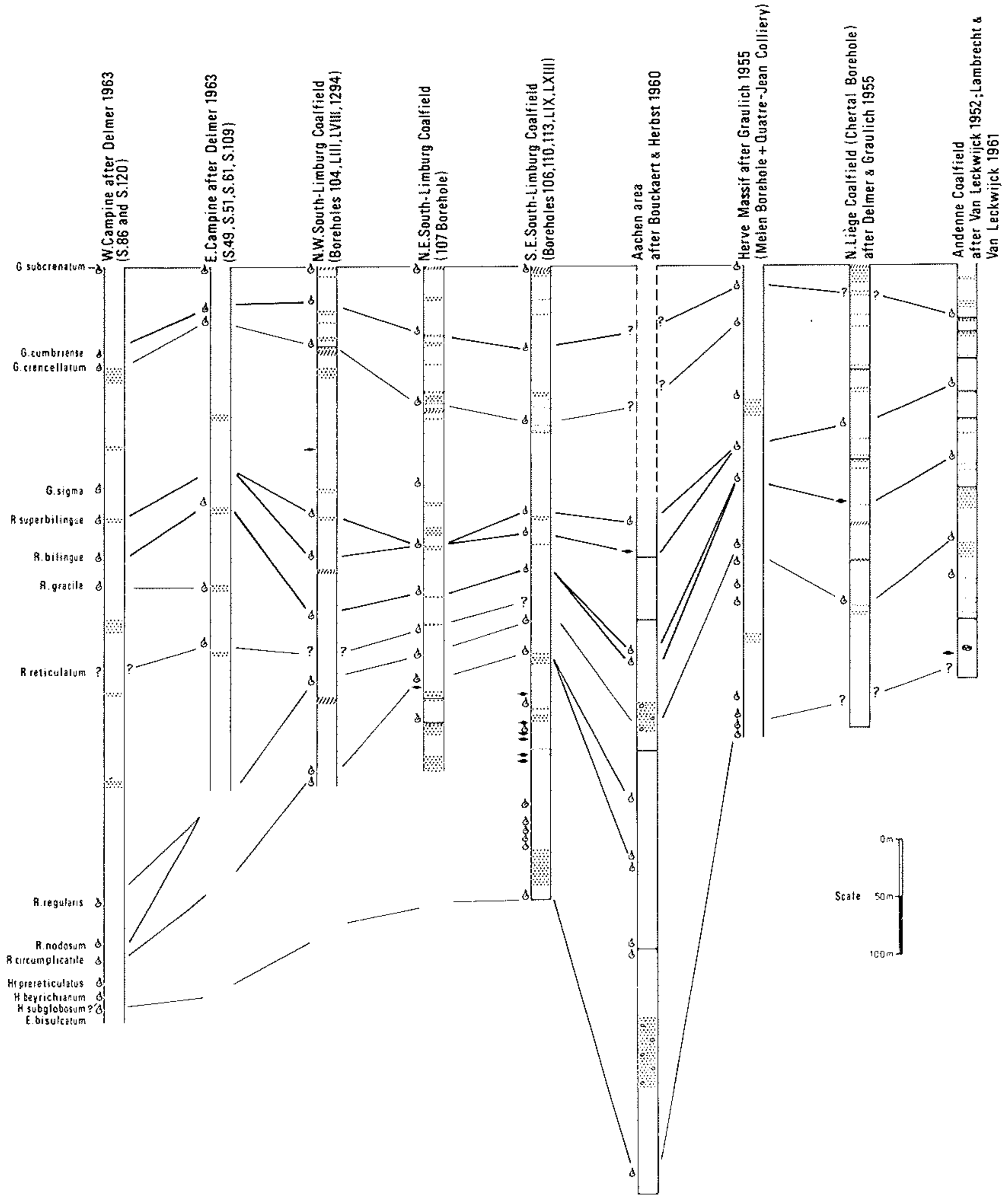


Fig. 5 — Correlation of goniatite-bearing marker bands in sections along the eastern part of the Brabant Massif. The *G. cumbriense, R. superbilingue* and *R. bilingue* Bands are considered as the most widespread. Differences in thickness of the deposits are especially important in the sequence below the *R. bilingue* Band.

barite. The occurrence of accessory Ni-Co-Sn minerals (linnaeite, bravoite and stannite) mentioned by DE WIJKERSLOOTH (1949) has not been substantiated by later investigations (DOUW & OORTHUIS 1945). This means that no arguments exist for the supposition that a deep-seated magma is related to these mineralizations (DOUW & OORTHUIS 1945). On the other hand, the mineral association in the Silesian of South Limburg is relatively high-thermal as compared with the ore deposits in the Dinantian and Lower Namurian rocks of the Moresnet area in northeastern Belgium (DE WIJKERSLOOTH 1949). This means that the younger (Upper Namurian and Westphalian A) rocks of the Waubach area display a relatively higher-thermal mineralization than the older Dinantian to Lower Namurian rocks of northeastern Belgium.

It is noteworth to observe that the most important warm salt water springs ("brines") in the coalmines of South Limburg have been found in the Waubach area (KIMPE 1963).

Sulfur-rich spring in Oranje Nassau I with chloride content of 24.000 ppm had a temperature of more than 50°C.
Helium-rich spring in Wilhelmina with chloride content of 13.000 ppm had a temperature of 38°C.

The Waubach Anticline also coincides with increased chloride contents of the mining water (KIMPE 1963).

Spring in Oranje Nassau IV showed a chloride content increasing from 210 ppm in 1948 to 9.000 ppm in 1962.

Finally, the Waubach area matches the area of relatively high temperature in the Carboniferous rocks according to the isotherm map of SADÉE (1975).

5. BIOSTRATIGRAPHY OF THE NAMURIAN

Correlation of sections through the Namurian of NW Europe is based on the occurrence of widespread goniatite-bearing marine bands. These can be followed along the southern and northern borders of the Wales-Brabant Massif from Great Britain into Germany.

A revision of the goniatites occurring in the Namurian of South Limburg is presented on Enclosure VII, whereas fig. 5 shows the correlation of goniatite marker bands in the areas surrounding the eastern end of the Brabant Massif.

The most important difference between the sections of the eastern Campine and South Limburg on the one hand and of the Herve, Liège and Andenne areas on the other is the reduced thickness of the Namurian in the latter regions.

6. DEVONO-DINANTIAN BIOSTRATIGRAPHY IN VISÉ AREA

Devono-Dinantian rocks from boreholes at Chertal and Hermalle-sous-Argenteau and from some outcrops near Berneau, Visé, Richelle and Argenteau have been dated by means of miospores, acritarchs, foraminifers, conodonts and corals. The different fossil assemblages are compared at the end of this chapter with those of the same age in the Dinant-Namur Basin, the Campine-Brabant Basin and the British basins North and South of the Wales-Brabant Massif.

6.1. BIOSTRATIGRAPHY

6.1.1. Chertal Borehole (121E-15)

Literature: LOHEST (1911), DELMER & GRAULICH (1955), CONIL (1964), GROESSENS (1974), GRAULICH (1975a).

General information: The Namurian-Tournaisian boundary was found at 494.30 m. LOHEST (1911) observed a dip of 15° in the Namurian strata against 38° in the Dinantian. CONIL (1964) cited a Tn1a microfossil assemblage (including the ostracode *Cryptophyllus*) from the 506.10-503.20 m interval. Upper Famennian foraminifera and algae have been recovered from the 517.95-512.55 m interval. GRAULICH (1975a) presumed that the complete Dinantian sequence of this borehole should be included in the Tournaisian.

Sample:	497.8-498.1 m	498.6-498.7 m	513 m
Aneurospora incohata (SULLIVAN) STREEL in BBST 1974	x	x	x
Aneurospora greggsii (MCGREGOR) STREEL in BBST 1974	x	x	x
Apiculiretusispora verrucosa (CARO-MONIEZ) STREEL in BBST 1974	x		
Apiculiretusispora plicata (ALLEN) STREEL 1967	x		
Retusotriletes planus DOLBY & NEVES 1969		x	
Grandispora echinata HACQUEBARD 1957	x		
Grandispora gracilis (KEDO) STREEL in BBST 1974		x	
Grandispora microseta (KEDO) STREEL in BBST 1974		x	
Grandispora uncata (HACQUEBARD) PLAYFORD 1971	x		
Grandispora cf. *tenuispina* (HACQUEBARD) PLAYFORD 1971		x	
Raistrickia variabilis DOLBY & NEVES 1969	x	x	x
Spelaeotriletes lepidophytus (KEDO) STREEL IN BBST 1974	x	x	x
Cristatisporites echinatus PLAYFORD 1963	x		
Vallatisporites pusillites (KEDO) DOLBY & NEVES 1969		x	
Auroraspora hyalina (NAUMOVA) STREEL in BBST 1974	x	x	x
Auroraspora macra SULLIVAN 1968		x	x
Auroraspora cf. *perplexa* BALME & HASSELL 1962			x
Auroraspora cf. *perinatus* HUGHES & PLAYFORD 1961	x	x	x
Rugospora versabilis DOLBY & NEVES 1969	x	x	x
Age:	PLs1 (Upper Tn1a)		PLi to PLm (Fa2d-Tn1a)

Table I — Miospores from the Chertal (121E-15) Borehole

Spores: Three samples have been investigated on their miospore contents (Table I). The highest sample (497.8-498.1 m) is characteristic of the Upper Tn1a. The lowermost sample (513 m) has yielded an assemblage of Fa2d to Tn1a age. This suggests that the borehole has only recognized Strunian and Upper Famennian strata immediately underlying the Namurian. The boundary between the Tn1a and the Fa2d has not been established, but should be located between 506 and 512 m.

6.1.2. *Hermalle-sous-Argenteau Borehole (122W-258)*

Literature: GRAULICH (1975a).

General information: The Namurian-Visean boundary was found at 56.40 m, the Visean-Frasnian boundary at 217.70 m. The interval between 56.40 and 69.60 m has yielded a foraminifer assemblage of V3c age, whereas the interval between 69.60 and 217.70 m has been attributed to the V3b. The base of the V3b consists of a breccious limestone including reworked foraminifera and algae of uppermost Tournaisian to Middle Visean age.

A cyclopean breccia of Frasnian carbonates - characterized by the occurrence of branching, massive and tabular stromatoporoids and Frasnian foraminifers - has been described by GRAULICH (1975a) from the interval between 217.70 and 299.95 m. This author attributed the underlying sandstones and shales (299.95-308.50 m) to the Fromelennes Formation of the Upper Givetian. The Fromelennes Formation is usually characterized by a relatively high feldspar contents. Therefore, a petrographic analysis of some samples has been made for the present report.

Givetian limestones with a rich macrofauna of stromatoporoids, corals, crinoids and brachiopods have been reported from the interval between 308.50 and 338.30 m. In the lower half of this sequence, pebbles of limestone, quartz and eruptiva are frequent. They overlie subvertical rhyolitic tuffs of presumably Silurian (Llandoverian) age.

Acritarchs and scolecodonts: Sample 300 m: no microfossils. Sample 307 m: few scolecodonts and one specimen of *?Solisphaeridium spinoglobosum* (STAPLIN) WICANDER 1974. Sample 308 m: few opaque scolecodonts.

Petrography: Four samples have been analyzed.

300 m: Highly silicified quartzitic rock with subordinate euhedral dolomite, xenomorphic calcite and pyrite. Bipyramidal quartz crystals are embedded in the quartzitic matrix that displays interlocking xenomorphic recrystallized quartz. No feldspars occur. This sample may have been derived from a rhyolitic rock, similar to the one discovered by the same borehole below 338.30 m. 303, 307 and 308 m: Heterogranular dolomitic-calcitic microquartzites with euhedral dolomite, xenomorphic calcite and framboidal pyrite. The (angular) quartz grains have been derived from veins, metamorphic quartz veins and sedimentary quartzite. The heavy mineral suite includes rare grains of green tourmaline, red and yellow rutile and rounded zircon. Muscovite and rare muscovite-biotite flakes are scattered throughout the sediment. Intergranular sericite locally occurs. Rare albitized K-feldspar (less than 3%) crystals and silicified volcanic microfragments have been observed in one sample. The practical absence of feldspars is not characteristic of the Fromelennes Formation. The angular quartz grains indicate a local source for the sediment.

6.1.3. *Argenteau-Castle (Site "S" of HORION & GOSSELET 1892)*

Literature: HORION & GOSSELET (1892), FOURMARIER (1902), PLISNIER (1931).

General information: This site is indicated with "S" on the map of HORION & GOSSELET (1892). This is a steep rock on top of which the castle of Argenteau is located. The sampled site is the base of this rock just opposite the corner of the local road between Argenteau and Cheratte and the entrance to the highway Maastricht-Liège.

Corals: *Dibunophyllum* cf. *bipartitum* (McCOY)
Axophyllum sp.
Siphonodendron sp.
This assemblage is characteristic of the V3b.
Foraminifers: *Diplosphaerina inaequalis*
Earlandia minor
Earlandia vulgaris
TOURNAYELLIDAE
FORSCHIINAE
cf. *Eotournayella diversa*
Tetrataxis sp.
Endothyra sp.
cf. *Dainella* sp.
This assemblage might indicate a V1-V2a age. Since this fauna occurs amongst a V3b coral fauna, we presume that the foraminifers have been reworked. It should be remembered that the V3b of the Hermalle-sous-Argenteau Borehole contains also reworked V1-V2a elements (GRAULICH 1975a).

6.1.4. *Quarries "M"-"N" North of Richelle*

Literature: HORION & GOSSELET (1892), PIRLET 1967b, 1970).

General information: These quarries have been lettered "M" and "N" on the map of HORION & GOSSELET (1892). PIRLET (1967b) published and updated map of this location. The quarries display a cyclopean breccia of Frasnian dolomites and limestones with a rich coral-stromatoporoid assemblage (PIRLET 1970).

Corals: Sample collected along foot-path in between the quarries displaying compression-solution structures in karstified limestone (pl. 1, fig. 1) contains *Amphipora* sp.

Foraminifers: Two samples collected along foot-path in between the quarries have yielded *Displosphaerina inaequalis*, cf. *Bisphaera irregularis* and *Paratikhinella* sp. These indicate a Frasnian (F1?) age.

6.1.5. *Quarries "F"-"L" North of Richelle*

Literature: HORION & GOSSELET (1892), PIRLET (1967b).

General information: These quarries have been indicated as ''F''-''L'' on the map of HORION & GOSSELET (1892). They display the type-section of the Visean limestone (DUMONT 1832). A complete description of these quarries - including fauna lists compiled from earlier authors - was published by PIRLET (1967b). The lower lithological unit ''g'' of PIRLET (1967b) is characterized by a polygenetic breccia overlying the paleorelief of Frasnian carbonates. This unit contains a V1a foraminifer assemblage characterized by *Earlandia vulgaris, Brunsia* sp., *Tetrataxis* sp., *Eotextularia diversa,* TOURNAYELLIDAE, *Quasiendothyra rotai* and *Eoparastaffella.* The breccia of lithological unit ''f'' of PIRLET (1967b) cannot be exactly dated by means of foraminifers. Presumably, this breccia is to be compared with the V3b? breccias usually overlying V1-V2a deposits in the Campine-Brabant Basin. The lithological unit ''e'' of PIRLET (1967b) contains an assemblage characteristic of the V3bß-γ. This assemblage includes bilamellar PALAEOTEXTULARIIDAE which are common in the V3bγ, but may appear slightly earlier in the V3b of England (A. STRANK & R. CONIL, non published data).

Corals: The diverse coral assemblages of the Upper V3bγ and V3c of these quarries are indicated on table II. This list is partly based on material collected in the past from inaccurately known stratigraphic horizons and may be improved in the future.

The assemblages of the lithological units ''f'' to ''d2'' are incomplete for the same reason. Presumably, the presence of cf. *Carruthersella garwoodi* and the absence of *Dibunophyllum bipartitum* in lithological unit ''f'' is characteristic of the V3a. The same observation has been made in the section of the railway cutting West of Berneau (cf. 6.1.9.).

Carruthersella garwoodi is characteristic of the V3a in the Dinant-Namur Basin (E. POTY, non-published data).

6.1.6. Souvré Valley

Literature: HORION & GOSSELET (1892), FOURMARIER (1902), PLISNIER (1931).

General information: A cyclopean breccia of Frasnian carbonates with a rich coral-stromatoporoid assemblage is exposed in the bottom of the valley. This location is marked 108W-122 on the map of the Geological Survey of Belgium, and sites ''A'', ''C'' and ''D'' on the map of HORION & GOSSELET (1892). On the map of PLISNIER (1931), this location is marked ''C''. On the southern and northern slopes of the valley, Visean limestones and phthanites occur. Presumably, the contact with the some five to ten meter lower occurring Frasnian is discordant.

Corals: The Frasnian limestone in the bottom of the valley contains abundant massive stromatoporoids and *Amphipora* sp. One colony of *Hexagonaria* sp. has been observed. This association is common in the Fr1 limestones of the eastern part of the Dinant-Namur Basin.

Age:	V3a	V3b	V3bγ					Lower V3c		Upper V3c
Lithological units of PIRLET 1967b:	f	e	d5	d4	d3	d2	d1	c	b	a
Clisiophyllum kayserlingi McCOY							X	X	x	
Dibunophyllum bipartitum (McCOY)			x	x	x	x	X	X	x	
Koninckophyllum sp.							X	X		
Paleosmillia murchisoni MILNE-EDWARDS & HAINE			x	x	x	x	X	X		
Axophyllum radicatum MILNE-EDWARDS & HAINE							X	X	x	
Axophyllum lonsdaleiforme (SALÉE)							X	X	x	
Axophyllum delepinei (SALÉE)							X	X	x	
Londsdaleia duplicata (MARTIN)							X	X	x	
Londsdaleia floriformis (MARTIN)										X
? *Pareynia splendens* SEMENOFF								X	X	
cf. *Carruthersella garwoodi* SALÉE	X									
Lithostrotion maccoyanum MILNE-EDWARDS & HAINE							X	X	X	
Lithostrotion decipiens (McCOY)							X	X	X	
Lithostrotion vorticale (PARKINSON)							X	X	x	
Siphonodendron junceum (FLEMING)							X	X	X	X
Siphonodendron pauciradiale (McCOY)							X	X	x	
Siphonodendron aff. *fraiponti* (CHARLES)	x	x	x	x	x	x	X	X	x	
Siphonodendron scoticum (HILL)							X	X		
Siphonodendron sociale (PHILIPS)									X	x
Diphyphyllum furcatum (THOMSON)							X	X	X	
Aulina furcata SMITH									X	
Aulina cf. *carinata* (CARRUTHERS)									X	
Rotiphyllum rushianum VAUGHAN							x	X	X	
Cyathaxonia cornu MICHELIN	X	x	x	x	x	x	X	X	x	
Cyathaxonia rushiana VAUGHAN							X	X	X	
Amplexus coralloide SOWERBY								X	X	

Table II — Coral assemblages from the ''F''-''L'' Quarries North of Richelle.
X = species present.
x = presence of species yet to be confirmed.
The above list is partly based on material collected in the past from inaccurately known stratigraphic horizons and should therefore be considered as provisional.

Foraminiferes: One sample collected along the road from Visé to Dalhem on the northern slope of the valley where phthanites are exposed in a bend of the road has yielded poorly preserved (silicified) ARCHAEDISCIDAE and cf. *Pachysphaerina* sp. These confirm the Visean age of the phthanites.

6.1.7. *La Folie Quarry*

Literature: HORION & GOSSELET (1892), FOURMARIER (1902), CHARLES (1946), LEGRAND (1959), CONIL & LYS (1964), PIRLET (1967a, 1970). LIPINA (1970), GROESSENS (1974).

General information: In 1892 and 1902, this quarry had only uncovered Visean limestones. In 1946, CHARLES discovered a small exposure of Tournaisian rocks underlying the Visean in the center of the western front. In 1958, the occurrence of Frasnian dolomites below the Tournaisian was observed (LEGRAND 1959). In 1964, the western front had moved again, now uncovering Devonian shales, limestones and dolomites underlying the Tournaisian and Visean (PIRLET 1967a). In 1966, a second outcrop of Devonian black shales appeared at some 20 to 25 m distance to the South from the 1964 outcrop (PIRLET 1967a, 1970). In this second outcrop, the black shales are directly overlain by Visean limestones. In the first half of 1978, a third outcrop of Devonian black shales was found by the present authors in the southwesternmost corner of the quarry. These are also overlain by Visean limestones.

PIRLET (1967a) distinguished fourteen lithological units - five of Devonian, two of Tournaisian and seven of Lower Visean age (fig. 6). Presumably, the contact between most of these units is discordant. In between the Devonian black shales in the floor of the quarry and the discordantly overlying Visean (partly breccious or conglomeratic) limestones, irregular and discontinuous masses of breccias, conglomerates and blocks of Devonian, Tournaisian and lowermost Visean carbonate rocks occur. Up to now, the quarry had not yielded fossils of Famennian or Strunian age, nor of the Upper Tournaisian (Tn3).

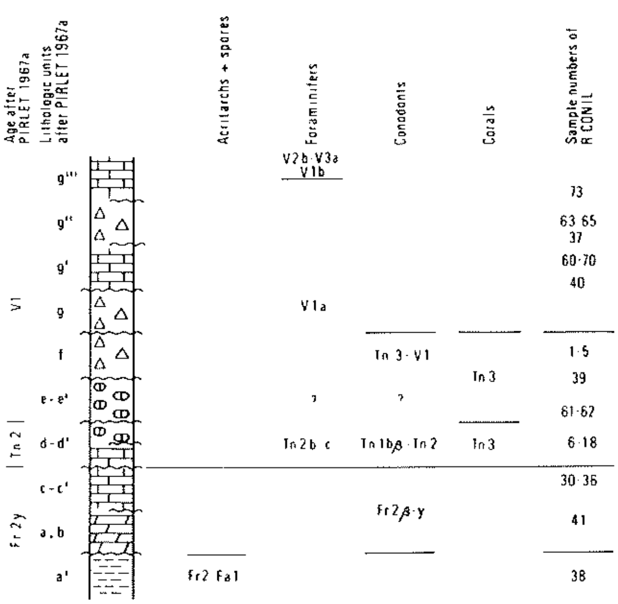


Fig. 6 — Simplified stratigraphic column of La Folie Quarry. The exact stratigraphic succession of the lithological units is yet to be proven.

Petrography: The Devonian black shales contain some 30-50% of secondary dolomite in the form of small euhedral crystals which are embedded in a clayey, more or less recrystallized pyriteous matrix. This matrix is characterized by xenomorphic, interlocking phyllites with a rather low birefringence usually not occurring in a normal pelitic sediment. Further analysis might prove that these black shales have been derived from a strongly altered, weathered pyroclastic rock.

Spores, acritarchs, chitinozoa and scolecodonts: Samples collected from the three outcrops of Devonian black shales as well as a shale fragment occurring in a Lower Visean breccia have been investigated on their spore, acritarch, chitinozoa and scolecodont contents.

a - sample of shale fragment occurring in Lower Visean breccia located halfway in between the Devonian black shale outcrops figured by PIRLET (1967a, fig. 3). This sample has not yielded any microfossils.

b - sample collected from the southwesternmost outcrop of Devonian black shales. This sample has not yielded any microfossils.

c - sample (sample 4) collected from Devonian black shale in the second outcrop of PIRLET (1967a). This is a dark grey dolomite shale. The following microfossils have been recognized.

Acritarchs: *Solisphaeridium astrum* WICANDER 1974
Solisphaeridium spinoglobosum (STAPLIN) WICANDER 1974
Micrhystridium tornacense STOCKMANS & WILLIÈRE 1960
Veryhachium cf. *downiei* STOCKMANS & WILLIÈRE 1962
Chitinozoa: Abundant specimens amongst which *Angochitina* spp.
Scolecodonts: Opaque specimens
Spores: Opaque specimens

The assemblage is predominated by the genera *Micrhystridium* and *Solisphaeridium* (80%). *Micrhrystridium tornacense* has only been cited in the literature from the Upper Frasnian.

d - four samples collected from the first (and largest) outcrop of Devonian black shales (PIRLET 1967a). One sample had been collected by PIRLET some ten years ago (PIRLET sample) and is treated separately since it may correspond to a slightly different stratigraphic horizon. The other three samples (samples 1, 2, 3) are treated as one sample. These have been collected in 1977.

PIRLET sample

Acritarchs: *Daillydium quadridactylites* (STOCKMANS & WILLIÈRE 1962) 1969
Diexallophasis cleopatra (DEUNFF) VANGUESTAINE 1978,

nov. comb.
Solisphaeridium spinoglobosum (STAPLIN) WICANDER 1974
Stellinium octoaster (STAPLIN) JARDINÉ et al. 1972
Verybachium downiei STOCKMANS & WILLIÈRE 1962
aff. *Acanthotriletes(?) naumovae* STOCKMANS & WILLIÈRE 1962
Verybachium cf. *nasicum* (STOCKMANS & WILLIÈRE 1960) 1962
Winwaloeusia sp.
Chitinozoa: present
Spores: present
Scolecodonts: present

The poor quality of the slides does not permit exhaustive examination of the fossils. This sample is distinguished from the samples 1-3 by the presence of *Diexallophasis cleopatra* and *Winwaloeusia* sp., by the abundance of *Verybachium downiei* and by the low percentage of *Solisphaeridium* and aff. *Acanthotriletes*(?) *naumovae.*

STOCKMANS & WILLIÈRE (1969, 1974) cited *Diexallophasis cleopatra* from the Fa1a and Fa1b of Senzeilles and Dailly. ROUHART (1973) mentioned the species from the topmost Frasnian and from the Fa1a of Senzeilles, Hony and Sinsin.

Winwaloeusia sp. is known from the Fa1a of Hony (VANGUESTAINE, non-published data) and from the Fa1a and Fa1b of Senzeilles and Dailly (= *Verybachium lairdi* in STOCKMANS & WILLIÈRE 1969, pl. 1, figs. 15, 16).

The assemblage characterizes the Upper Frasnian and Lower Famennian.

Samples 1, 2, 3 have been collected from dark-grey dolomitic shale at three differents points within the same stratigraphic horizon.

Acritarchs: *Daillydium quadridactylites* (STOCKMANS & WILLIÈRE 1962) 1969
Dasypilula storea WICANDER & LOEBLICH 1977
aff. *Acanthotriletes(?) naumovae* STOCKMANS & WILLIÈRE 1962
Cymatiosphaera sp.
Gorgonisphaeridium piliferum (STOCKMANS & WILLIÈRE) VANGUESTAINE 1978, nov. comb.
Hercyniana sprucegrovensis (STAPLIN) VANGUESTAINE 1978, nov. comb.
Solisphaeridium astrum WICANDER 1974
Solisphaeridium spinoglobosum (STAPLIN) WICANDER 1974
Micrhystridium tornacense STOCKMANS & WILLIÈRE 1960
Stellinium octoaster (STAPLIN) JARDINÉ et al. 1972
Verybachium downiei STOCKMANS & WILLIÈRE 1962
Villosacapsula sp. A n.sp.

Chitinozoa: several specimens have been observed, a.o. *Angochitina* sp.
Scolecodonts: relatively frequent. Specimens belong to several species as can deduced from figs. 7-15 on pl. 15.
Spores: *Samarisporites* sp. cf. *Acanthotriletes hirtus* NAUMOVA 1953 sensu STREEL in BBST 1974
Aneurospora greggsii (McGREGOR) STREEL in BBST 1974
Retusotriletes planus DOLBY & NEVES 1969

The above assemblage is characteristic of the Upper Frasnian and Lower Famennian (STOCKMANS & WILLIÈRE 1960, 1962a, 1962b, 1969, 1974; DRICOT 1971; ROUHART 1973; VANGUESTAINE, non published data). Some species have a restricted stratigraphic range. *Micrhystridium tornacense* has been described only from the Upper Frasnian of the Tournai and Wépion Boreholes. *Villosacapsula* sp. A is known from the Fa1a of Senzeilles (= *Micrhystridium stellapilosum* MARTIN in STOCKMANS & WILLIÈRE 1974, pl. IV, figs. 5-7) and Hony (VANGUESTAINE, non-published data). Aff. *Acanthotriletes(?) naumovae* has been recognized from the boundary beds between the Upper Frasnian and Lower Famennian at Hony and Senzeilles (VANGUESTAINE, non-published data). *Retusotriletes planus* is unknown from strata older than the Upper Frasnian *Palmatolepis gigas* Conodont Zone.

Corals: Upper Tournaisian corals have been observed in the lower part of the limestones attributed by PIRLET (1967a) to the V1. These are the following species: *Siphonophyllia cylindrica* SCOULER, *Caninia cornucopiae* MICHELIN and *Michelinia* sp. A specimen of cf. *Lophophyllum* sp. has been observed in sample 61 and is also indicative for the Tournaisian.

Conodonts: Three assemblages, representing the uppermost Frasnian, the Lower to Middle Tournaisian and the Upper Tournaisian to Lower Visean have been recognized (table III). Their approximate position in PIRLET's lithological subdivision of 1967a is indicated on fig. 6.

Foraminifers: The Tn2 limestones and conglomerates had yielded thus far a poor microfauna including a.o. *Endothyra bulbisepta* (CONIL & LYS 1964, fig. 500). In 1977, the quarry had uncovered some 2 m of Tournaisian rocks just South of the main outcrop of Devonian black shales (cf. PIRLET 1967a, fig. 3). These include some bands of limestone nodules in a dolomitic matrix. Whether these are true nodular limestones or conglomeratic layers is difficult to determine. The nodules have only yielded a Middle Tournaisian foraminifer assemblage. These Tournaisian rocks pass into V1a breccias containing pebbles and blocks of different ages (V1a and Tn2). It is possible that the Tournaisian rocks form part of a residual cyclopean breccia in this location. The breccia bordering the Tournaisian rock in the eastern part contains fragments of Tn2 age with *Girvanella ducii, Earlandia elegans, Earlandia minor, Bisphaera* sp., *Chernyshinella* sp., *Septabrunsiina* sp., *Endothyra* spp. and *Palaeospiroplectammina* sp., as well as pebbles of V1a age with Caulerpales, Rhodophyceans, *Earlandia* spp., *Conilites kimpei* (abundant in the V1a of Oughterard (CONIL & LEES 1974: *Conilites* sp. 2)), *Eotextularia diversa, Dainella* sp., *Endothyra* spp. and *Spinoendothyra* sp.

6.1.8. Berneau Quarry

Literature: HORION & GOSSELET (1892), FOURMARIER (1902).

General information: A small outcrop of blueish limestone occurs in an abandoned quarry along the road from Berneau to Warsage. This location is marked 108-1 on the map of the Geological Survey of Belgium. It represents the easternmost outcrop of Dinantian limestone

Biostratigraphic age	Fr2ß-y						Tn1by-Tn2						Tn3-V1		
Sample number of R. CONIL	30	32	33	34	35	39	6	9	12	13	15	17	4	37	40
Ancyrodella curvata (BRANSON & MEHL)	X			X	X	X									
A. asymetricus (ULRICH & BASSLER)	X				X	X									
Icriodus sp					X	X									
Palmatolepis subrecta MILLER & YOUNGQUIST	X		X	X	X	X							O		
P. gigas MILLER & YOUNGQUIST	X			X	X	X									
Polygnathus sp.	X	X	X	X	X				X						
P. distortus BRANSON & MEHL									X		X				
P. inornatus BRANSON								X	X	X	X	X		X	X
P. inornatus BRANSON & MEHL									X		X				
Pseudopolygnathus dentilineatus BRANSON									X						
Siphonodella obsoleta HASS							X								
Gnathodus delicatus BRANSON & MEHL															X
G. semiglaber BISCHOFF															X
G. texanus pseudosemiglaber THOMPSON													X	X	
Scaliognathus anchoralis BRANSON & MEHL														X	X

X = species present in sample
O = reworked specimen

Table III — Conodonts from La Folie Quarry showing the presence of Upper Frasnian and Dinantian deposits in this area.

in the Visé area. HORION & GOSSELET (1892) and FOURMARIER (1902) described the limestone as non-fossiliferous.

Foraminifers: One sample (out of eight) has yielded a poor microfauna including abundant debris of Moravaminidae, cf. *Pachysphaerina* sp., *Earlandia minor, Earlandia elegans, Endothyra* sp. and Paleotextularidae with monolamellar wall. No algae have been observed. This assemblage indicates a V2-V3 age. The microfacies of the limestones may be compared with that of sample 61 of V3by-V3c age from the railway cutting West of Berneau (cf. 6.1.9.).

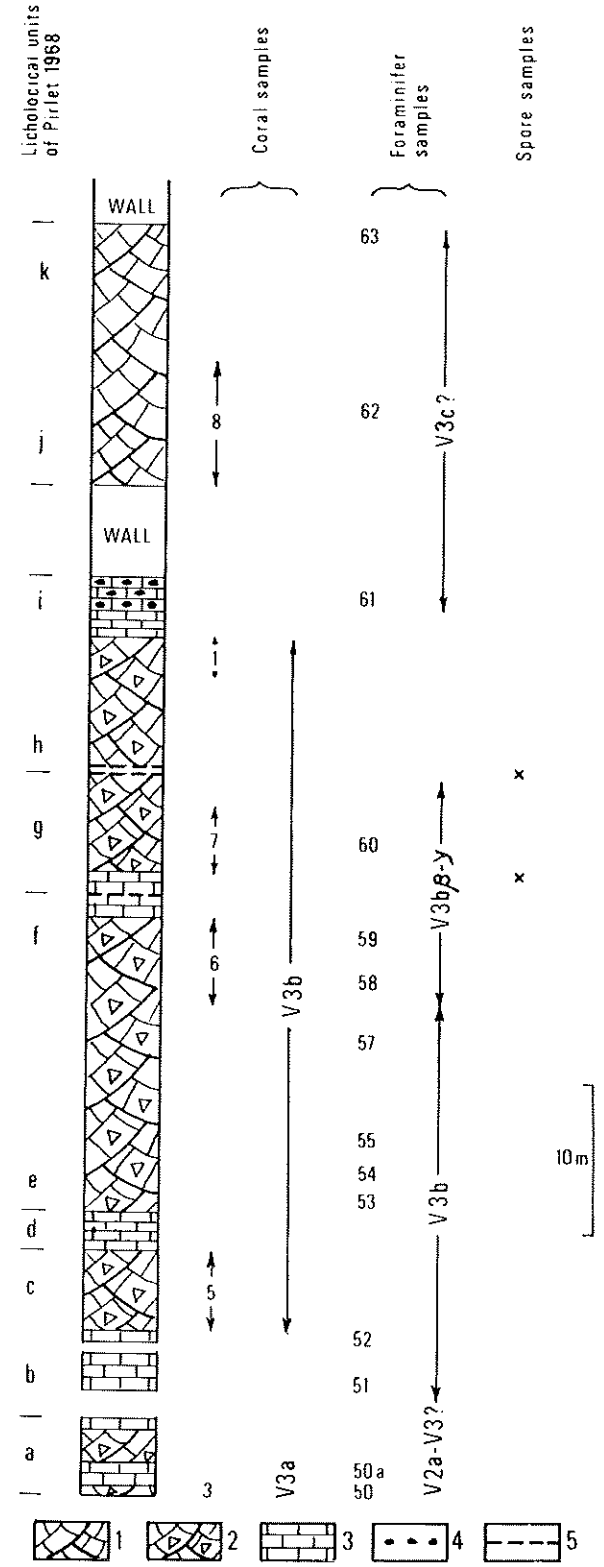
6.1.9. *Railway Cutting West of Berneau*

Literature: FOURMARIER (1923), PIRLET (1968, 1970).
General information: This section is marked 108W-127 on the map of the Geological Survey of Belgium. FOURMARIER (1923) mentioned the occurrence of phthanites in this section. These had already been covered by a wall when PIRLET (1968) studied the lower half of the sequence. The exact age of the phthanites can therefore not be determined. Provisionally, we include them in the topmost Dinantian. PIRLET (1970) mentioned the occurrence of reworked *Amphipora* sp. of Frasnian age in the basal breccias of the Visean limestone in this section. A simplified lithostratigraphic column of this section is shown on fig. 7.

Corals: The coral assemblages are shown on table IV. The lowermost sample from this sequence may be compared with the lithological unit "f" of Richelle (cf. 6.1.5.) because of the presence of cf. *Carruthersella garwoodi* and the absence of *Dibunophyllum bipartitum*. The assem-

Coral samples:	3		5			6	7		1	8	
Age:	V3a	V3b								V3c	
Lithological units of PIRLET 1968:	a	b	c	d	e	f	g	h	i	j	k
Clisiophyllum sp. A									X		
Clisiophyllum cf. *multiseptatum* GARWOOD	X										
Dibunophyllum bipartitum (MCCOY)			X			x	X		x		
Paleosmilia murchisoni MILNE-EDWARDS & HAINE	X		x			x	x		X	X	
Amygdalophyllum cf. *turbophylloides* SEMENOFF	X										
Amygdalophyllum sp.	X										
Axophyllum sp.	X		X			X	X		X		
cf. *Carruthersella garwondi* SALEE	X										
Lithostrotion aranea (MCCOY)			X			x	X		X		
Siphonodendron pauciradiale (MCCOY)			X			X					
Siphonodendron fraiponti (CHARLES)	X		X			X	X		x		
Cyathaxonia cf. *rushiana* VAUGHAN	X		x			x	x		x		
Hexaphyllia mirabilis DUNCAN						X	X				
Heterophyllia ornata MCCOY	X										

Table IV — Coral assemblages from railway cutting West of Berneau.
X = species present
x = presence of species yet to be confirmed



1 massive limestone 2 limestone breccia 3 thin-bedded limestone 4 chert 5 shale

Fig. 7 — Simplified stratigraphic column of railway cutting West of Berneau.

blages of the samples 5, 6, 7 and 1 contain species which are restricted to the V2b-V3a of the Namur Synclinorium (*Lithostrotion aranea,* several subspecies of *Siphonodendron pauciradiale*) as well as guide fossils of the V3by of the Namur Synclinorium (*Dibunophyllum bipartitum* and *Clisiophyllum* sp. *A*). The faunas are less diversified than those of the Upper V3by of Richelle. This may be due to local ecological conditions. The upper part of the sequence has yielded one coral species. It is noteworthy to observe that also the foraminifer assemblage of this upper part is rather impoverished.

Spores: Two calcareous shales (one at the base of lithological unit "g" and the other at the base of unit "h" of PIRLET 1967a) have been investigated on the occurrence of spores (fig. 6). The results have been negative.

Conodonts: Ten samples scattered throughout the sequence have been investigated on the occurrence of conodonts. The results have been negative.

Foraminifers: The basal sample 50 of this sequence has yielded a rich microflora and -fauna: *Koninckopora tenuiramosa, Koninckopora inflata, Koninckopora mortelmansi, Earlandia vulgaris,* FORSCHIINAE, *Pseudolituotubella* sp., cf. *Condrustella modavensis, Tetrataxis* spp., *Valvulinella* sp., *Endothyra* sp., *Plectogyranopsis* sp., *Latiendothyranopsis* sp., *Archaediscus* sp., *Glomodiscus miloni, Eostaffella* sp. These are characteristic of the V2a. We have also recognized one specimen of cf. *Quasiendothyra(?) nibelis,* that normally indicates a V2b-V3 age. However, AUSTIN, CONIL & RHODES (1973) recognized *Q.(?) nibelis* together with typical V2a foraminifers in the Burrington Oolite of Mendips (Great Britain). We presume a provisional age of V2a-V3? for this assemblage. The fact that the coral assemblage is indicative for the V3a suggests that the foraminifers may be reworked.

The microfauna and -flora of the samples 51-60 indicate a V3b to V3by age: *Cytosphaera bulla, Pseudolituotuba gravata, Forschiella* sp. PALAEOTEXTULARIIDAE with monolamellar wall, *Quasiendothyra(?) nibelis, Planoendothyra* sp., *Mediocris* sp., *Eostaffella* sp. and cf. *Pseudoendothyra* sp. Sample 52 has yielded presumably reworked specimens: *Archaediscus* stage *angulatus* of V3b age together with *Glomodiscus* sp. of V1b-V2a age. The *Asperodiscus* sp. of sample 58 characterizes the V3b, whereas PALAEOTEXTULARIIDAE with bilamellar wall in sample 60 indicate the V3bß-y.

Samples 61-63 have yielded a poor asemblage, including TOURNAYELLIDAE, *Endothyra* sp., *Endothyranopsis* sp., *Eostaffella* sp. and cf. *Pseudoendothyra* sp. These may eventually belong to the V3c.

6.2. REMARKS ON FOSSIL ASSEMBLAGES

6.2.1. Palynological data

The rich microfloras from the Upper Frasnian shales of La Folie and from the Uppermost Devonian (Fa2d-Tn1a) of Chertal can be compared with similar assemblages from the Dinant-Namur Basin.

The higher strata of Dinantian age in the Visé area have not yielded any miospores. This matches the (negative) results of the Dinant-Namur Basin. The hypothesis that the energy level of the water was to high for deposition of the miospores seems invalid, since clayey shales of V3b age point to a rather low energy level. Moreover, diminuted plant debris and sclerotioid grains occur in many V3b-V3c shales and limestones of this area.

6.2.2. Conodonts

The Upper Frasnian conodont assemblage from the La Folie Quarry (Upper *Palmatolepis gigas* Zone) may be slightly older than the Upper Frasnian to Lower Famennian conodont assemblages recovered from the Booischot Borehole at the northern flank of the Brabant Massif. Table V lists the conodonts recognized from the 803-877 m interval of this borehole. The same assemblages have been recognized at several places in the Dinant-Namur Basin and indicate good intercommunication between the Campine-Brabant and Dinant-Namur Basins during the Upper Frasnian and Lower Famennian.

The Dinantian conodont assemblages from the La Folie Quarry (Tn1by-Tn2, Tn3-V1) as well as those of V3b-V3c age from the "F"-"L" Quarries North of Richelle and from the Houthem Borehole (Bless et al. 1976) can be compared with assemblages of the same age throughout NW Europe.

803-810 m		*Icriodus alternatus* *Spathognathodus* sp. *Palmatolepis delicatula* *P. delicatula clarcki* *P. quadrantinodosa lobata* *P. triangularis* Middle *Palmatolepis triangularis* Zone (Fa1a)
838 m	?	*Icriodus nodosus* *I. alternatus* *Polygnathus* cf. *brevilaminus* Lower *Palmatolepis triangularis* Zone (Fa1a)
842-852 m	?	*Icriodus nodosus* *I. alternatus* *Ancyrodella curvata* *Acodina curvata* *Palmatolepis subrecta* (aff. *gigas*) *P. subrecta* *Polygnathus decorosus* s.l. *P. webbi* *Palmatolepis gigas* Zone (Fr2)
870-877 m		*Icriodus alternatus* *Polygnathus decorosus* s.l. *P. webbi*

Table V — Conodonts from the Booischot Borehole (51E-146) along the southern border of the Campine-Brabant Basin (E. Groessens, Geological Survey of Belgium, Brussels)

6.2.3. Foraminifers

The Frasnian foraminifer assemblage of the "M"-"N" Quarries North of Richelle is comparable to those of the

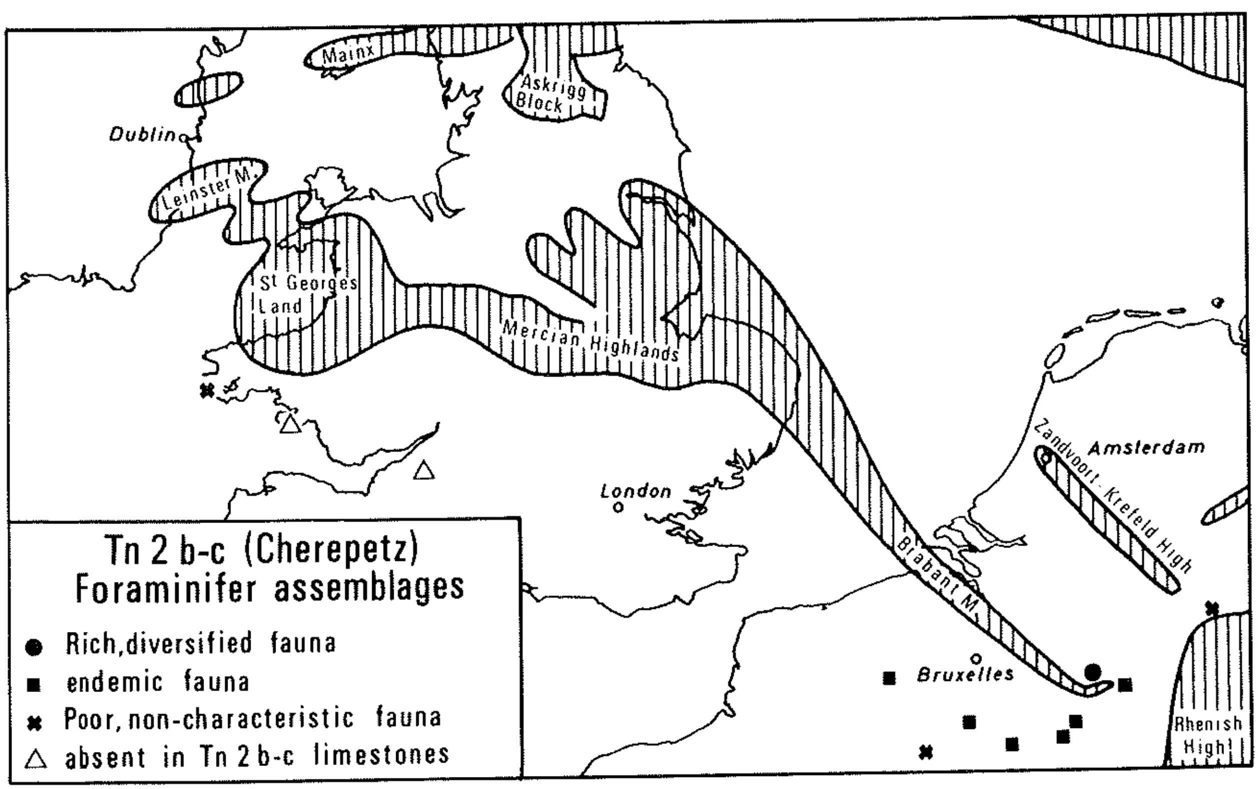


Fig. 8 — Tn2b-c foraminifer assemblages in NW Europe.

same age in the Dinant-Namur Basin.

A remarkable difference exists between the Tn2 foraminifer assemblage from La Folie Quarry and those from other places in NW Europe, including the Dinant-Namur Basin (Fig. 8). This assemblage is characteristic of the Tn2b-c and comparable to the typical Cherepetz faunas of the U.S.S.R. This fauna is much more diversified than the assemblages hitherto known from the Dinant-Namur Basin. This suggests an effective barrier between the Visé area and the Dinant-Namur Basin. The main characteristics are: different species of *Endothyra*, remarkable development of biserial foraminifers, TOURNAYELLIDAE are more abundant and diverse, large species of *Chernyshinella*. A direct communication between this part of the Campine-Brabant Basin and the U.S.S.R. during Cherepetz time is presumed.

Remarkable are the breccias occurring at the railway cutting West of Berneau at the base of the sequence and in the "F"-"L" Quarries North of Richelle overlying the V1a, which contain typical V2a elements. The age of these breccias has been determined by corals as V3a. These underlie V3b-V3bγ limestones. Similar breccias have been observed below the V3b-V3bγ of Turnhout, Halen and Houthem (Bless et al. 1976). In the Campine-Brabant Basin, non-breccious V2b-V3a limestones are confined to the Woensdrecht area.

6.2.4. Corals

The Visean coral assemblages of the "F"-"L" Quarries North of Richelle, the railway cutting West of Berneau and site "S" at Argenteau-Castle differ from those of the Dinant-Namur Basin. We note for example:

The range of *Lithostrotion araneа* into the V3b of the Visé area, whereas this species does not occur in levels younger than V2b in the Dinant-Namur Basin.

The presence of genera with Asian or African affinities such as *Pareynia* and *Amygdalophyllum* and of a.o. the species *Rotiphyllum rushianum* and *Clisiophyllum keyserlingi* in the Visé area. These are absent in the Dinant-Namur Basin.

The occurrence of geographic subspecies which are restricted to either the Dinant-Namur Basin or to the Campine-Brabant Basin.

This suggests the existence of two coral provinces during the Visean separated by some kind of a barrier. The southern province extended from the Dinant-Namur Basin into the Bristol/South Wales area of Great Britain. The northern one included the Campine-Brabant Basin and the Midlands. Intercommunication of coral faunas was possible via the Irish area as shown in fig. 9. The Brabant Massif and Booze-Le Val Dieu Ridge have acted as an effective barrier to faunal intercommunication between the Visé area and the Liège region. The absence of genera and species with affinities to the Asian and African faunas in the Dinant-Namur Basin suggests that this has been a relatively closed environment during the Visean.

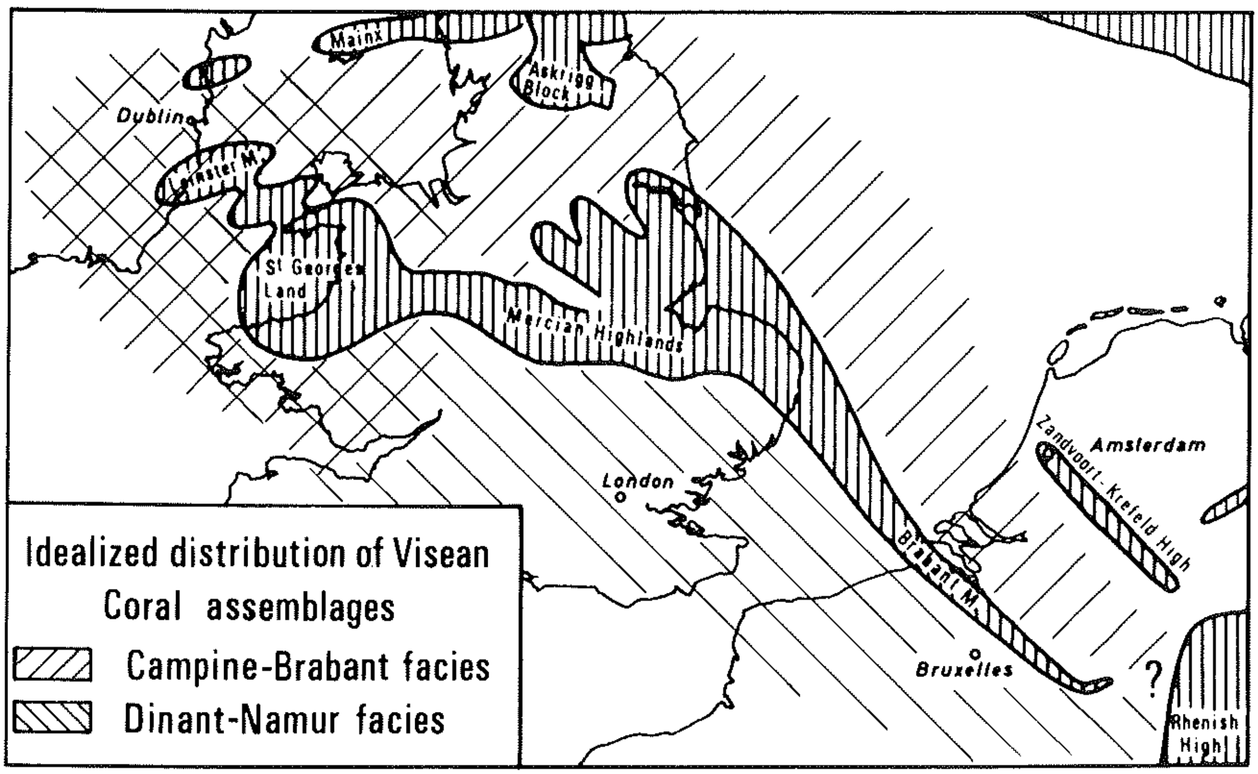


Fig. 9 — Idealized distribution of Visean coral assemblages.

6.3. SYSTEMATIC DESCRIPTIONS OF FORAMINIFERS

Fam. TOURNAYELLIDAE DAIN 1953

Conilites kimpei CONIL sp. nov.
(pl. 9, fig. 46)

1974: *Conilites* sp. 2 - CONIL & LEES, pl. II, figs. 17-19.
Derivatio nominis: Dedicated to Dr. W. F. M. KIMPE, Head of the Geological Bureau of Heerlen from 1966 to 1978.
Holotype: RC14010 (15132), pl. 9, fig. 46.
Paratype: RC7024 (8882) in CONIL & LEES 1974, fig. 19.
Locus typicus: La Folie Quarry, NE Belgium, Visé Region.
Stratum typicum: V1a, Foraminifer zone Cf4α

Diagnosis: Test consisting of relatively large involute portion followed by short evolute portion (1-2 chambers). Planispiral coiling, plane of coiling eventually slightly oscillating. About six pseudochambers in involute portion. Number of whorls: 2½-3. Total lenght: 850-900 μ in complete specimens. Diameter of involute portion: about 650-750 u. Aperture: 1 or 2 terminal cribra. Wall about 40μ thick.

Description: Tubular chamber regularly expanding until last whorl when rapid expansion is observed. Pseudochambers poorly defined in inner whorls. True chambers - bulging, irregular and unsymmetrical - suddenly appear in the last whorl. These are separated by short, thick septa which are directed towards the aperture. Terminal portion is uncoiled or simply rectilinear. Microgranular wall shows variable tendency to agglutination and to the formation of a darker inner layer.

Comparison with other species: Distinguished from *Conilites dinantii* (CONIL & LYS 1964) by a shorter involute portion which is more rapidly extended, by less tightened chambers and by a shorter and more expanded terminal rectilinear portion.

Stratigraphic distribution: V1a (Foraminifer zone Cf4α) of La Folie Quarry in southeastern part of Campine-Brabant Basin, and of Oughterard (Ireland). Incertain in V1a of Velbert area (Germany) and in Upper Tn3c (Foraminifer zone Cf3) of Dinant-Namur Basin.

Fam. ENDOTHYRIDAE BRADY 1884

Endothyra parakosvensis beruinae CONIL subsp. nov.
(pl. 8, figs. 24, 30; pl. 9, figs. 31-36)

Derivatio nominis: Beruina, the Berwinne River along which the La Folie Quarry is located.
Holotype: RC13187 (14191), pl. 9, fig. 33.
Paratype: RC13226 (14752), pl. 9, fig. 34.
Locus typicus: La Folie Quarry, NE Belgium, Visé Region.
Stratum typicum: Tn2b-c, Upper Foraminifer zone Cf1.

Diagnosis: Plane of coiling moderately oscillating; small initial clew present. Spire consisting of 2½-3 whorls. 6-7 chambers. Sutures well visible. No secondary deposits. Diameter: 450-650μ. Wall microgranular.

Description: Initial portion of test subdivided into bulbous, slightly unsymmetrical chambers. The spire is then rapidly extended. The chambers are bulging and separated by short septa directed towards the aperture. The wall is 20-25 μ thick in adult specimens and shows some tendency to recrystallisation in its axial part.

Comparison with other species: Distinguished from *Endothyra parakosvensis nigra* CONIL & LYS 1964 by the oscillating plane of coiling and by a more rapidly extended spire. The general aspect of the coiling is more irregular.

Stratigraphic distribution: This subspecies is only known from the Tn2b-c (Upper Foraminifer zone Cf1) of La Folie Quarry, where it is relatively abundant. Presumably, this is a geographic subspecies confined to the Campine-Brabant Basin.

7. PALEOGEOGRAPHY

7.1. DEVONIAN

7.1.1. Lower Devonian

During the Lower Devonian, a marine belt extended from the Holy Cross Mountains in Poland thru the Rhenish Slate Mountains and the Dinant-Namur Basin into the Armorican Massif of NW France and the Cornwall-Devon area of SW England. This belt was bordered in the South by the Franco-Alemannian Island and in the North by the Old Red Continent. The southern part of this continent included the Brabant Massif, the "Bande condrusienne" of MICHOT (1976) and part of the Booze-Le Val Dieu Ridge.

Lower Devonian deposits are absent in the boreholes Loenhout, Booischot, Wepion and Hermalle-sous-Argenteau (LEGRAND 1968, GRAULICH 1961, 1975a). These occur however in the autochthonous sequence of Bolland (GRAULICH 1975b) at the southern flank of the Booze-Le Val Dieu Ridge and in the Dinant Synclinorium (FOURMARIER 1954), where a coarse conglomerate at their base marks the transgression of the Lower Devonian over the Caledonian folded Cambro-Silurian basement.

7.1.2. Givetian

During the Middle and Upper Devonian, the Old Red Continent was broken up into smaller segments with different rates of subsidence. Transgressions of the Middle Devonian Sea reached into the North Sea (Argyll 30/24-3 Borehole, PENNINGTON 1975) where a basin developed. A large graben originated also in the Belgian Campine and southern Netherlands, the Campine-Brabant Basin (MICHOT 1976). Sedimentation in the southeastern part of this graben started somewhere during the Middle Devonian - as shown by the occurrence of 30 m of Givetian (partly biostromal) limestones and shales in the Hermalle-sous-Argenteau Borehole (GRAULICH 1975a) - and continued until the Upper Carboniferous.

A chain of horst-like structures - including the Brabant Massif and the Booze-Le Val Dieu Ridge -separated the Campine-Brabant Basin from the Dinant-Namur Basin. Sedimentation on these horsts was more condensed and incomplete than in the central parts of the basins and sometimes characterized by paralic to non-marine conditions. Conglomeratic deposits at the base of the Middle to Upper Devonian sequences mark the gradual transgression of the sea over the flanks of the horsts. Examples are the Alvaux Conglomerate containing plant-debris at the base of the Givetian in the Orneau Valley at the southern edge of the Brabant Massif and the conglomeratic base of the Givetian at Hermalle-sous-Argenteau at the northern flank of the Booze-Le Val Dieu Ridge.

The Givetian is absent at Loenhout and Booischot at the northern flank of the Brabant Massif and also in the autochthonous sequence of the Bolland Borehole at the southern flank of the Booze-Le Val Dieu Ridge (LEGRAND 1968, GRAULICH 1975b). Presumably the Givetian was not deposited on the culmination of these horsts. The land-derived plant debris in the Orneau Valley suggests the existence of vegetation on the Brabant Massif during Givetian time. On the other hand, these horsts have not formed a barrier to intercommunication between the Dinant-Namur and Campine-Brabant Basins. This is deduced from the fossil assemblage of Hermalle-sous-Argenteau which is comparable with those of the Dinant-Namur Basin.

7.1.3. *Frasnian*

Part of the Brabant Massif and Booze-Le Val Dieu Ridge remained erosive highs - probably covered by vegetation - during at least the Lower Frasnian. This is indicated by the thick (400 m) plant-bearing conglomerate of Booischot at the northern edge of the Brabant Massif which may represent a non-marine valley-fill (LEGRAND 1964, STREEL 1965, BECKER et al. 1974) and by the heterogranular breccious quartzites, breccias and sandy shales at La Folie and Hermalle-sous-Argenteau (cf. 6.2. and 6.7.) on the northern flank of the Booze-Le Val Dieu Ridge. Towards the close of the Frasnian period, the transgression will have covered almost completely the Brabant Massif and the Booze-Le Val Dieu Ridge. Marine Frasnian strata occur at Loenhout (LEGRAND 1968) and Booischot (156 m; STREEL 1965) at the northern flank of the Brabant Massif. At the southern flank of the Massif, some 240 m of Frasnian shales and carbonates exists in the Orneau Valley. At the northern flank of the Booze-Le Val Dieu Ridge, some 82 m of Frasnian carbonates overlie 9 m of Frasnian shales in the Hermalle-sous-Argenteau Borehole (GRAULICH 1975a). This carbonate sequence has been described as a cyclopean breccia consisting of large blocks of dolomite and limestone containing a diversified biostrome assemblage of stromatoporoids and corals, and can be observed at several places in the Visé area. Presumably, it represents the remnant of an old mogote karst landscape formed since the Famennian or Strunian until the end of the Dinantian. The cement between the blocks consists of calcite exhibiting typical compression-solution phenomena (pl. 1, fig. 1). This suggest that the observed actual thickness of Frasnian rocks in the Visé area represents only a fraction of that of the orginally deposited sediments. At the southern flank of the Booze-Le Val Dieu Ridge, the Frasnian shales and carbonates have a total thickness of only 44 m in the autochthonous sequence of Bolland (GRAULICH 1975b).

The thickness of the Frasnian deposits in the central part of the Campine-Brabant Basin eventually matches that of the Frasnes area in the Dinant Synclinorium, where up to 500 m of Frasnian rocks have been recognized (FOURMARIER 1954).

Intercommunication between faunal communities of the two basins occurred throughout the Frasnian as indicated by the comparable fossil assemblages.

7.1.4. *Famennian*

Renewed uplift of the Brabant Massif and Booze-Le Val Dieu Ridge during the (Upper) Famennian is indicated by the extremely reduced Famennian deposits at the southern flank of the Brabant Massif (12 m in the Orneau Valley, 0.5 m at Horion-Hozemont; FOURMARIER 1954) and the southern flank of the Booze-Le Val Dieu Ridge (185 m in the autochthonous sequence of Bolland; GRAULICH 1975b) which sharply contrast with the 750 m of the Ourthe Valley in the Dinant Synclinorium. Famennian rocks have not been recognized at Hermalle-sous-Argenteau (GRAULICH 1975a), La Folie (PIRLET 1967a) and Richelle (PIRLET 1967b) on the northern flank of the Booze-Le Val Dieu Ridge. Presumably, they do exist slightly further northwards in the area E of the Brabant Massif and may increase to a total thickness of at least 400-500 m in the central part of the Campine-Brabant Basin. This is deduced from the more than 315 m thick Famennian of Wachtendonk at the northern border of this basin (ELBERSKIRCH & WOLBURG 1962). At the northern flank of the Brabant Massif, the Famennian has been recognized in the boreholes Loenhout and Booischot (136 m; STREEL 1965).

7.1.5. *Strunian*

In the Booze-Le Val Dieu area, thin Strunian deposits occur at Chertal (CONIL 1964, this paper). These are absent at absent Hermalle-sous-Argenteau, La Folie, Booze-Le Val Dieu and in the autochthonous sequence of Bolland. Strunian deposits have not been observed in the boreholes Booischot and Loenhout at the northern flank of the Brabant Massif. Whether sediments of this age occur in the Campine-Brabant Basin is virtually unknown. At the southern flank of the Brabant Massif, the Strunian is apparently absent at Horion-Hozemont and less than 6 m thick in the Orneau Valley. In the Dinant Synclinorium the Strunian increases from ± 50 m in the Ourthe Valley thru ± 80 m near Dinant to about 150 m in the Avesselles region of northern France.

7.2. DINANTIAN

It seems likely that the Wales-Brabant-Booze-Le Val Dieu Chain inhibited intercommunication between faunas of the Campine-Brabant and Dinant-Namur Basins during

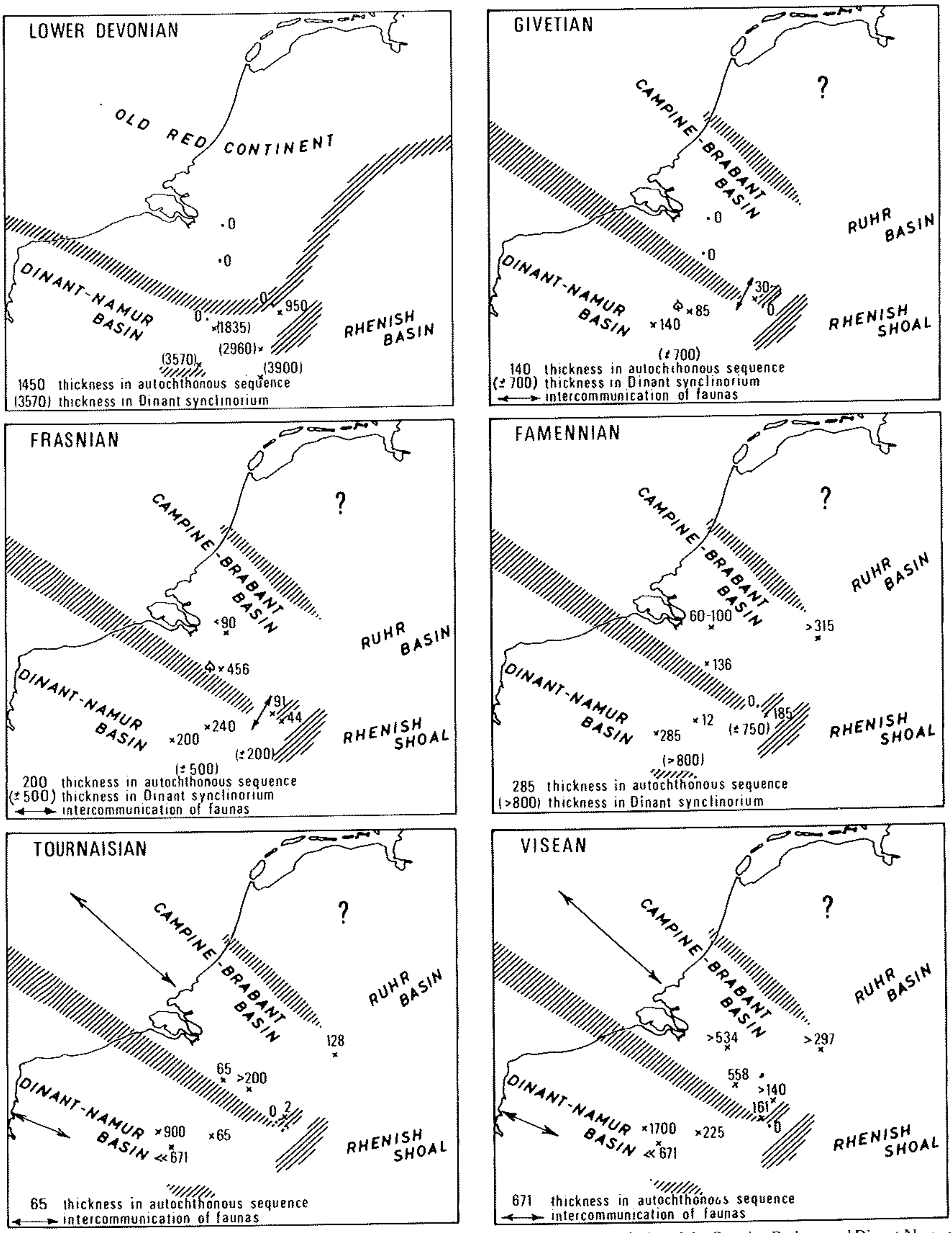


Fig. 10 — General position of the area East of the Brabant Massif during the paleogeographic evolution of the Campine-Brabant and Dinant-Namur Basins in the Devono-Dinantian time. Thicknesses of deposits are indicated in so as far as relevant for understanding the role of the Brabant Massif and the Booze-Le Val Dieu Ridge.

the Dinantian. Along the southern border of this barrier, faunal cross-migration between the Dinant-Namur Basin and the South-Western Province occurred until the late Visean (GEORGE 1969). Exchange of communities belonging to the South-Western Province and the Central Province was possible around the western edge of the chain in the Irish area where mixed fossil assemblages have been observed. During the Lower Dinantian, an (ecological?) barrier may have existed between the Central Province and the Campine-Brabant Basin. Isolation of the latter basin during the Tournaisian may be deduced from the rich Tn2 foraminifer assemblage of La Folie (this paper) in the southeastern part of the basin. This assemblage has not been recognized elsewhere in NW Europe. By the end of the Tournaisian the increasing analogies of the lithological succession and faunal assemblages suggest that this barrier between the Campine-Brabant Basin and Central Province had disappeared.

7.2.1. Tournaisian

Tournaisian carbonates have been deposited in the area East of the Brabant Massif on the northern flank of the Booze-Le Val Dieu Ridge. The section at La Folie (PIRLET 1967a) displays thin, discontinuous beds of partly nodular Tournaisian limestone with a thickness of 1 to 2 m. They rest on Frasnian shales and carbonates and are followed by Lower Visean breccias and conglomerates containing reworked Tournaisian fossils. Reworked conodonts of Tn1-Tn3 age occur also in the Upper Visean limestones of Houthem (BLESS et al. 1976). Part of the Tournaisian in this area must have been removed by erosion during the Visean. The original total thickness of the Tournaisian deposits may therefore have exceeded the few meters observed at La Folie.

The existence of Tournaisian strata elsewhere in the Campine-Brabant Basin has not been proven beyond doubt. However, it is believed that the dolomites in between V1 limestones and Famennian sandstones at Booischot (65 m) and Wachtendonk-1 (128 m) - respectively, at the southern and northern border of the basin - as well as the at least 200 m thick dolomite underlying the V1a of Halen have been deposited during the Tournaisian. If this supposition is correct, we may expect a northward increase in thickness of the La Folie limestones which somewhere should interfinger with the secondary dolomites fringing the eastern border of the Campine-Brabant Basin.

The Tournaisian has not been recognized in the Loenhout Borehole (LEGRAND 1968) where Visean limestones rest directly on the Famennian sandstones. Tournaisian deposits are also absent at Booze-Le Val Dieu and in the autochthonous sequence of Bolland (ANCION et al. 1943; GRAULICH 1975b). An incomplete sequence of Tournaisian shales and carbonates (Tn1-Tn2b) with a total thickness of 22 m has been cited from the upper allochthonous sequence of Bolland which belongs to the northern part of the Dinant Synclinorium (GRAULICH 1975b). On the southern flank of the Brabant Massif, the Tournaisian has a thickness of some 65 m in the Orneau Valley (FOURMARIER 1954). Over 900 m have been found in the autochthonous sequence of the St. Ghislain Borehole (Ir. A. DELMER, communication at meeting of Société Géologique de Belgique on 7 March 1978 at Brussels). But in the autochthonous sequence of Jeumont (personal communication, D. MASSA, Compagnie Française des Pétroles, Paris) this thickness is reduced again to much less than 761 m.

7.2.2. Visean

The Visean along the southern border of the Campine-

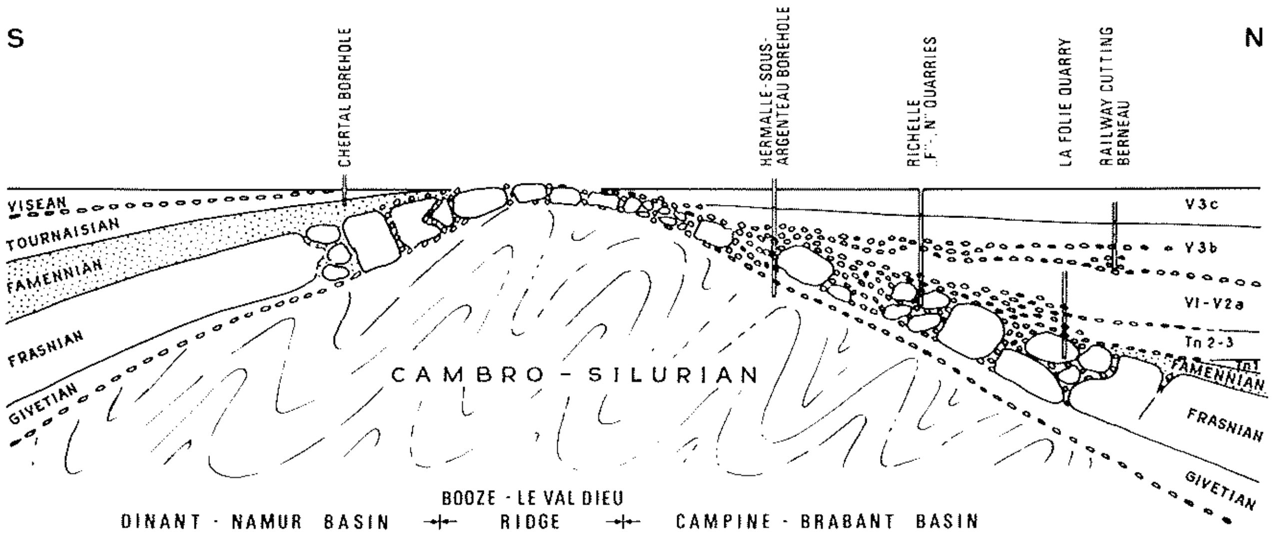


Fig. 11 — Idealized palinspastic section through the Booze-Le Val Dieu Ridge at the end of the Dinantian (not to scale!).

Brabant Basin is characterized by a general absence of V2b-V3a strata which have only been recognized at Woensdrecht (total thickness 14 m). V3b-V3c beds with a breccious interval of V3b age at their base rest on V1-V2a carbonates in the boreholes Turnhout and Halen (Bless et al. 1976). At Hermalle-sous-Argenteau, the V3b-V3c with a breccia containing reworked Tn3c-V2 elements at the base rests on a cyclopean breccia composed of Frasnian carbonates (Graulich 1975a). In the "F"-"L" Quarries of Richelle (Pirlet 1976b) the V3b-V3c - with an important (V3a?) breccia containing reworked Frasnian and Lower Visean rocks at the base - rests on a V1 breccia containing reworked blocks and boulders of Frasnian carbonates. Breccias containing reworked Tournaisian and V1-V2a fossils have been recognized also in the lower part of the V3by of Houthem (Bless et al. 1976) and the railway cutting West of Berneau (this paper).

The thickness of the Lower Visean (V1-V2a) carbonates varies from 0 m at Hermalle-sous-Argenteau (Graulich 1975a), 12 m at Richelle (Pirlet 1967b) and 182 m at Halen (Bless et al. 1976) to more than 430 m at Turnhout (Bless et al. 1976). Along the northern border of the Campine-Brabant Basin, the Lower Visean (V1) has a thickness of 297 m at Wachtendonck (Elberskirch & Wolburg 1962). The upper part of the Dinantian sequence in that area has been eroded in post-Carboniferous time.

The thickness of the Upper Visean (V3b-V3c) varies considerably in the southern part of the Campine-Brabant Basin: 104 m at Turnhout, 376 m at Halen, more than 140 m at Houthem and 161 m at Hermalle-sous-Argenteau.

Visean strata are absent at Chertal, Booze-Le Val Dieu and in the autochthonous sequence of Bolland. This suggests that the Booze-Le Val Dieu Ridge remained a high during this timespan (fig. 11). A mogote karst lanscape developed on the western portion of this ridge where Frasnian carbonates have been exposed to sub-aerial erosion during the Tournaisian and Lower Visean resulting in the formation of irregularly distributed mogotes surrounded by a cyclopean breccia with a calcite cement. Comparable mogote karst landscapes have been described from a.o. the Chinese Sea and the Caribbean area (Glazek 1968; Nagel 1973) and characterize a tropical climate. The irregular thickness of the Dinantian deposits and the discordant contacts between Frasnian cyclopean breccias and Dinantian carbonates at the "L" Quarry of Richelle (Pirlet 1967b) and La Folie (Pirlet 1967b) mark the drowning of these mogotes by Tournaisian and Visean sediments in the Visé area.

The Visean of the Dinant-Namur Basin thickens from some 225 m at the southern flank of the Brabant Massif (Orneau Valley; Fourmarier 1954) to 1700 m in the autochthonous sequence of St. Ghislain (Bless et al. 1977), where a sequence of 600 m of V1b-V3b∝-ß evaporites (anhydrite) occurs. Further southwards, the Visean reaches a thickness of much less than 761 m in the autochthonous sequence of the Jeumont Borehole in northern France (personal communication, D. Massa, Compagnie Française des Pétroles, Paris).

7.3. NAMURIAN

Evidence of an overall regression during the lowermost Namurian is the absence of basal (E1) strata along the southern and northern flanks of the Brabant Massif and Booze-Le Val Dieu Ridge. The subsequent slow transgression of the sea covered the Booze-Le Val Dieu Ridge since E2 time (Ancion 1960) and the larger part of the Brabant Massif by the end of the R1 period (Bouckaert 1967; Bless et al. 1976). The whole area was flooded by terrigenes (shales, sandstones and occasionally conglomerates) from the South. The Wales-Brabant-Booze-Le Val Dieu Upwarp remained a positive area throughout the Silesian as shown by the reduced thickness of Namurian and Westphalian deposits along its flanks. The Namurian increases from 400 m at Chertal thru 600-700 m in the Belgian Campine and South Limburg to over 1800 m at Rijsbergen in the southern Netherlands. A similar rapid thickening of the Namurian in the Central Province of Great Britain has been described by Ramsbottom (1969).

During the Namurian, depositional conditions gradually changed from purely marine to paralic. Towards the close of the period, rootlet beds - sometimes overlain by thin coalseams - become more frequent. Sedimentation is essentially cyclic. Examples have been described by a.o. Lambrecht (1955) and Lambrecht & Charlier (1956) from the Booze-Le Val Dieu and Visé areas. Correlation of sections is based on widespread goniatite marker bands.

It is presumed that the Namurian (E2-G1) covered the Dinantian subscrop of the Visé-Puth Anticline East of the Brabant Massif. A rapid northward thickening beyond the explored region (boreholes DB104, DBLIII and DBLVIII) in South Limburg - analogous to the development observed between Turnhout and Rijsbergen - is likely.

7.4. WESTPHALIAN

7.4.1. *Westphalian A-B*

The paralic Westphalian A-B deposits characterized by numerous workable coalseams exhibit a relatively constant thickness in the Campine and South Limburg. A minor reduction of Westphalian A strata is observed however in the southeastern part of the South Limburg Coalfield (1050 m in Maurits Colliery in NW against 850 m in Domaniale Colliery in SE: (Bachmann, Herbst & Kimpe 1970) where the eastern continuation of the Booze-Le Val Dieu Ridge may be located.

The thickness of the incompletely preserved Westphalian A-B sediments on the southeastern flank of the Brabant Massif and Booze-Le Val Dieu Ridge shows that these structures remained positive areas in the sedimentary basin.

The Brabant Massif has influenced at least at intervals the sedimentation of the Westphalian A-B. This can be deduced from the paleofacies in the area East of this massif. An example is the Finefrau Nebenbank Transgression (BLESS 1973). This sedimentation pattern in the area East of the Brabant Massif was also influenced by oscillating movements parallel to the strike of the anticlinal structures of Visé-Puth, Waubach and Ham. Examples are the N-S striking sandstone bodies and wash-outs of the Finefrau coalseam group along the eastern border of the Ham Anticline (KIMPE & THIADENS 1951), the SW-NE strike of the Lower Lithosome of the Finefrau Nebenbank Marine Band in between the Visé-Puth and Waubach Anticlines and the strike of a large number of wash-outs in the Westphalian A an B which parallels the axes of these anticlines (BLESS 1973).

Several thick Westphalian A coalseams (Enclosures V-VI) tend to be split by intercalated shales and sandstones (partly developed as wash-outs) into thinner offshoots across the Waubach and Visé-Puth Anticlines. This suggests that these structures are located on fault zones separating oscillatting segments of the pre-Westphalian basement.

7.4.2. *Westphalian C-D*

Presumably, sedimentation ceased somewhere during the Lower Westphalian C in the Andenne-Liège-Aachen area under influence of the quickly northward shifting folding and uplift of the Ardenno-Rhenish Massif. But in the Campine-Brabant Basin, deposition continued until the end of the Westphalian D. A gradual decrease of coalseams which disappear in the Lower Westphalian D and the occurrence of red beds in the Upper Westphalian D mark the change to a more arid climate.

Thickness of Westphalian C in the area East of the Brabant Massif is slightly less than 600 m (BLESS et al. 1977). Towards the western part of the Campine-Brabant Basin, the thickness is reduced to some 311 m at Hellevoetsluis (VAN WIJHE & BLESS 1974) and to only 136 m at Rijsbergen on the northern flank of the Brabant Massif (VAN WIJHE & BLESS 1974).

The incomplete Westphalian D of Hellevoetsluis (topmost beds have been eroded) displays a thickness of some 770 m. In the southeastern part of the basin, the lower part of the Westphalian D includes thick porous sandstones. It is suggested that the Upper Westphalian D consists of a more shaly sequence. A similar development is observed at Hellevoetsluis. A hypothetical section through the Roer Valley Graben between South Limburg and the Venlo Horst learns that some 600 m of Westphalian D deposits may be present below the Carboniferous subcrop.

7.5. *LATE PALEOZOIC*

Late Variscan movements strongly affected the area East of the Brabant Massif. These resulted in the WSW-ENE striking thrust-faults and folds which predominate in the Liège Coalfield and the southeastern part of South Limburg. Presumably, the entire region was subjected to uplift and subsequent erosion since the Stephanian. No traces of Stephanian or Permian deposits have been recognized. The horst-like anticlines of Visé-Puth, Waubach and Ham - which influenced already the Lower Westphalian sedimentation pattern (cf. 7.4.1.) - have become more prominent during this period. The crests of these structures were eroded before the Triassic sedimentation started.

7.6. *POST-PALEOZOIC*

The Paleozoic abrasion surface was mantled in Lower Triassic time by a thick cover of up to 400 m Lower to Middle Bunter Sandstones suggesting strong subsidence of the area during that period. Except for the northwestern part of the area, these Triassic deposits have been eroded before Upper Cretaceous sedimentation started.

Rejuvenation of NW-SE stroking normal faults bordering the southeastern part of the former Campine-Brabant Basin has broken up the area East of the Brabant Massif into several smaller segments since the Triassic. Oscillating movements of the individual segments have resulted in a complex process of deposition and subsequent removal of Upper Cretaceous and Tertiary sediments on the Paleozoic abrasion surface (Enclosure II). It is beyond the scope of this paper to unravel this process.

Not only block movements along the NW-SE fault pattern have influenced Upper Cretaceous and Tertiary sedimentation and erosion. PATIJN & KIMPE (1961) described the remarkable absence of the Campanian Aachen and Herve sands on the Puth Flexure, the northern end of the Visé-Puth Anticline. PATIJN (1963) suggested that this was a geomorphological high during the deposition of these sediments. E-W cross-sections over this structure show however that the base of the overlying Maastrichtian Kunrade Limestone as well as the base of the still younger Oligocene sands is lower on the crest of this anticline than on its eastern and western flanks (Enclosure III, section H-H') suggesting post-Oligocene downwarp of the anticline. A similar feature is observed in the Eijsden area in the southern part of the same anticline (Enclosure III, section F-F'), where the base of a well-dated horizon within the Gulpen Limestone is lower on the place where the Aachen and Herve sands have been removed from the Paleozoic abrasion surface than towards the SW or NE where these formations underlie the Gulpen Limestone. A similar observation has been made in the southeastern part of South Limburg East of Gulpen (Enclosure III, section G-G').

The hypothesis that these phenomena represent wash-out channels in the Aachen-Herve sands which have been filled by younger deposits is not matched by the observation that the thickest Gulpen or Kunrade deposits do not necessarily occur in these so-called channels. We are inclined to believe that local upward of the Visé-Puth Anticline has caused removal of the unconsolidated Aachen-Herve sands. After the deposition of the Gulpen, Kunrade and Houthem limestones and of at least the basal Oligocene sands, the same area was warped again. The same phenomenon has been observed for the Waubach Anticline. The sediments on the crest of this anticline are younger than those on its flanks (Enclosure II).

A structural high of Dinantian rocks has been established on the depth contour map of the top of the Dinantian in the area of Eys-Wittem. This high roughly coincides with an area where the Campanian Aachen-Herve sands have been removed and where the younger Gulpen Limestone rests immediately on the Carboniferous basement (Enclosure III, section G-G').

A similar feature has been described by CORNET (1928) for the Mesozoic-Cenozoic strata overlying the Hensies Dome near St. Ghislain in the Mons area of SW Belgium (fig. 12). This dome consists of Paleozoic rocks. The St. Ghislain Borehole has explored this structure to a depth of 4437.25 m and recognized 600 m of Visean evaporites overlying a karst zone of 130 m (DELMER, GRAULICH & LEGRAND 1978). Upwarp caused by halokinesis and subsequent downwarp as a result of leaching of evaporites in the core of the dome may have been responsible for the oscillating movements in this area.

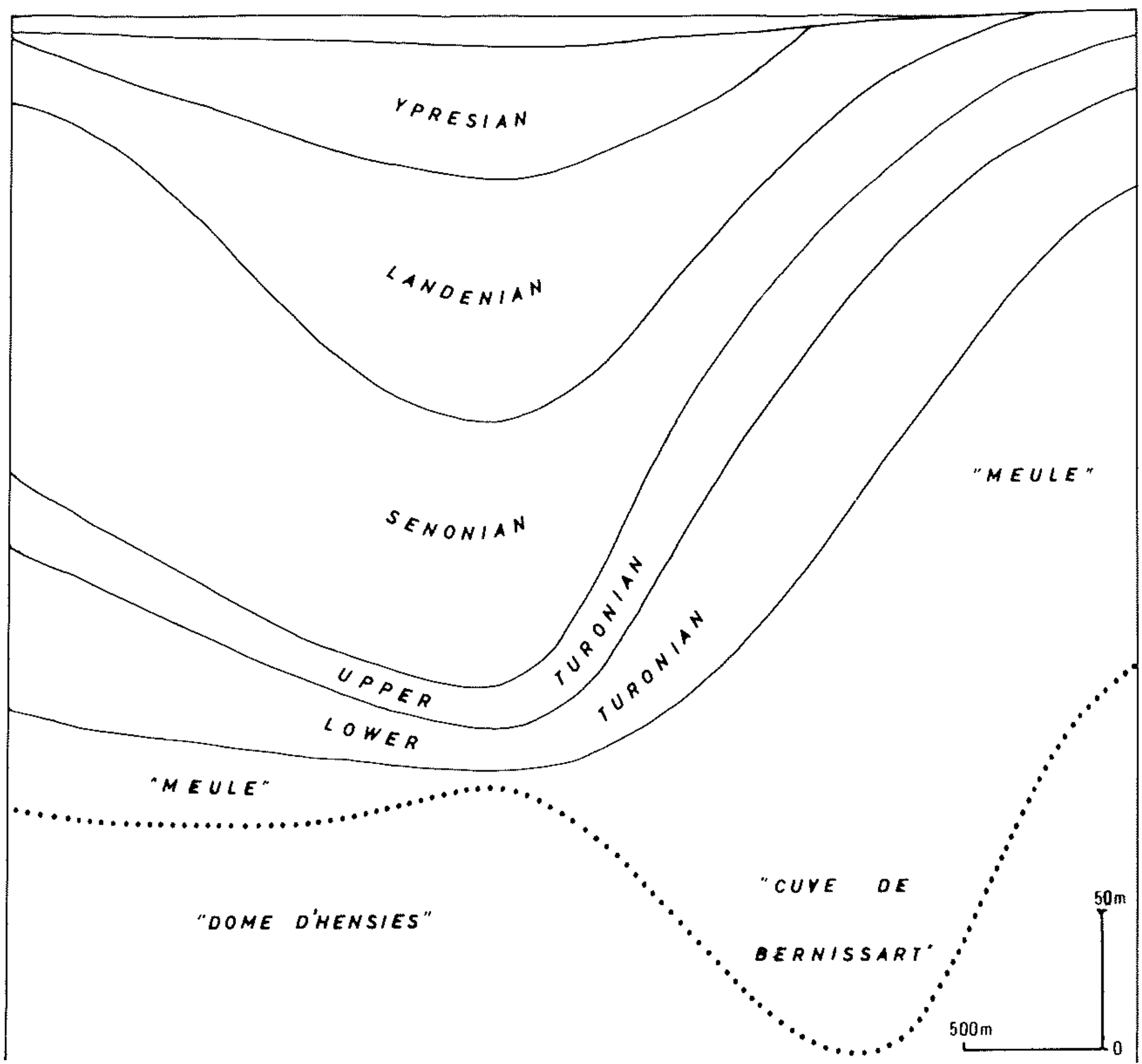


Fig. 12 — Cross-section through the post-Paleozoic deposits on the "Dome d'Hensies" in southwestern Belgium after CORNET (1928). Note depression of strata on top of dome, comparable to pheneomenon recognized on top of Visé-Puth and Waubach Anticlines and on Eys-Wittem High in South Limburg!

8. CONCLUSIONS

The area East of the Brabant Massif has formed part of the Campine-Brabant Basin since the Middle Devonian until the Late Westphalian. It was separated from the Dinant-Namur Basin by the Booze-Le Val Dieu Ridge which acted as a barrier to intercommunication of faunal communities during the Dinantian. The paleogeographic development of the area is known for the period Middle Devonian until the end of the Dinantian from the Visé area. The paleogeographic development during the Namurian has been reconstructed from boreholes and outcrops surrounding the Visé-Puth Anticline from the easternmost Campine thru South Limburg and the Sippenaeken area into the northern border of the Liège Coalfield. The evolution of this area during the Westphalian can be reconstructed from the many boreholes and exposures in coalmines in the coalfields of the Campine, South Limburg and the Liège area.

The area displays three types of structural elements.

1 - Variscan folded and thrust-faulted structures with an overall WSW-ENE strike, which have not been active in post-Variscan periods.

2 - NW-SE striking faults bordering the Roer Valley Graben, which may have originated in Paleozoic times and along which oscillating block movements occurred during the Mesozoic and Cenozoic.

3 - Horst-like anticlines (Visé-Puth, Waubach, Ham and the Eys-Wittem High, presumably located on tectonic hinge lines in the pre-Westphalian basement, which have been subjected to uplift and downwarp during the Upper Cretaceous and Tertiary.

The N-S striking axes of the Visé-Puth and Ham Anticlines indicate that these structures are not related to the Variscan fold system, nor to the Roer Valley Graben fault system. The post-Paleozoic uplift and downwarp of the Waubach Anticline (although its axis is parallel to the strike of the Variscan structures) suggests that this structure is not related to the Variscan movements. The strike of the Eys-Wittem High is unknown. However, the Post-Paleozoic uplift and downwarp of this structure exclude a relationship with the Variscan folding. The apparently reduced size of the Eys-Wittem High make a relationship with the Roer Valley Graben faults unlikely.

These structures are characterized by local uplift without corresponding depressions on their flanks. This suggests vertical rather than horizontal stress.

The significant increase of the chloride contents in the ground and mining water in the Visé-Puth and Waubach Anticlines, the coincidence between the area of relatively high-thermal mineralizations with the Waubach Anticline and the coincidence of the negative gravity anomaly with the Dinantian subcrop of the Visé-Puth Anticline are presumably related to a common origin.

The origin of these features must be sought in the pre-Silesian rocks. This is deduced from the negative gravity anomaly matching the Dinantian subcrop of the Visé-Puth Anticline and from the Lower Westphalian sedimentation pattern influenced by tectonic hinge lines in the pre-Westphalian basement. On the other hand, the known paleogeographic evolution of the area during the pre-Silesian (essentially based on observations on the immediate edges of the Booze-Le Val Dieu Ridge) does not give a clue to the nature of this cause.

The relatively high-thermal mineralizations in the Waubach area might be related to the magmatic body underneath. However, such a body might have produced a distinct positive gravity anomaly unless it it rather deep-seated.

However, it is not very likely that such a deep-seated magmatic body would have caused the extremely local uplift and downwarp of these anticlines in Post-Paleozoic periods.

The coincidence of the negative gravity anomaly and the increased chloride contents of the ground water in the Visé-Puth Anticline might indicate the existence of evaporites in the Devono-Dinantian rocks or even in the Cambro-Sulurian basement. Hydration of anhydrites and dehydration of gypsum as well as leaching of evaporites by circulating ground water might have caused the relatively small uplift and downwarp of these structures during the post-Paleozoic. Leaching of salt in pre-Frasnian rocks might have contributed - along with sub-aerial karstification during the higher Famennian and Dinantian - to the formation of the cyclopean breccias of Frasnian carbonates in the Visé area. Circulating ground water with increased chloride and sulfide contents produced by leached salt in the subsurface might have transported the Zn-Pb-Cu complexes in the Waubach Anticline.

The hypothesis that pre-Silesian evaporites may occur in this area and that they have influenced its tectonic history can only be confirmed by further multidisciplinary investigations which imply one or more boreholes. At this time, the most suitable location for such boreholes seems the area of the Dinantian subcrop of the Visé-Puth Anticline that matches the negative gravity anomaly. In that area the pre-Silesian occurs practically immediately below the surface or is overlain by less than 250 m of Post-Paleozoic sediments.

Whatever will be the result of such an investigation, it will substantially contribute to a better understanding of the geological history of pre-Permian or pre-Silesian strata in the Campine-Brabant Basin.

9. REFERENCES

ANCION, CH., 1960: Le Namurian et le Famennien de la vallée de la Berwinne aux environs du Val-Dieu. — C. R. 4e Congr. Intern. Strat. Géol. Carb., I, pp. XXXVII-XLI.

ANCION, CH., W. VAN LECKWIJCK & G. UBACHS, 1943: A propos de la bordure méridionale du synclinale de Liège, à l'aval de Liège: la ride famennienne de Booze-Le Val Dieu, à la limite septentrionale du plateau de Herve. — Ann. Soc. Géol. Belg., LXVI, pp. M299-M335.

AUSTIN, R. L., R. CONIL & F. H. T. RHODES, 1973: Recognition of the Tournaisian-Visean boundary in North America and Britain. — Ann. Soc. Géol. Belg., 96, pp. 165-188.

BACHMANN, M., G. HERBST & W. F. M. KIMPE, 1970: Derzeitiger Stand der Flözparallelisierung zwischen den Steinkohlenrevieren der Niederlande, von Aachen-Erkelenz und vom Niederrhein. — C. R. 6e Congr. Intern. Strat. Géol. Carb., II, pp. 445-452.

BECKER, G., M. J. M. BLESS, M. STREEL & J. THOREZ, 1974: Palynology and ostracode distribution in the Upper Devonian and basal Dinantian of Belgium and their dependence on sedimentary facies. — Med. Rijks Geol. Dienst, N.S., 25(2), pp. 9-99.

BLESS, M. J. M., 1973: The history of the Finefrau Nebenbank Marine Band (Lower Westphalian A) in South Limburg (the Netherlands). A case of interaction between Paleogeography, Paleotectonics and Paleoecology. — Med. Rijks Geol. Dienst, N.S., 24 pp. 57-103.

BLESS, M. J. M., J. BOUCKAERT, PH. BOUZET, R. CONIL, P. CORNET, M. FAIRON DEMARET, E. GROESSENS, P. J. LONGERSTAEY, J. P. M. TH. MEESSEN, E. PAPROTH, H. PIRLET, M. STREEL, H. W. J. VAN AMEROM & M. WOLF, 1976: Dinantian rocks in the subsurface North of the Brabant and Ardenno-Rhenish massifs in Belgium the Netherlands and the Federal Republic of Germany. — Med. Rijks Geol. Dienst, N.S. 27(3), pp. 81-195.

BLESS, M. J. M., J. BOUCKAERT, M. A. CALVER, J. M. GRAULICH & E. PAPROTH, 1977: Paleogeography of Upper Westphalian deposits in NW-Europe with reference to the Westphalian C North of the mobile Variscan belt. — Med. Rijks Geol. Dienst, N.S., 28(5), pp. 101-127.

BLESS, M. J. M., J. BOUCKAERT, M. A. CALVER, L. DEJONGHE, J. M. GRAULICH, M. HORN, W. F. M. KIMPE, J. KULLMANN, J. P. M. TH. MEESSEN, D. NAYLOR, J. T. OLIVEIRA, E. PAPROTH, F. PARIS, J. C. PERDIGAO, A. RIBEIRO, M. ROBARDET, L. SANCHEZ DE POSADA & J. TRUYOLS, 1978: Ya-t-il des hydrocarbures dans le Pre-Permien de l'Europe occidentale. — Serv. Géol. Belg., Prof. Paper, 1977/11, 58 pp.

BOUCKAERT, J., 1960: Stratigraphie et Paléontologie de la superzone R1 dans les vallées de la Berwinne et de la Geulle. — Mém. Inst. Géol. Univ. Louvain, XXI, pp. 3-94.

BOUCKAERT, J., 1967: Namurian transgression in Belgium. — Ann. Soc. Géol. Pologne, 37, pp. 145-150.

BOUCKAERT, J., 1971: Das Oberkarbons Belgiens. - Serv. Géol. Belg., Prof. Paper, 1971-2, chapt. III, 11 pp.

BOUCKAERT, J. & G. HERBST, 1960: Zur Gliederung des Namurs im Aachener Gebiet. — Fortschr. Geol. Rheinld. Westf., 3, pp. 369—384.

CHALARD, J., 1960: Les horizons à Goniatites du Namurien du nord de la France. — C.R. 4e Congr. Intern. Strat. Géol. Carb., I. pp. 87-92.

CHARLES, F. L., 1946: Observations sur le massif de Visé. — Bull. Soc. belge Géol. Pal. Hydr., LV, pp. 50-53.

CHAUDIOR, H., 1953: Etude géologique du basin houiller de Liège. Les concessions Cheratte et Argenteau-Trembleur. — Publ. Ass. Etud. Paléont., 17, 109 pp.

CONIL, R., 1964: Localités et coupes types pour l'étude du Tournaisien inférieur. — Mém. Acad. Roy. Belg. Comm. Nat. Sc. Géol., XV, 87 pp.

CONIL, R. & A. LEES, 1974: Les transgressions Viséennes dans l'ouest de l'Irlande. — Ann. Soc. Géol. Belg., 97, pp. 463-484.

CONIL, R. & M. LIJS, 1964: Matériaux pour l'étude micropaléontologique du Dinantien de la Belgique et de la France (Avesnois). Première partie: Algues et Foraminifères. — Mém. Inst. Géol. Univ. Louvain, XXIII, 296 pp.

CONIL, R. & M. LIJS, 1977: Les transgressions dinantiennes et leur influence sur la dispersion et l'evolution des foraminifères. — Mém. Inst. Géol. Univ. Louvain, 29, pp. 9-55.

CORNET, J., 1928: Les plissements des terrains crétaciques et tertiaires du bassin de Mons. III. Entre Thivencelles et Harchies. — Ann. Soc. Géol. Belg., LI; pp. B275-B288.

DELMER, A., 1963: Carte des mines du bassin houiller de la Campine. — Ann. Mines Belg., pp. 739-754.

DELMER, A. & CH. ANCION, 1954: Le Namurien. — Prodome d'une description géologique de la Belgique, pp. 323-352.

DELMER, A. & J. M. GRAULICH, 1955: Description des terrains houillers traversés par le sondage de Chertal (Bassin de liège). — Ann. Soc. Geol. Belg., LXVIII, pp. B139-B146.

DELMER, A. & J. M. GRAULICH, 1959: Solution de quelques problèmes de stratigraphie houillère par la découverte de niveaux à Goniatites. — Bull. Soc. belge Géol. Pal. Hydr., LXVII, pp. 425-453.

DELMER, A., J. M. GRAULICH & R. LEGRAND, 1978: La recherche d'hydrocarbures en Belgique. Situation 1977. — Ann. Mines Belg. (in press).

DIJKSTRA, S. J., 1949: Megaspores and some other fossils from the Aachenian (Senonian) in South-Limburg, Netherlands. — Med. Geol. Sticht., N.S., 3, pp. 19-32.

DIKKERS, A. J., 1945: De geologie van het veld van Staatsmijn Maurits. — Med. Geol. Sticht., Ser. C-I-I-No 1, 88 pp.

DOUW, A. H. & G. J. OORTHUIS, 1945: Verslag over de vindplaatsen van mineralen in de Zuid-Limburgse mijnen, 39 pp.

DRICOT, E. M., 1971: Acritarches du Frasnien moyen et supérieur de la Belgique. Systématique et aspects écologiques. — Univ. Cath. Louvain (unpublished PhD Thesis).

DUMONT, A., 1832: Mémoire sur la constitution géologique de la province de Liège. — Mém. cour. Acad. roy. Belg., VIII, 374 pp.

ELBERSKIRCH, W. & J. WOLBURG, 1962: Zur Tektonik des Karbons am linken Niederrhein im Profil der Bohrungen Wachtendonk 1 — Emmerich 1. — Fortschr. Geol. Rheinld. Westf., 6 pp. 407-432.

FOURMARIER, P., 1902: Etude stratigraphique du massif calcaire de Visé. — Ann. Soc. Géol. Belg., XXXIX, pp. M225-M235.

FOURMARIER, P., 1923: Sur la présence d'une faille antécrétacée dans la vallée de la Berwinne au Nord de Dalhem. — Ann. Soc. Géol. Belg., XLIV, pp. B189-B193.

FOURMARIER, P., ed., 1954: Prodome d'une description géologique de la Belgique, 826 pp.

GEORGE, T. N., 1969: British Dinantian Stratigraphy. — C. R. 6e Congr. Intern. Strat. Géol. Carb., I, pp. 193-218.

GLAZEK, J., 1968: Some observations on karst phenomena in North Vietnam. — Proc. 4th Intern. Congr. Speleol., Yugoslavia 1965, 3, pp. 451-455.

GRAULICH, J. M., 1955: La faille Eifelienne et le Massif de Herve. Ses relations avec le Bassin Houiller de Liège. — Mém. Expl. Cartes Géol. Min. Belg., 1, 32 pp.

GRAULICH, J. M., 1961: Les résultats du sondage de Wépion. — Ann. Mines Belg., pp. 156-160.

GRAULICH, J. M., 1962: La phase sudète de l'Orogène varisque dans le synclinorium de Namur à l'Est du Samson. — Bull. Soc. belge Géol. Pal. Hydr., LXXI, pp. 181-199.

GRAULICH, J. M., 1975a: Le sondage de Hermalle-sous-Argenteau. — Serv. Géol. Belg., Prof. Paper, 1975-4, 12 pp.

GRAULICH, J. M., 1975b: Le sondage de Bolland. — Serv. Géol. Belg. Prof. Paper, 1975-9, 38 pp.

GROESSENS, E., 1974: Distribution de conodontes dans le Dinantien de la Belgique. — Intern. Symp. Belg. Micropal. Limits, 17, 193 pp.

HOFKER, J., 1966: Maestrichtian, Danian and Paleocene Foraminifera. The Foraminifera of the type-Maestrichtian in South-Limburg, Netherlands, together with the Foraminifera of the underlying Gulpen Chalk and the overlying calcareous sediments, the Foraminifera of the Danske Kalk and the overlying greensands and clays as found in Denmark. — Palaeontographica, Suppl. Band 10, 375 pp.

HORION, CH. & J. GOSSELET, 1892: Etude stratigraphique sur les calcaires de Visé. — Ann. Soc. Géol. Nord, 20, pp. 194-212.

HUMBLET, E., 1941: Le Bassin Houiller de Liége. — Rev. Univ. Mines, Ser. 8, XVII, 21 pp.

HUMBLET, E. & CH. ANCION, 1949: Géologie minières des bassins houillers belges. - Le bassin de Liège. — Ann. Mines Belg., 48, pp. 377-384.

JONGMANS, W. J. & CL. G. DRIESSEN, 1932: De mineraalwaterbron te Maastricht. — Water, 13, pp. 1-11.

JONGMANS, W. J., W. F. J. M. KRUL & J. J. H. VOS, 1941: Waterwinning in Zuid-Limburg, 222 pp.

JONGMANS, W. J. & F. H. VAN RUMMELEN, 1930: Bijdrage tot de kennis van de samenstelling van den ondergrond onder Maastricht en

omgeving. — Jaarverslag Geol. Bureau voor het Nederlandse Mijngebied te Heerlen, 1929, pp. 89-98.
KIMPE, W. F. M., 1963: Géochimie des eaux dans le Houiller du Limbourg (Pays-Bas). — Verh. Kon. Ned. Geol. Mijnb. Gen., 21, pp. 25-45.
KIMPE, W. F. M., 1969: Répartition et caractères pétrographiques des Tonstein dans le Westphalien A et B du bassin houiller du Limbourg (Pays Bas). — Ann. Soc. Géol. Nord, LXXXIX, pp. 249-260.
KIMPE, W. F. M. & A. A. THIADENS, 1951: On the occurrence of coal rafts above and rhizome inclusions in seam Finefrau B, South Limburg, Holland. — Proc. 3d Intern. Congr. Sediment., pp. 167-173.
LAMBRECHT, L., 1955: Contribution à l'étude du Namurien de la vallée de la Berwinne (province de Liège-Belgique). — Publ. Ass. Etud. Paléont., 21, pp. 189-201.
LAMBRECHT, L. & J. BOUCKAERT, 1973: Sondages à Hermalle-sous-Argenteau. — Serv. Géol. Belg., Prof. Paper, 1973 No 2, 18 pp.
LAMBRECHT, L. & P. CHARLIER, 1956: Le Westphalien inferieur et le Namurien de la région Cheratte-Argenteau. — Publ. Ass. Etud. Paléont., 25, 98 pp.
LAMBRECHT, L. & W. P. VAN LECKWIJCK, 1961: Contribution à l'étude de la zone à *Gastrioceras* dans la bassin houiller de Huy-Andenne. — Bull. Soc. belge Géol. Pal. Hydr., LXIX, pp. 163-190.
LECKWIJCK, W. P. VAN, 1952: Etude géologique du gisement houiller d'Andenne-Huy. Le Namurien dans le bassin d'Andenne. — Publ. Ass. Etud. Paléont., 11, 107 pp.
LECKWIJCK, W. P. VAN, 1956: Tableau d'une aire instable au Paleozoique Superieur: La terminaison oriental du Massif du Brabant aux confins Belgo-Neerlandais. — Kon. Ned. Geol. Mijnb. Gen., Geol. Ser., XVI, pp. 252-273.
LEDOUBLE, O., 1905: Notice sur la constitution du bassin houiller de Liège. — Congr. Intern. Mines, Metallurgie, Mecanique, Géol. appl., pp. 553-737.
LEGRAND, R., 1959: Compte rendu de l'excursion du 26 juin 1958 dans la région de Visé. — Bull. Soc. belge Géol. Pal. Hydr., LXVII, pp. 290-295.
LEGRAND, R., 1964a: Coupe résumée du forage de Booischot. — Bull. Soc. belge Géol. Pal. Hydr., LXXII, pp. 407-409.
LEGRAND, R., 1964b: Sondage de Booischot. — Ann. Mines Belg., pp. 462-463.
LEGRAND, R., 1968: Le Massif de Brabant. — Mém. Expl. Cartes Géol. Min. Belg., 9, 148 pp.
LIPINA, O. A., 1970: Evolution of biserial rectilinear early Carboniferous foraminifers (in Russian). — Vopr. Mikropaleont., 13, pp. 3-29.
LOHEST, M., 1911: Le sondage de Herstal. La discordance du Houiller et du Calcaire Carbonifère et le charriage du massif de Visé. — Ann. Soc. Géol. Belg., XXXVIII, pp. B186-B192.
MEESSEN, J. P. M. TH., 1977: Foraminiferen onderzoek van enige monsters van het Onder Tertiair en Boven Krijt van drie diepboringen uit noord-oost België. — Serv. Géol. Belg., Prof. Paper, 1977 No 1, 5 pp.
MERRIAM, D. F., 1963: The geological history of Kansas. — Bull. State Geol. Surv. Kansas, 162, 317 pp.
MICHOT, P., 1976: Le segment varisque et son antécédent calédonien dans le cadre de la Belgique et des régions limitrophes. — Nova Acta Leopoldina, N.F., N. 224, B. 45, pp. 201-228.
NAGEL, G., 1973: Kriterien zur Deutung fossiler und rezenter Karstformen in Mitteleuropa. — Geograph. Zeitschr., 32, pp. 93-103.
PAPROTH, E., 1971: Megafauna. In: Die Karbonablagerungen in der Bundesrepublik Deutschland. III. A. 5. Die Fossilien und Kaolin-Kohlentonsteine. — Fortschr. Geol. Rheinld. Westf., 19, pp. 109-112.
PATIJN, R. J. H., 1963: Het Carboon in de ondergrond van Nederland en de oorsprong van het Massief van Brabant. — Geologie en Mijnbouw, 42, pp. 341-349.
PATIJN, R. J. H., 1966: Waterwinning in Zuid- en Midden-Limburg nu en in de toekomst. — Med. Geol. Sticht., Ser. C-VI-No. 8, 21 pp.
PATIJN, R. J. H. & W. F. M. KIMPE, 1961: De kaart van het Carboonoppervlak, de profielen en de kaart van het dekterrein van het Zuid-Limburgs mijngebied en de staatsmijn Beatrix met omgeving. — Med. Geol. Sticht., Ser. C-I-1-No. 4, 12 pp.
PENNINGTON, J. J., 1975: The Geology of the Argyl Field. — Petroleum and the continantal shelf of North West Europe, vol. 1, pp. 285-291.
PIRLET, H., 1967a: Mouvements épeirogéniques Dévono-Carbonifère dans la région de Visé; la carriere de "La Folie" à Bombay. — Ann. Soc. Géol. Belg., 90, pp. B103-B117.
PIRLET, H., 1967b: Nouvelle interprétation des carrieres de Richelle; le Viséen de Visé. — Ann. Soc. Géol. Belg., 90, pp. B299-B328.
PIRLET, H., 1968: La tranchée de Berneau a Visé et la sedimentation Dévono-Carbonifère dans la région de Visé. — Ann. Soc. Géol. Belg., 90, pp. B751-B765.
PIRLET, H., 1970: Compte-rendu de l'excursion de la Société Géologique de Belgique tenue dans la region de Visé le 19 octobre 1968. — Ann. Soc. Géol. Belg., 92, pp. 455-466.
PLISNIER, M., 1931: Observations sur la tectonique des terrains primaires de la rive droite de la Meuse à Visé. — Ann. Soc. Géol. Belg., LIV, pp. B207-B213.
RAMSBOTTOM, W. H. C., 1969: The Namurian of Britain. — C. R. 6e Congr. Intern. Strat. Géol. Carb., I, pp. 219-232.
ROMEIN, B. J., 1962: On the type locality of the Maastrichtian (DUMONT 1849), the upper boundary of that stage and on the transgression of a Maastrichtian s.l. in Southern Limburg. — Med. Geol. Sticht., N.S., 15, pp. 77-84.
ROUHART, A., 1973: Palynologie quantitative à la limite Frasnien-Famennien. — Univ. Liège (unpublished thesis).
SADEE, C. P. M., 1975: An interpretation of South-Limburg subsurface temperature data. — Geologie en Mijnbouw, 54, pp. 184-194.
SAX, H. G. J., 1946: De tectoniek van het Carboon in het Zuid-Limburgse mijngebied. — Med. Geol. Sticht., Ser. C-I-1-No. 3, 77 pp.
STAINIER, X., 1941: Le Houiller inférieur du bassin de Liège. — Ann. Soc. Géol. Belg., LXIV, pp. B93-B159.
STOCKMANS, F. & Y. WILLIERE, 1960: Hystrichosphères du Dévonien belge (sondage de l'asile d'aliénés à Tournai). — Senck. Leth., 41, pp. 1-11.
STOCKMANS, F. & WILLIÈRE, 1962a: Hystrichosphères du Dévonien belge (sondage de l'asile d'aliénés à Tournai). — Bull. Soc. belge Géol. Pal. Hydr., LXXI, pp. 41-77.
STOCKMANS, F. & Y. WILLIERE, 1962b: Hystrichosphères du Dévonien belge (sondage de Wépion). — Bull. Soc. belge Géol. Pal. Hydr., LXXI, pp. 83-104.
STOCKMANS, F. & Y. WILLIÈRE, 1969: Acritarches du Famennien inférieur. — Mém. Acad. Roy. Belg., Cl. Sc., 38, pp. 1-63.
STOCKMANS, F. & Y. WILLIERE, 1974: Acritarches de la "tranchée de Senzeille" (Frasnien supérieur et Famennien inférieur). — Mém. Acad. Roy. Belg., Cl. Sc., 61, pp. 1-79.
STOCKMANS, F. & Y. WILLIERE, 1975: Sondages No 113 (Neerheide) et No 117 (De Hoeven) à Neeroeteren. — Serv. Géol. Belg., Prof. Paper, 1975-11, 54 pp.
STREEL, M., 1965: Etude palynologique du Dévonien du sondage de Booischot (Belgique). Note préliminaire. — Bull. Soc. belge Géol. Pal. Hydr., LXXIII, pp. 172-190.
TSIEN, H. H., 1974; Paleoecology of middle Devonian and Frasnian in Belgium. — Intern. Symp. Belg. Micropal. Limits, 12, 53 pp.
WATERSCHOOT VAN DER GRACHT, W. A. J. M. VAN, 1909: The deeper geology of the Netherlands and adjacent regions, with special reference to the latest borings in the Netherlands, Belgium and Westphalia. — Mem. Government Inst. Geol. Expl. Netherlands, 2. 437 pp.
WATERSCHOOT VAN DE GRACHT, W. A. J. M. VAN, 1912: De huidige stand der rijksopsporingen naar delfstoffen, voornamelijk de aangevangen onderzoekingen in westelijk Noord-Brabant en Zeeland. — Verh. Geol. Mijnb. Gen., Geol. Ser., I, pp. 1-30.
WATERSCHOOT VAN DER GRACHT, W. A. J. M. VAN, 1918: Eindverslag van de dienst der Rijksopsporingen van Delfstoffen in Nederland 1903-1916, 664 pp.
WATERSCHOOT VAN DER GRACHT, W. A. J. M., VAN, 1938: Lateral movements on the alpine foreland of northwestern Europe. — Proc. Kon. Ned. Akad. Wetenschappen, XLI, 22 pp.
WIJHE, D. H. VAN & M. J. M. BLESS, 1974: The Westphalian of the Netherlands with special references to miospores assemblages. — Geologie en Mijnbouw, 53, pp. 295-326.
WIJKERSLOOTH, P. DE, 1949: Die Blei-Zink-Formation Süd-Limburgs (Holland) und ihr mikroskopisches Bild. — Med. Geol. Sticht., N.S., 3, pp. 83-102.

Plates

PLATE 1

1 Compression-solution structure in karstified Frasnian limestone containing *Amphipora* sp. Natural size. Coll. Geol. Bureau Heerlen. Outcrop along footpath between "M"-"N" Quarries North of Richelle.

2 Breccia of V1a age from lithological unit "f" of PIRLET (1967a) of La Folie Quarry (sample 4 of R. CONIL). This breccia has yielded foraminifers characteristic of the V1a, conodonts characteristic of Tn3-V1a and reworked conodonts of Frasnian age. Natural size Coll. Geol. Bureau Heerlen.

1

2

PLATE 2

Plates 2-4 display some of the marker goniatite species for the Namurian around the Brabant Massif. The specimens have been collected from outcrops and boreholes in the Dinant-Namur and Campine-Brabant Basins.

1 *Cravenoceras edalensis* BISAT
Outcrop 153W-310 in Dinant-Namur Basin; Coll. Serv. Géol. Belgique.
X 7.

2 *Homoceras beyrichianum* (DE KONINCK)
Outcrop 122E-355 in Dinant-Namur Basin; Coll. Serv. Géol. Belgique.
X 7.

3 *Homoceratoides divaricatus* (HIND)
Outcrop 122W-256 in Dinant-Namur Basin; Coll. Serv. Géol. Belgique.
X 3.

4 *Reticuloceras metabiligue* WRIGHT
17E-225 (= Turnhout) Borehole, 1805.5 m, in Campine-Brabant Basin; Coll. Serv. Géol. Belgique.
X 2.

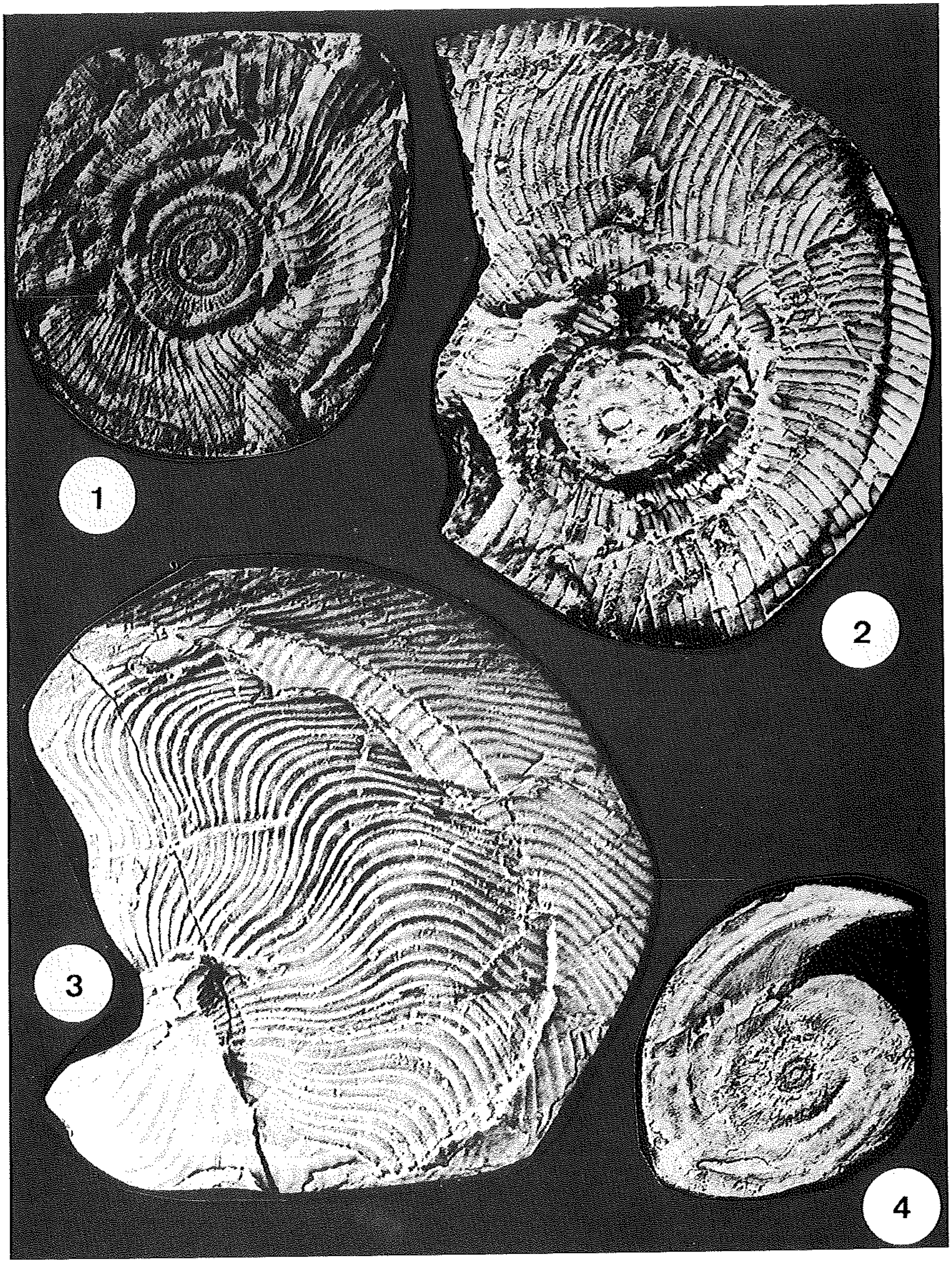


PLATE 3

1 *Reticuloceras todmordenense* BISAT & HUDSON
Outcrop 122W-256 in Dinant-Namur Basin; Coll. Serv. Géol. Belgique.
X 3.

2 *Reticuloceras paucicrenulatum* BISAT & HUDSON
Outcrop 122E-356 in Dinant-Namur Basin; Coll. Serv. Géol. Belgique.
X 3.

3 *Reticuloceras bilingue* BISAT
LIII Borehole, 560.5 m, area East of Brabant Massif; Coll. Geol. Bureau Heerlen.
X 3.

4 *Gastrioceras cumbriense* BISAT
Outcrop 122E-342 in Dinant-Namur Basin; Coll. Serv. Géol. Belgique.
X 5.

5 *Reticuloceras circumplicatile* (FOORD)
Outcrop 122E-356 in Dinant-Namur Basin; Coll. Serv. Géol. Belgique.
X 5.

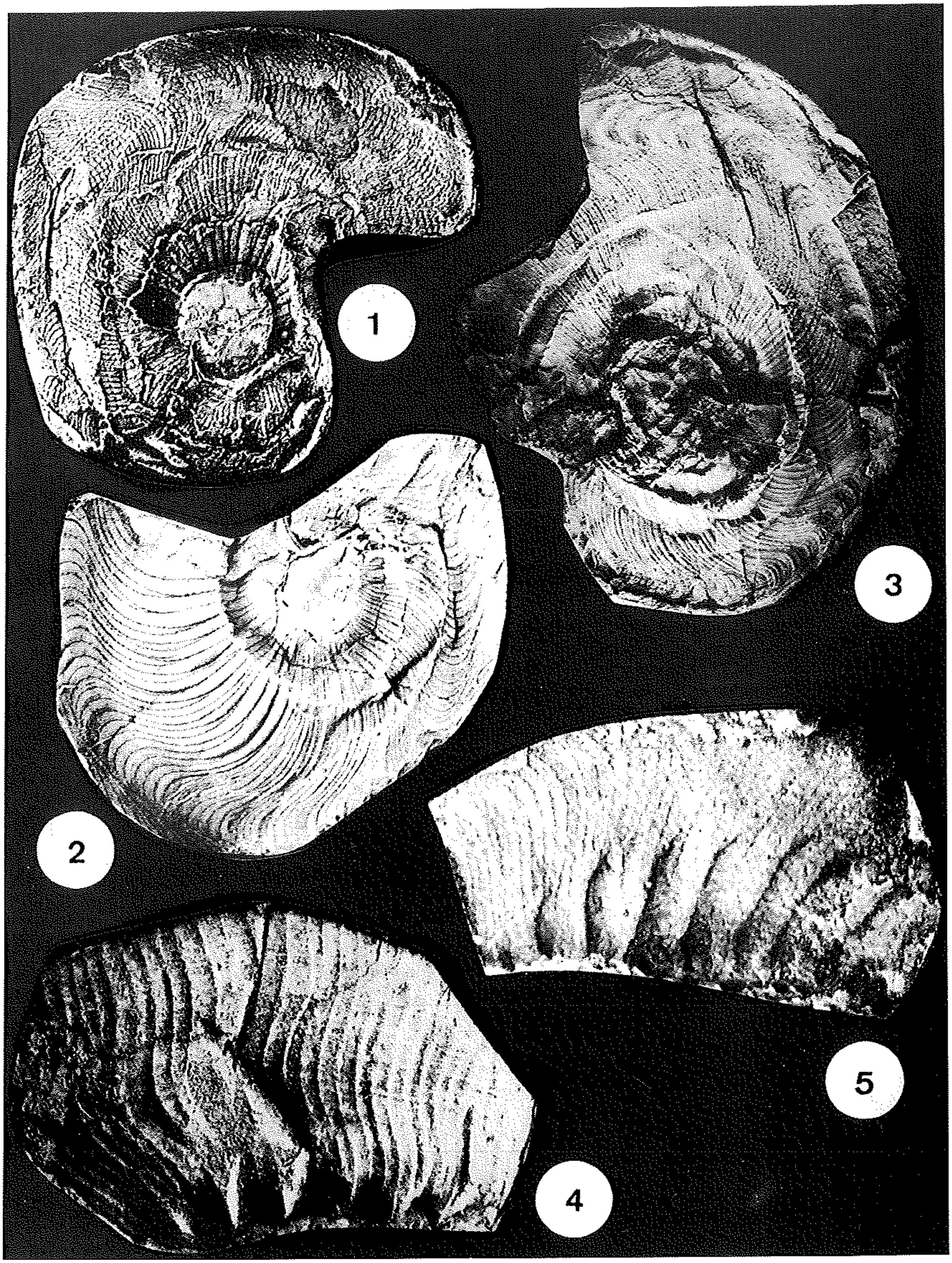

1
3
2
5
4

PLATE 4

1 *Gastrioceras crenulatum* BISAT
110 Borehole, 108-110 m, area East of Brabant Massif; Coll. Geol. Bureau Heerlen.
X 2.

2 *Gastrioceras cancellatum* BISAT
107 Borehole, 791 m, area East of Brabant Massif; Coll. Geol. Bureau Heerlen.
X 3.

3 *Reticuloceras superbilingue* BISAT
LIII Borehole, 472 m, area East of Brabant Massif; Coll. Geol. Bureau Heerlen.
X 3.

4 *Gastrioceras demaneti* PATTEISKY
115 Borehole, 232 m, area East of Brabant Massif; Coll. Geol. Bureau Heerlen.
X 3.

5 *Reticuloceras wrighti* HUDSON
135W-376 (= Soiron) Borehole, 1115 m, in Dinant-Namur Basin; Coll. Serv. Géol. Belgique.
X 4.

6 *Reticuloceras* aff. *nodosum* BISAT & HUDSON
LVIII Borehole, 454 m, area East of Brabant Massif; Coll. Geol. Bureau Heerlen.
X 3.

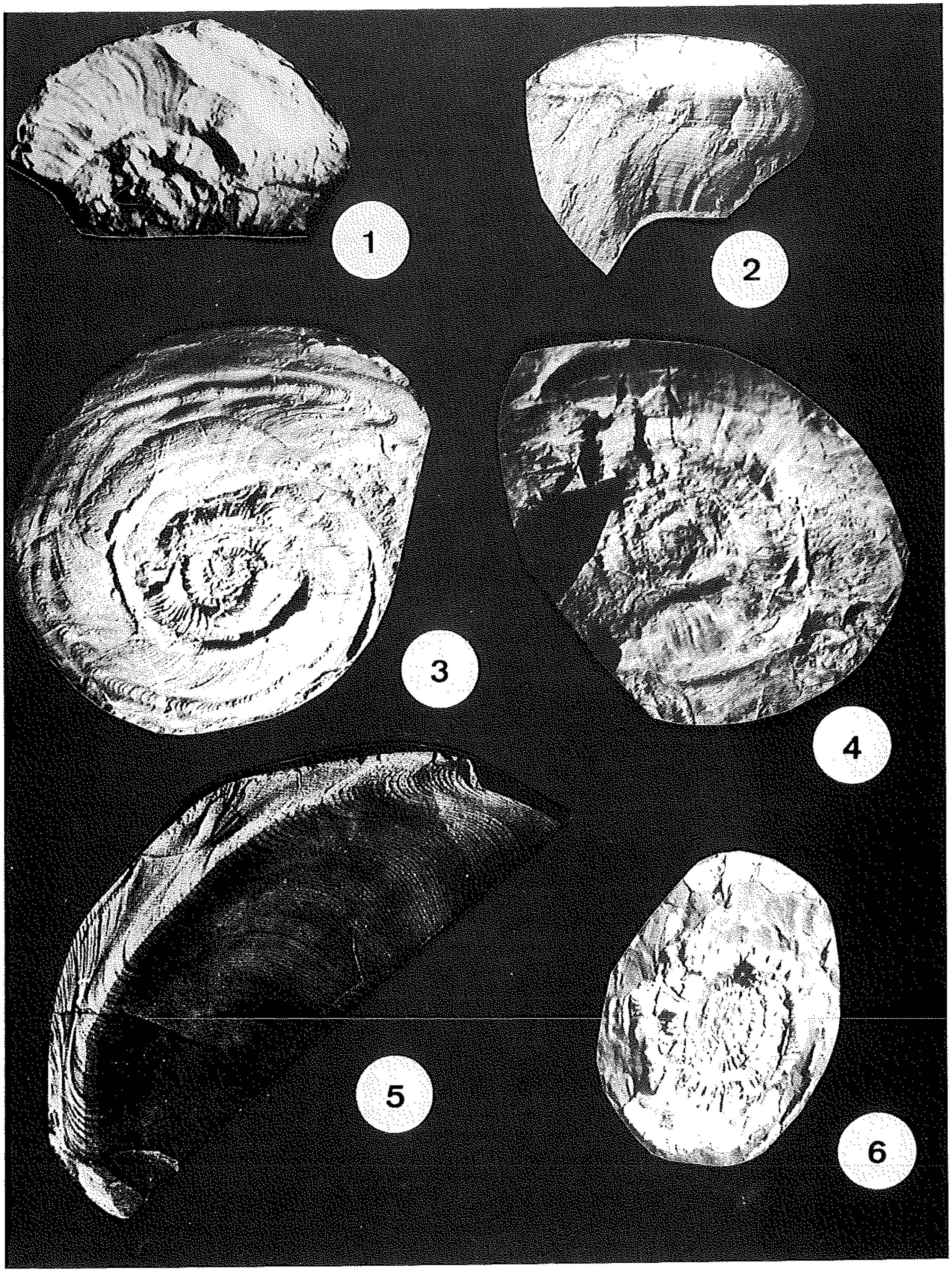

1
2
3
4
5
6

PLATE 5

Plates 5-7 display an assemblage of Upper Visean corals from "F"-"L" Quarries North of Richelle and from the railway cutting West of Berneau. For remarks on the distribution of several of these species, the reader is referred to chapter 6.

1-2	*Dibunophyllum bipartitum* (McCoy) "F"-"L" Quarries North of Richelle, V3by; Coll. A. Salée, sp. 503. 1: Transverse section, X 2. 2: Vertical section, X 2.
3-4	*Dibunophyllum* sp. Railway cutting West of Berneau, V3b, sample 7; Coll. E. Poty, B-7-33. 3: Transverse section, X 2. 4: Vertical section, X 2.
5	*Cyathaxonia cornu* Michelin "K" Quarry North of Richelle, V3a; Coll. E. Poty, Visé-63. Transverse section, X 3.
6-7	*Palaeosmilia murchisoni* Milne-Edwards & Haime Railway cutting West of Berneau, V3; Coll. E. Poty, B-S.L.2. 6: Transverse section, X 2. 7: Vertical section, X 2.
8-9	*Koninckophyllum* sp. "F"-"L" Quarries North of Richelle, V3by; Coll. Instit. Royal Sciences Naturelles Belgique, I.G.2739-1.

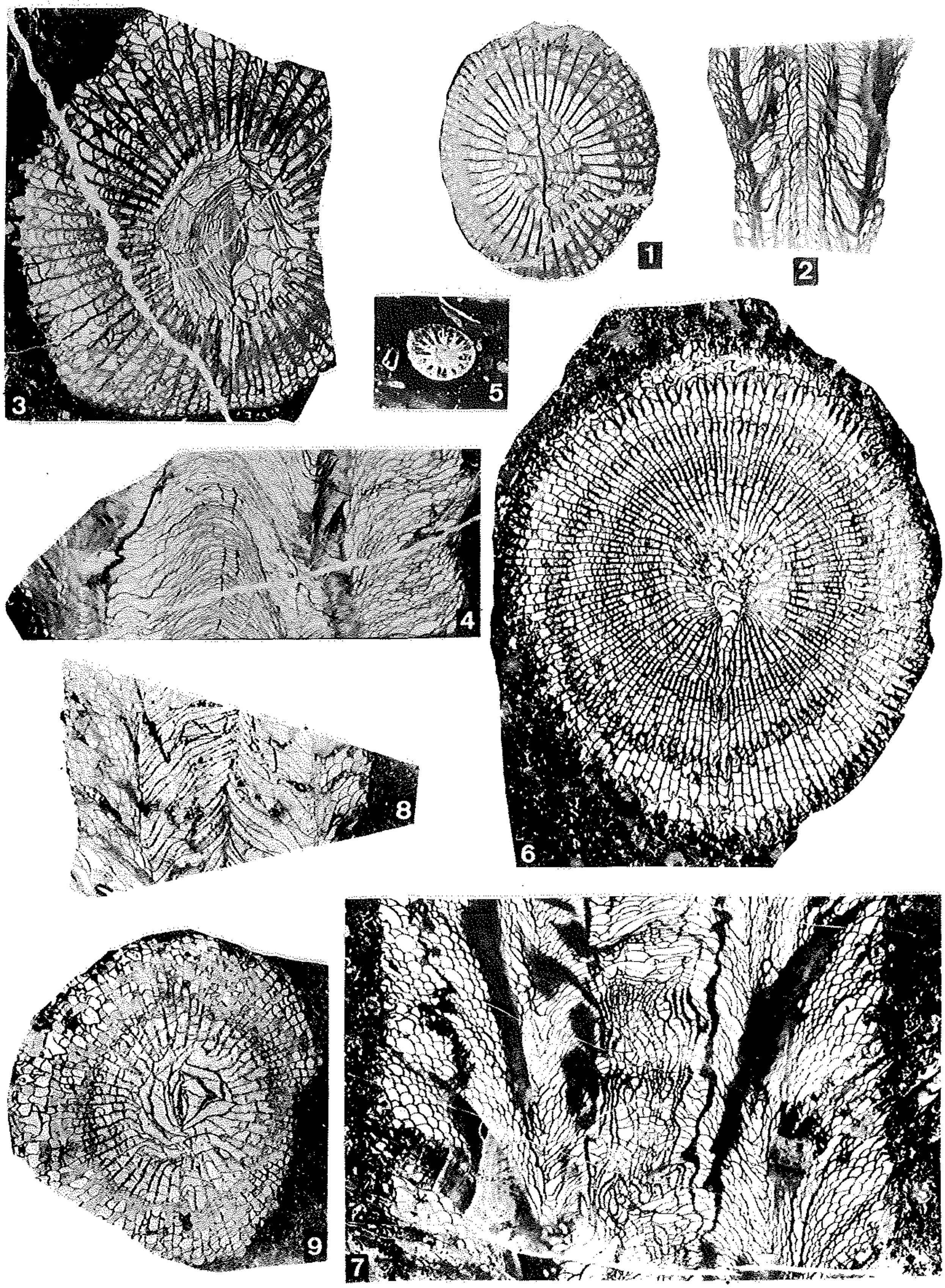

1
2
3
4
5
6
7
8
9

PLATE 6

1 *Lonsdaleia floriformis* (MARTIN)
"F"-"L" Quarries North of Richelle, Upper V3c; Coll. Inst. Royal Sciences Naturelles Belgique.
Transverse section, X 2.

2-3 *Lonsdaleia duplicata* (MARTIN)
"F"-"L" Quarries North of Richelle, V3by; Coll. Instit. Royal Sciences Naturelles Belgique, I.G.3440-3.
2: Transverse section, X 2.
3: Vertical section, X 2.

4 *Amygdalophyllum* sp.
Railway cutting West of Berneau, V3a, sample 3; Coll. E. POTY, B-3-3.
Transverse section, X 4.

5 cf. *Carruthersella garwoodi* SALÉE
Railway cutting West of Berneau, V3a, sample 3; Coll. E. POTY, B-2-1.
Transverse section, X 4.

6 cf. *Pareynia splendens* SEMENOFF
"F"-"L" Quarries North of Richelle, Lower V3c; Coll. E. POTY, Visé-41.
Transverse section, X 1.5.

7-8 *Axophyllum* sp.
Railway cutting West of Berneau, V3b, sample 7; Coll. E. POTY, B-7-1.
7: Transverse section, X 2.
8: Vertical section, X 2.

9-10 *Aulina furcata* SMITH
"F"-"L" Quarries North of Richelle, Lower V3c; Coll. Inst. Royal Sciences Naturelles Belgique, I.G. 3000-244.
9: Transverse section, X 2.
10: Vertical section, X 2.

11-12 *Aulina amarensis* SEMENOFF
"F"-"L" Quarries North of Richelle, stratigraphic horizon unknown; Coll. E. POTY, Visé 52.
11: Transverse section, X 3.
12: Vertical section, X 3.

13-14 *Rotiphyllum rushianum* VAUGHAN
"F"-"L" Quarries North of Richelle, V3by-V3c; Coll. E. POTY, Visé 54.
13: Transverse section, X 3.
14: Vertical section, X 3.

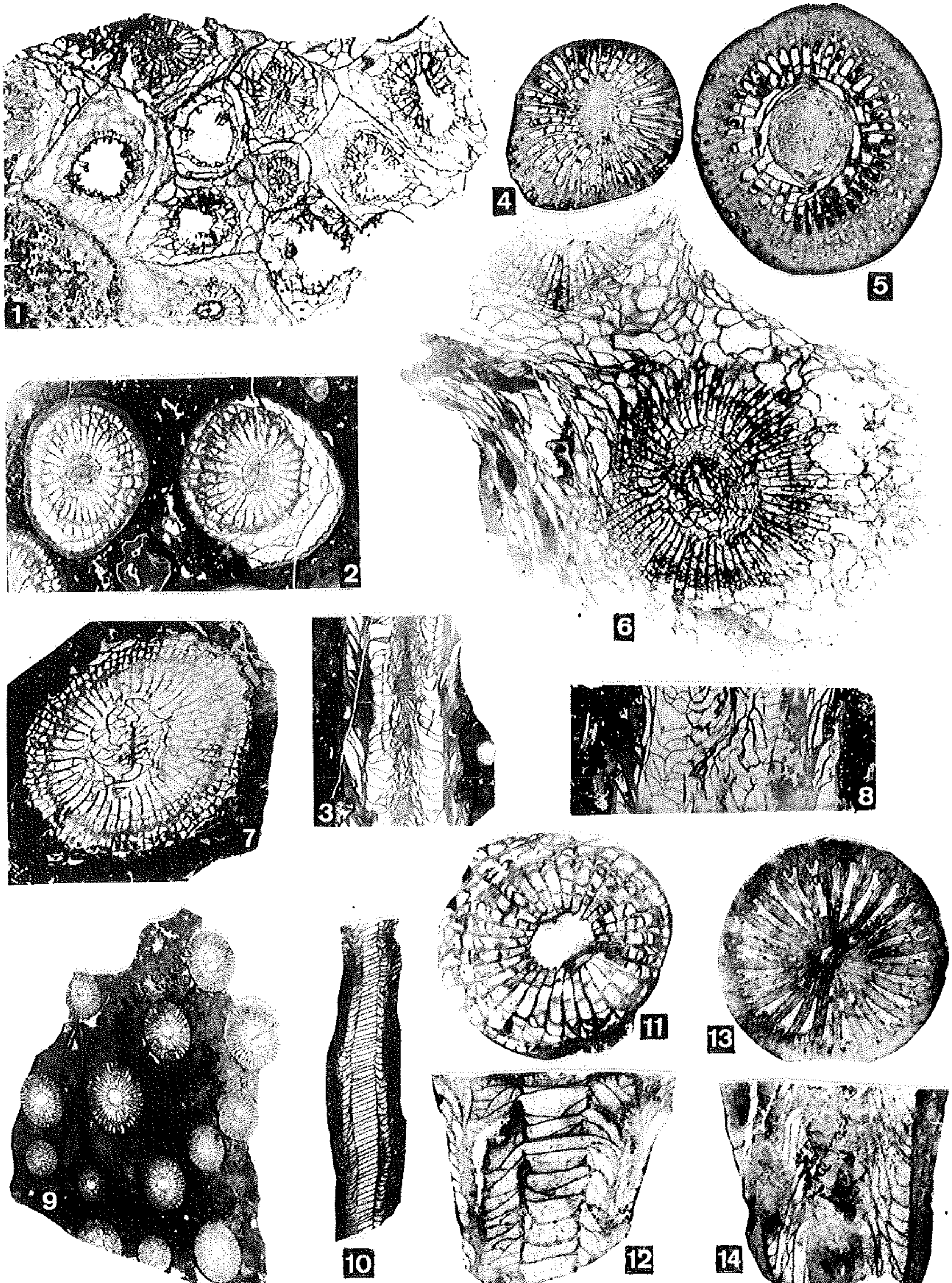

1
2
3
4
5
6
7
8
9
10
11
12
13
14

PLATE 7

1 *Lithostrotion maccoyanum* MILNE-EDWARDS & HAIME
"F"-"L" Quarries North of Richelle, V3by; Coll. E. POTY, Visé 47.
Transverse section, X 2.

2-3 *Lithostrotion decipiens* MCCOY
"F"-"L" Quarries North of Richelle, V3by; Coll. E. POTY.
2: Visé-49; Transverse section, X 2.
3: Visé-48; Transverse section, X 2.

4-5 *Lithostrotion vorticale* PARKINSON
"F"-"L" Quarries North of Richelle, V3by; Coll. Instit. Royal Sciences Naturelles Belgique.
4: I.G.3440-4a; Transverse section, X 2.
5: I.G.3440-4b; Vertical section, X 2.

6-7 *Lithostrotion aranea* (MCCOY)
Railway cutting West of Berneau, V3b, sample 7; Coll. E. POTY.
6: B-7-34; Vertical section, X 2.
7: B-7-17d; Transverse section, X 2.

8-9 *Siphonodendron scoticum* (HILL)
"F"-"L" Quarries North of Richelle, V3by; Coll. E. POTY.
8: Visé-46a; Transverse section, X 2.
9: Visé-46c; Vertical section, X 2.

10 *Siphonodendron pauciradiale* (MCCOY)
Railway cutting West of Berneau, V3b, sample 6; Coll. E. POTY, B-6-3d.
Transverse and vertical sections, X 2.

11 *Siphonodendron* sp.
Railway cutting West of Berneau, V3b, sample 7; Coll. E. POTY, B-7-35.
Transverse section, X 2.

12 *Diphyphyllum furcatum* (THOMSON)
"F"-"L" Quarries North of Richelle, V3by; Coll. E. POTY, Visé-67.
Transverse section, X 2.

13 *Diphyphylum* aff. *lateseptatum* MCCOY
"F"-"L" Quarries North of Richelle, V3by; Coll. Instit. Royal Sciences Naturelles Belgique, I.G.9878.
Transverse section, X 2.

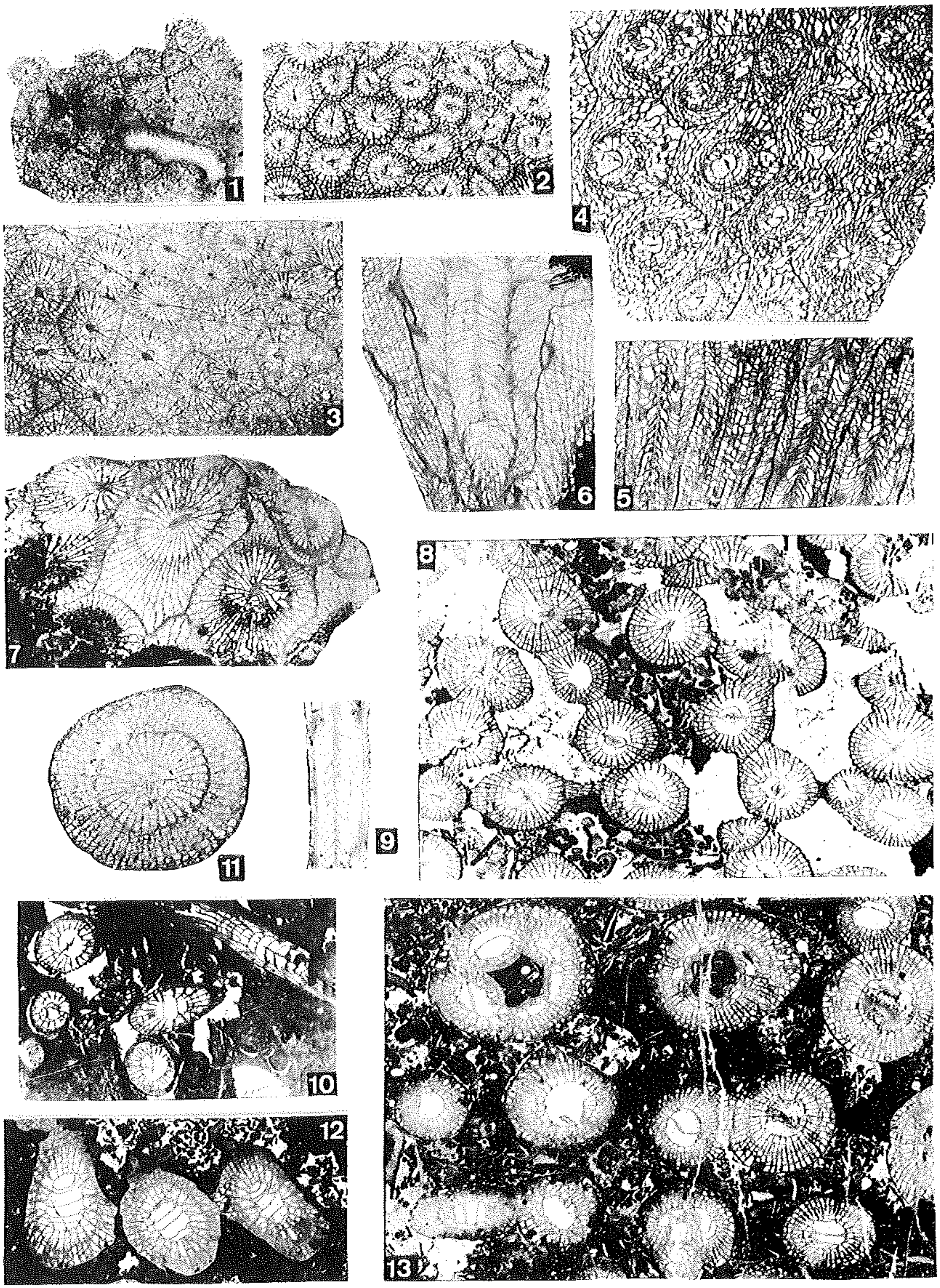

1
2
3
4
5
6
7
8
9
10
11
12
13

PLATE 8

Plates 8-10 display Tournaisian and Visean foraminifer assemblages from the Visé area. For remarks and systematic descriptions of some of these species, the reader is referred to chapter 6. Specimens marked RC have been stored with the collections of R. CONIL, Institut de Géologie, Université Catholique de Louvain, B1348 Louvain-La-Neuve. Specimens marked GB have been stored with the collections of the Geologisch Bureau at Heerlen. Numbers between brackets refer to the iconographic card system of the Paleontology Department of the Université Catholique de Louvain.

1-30 Foraminifers from Tn2b-c (upper Foraminifer zone Cf1) of La Folie Quarry. All specimens X 75.

1	cf. TOURNAYELLIDAE Visé 1/11, RC13187 (14190)
2	*Bisphaera* sp. Visé 1/11, RC13187 (14193)
3	*Bisphaera irregularis* BIRINA 1948 Visé 1/11, RC 13226 (14750)
4	*Parathurammina suleimanovi* LIPINA 1949 Visé 1/11, RC13184 (14208)
5	*Chernyshinella glomiformis* LIPINA 1948 Visé 1/15, RC13914 (14897)
6-7	*Septabrunsiina (Septabrunsiina) kingirica* (REITLINGER 1961) Visé 1/15, RC13351. 6: (14757); 7: (14756)
8-9	*Septabrunsiina* sp. 8: Visé 1/11, RC13187 (14186); 9: Visé 1/11, RC13186 (14195)
10-12	*Septabrunsiina (Septabrunsiina) comblaini* CONIL & LYS 1964 10: Visé 1/11, RC13226 (14753); 11: Visé 1/11, RC13187 (14188); 12: Visé 1/11, RC13185 (14215)
13	*Septabrunsiina (Septabrunsiina)* aff. *rudis* (CONIL & LYS 1964) Visé 1/11, RC13227 (14678)
14-15	*Granuliferella* sp. 14: Visé 1/11, RC13187 (14187); 15: Visé 1/11, RC13187 (14192)
16	cf. *Chernyshinella* sp. Visé 1/15, RC13351 (14755)
17	*Septabrunsiina* sp. Visé 1/11, RC13184 (14203)
18	cf. *Palaeospiroplectammina* sp. Visé 1/11, RC13226 (14751)
19-21	*Palaeospiroplectammnia tchernyshinensis* (LIPINA 1948) 19: Visé 1/11, RC13226 (14754); 20: Visé 1/11, RC13184 (14204); 21: Visé 1/11, RC13184 (14202)
22	cf. *Eotextularia* sp. Visé 1/11, RC13185 (14214)
23	*Chernyshinella (Chernyshinella) glebovskayae* (DAIN 1953) Visé 1/11, RC13913 (14950)
24	*Endothyra parakosvensis beruinae* CONIL, subsp. nov. Visé 1/11, RC13184 (14206)
25	cf. *Endothyra parakosvensis nigra* CONIL & LYS 1964 Visé 1/7, RC13344 (14676)
26-27	*Endothyra* sp. 26: Visé 1/11, RC13184 (14205); 27: Visé 1/11, RC13184 (14211)
28	cf. *Septabrunsiina* sp. Visé 1/7, RC13344 (14677)
29	*Endothyra* cf. *rjausakensis* CHERNUSHEVA 1940 Visé 1/11, RC13185 (14213)
30	*Endothyra parakosvensis beruinae* CONIL, subsp. nov. Visé 1/11, RC 13185 (14212b)

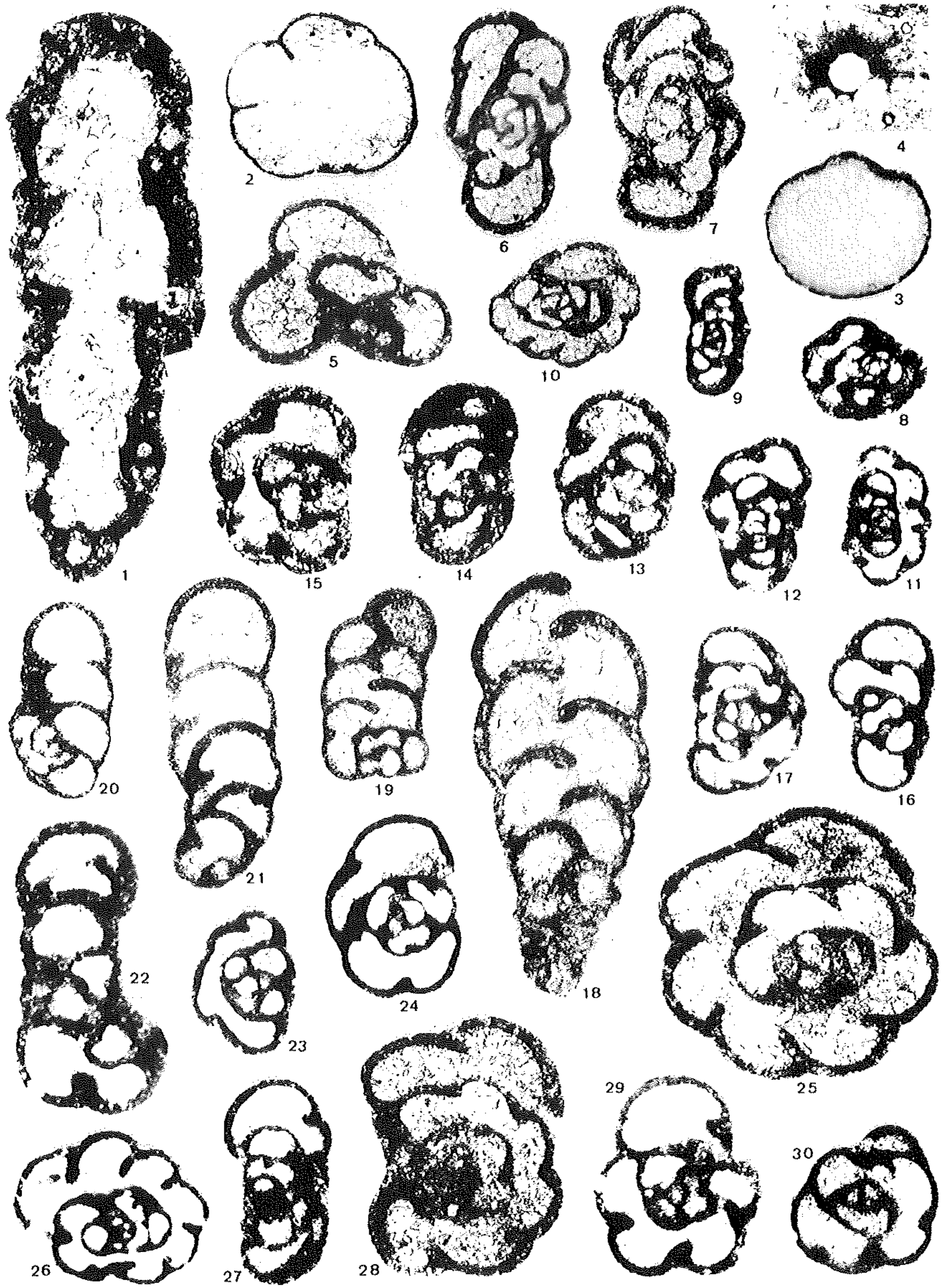

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

PLATE 9

31-38	Foraminifers from Tn2b-c (Upper Foraminifer zone Cf1) of La Folie Quarry. All specimens X 75.
31-36	*Endothyra parakosvensis beruinae* CONIL, subsp. nov. 31: Visé 1/11, RC13185 (14213); 32: Visé 1/11, RC13187 (14189); 33: Holotype, Visé 1/11, RC13187 (14191); 34: Paratype, Visé 1/11, RC13226 (14752); 35: Visé 1/11, RC13187 (14194); 36: Visé 1/11, RC13173 (15148)
37	*Septabrunsiina (Septabrunsiina) comblaini* CONIL & LYS 1964 Visé 1/11, RC13173 (15146)
38	cf. *Palaeospiroplectammina tchernyshinensis globata* LIPINA 1965 Visé 1/11, RC13173 (15147)
39-47	Foraminifers from V1a (Foraminifer zone Cf4α) of La Folie Quarry. All specimens X 75.
39	*Endothyra* sp. Visé 1/40, RC13356 (14745)
40	*Spinoendothyra* cf. *costifera* (LIPINA 1955) Visé 1/40, RC13356 (14747)
41	*Dainella exuberans* (CONIL & LYS 1964) Visé 1/65, RC14009 (15133)
42	*Latiendothyranopsis latispiralis grandis* LIPINA 1955 Visé 1/40, RC14009 (15134)
43	*Endothyra paraukrainica* LIPINA 1955 Visé 1/40, RC13356 (14749)
44	*Paraendothyra cummingsi* (CONIL & LYS 1964) (similar to specimen of fig. 16 in CONIL, AUSTIN, LYS & RHODES 1969) Visé 1/73, RC14011 (15131)
45	cf. *Endothyra* sp. Visé 1/60, RC14006 (15129)
46	*Conilites kimpei* CONIL, sp. nov. Holotype, Visé 1/70, RC 14010 (15132)
47	*Endothyra* sp. Visé 1/40, RC13356 (14746)


31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

PLATE 10

48-52 Foraminifers from V1a (Foraminifer zone Cf4α) of La Folie Quarry. All specimens X 75.

48 *Septabrunsiina (Spinobrunsiina)* sp.
Visé 1/39, GB31 (15165)
49 cf. *Endospiroplectammina* sp.
Visé 1/40, RC13356 (14748)
50 *Spinoendothyra costifera* (LIPINA 1955)
Visé 1/4, GB25 (15162)
51 *Endothyra* sp.
Visé 1/4, GB25 (15163)
52 *Quasiendothyra* sp.
Visé 1/4, RC14005 (15130)

53-55 Foraminifers from V1a (Foraminifer zone Cf4α) of "L" Quarry North of Richelle, lithological unit "g" of PIRLET (1967b). All specimens X 75.

53-54 *Quasiendothyra rotai* DAIN 1958
53: Dalhem 1, RC 13166 (15136); 54: Dalhem 1, RC13165 (15137)
55 *Eotextularia diversa* (N. TCHERNYSHEVA 1948)
Dalhem 1, RC13163 (15135)

56-58 Foraminifers from V2a-V3? (Foraminifer zones Cf4α-Cf6?) of the railway cutting West of Berneau, lithological unit "a" of PIRLET (1968).

56 *Endothyra* sp.
Visé 2/50, RC13403 (15064), X 75
57 *Quasiendothyra(?)* cf. *nibelis* DURKINA 1959
Visé 2/50, RC13402 (15066), X 75
58 *Archaediscus (Glomodiscus) miloni* (PELHATE 1967)
Visé 2/50, RC13402 (15068), X 140

59-69 Foraminifers from V3b-V3c? (Foraminifer zone Cf6) of the railway cutting West of Berneau, lithological units "b"-"i" of PIRLET (1968).

59 *Quasiendothyra(?)* ex. gr. *nibelis* DURKINA 1959
Visé 2/58, RC13412 (15059), X 75
60-61 cf. *Endothyra* sp. ("dainellid" forms)
60: Visé 2/69, RC13414 (15052), X 75; 61: Visé 2/58, RC13412 (15060), X 75
62 cf. *Endothyra* sp.
Visé 2/55, RC13408 (15062), X 75
63 *Endothyra cuneisepta* (CONIL & LYS 1964)
Visé 2/61, RC13415 (15055), X 75
64 *Archaediscus (Archaediscus) grandiculus* SCHLIKOVA 1951 stage *angulatus*
Visé 2/52, RC13405 (15071), X 140
65 *Archaediscus (Archaediscus)* aff. *subangustus* CONIL & LYS 1964
Visé 2/51, RC13404 (15069), X 140
66 *Archaediscus (Archaediscus)* sp. *1* ex gr. *grandiculus* SCHLIKOVA 1951
Visé 2/58, RC13412 (15070), X 140
67 *Planoendothyra* sp.
Visé 2/59, RC13413 (15057), X 75
68 *Quasiendothyra(?) nibelis* DURKINA 1959
Visé 2/51, RC13404 (15063), X 75
69 *Planoendothyra* sp.
Visé 2/59, RC13413 (15058), X 75

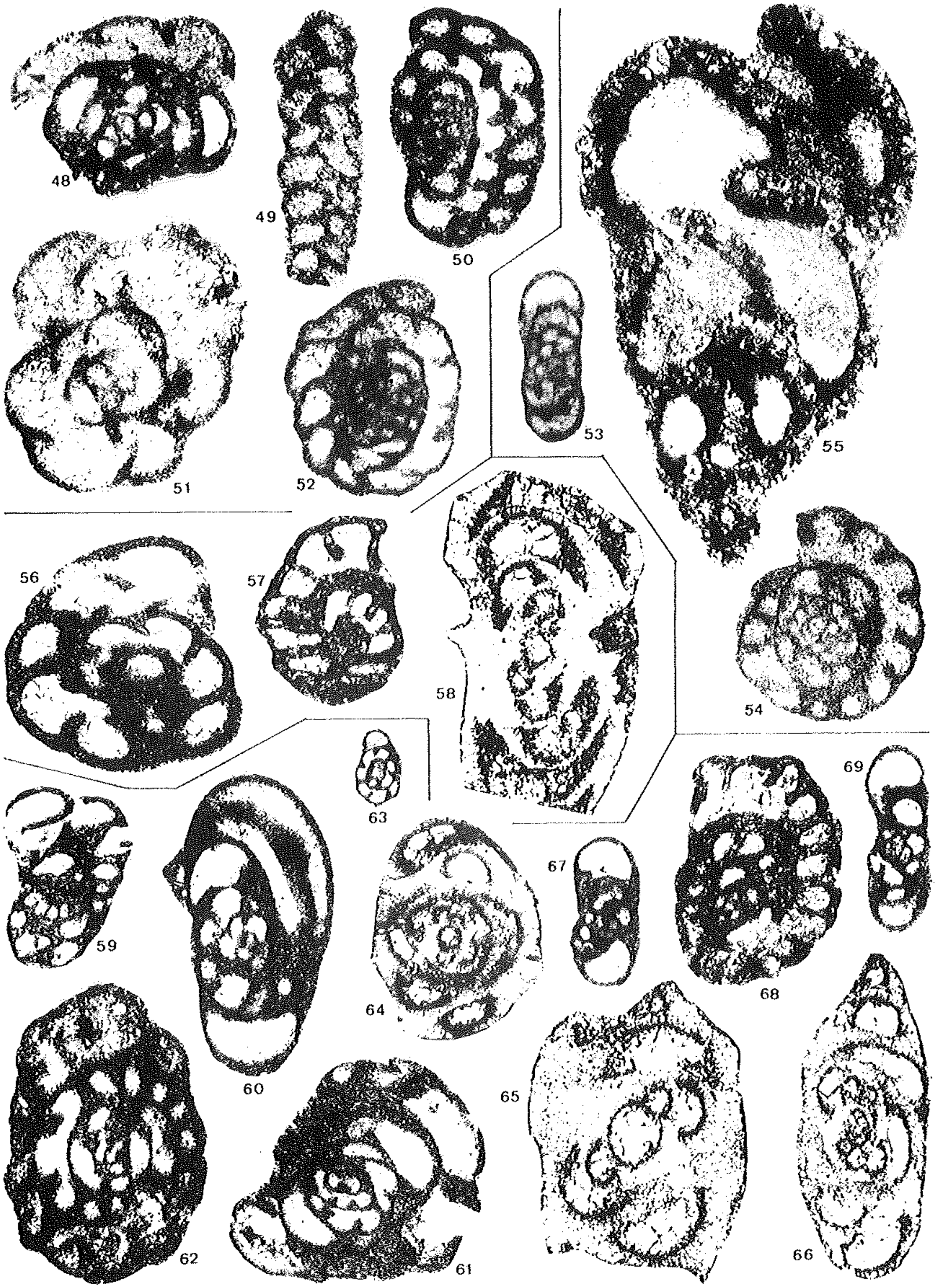

48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69

PLATE 11

Plates 11-12 display conodonts from the Upper Frasnian to Lower Visean of La Folie Quarry. All specimens X 20. All specimens have been stored with the paleontological collections of the Service Géologique de Belgique.

1-4	*Ancyrognathus asymetricus* (ULRICH & BASSLER) 1: oral view, specimens 30/3 (platform broken) 2: oral view, specimen 39/3 3: oral view, specimen 39/1 4: oral view, specimen 39/2 (platform broken)
5-10	*Ancyrodella curvata* (BRANSON & MEHL) 5: aboral view, specimen 30/2 6: oral view, specimen 35/18 (juvenile) 7: oral view, specimen 35/20 8: oral view, specimen 35/21 9: oral view, specimen 35/23 (free blade broken) 10: oral view, specimen 34/20
11-14, 17-19	*Palmatolepis subrecta* MILLER & YOUNGQUIST 11: oral view, specimen 35/30 12: oral view, specimen 39/17 13: oral view, specimen 33/11 14: oral view, specimen 33/12 17: oral view, specimen 39/16 18: oral view, specimen 39/24 19: oral view, specimen 39/19
15, 20, 21, 23	*Palmatolepis subrecta* MILLER & YOUNGQUIST tendency to *P. gigas* 15: oral view, specimen 35/28 20: oral view, specimen 34/14 21: oral view, specimen 35/29 23: oral view, specimen 34/19
16, 22, 24	*Palmatolepis gigas* MILLER & YOUNGQUIST 16: oral view, specimen 35/13 22: oral view, specimen 30/6 24: oral view, specimen 39/21

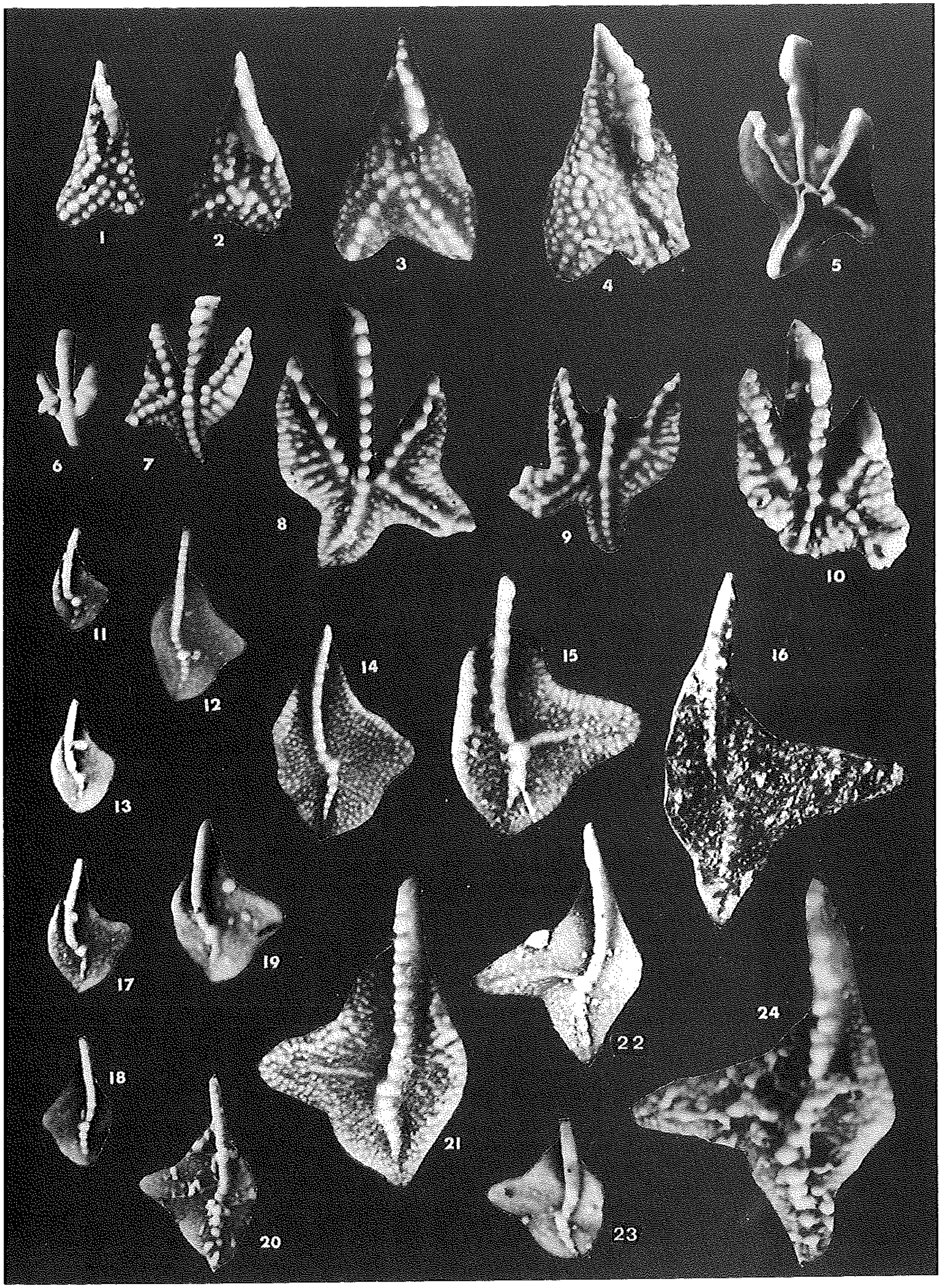
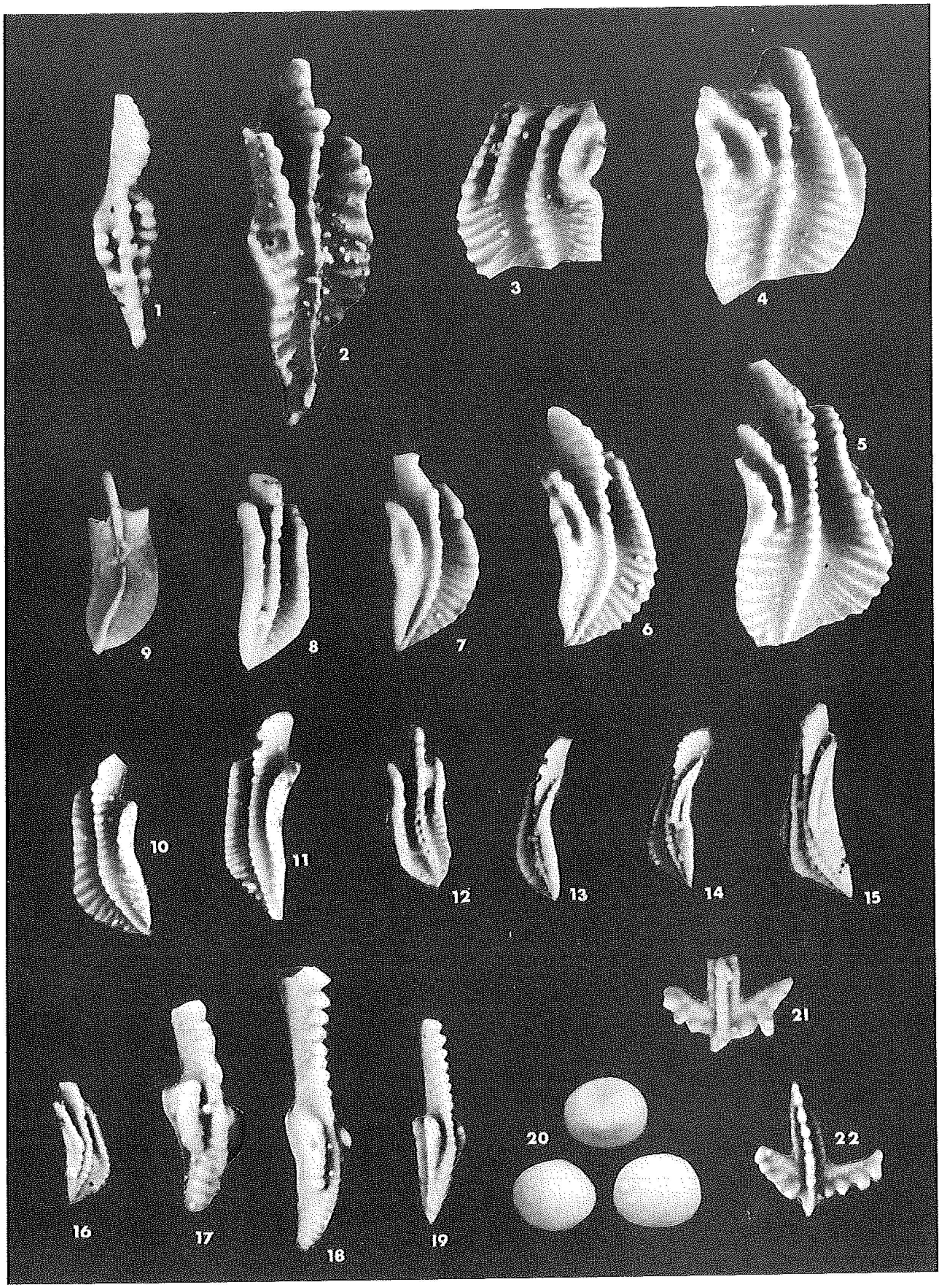

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

PLATE 12

1	*Pseudopolygnathus dentilineatus* BRANSON Oral view, specimen 12/25
2-7	*Polygnathus distortus* BRANSON & MEHL 2: oral view, specimen 15/6 3: oral view, specimen 12/20 (platform broken) 4: oral view, specimen 12/23 (platform broken) 5: oral view, specimen 12/21 6: oral view, specimen 12/18 7: oral view, specimen 12/26
8-12	*Polygnathus inornatus* BRANSON 8: oral view, specimen 13/17 9: aboral view, specimen 12/24 10:oral view, specimen 12/22 11: oral view, specimen 12/19 12: oral view, specimen 37/13
13-16	*Siphonodella obsoleta* HASS 13; oral view, specimen 6/11 14: oral view, specimen 6/12 15: oral view, specimen 6/9 16: oral view, specimen 6/10
17	*Gnathodus semiglaber* BISCHOFF Oral.view, specimen 40/25
18-19	*Gnathodus texanus pseudosemiglaber* THOMPSON 18: oral view, specimen 37/16 19: oral view, specimen 37/15 (tendency to *G. girtyi*)
20	Phosphatic pearls? Sample 37 of R. CONIL
21-22	*Scaliognathus anchoralis* BRANSON & MEHL 21: oral view, specimen 40/26 (specimen broken) 22; oral view, specimen 37/14



1
2
3
4
5
9
8
7
6
10
11
12
13
14
15
21
16
17
18
19
20
22

PLATE 13

Plates 13-16 display an assemblage of acritarchs, miospores, chitinozoa and scolecodonts from the Upper Frasnian-Lower Famennian black shales of La Folie Quarry. Dolomites and limestones immediately overlying these shales have yielded an Upper Frasnian conodont assemblage. There is no absolute proof, however, that these are in place.
All specimens are stored in the palynological collections of the Paleobotany and Paleopalynology Department of the University of Liège.
All specimens of this plate are enlarged X 1000.

1-2	aff. *Acanthotriletes(?) naumovae* STOCKMANS & WILLIÈRE 1962a (*Stellinium*-like broad-based triangular process with a median ridge and heteromorphic terminations which may be simple as in typical *naumovae* or with bifurcated or trifurcated filamentous distal end as in *Vulcanisphaera)* 1: La Folie-3, 4784, 0889; central body 40 u. 2: La Folie-3, 4776, 1244; processes 16 u.
3	*Daillydium quadridactylites* (STOCKMANS & WILLIÈRE 1962b) 1969 La Folie-3, 4783, 2035.
4	*Gorgonisphaeridium piliferum* (STOCKMANS & WILLIÈRE) VANGUESTAINE nov. comb. (= *Baltisphaeridium piliferum* STOCKMANS & WILLIÈRE 1962b, p. 89, pl. 2, fig. 14) La Folie-1, 4787, 1934; scabrate central body with diameter of 33 µ, conical spines and rod-like processes with length of 3 u.
5-6	*Hercyniana sprucegrovensis* (STAPLIN) VANGUESTAINE nov. comb. (= *Multiplicisphaeridium sprucegrovensis* STAPLIN 1961, p. 141, pl. 48, fig. 22; pl. 49, fig. 6; text-fig. 9) *Baltisphaeridium microfurcatum* (DEUNFF 1957) sensu STOCKMANS & WILLIÈRE 1962b and 1969, and *B. paleozoicum* STOCKMANS & WILLIÈRE 1962a, 1969 and 1974 are here regarded as junior synonyms of *H. sprucegrovensis*. 5: La Folie-3, 4783, 0536; smooth central body 6: La Folie-3, 4784,0506; reticulate central body
7	*Dasypilula storea* WICANDER & LOEBLICH 1977 La Folie-3, 4776
8, 11	*Winwaloeusia* sp. 8: La Folie-PIRLET sample, 2265, 2370 11: La Folie-PIRLET sample, 2264, 1186
9, 13	*Stellinium octoaster* (STAPLIN) JARDINÉ et al. 1972 (the species is used her in a very broad sense including all *Stellinium* species of STOCKMANS & WILLIÈRE: *S. belgicum, S. micropolygonale* and *S. vandenbergheni*) 9: La Folie-3, 4783, 1411; 8 processes 13: La Folie-PIRLET sample, 2265, 1617; 6 or 7 processes
10	*Diexallophasis cleopatra* (DEUNFF) VANGUESTAINE nov. comb. (= *Verybachium cleopatra* DEUNFF 1966, p. 42, pl. 2, fig. 15) The possible synonymy of *D. cleopatra* with other species of *Diexallophasis* is not discussed here. La Folie-PIRLET sample, 2264, 2666.
12	*Verybachium* cf. *nasicum* (STOCKMANS & WILLIÈRE 1960) 1962a La Folie-PIRLET sample, 2265, 1938; 6 processes

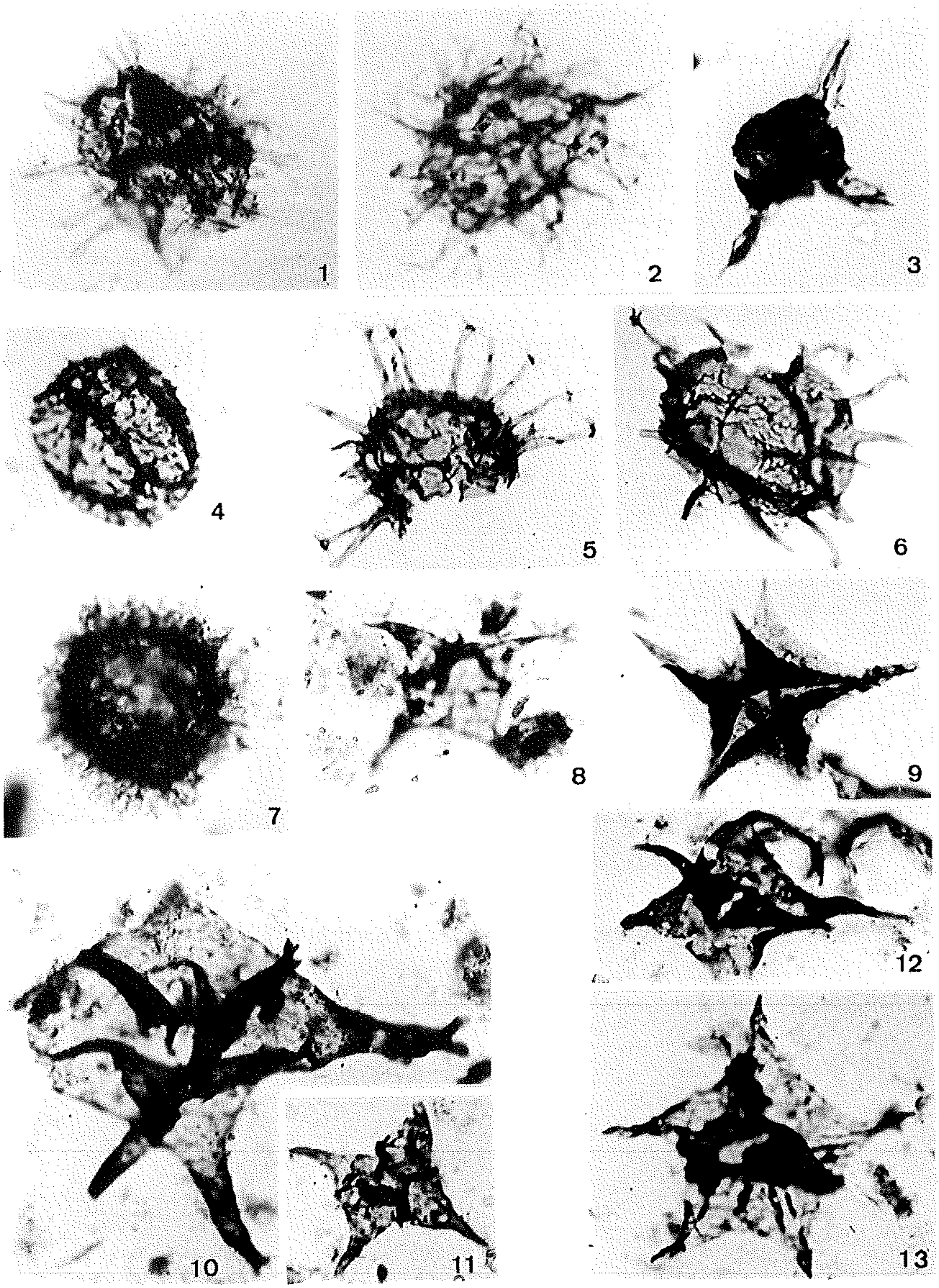

1
2
3
4
5
6
7
8
9
10
11
12
13

PLATE 14

(all specimens X 1000)

1-4	*Villosacapsula* sp. A nov. sp. (= *Micrhystridium stellapilosum* MARTIN 1969 in STOCKMANS & WILLIÈRE 1974) 1-2: La Folie-3, 4784, 1461; triangular convex central body, diameter 22 u, microgranulate to baculate ornamentation, 9 processes with length of 12 U, micro-elements up to 2 u. 3: La Folie-3, 4784, 1307; subtriangular body, 9 processes 4: La Folie-3, 4784, 1236; subquadrate central body, 7 processes, scabrate to finely microgranulate ornamentation on both central body and processes.
5	*Cymatiosphaera* sp. La Folie-3, 4784, 2536; opaque central body.
6, 7	*Micrhystridium tornacense* STOCKMANS & WILLIÈRE 1960 (probably incorrect generic attribution) 6: La Folie-4, 4774, 1668; 5 processes visible 7: La Folie-1, 4787, 1851; 6 processes visible
8-14	*Solisphaeridium astrum* WICANDER 1974 (This species is probably a junior synonym of *Micrhystridium kufferathi* STOCKMANS & WILLIÈRE 1962a and difficult to distinguish from the following species of STOCKMANS & WILLIÈRE: *Micrhystridium heurcki, M. pentagonale, M. stellatum, M. vulgare* and *M. wepionense)* 8: La Folie-3, 4776, 1405; 7 processes visible with hair-like distal tips 9: La Folie-1, 4787, 2583; 8 processes visible 10: La Folie-3, 4783, 1060; 9 processes 11: La Folie-2, 4781, 2438; 10 processes 12: La Folie-1, 4787, 2040; 11 processes visible 13: La Folie-3, 4787, 0975; 12 processes 14: La Folie-4, 4774, 1670; 13 processes visible
15	*Solisphaeridium astrum-spinoglobosum* La Folie-3, 4784, 0403; about 10 processes
16-20	*Solisphaeridium spinoglobosum* (STAPLIN) WICANDER 1974 (some specimens probably have solid rather than hollow processes) 16: La Folie-3, 4784, 2474; 13 processes 17: La Folie-3, 4776, 1716; 14 processes 18: La Folie-3, 4784, 0455; 16 processes 19: La Folie-3, 4776, 1311; about 20 processes 20: La Folie-3, 4783, 1265; about 17 processes

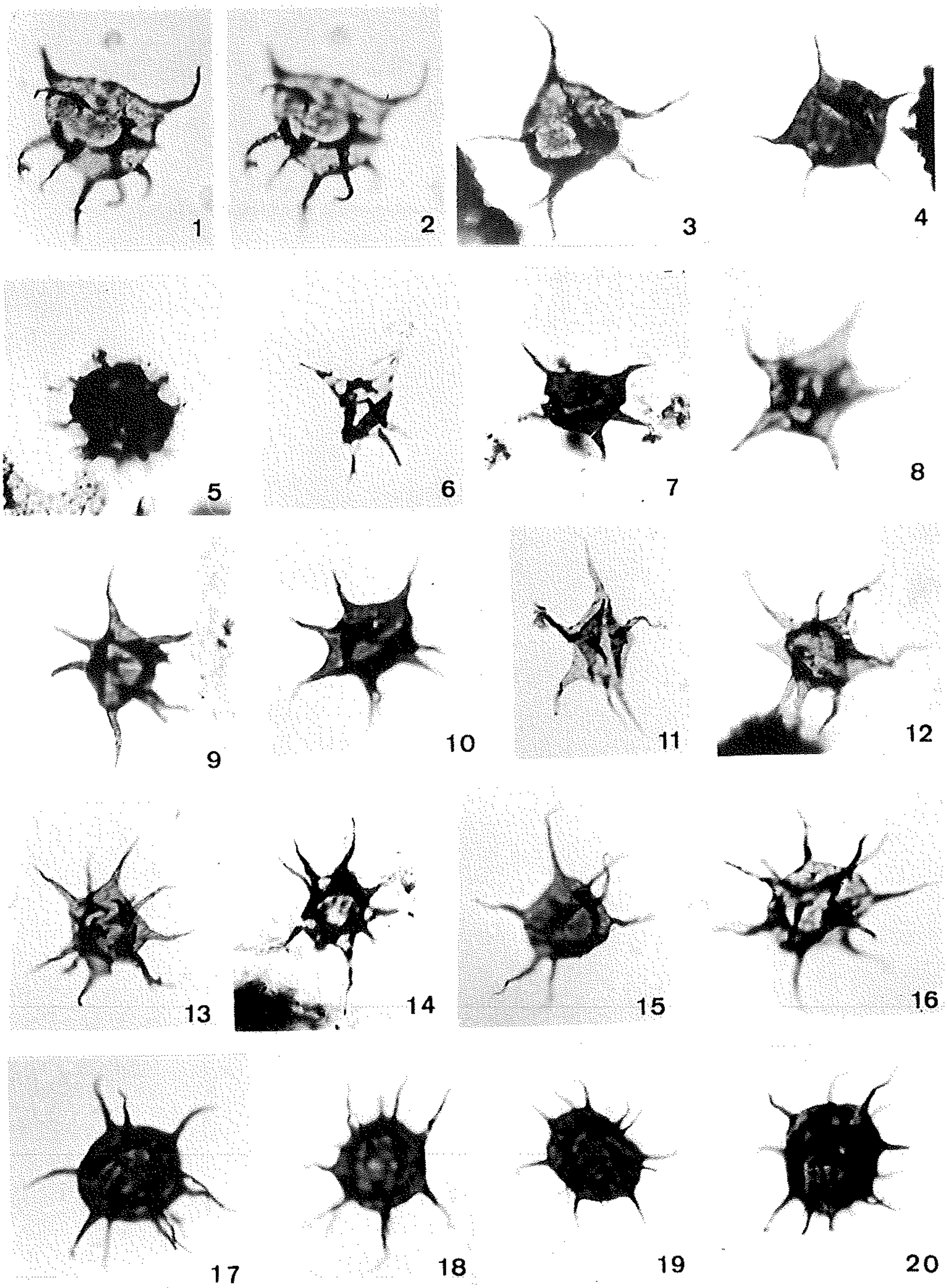

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

PLATE 15

(all specimens x 500)

1	*Retusotriletes planus* DOLBY & NEVES 1969 La Folie-2, 4782, 0415
2	*Samarisporites* sp. cf. *Acanthotriletes hirtus* NAUMOVA 1953 sensu STREEL in BBST 1974 La Folie-1, 4787, 1071
3-4	*Aneurospora greggsii* (MCGREGOR) STREEL in BBST 1974 3: La Folie-3, 4783, 0604 4: La Folie-3, 4784, 1040
5-6	*Angochitina* spp. 5: La Folie-4, 4774, 1801 6: La Folie-4, 4774, 2631
7-15	Scolecodonts 7: La Folie-3, 4784, 1110 8: La Folie-3, 4784, 0776 9: La Folie-3, 4784, 2333 10: La Folie-3, 4784, 1450 11: La Folie-3, 4783, 0921 12: La Folie-3, 4784, 1690 13: La Folie-3, 4784, 1315 14: La Folie-3, 4784, 1289 15: La Folie-3, 4784, 1324

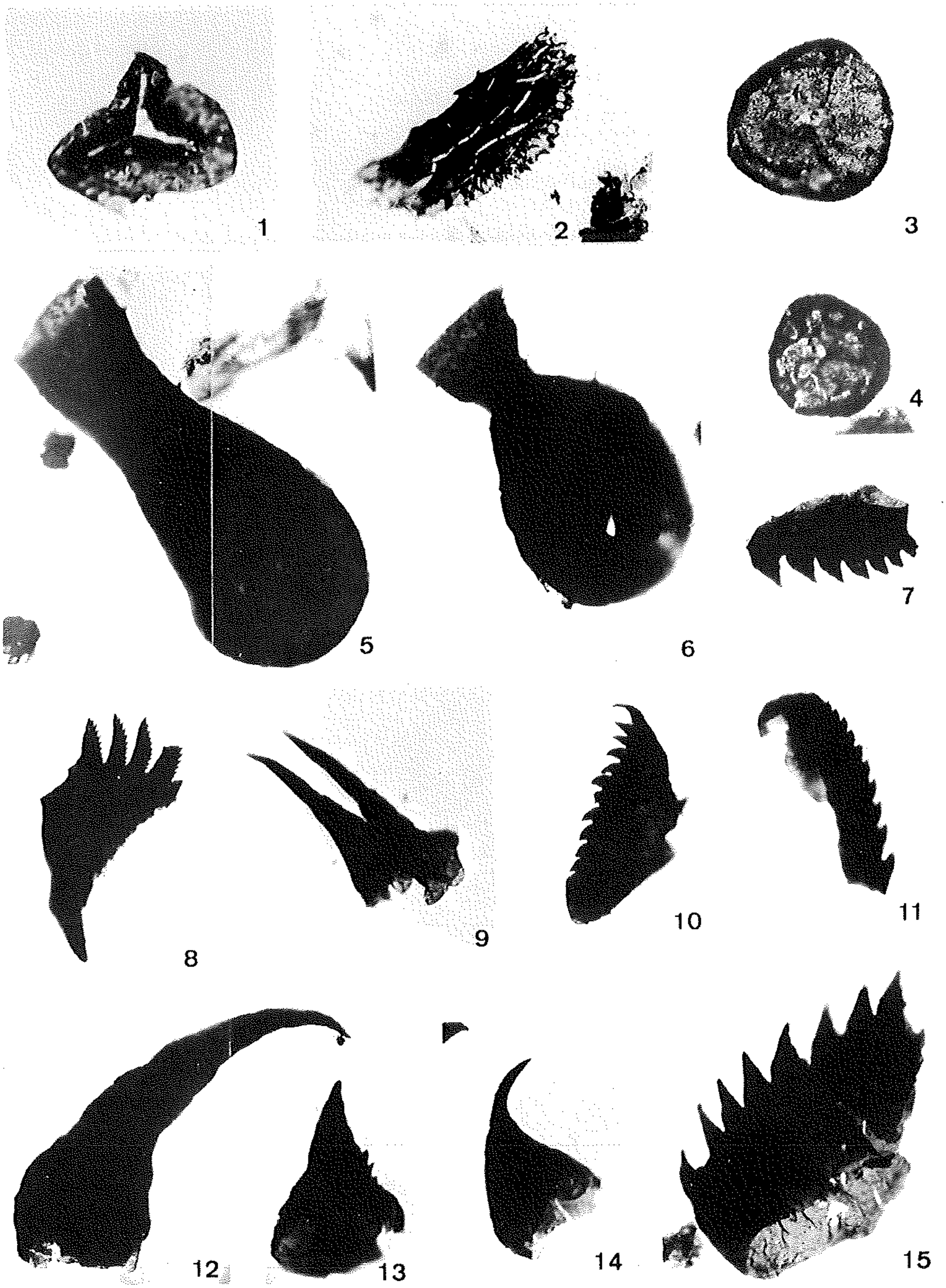
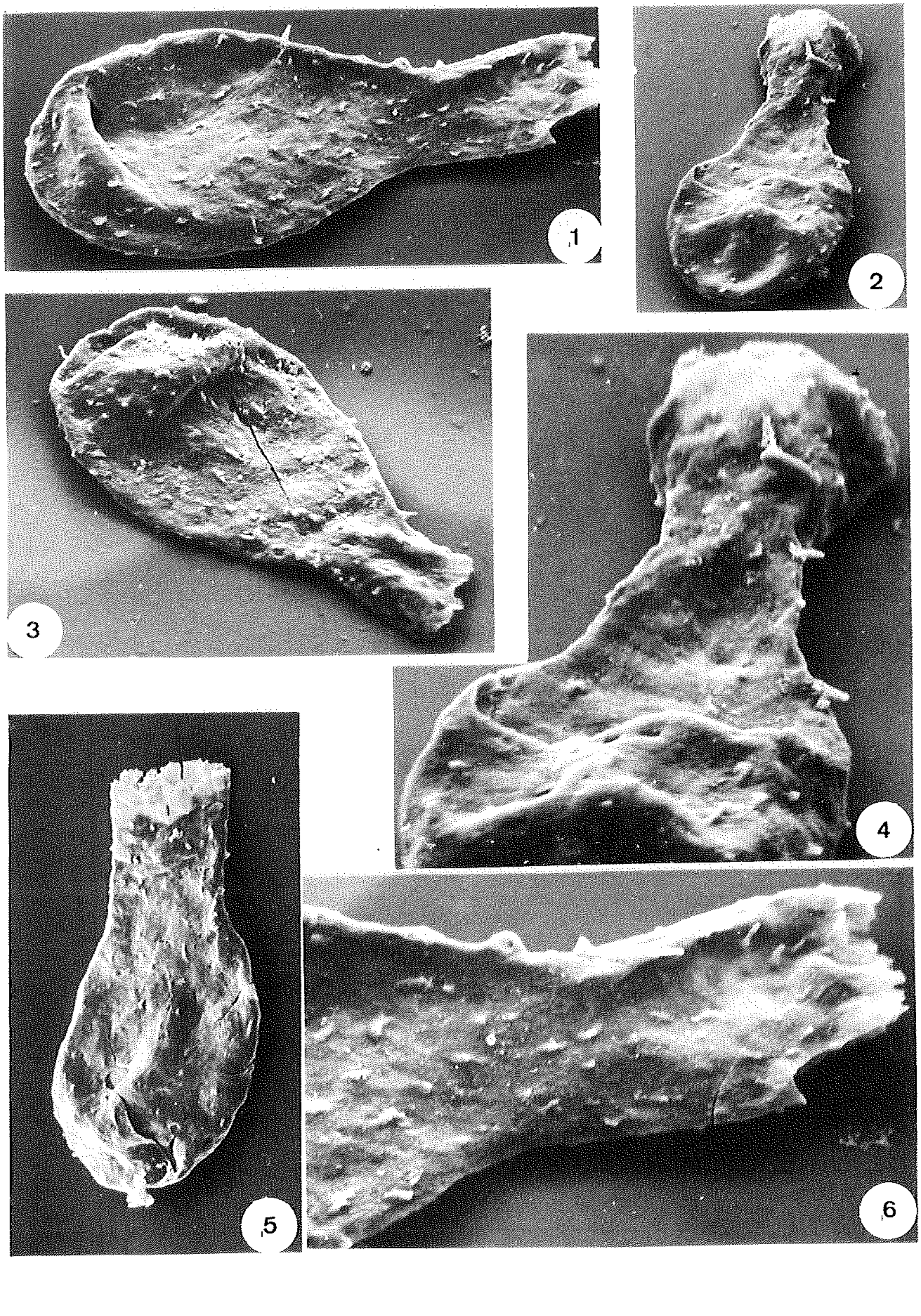

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

PLATE 16

1-6	Chitinozoa specimens from La Folie-4
1, 6	*Angochitina* sp. spines 5-6 u; slightly microgranulate wall surface; same species as plate 15, fig. 15; X 560 and X 1120
3	*Angochitina* sp. spines 6-7 u; slightly microgranulate wall surface; same species as here above; X 600
2, 4	*Angochitina* sp. spines 4-5 u; smooth to microgranulate wall surface; same species as plate 15, fig. 6; X 425 and X 1100
5	?*Angochitina* sp. with conical verrucae or broken spines; smooth wall; X 500


1
2
3
4
5
6