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UPPER CRETACEOUS TO EARLY TERTIARY DEPOSITS (SANTONIAN - PALEOCENE) IN NORTHEASTERN BELGIUM AND SOUTH LIMBURG (THE NETHERLANDS) WITH REFERENCE TO THE CAMPANIAN - MAASTRICHTIAN

by
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FOREWORD

During more than forty years the Cretaceous deposits in the Campine have been regarded as the overburden of the Paleozoic rocks. The thickness of these deposits only increased the costs of the exploration for coal, hydrocarbons, etc. in the underlying Paleozoic. This explains why the geologists contented themselves with summary descriptions of cuttings and showed little interest in a more detailed correlation of the Cretaceous strata. But thanks to the painstaking work of P.J. Felder a new and successful method has been developed that enables us to translate cuttings related to borehole logs into a number of ecozones subdividing the Upper Cretaceous and Early Tertiary sediments. The method consists in characterizing the strata by their bioclast contents, using only bioclasts between 1.0 and 2.4 mm. At first sight the approach seems so obvious that one might question why this has not been done before. For frequently it are bioclasts which are used to characterize carbonates since Folk introduced a workable method to distinguish between different carbonate lithologies. Moreover, the method is so simple that one can learn it within a few weeks of practice. This doesn't detract anything from the merit of P.J. Felder who had to set out and try out this original method during many years. Moreover, the present report is a fine example of what may be achieved by team work in modern geology. This multidisciplinary study on the Upper Cretaceous and Early Tertiary deposits in Northeastern Belgium and Netherlands South Limburg combines the data on bioclast and ostracode assemblages, on planktonic and benthic foraminifera, and on borehole logs. It is hoped that this example will be followed by many others.

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RESUME

Dans le Nord-Est de la Belgique ainsi que dans le Limbourg méridionale des dépots du Crétacé Supérieur et du Tertiaire Inférieur ont été étudiés au moyen de quatre méthodes différentes: associations de bioclastes, associations de foraminifères benthiques et planctoniques, associations d'ostracodes ainsi que par diagraphies pétrophysiques. Une correlation stratigraphique plutôt précise a été établie. Les bioclastes et les associations d'ostracodes suggèrent que la partie inférieure de la Formation de Maastricht (Membre de Valkenburg) forme l'équivalent stratigraphique de la partie supérieure de la Formation de Gulpen (Membre de Lanaye).

De la même façon, la portion supérieure de la Formation de Vaals (caractérisée en partie par les zones à foraminifères A'-moyenne et supérieure) semble être l'équivalent écostratigraphique de la partie inférieure de la Formation de Gulpen (Membre de Zeven Wegen).

En Campine orientale une marne silteuse à sableuse, souvent glauconifère, située entre les Formations de Vaals et de Maastricht (définie dans ce travail comme Pré-Valkenburg strata) semble former l'équivalent écostratigraphique de la Formation de Gulpen. Ces corrélations écostratigraphiques s'accordent avec les corrélations par diagraphies.

Ceci suggère que la distribution verticale et latérale des associations à foraminifères (benthiques et planctoniques) est davantage influencée par des changements des conditions du paléoenvironnement que le fit penser jadis la littérature.

ABSTRACT

Upper Cretaceous and Early Tertiary deposits in Northeastern Belgium and South Limburg have been studied by four different methods: bioclast assemblages, benthic and planktonic foraminifer assemblages, ostracode assemblages and petrophysical borehole logs. A rather detailed correlation of the strata has been established. Bioclast and ostracode assemblages suggest that the basal portion of the Maastricht Formation (Valkenburg Member) is the ecostratigraphical equivalent of the upper portion of the Gulpen Formation (Lanaye Member). In a similar way, the upper portion of the Vaals Formation (characterized by part of the foraminifer zone A'-middle and the zone A'-upper) seems to be the ecostratigraphic equivalent of the lower portion of the Gulpen Formation (Zeven Wegen Member).

In the eastern Campine, a silty to sandy, frequently glauconiferous marl in between the Vaals and Maastricht Formations (here called the Pre-Valkenburg Strata) seems to be the ecostratigraphic equivalent of the Gulpen Formation.

These ecostratigraphic correlations match the petrophysical borehole log correlations. These suggest that the lateral and vertical distribution of foraminifer assemblages (both benthic and planktonic) is more influenced by changes in the paleoenvironmental conditions than was accepted in the previous literature.

1. INTRODUCTION

The Late Cretaceous to Early Tertiary deposits in South Limburg and surrounding areas are subdivided into five formations (W.M. FELDER 1975):

HOUTHEM FORMATION
MAASTRICHT FORMATION
GULPEN FORMATION
VAALS FORMATION
AKEN FORMATION.

Each of these formations has been subdivided into several members which are separated by marker horizons (table 1). For each of these members and marker beds a reference section has been designated (W.M. FELDER 1975). These formations and members have been distinguished also by their fossil contents. Originally, this has been done by means of macrofossils. But since the publication on the benthic foraminifera by HOFKER in 1966 (who recognized seventeen foraminifer zones), it has become common practice to identify these strata by means of foraminifera. This method has proved to be very useful in the southwestern part of South Limburg and adjacent area of Belgium (Halembaye-Lanaye). However, lateral changes in the sedimentary environment towards the North-East (the former Dutch coal-mining area) have produced such changes in the foraminifer assemblages of the Maastricht Formation, that HOFKER was forced to create a different zonation in that area. The differences in the lithology and in the foraminifer assemblages are so important that the detailed chronostratigraphic correlation between the deposits of the Maastricht Formation around Maastricht (the Maastricht Chalk or facies) and those in the Dutch coal-mining district (the Kunrade Chalk or facies) has been disputed repeatedly (cf. ROMEIN 1963, ROMEIN et al. 1977, W.M. FELDER 1980).

In recent years, an attempt has been made to distinguish the various lithologic units by their bioclast contents (P.J. FELDER 1981, 1982, ROBASZYNSKI et al. 1985). In this way, it was possible to characterize these units by the quantitative composition of the bioclast assemblages. And also, new arguments were brought forward for comparing into detail the sediments of the Maastricht and Kunrade facies within the Maastricht Formation. Also recently , it has been discovered that ostracode assemblages may be used for this purpose (BLESS et al. 1983, ROBASZINSKY et al. 1985). In the latter case, the quantitative distribution of ornamented versus smooth-shelled ostracode specimens in the sequence permits the recognition of fifteen ostracode ecozones within the Campanian to Early Paleocene deposits.

Because benthic foraminifera, bioclasts and ostracodes are easily recovered from the cuttings of boreholes, these form a valuable tool for correlation. However, one should keep in mind that correlations based on these methods are biostratigraphic or ecostratigraphic ones, and that these correlations do not necessarily match lithostratigraphic or chronostratigraphic correlations.

A modern tool for correlation is also provided by the borehole logging of formation characteristics. This method helps in tracing similar lithologies from one borehole into another, or to detect minor lateral or vertical changes in the lithologic properties. Thus, the correlations based upon borehole logs are lithostratigraphic and not necessarily biostratigraphic or chronostratigraphic ones.

We have emphasized on the distinction between lithostratigraphic, biostratigraphic, ecostratigraphic and chronostratigraphic correlations. This is desirable, since it seems that sometimes indiscriminate use is made of the same. For example, biostratigraphic methods were used for recognizing lithological units. Thus, the subdivision of the Vaals Formation into a lower, middle and upper zone is based upon benthic foraminifera (cf. KUYL 1983, p. 402). This subdivision doesn't match the lithologic one into an Upper and Lower Vaals Formation by ALBERS (1976). And also, it may be disputed if the fact that benthic foraminifera of HOFKER's zone G had been recognized "in the upper part of the Gulpen Formation" in the Schin op Geul area of South Limburg "means that it certainly belongs to the Maastricht Formation" (KUYL 1983, p. 405).
These examples show that the Late Cretaceous to Early Tertiary deposits in South Limburg cannot be distinguished always by their lithology alone. And a review of the literature learns that the lithostratigraphic, biostratigraphic or chronostratigraphic contents of the various names used for these deposits in Northeastern Belgium and South Limburg has changed repeatedly in the past. This will be discussed in the chapter on the historical evolution and application of stratigraphic terms.

The purpose of the present study was twofold. In the first place, it was tried to achieve a correlation of the Upper Cretaceous to Early Tertiary deposits in Northeastern Belgium and South Limburg by means of benthic foraminifera, bioclasts, lithology and borehole logs. And secondly, the possibility has been investigated to use the formation names of W.M. FELDER (1975) in Northeastern Belgium.

2. STRUCTURAL SETTING

The Campine basin forms the southern, Belgian part of the Campine-Brabant Basin situated on the northeastern flank of the Brabant Massif. This sedimentary-tectonic basin is characterised by a sequence of sedimentary formations progressively increasing in thickness and depth toward the centrally located Rur Valley Graben (fig. 1). The Tertiary-Upper Cretaceous cover dips at ± 1.75° towards the North and unconformably overlies an upper Permian to lower Jurassic sequence, a Devono-Carboniferous sequence and the Cambro-Silurian rocks of the Brabant Massif. Generally the stratigraphic gap at the base of the Cretaceous increases towards the South. However the stratigraphic level of the underlying beds does not seem to have a major impact on the Cretaceous cover.
The Cretaceous beds are affected by normal faults related to the formation of the Rur Valley Graben, but also show signs of a syn-sedimentary tectonic inversion in the same direction. This is particulary noticeable for borehole KS 21 situated East of the Dilsen Fault and borehole KS 2 situated East of the Stokkem or Heerlerheide Fault, already in the graben. The Antwerp Campine localities fall outside the graben influence zone: here increasing subsidence to the North of the Brabant Massif lead to increasing sediment accumulations.

The calcareous sediments are not confined to the Cretaceous s.s. but include the Lower Paleocene Houthem Formation which does not differ in petrophysical character nor in general lithological aspect from the underlying Maastricht Formation sediments. For this reason they have been included in this report. These sediments are covered in the eastern Campine mining district by the continental Paleocene Zwartberg clay. Towards the west they are covered by Paleocene glauconitic sands and marls of the Heers Formation (including the Orp Sand and Gelinden Marl), which mark the first widespread Tertiary transgression. In this way several geographically distinct groups of boreholes can be characterized also by their stratigraphic constitution:

- On the eastern spur of the Brabant Massif, including the classical outcrops between Visé and Maastricht along the Meuse Valley, with limited Aachen and Vaals, well-developed Gulpen and Maastricht and preserved Houthem Formations (thickness may attain 200 m).

- On the Brabant Massif, characterised by the absence of the Houthem and Aachen Formations and a reduced thickness of the other formations (thickness max. 110 m), nevertheless very similar in facies development to the Meuse Valley outcrops along the eastern spur of the Brabant Massif.

- In the Antwerp Campine, equally characterised by absence of the Houthem and Aachen Formations , a reduced thickness of the Vaals Formation but expanding thickness in the Maastricht and Gulpen Formations (thickness 240-375 m).

- In the western part of the Campine mining district, characterised by the presence of the Houthem and Aachen Formations, Maastricht and Gulpen Formations rather similar in petrophysical character to the Antwerp Campine, regular in thickness (250 m).

- In the eastern part of the Campine mining district, more affected by faults continuing into the South Limburg mining district and the Valkenburg area, characterised by the same formations although the Gulpen Formation displays a transitional facies between the Vaals and Maastricht Formations, here provisionally named the Pre-Valkenburg strata (thickness similar to western mining district ± 250 m).

- In the Rur Valley Graben: Houthem Formation and upper part of Maastricht Formation preserved in similar conditions to the adjoining eastern mining district; all older units are absent due to inversion tectonics (thickness 60 m, stepwise increasing in thickness towards the mining district).

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4. HISTORY OF THE STRATIGRAPHIC INVESTIGATIONS ON THE LATE CRETACEOUS BETWEEN AACHEN, LIEGE AND MAASTRICHT

The wealth of fossils in the Cretaceous sediments around Maastricht was one of the reasons that people became interested in their stratigraphic position as far back as the beginning of the nineteenth century. D'OMALIUS d'HALLOY (1822) was the first who dated these strata as Cretaceous ("Terrain Crétacé"). In 1829, the area between Maastricht and Aachen was visited by the British geologist FITTON. He compared the deposits with those of the British Cretaceous and recognized three units (FITTON 1834):

MAESTRICHT STRATUM
UPPER GREENSAND
LOWER GREENSAND.

Maybe following the reasoning of FITTON, DUMONT (1832) published a fivehold subdivision:

LE CALCAIRE DE MAESTRICHT
LA CRAIE
LE GREENSAND SUPERIEUR
LE GAULT
LE GREENSAND INFERIEUR.

In 1842, the term SENONIEN was created by d'ORBIGNY. This name was used for correlating strata of different lithologies by means of their fossil contents. Already in 1849, his example was followed by DUMONT, who assigned a part of the sediments around Maastricht to the Sénonien of d'ORBIGNY. DUMONT (1849) recognized four "systems":

SYSTEME MAESTRICHTIEN
SYSTEME SENONIEN
SYSTEME HERVIEN
SYSTEME AACHENIEN.

In about the same period, German geologists have investigated the stratigraphic position of the deposits around Aachen. DEBEY (1847) published a list of local names. F. ROEMER (1838, 1844 and 1854) compared the same with the Cretaceous of Northern Germany.

Also in the Netherlands an investigation was started (BINKHORST VAN DE BINKHORST 1859, STARING 1860, UBAGHS 1879). Lithological descriptions and fossil lists were published. STARING (1869) distinguished thirty-four lithologic "beds", whereas UBAGHS (1879) prepared a list of 1073 fossil species from the Late Cretaceous between Liège, Maastricht and Aachen.

The important lateral changes in the lithology made it very difficult to correlate the various local stratigraphic sequences. For example, UBAGHS (1887) came to the conclusion that his bed XIII, the Bryozoan Bed of Kunrade, could not be correlated with the Bryozoan beds of Valkenburg and Maastricht, because "the Chalk of Kunrade with the Bryozoan Breccia is capped between Kunrade and Ransdael by the middle chalk unit with greyish flints".

The international correlation was even more difficult, since the German stratigraphic subdivision did not match the Belgian and French ones. STARING (1860) used the German interpretation and considered that all the strata in this area were of Senonian age, whereas in Belgium the "Système Maestrichtien" was accepted as a separate unit on top of the Senonian (RUTOT 1894).
Thus, two schools were created in the Netherlands. The first school followed DUMONT (1849), for example UBAGHS (1879, 1887). The second school followed STARING (1860), for example UHLENBROEK (1912). And so, it happened that UBAGHS (1887) decided that the "Système Maestrichtien" of DUMONT (1849) started with the Coprolith Bed of the Pietersberg near Maastricht, whereas he placed the Kunrade Chalk in the "uppermost Senonian". This interpretation of UBAGHS and the Belgian geologists was not accepted in the Netherlands. And this difference in opinions has complicated considerably the later investigations.
In this situation, one had to accept that in the past too many lithologic units had been distinguished (WATERSCHOOT VAN DER GRACHT 1913). Thus, in the Netherlands an attempt was made for achieving a more simplified subdivision, for example by UHLENBROEK. Nevertheless, in 1905, this author used the Belgian terminology on his geological map. In 1912, UHLENBROEK slightly altered the symbols (instead of "Cp", he now used "Cr"). This "simplified" Dutch subdivision has been used for more than fifty years in the Netherlands (ROMEIN 1962).
One of the problems of this subdivision was that chronostratigraphic terms were applied to purely lithologic units. It is almost impossible to judge the value of correlations made during this period because of the lack of detailed descriptions, which seemed superfluous in the application of the "simplified" stratigraphy.

A further step in the recognition of stratigraphic units was made by VINCENT (1928), who described Paleocene (Montian) chalk from one of the mine shafts of Eisden in Northeastern Belgium. A few years later, similar deposits were recognized in the Netherlands, near Bunde (REINHOLD 1931, MARIE 1947). HOFKER (1956) described similar strata from Geulhem (South Limburg) and Vroenhoven (Belgium). In earlier times, these had been considered as belonging to the Maastricht Chalk. Today, these are placed in the Early Tertiary (Dano-Montien; cf. ROMEIN 1963).
In 1951, the stratigraphy of the Cretaceous in Northern Europe was described by JELETZKY, who placed the Campanian-Maastrichtian boundary at the first occurrence of the cephalopod Belemnella lanceolata (SCHLOTHEIM). This opinion is now generally accepted (ROMEIN 1963, ROBASZYNSKI et al. 1985). Also it was accepted that the Senonian of d'ORBIGNY (1842) can be subdivided as follows (BIRKELUND et al. 1984):

	DANIAN	DESOR 1846
	MAASTRICHTIAN	DUMONT 1849
SENONIAN d'ORBIGNY 1842	CAMPANIAN	COQUAND 1857
	CONIACIAN	COQUAND 1856, 1857, 1858
	TURONIAN	d'ORBIGNY 1842

This subdivision forced the geologists to review the former lithologic terminology. But now, it was noticed that this was very problematic because no detailed descriptions existed Moreover, the area that had to be investigated had been enlarged into the coal-mining areas where numerous shafts and boreholes had been made.

The problems which had to be faced, are best exemplified by the investigations on the foraminifera of the "Hervian Cretaceous". SCHIJFSMA (1946) was the first who described the foraminifera of these deposits. To this purpose he used samples from boreholes and shafts in the coal-mining area, and also some samples from outcrops. SCHIJFSMA concluded that the age of the Hervian Sands was Upper Senonian or Middle Campanian. However, HOFKER (1957) argumented that it is impossible to distinguish between "Hervian" and "Maastrichtian" when using exclusively lithological arguments. Furthermore, he stated: "In the uppermost 10 m of the Dutch "Hervian" (in lithological sense) many species occur characteristic for these younger sediments, here however occurring in reworked sands of Hervian aspect. These layers also contain some species which are known only from the Upper Maestrichtian (Cymbalopora radiata, Siderolites calcitrapoides, and many other species given by SCHIJFSMA). These species are obviously also found in upper layers mingled with much younger sediments; these layers, described by V.D. WEIJDEN and SCHIJFSMA as Hervian, - hard greyish fine limestones - do not show the typical sandy characters of the Hervian but seem to have been deposited in turbulent water in which the upper layers of the real Hervian mingled with layers originally overlying the Hervian sands" (HOFKER 1957, p. 31).

This kind of problems forced the geologists to prepare a new lithostratigraphic subdivision (W.M. FELDER 1975). For the first time, type areas and reference sections were described with an exactly defined base and top for each lithologic unit. W.M. FELDER distinguished twenty-four lithologic units and twenty-nine marker horizons (table 1). Also, he recognized differences in the lithologic facies. Thus, the Maastricht Chalk, which laterally passes into the Schaelsberg Chalk and the Kunrade Chalk, belongs to the Maastricht Formation. Notwithstanding the numerous names in the lithostratigraphical table of W.M. FELDER (1975), this presents a strongly simplified image of the many lateral and vertical changes of the sediments.

Similar changes in the lithologic properties have been observed for the Vaals Formation by ALBERS (1976). Also this author used marker horizons for his subdivision of the strata. But because of the rapidly changing lithology and the absence of marker horizons in the Vaals Formation at Halembaye, he was unable to correlate this section with other outcrops (ALBERS 1976, p. 28).

Lateral changes in the lithology have also been noticed for the Gulpen Formation. In some cases, it seems very difficult to distinguish between the Gulpen, Vaals and Maastricht Formations by using only lithologic arguments (compare also the lithostratigraphic sections in PATIJN & KIMPE 1961).

Biostratigraphic subdivisions of the deposits were published by a.o. VAN DER WEIJDEN (1943, only for the "Hervian" deposits) and HOFKER (1966, for the Upper Cretaceous to Lowermost Tertiary deposits). Both authors distinguished three fossil assemblage zones or subzones in the Vaals Formation or "Hervian" deposits of the coal-mining area, and they traced these also in some more or less isolated outcrops.
HOFKER (1966) subdivided the Late Cretaceous (including the "Hervian") into the (benthic) foraminifer assemblage zones "A' " to "O", and the Early Tertiary into the assemblage zones "P" to "S". But rapid lateral changes in the depositional environment forced him to distinguish a western (characterized by the zones H, I, K, L and M) and an eastern facies (characterized by the zones G, J and O) within the Maastricht Formation. And furthermore, the foraminifer assemblages of his Upper A' subzone and A zone are extremely similar. These must be distinguished by the lithology of the samples!

Recently, an ecostratigraphic subdivision of the Upper Cretaceous to Lowermost Tertiary formations has been proposed by P.J. FELDER (1982, in BLESS et al. 1981, in ROBASZYNSKI et al. 1985) using the quantitative composition of bioclast assemblages. A similar approach was made by BLESS et al. (1983) and ROBASZYNSKI et al. (1985) using the quantitative composition of ostracode assemblages.

In conclusion, we may state that today a well-defined lithostratigraphic subdivision of the Upper Cretaceous to Lowermost Tertiary deposits exists (W.M. FELDER 1975). But because of the rapid lateral changes in the lithology, this subdivision can only be used within the area described by that author.
And also, we have a biostratigraphic subdivision of these formations based on benthic foraminifer assemblages (HOFKER 1966). This matches the lithostratigraphic subdivision in the Gulpen Formation, and permits the recognition of three subzones within the Vaals Formation. However, the real problems occur in the Maastricht Formation, where a detailed bed-by-bed correlation by means of foraminifera is hampered by the rapid lateral changes in the assemblages.
And eventually, an ecostratigraphic subdivision of these formations based on bioclasts and ostracodes (ROBASZYNSKI et al. 1985) matches the lithostratigraphic and biostratigraphic subdivisions within this area.

5. HISTORY OF STRATIGRAPHIC INVESTIGATIONS ON THE LATE CRETACEOUS IN THE CAMPINE AND SOUTH LIMBURG COAL-MINING AREA

In the Campine basin and in the coal-mining area of South Limburg, and also in some valleys on the eastern part of the Brabant Massif, the Cretaceous is concealed and occurs at ever greater depth towards the North (LEGRAND 1969). Direct access to the Cretaceous strata is only possible through boreholes. Deep drilling for coal, also intersecting the overlying Cretaceous rocks, started in 1899. Since then, some 175 boreholes have traversed the Cretaceous in the Campine and some 192 in South Limburg. These were not only drilled for the exploration for coal, but also for the search for salt deposits (in the Rur Valley Graben), hydrocarbons, geothermics and underground gas storage (in the Antwerp Campine), and mineral water (near Maastricht). In addition, numerous water wells were drilled in the Cretaceous aquifer on the northern and eastern flanks of the Brabant Massif. The description of the Cretaceous strata was based on the subdivisions in the areas around Mons and between Liège, Maastricht and Aachen. Initially, the Belgian geologists followed the example of RUTOT (1894) and UBAGHS (1879) in preparing long megafossil lists which allowed a correlation with the better exposed and stratigraphically well-known sections around Mons and Maastricht. In South Limburg, this was impossible because the knowledge of the Cretaceous megafossils had disappeared with the death of UBAGHS in 1894. This explains why UHLENBROEK (1905) used the Belgian subdivision of the Upper Cretaceous in South Limburg without publishing similar megafossil lists. And thus, it became a tradition in the Netherlands to use a biostratigraphic subdivision in a lithostratigraphic sense. Since 1912, a slightly modified terminology has been used in the Netherlands following UHLENBROEK (1912).

In the meantime, the suggestion had been made that these fossil lists have no value. HOLZAPFEL (1889, p. 263) wrote already: "Listen der vorgekommenen Versteinerungen wie sie BOSQUET in STARING's Bodem van Nederland geliefert hat, sind wertlos." (Fossil lists as published by BOSQUET in STARING's Geology of the Netherlands are valueless). KAUNHOWEN (1898, p. 7) lamented the fact that BINKHORST VAN DE BINKHORST (1859) apparently had been somewhat careless in his description of new species and of their stratigraphic position. GROSSOUVRE (1901, p. 325) suggested that the names of the fossils used by UBAGHS should be revised.

Presumably, these negative opinions and also the statement by WATERSCHOOT VAN DER GRACHT (1913, p. 80), that the former geologists had distinguished too many layers in the Cretaceous, have been the reason for the fact that little attention has been paid to the Cretaceous in the Netherlands coal-mining area. Usually, the subdivision of these strata was based on summary descriptions of cuttings (WATERSCHOOT VAN DER GRACHT 1909, p. 383).

These descriptions have been interpreted in different ways in the course of the years. This is at least suggested by cross-sections parallel and perpendicular to the main faults in the Netherlands coal-mining area (fig. 2 and 3), which are based on JONGMANS & VAN RUMMELEN (1942) and on PATIJN & KIMPE (1961).

The subdivision of the Cretaceous strata in the Belgian boreholes is also frequently based on summary descriptions of cuttings. However, several cored sections through the Cretaceous also permit the recognition of a biozonation based on detailed fossil lists. These have been published in the "Annales des Mines de Belgique" since 1903. The subdivision used there is as follows:

	(Md, with Belemnitella mucronata
	(Mc, with Mosasaurus giganteus
MAESTRICHTIEN	(Mb, with grey flint
	(Ma, with coprolites and Thecidea
	(Cp4 (Assise de Spiennes), with Trigonosemus
	(Cp3 (Assise de Nouvelles), with Magas pumilus
SENONIEN	(Cp2 (Assise de Herve), with Belemnitella quadrata
	(Cp1 (Asside d'Aix la Chapelle), with flora

This subdivision is still in use today (table 2).

But cross-sections through the Cretaceous of the Campine, based on the data for the Belgian boreholes, suggest that the stratigraphical interpretation of these data was not always the same (fig. 4). The even more complicated problems in the correlation between the Campine and South Limburg are examplified in fig. 5.

A synthesis of the the Cretaceous strata in the boreholes between Woensdrecht and Leuth has been published by LEGRAND & TAVERNIER (1950).

A further problem formed the fact that fossils were discovered in beds, where they should not occur according to the accepted zonation. Thus, it was concluded that these had been reworked from older layers. Reworked fossils (belemnites) are mentioned in the legend for the Geological Map of Belgium (1932) for the Mons area, and in MARLIERE & ROBASZYNSKI (1975) for the northeastern part of Belgium.

A subdivision of part of the Cretaceous strata ("Hervian") based on fossil assemblages was made by VAN DER WEIJDEN (1943) and SCHIJFSMA (1946) for the coal-mining area of South Limburg. Unfortunately, these authors have made no reference to the occurrence of the same in the Campine, nor did they refer to the Belgian literature. Also HOFKER (1966) has not compared the coal-mining areas of the Campine and South Limburg. The first attempt since 1912 (UHLENBROEK) to correlate the Cretaceous strata of the Campine with those of South Limburg was made by MEESSEN (1977) and by ROBASZYNSKI et al. (1985).

The information available thus far clearly shows that no uniformity exists in the description of the lithology (see figures 2 to 5), nor in the lithostratigraphic interpretation. The existing macrofossil lists need a thorough revision before these can be interpreted biostratigraphically. And finally, the zonations based on fossil assemblages (VAN DER WEIJDEN 1943, SCHIJFSMA 1946, HOFKER 1966) are ecostratigraphic rather than biostratigraphic.

Since 1953, a new technique, geophysical borehole logging, has been used for correlation. This technique was first applied to the Turnhout well and is widely used since 1980. Up to now, logs of the Cretaceous rocks have been run in 36 boreholes by various companies (table 2). In most cases, only gamma ray and resistivity logs are available. But for a limited number of boreholes (Neer, Merksplas, BGD 174 and KS 22) a practically complete open hole logging suite is available.
A first attempt to use logs for correlation was carried out at the Belgian Geological Survey in 1981 (ELEWAUT: Interpretatie van geofysische boorgatmetingen in het Noordoosten van België, Belgische Geologische Dienst, internal report). But this attempt remained unpublished since it was not possible to translate the geophysical log sequences into meaningful lithostratigraphical terms. Therefore, since 1983, a multidisciplinary study has been started in tying the log data to litho-, bio- and ecostratigraphic interpretations of the Upper Cretaceous and Early Tertiary strata. This report is a first result of this massive effort. However, many boreholes (in part cored and sampled though not logged) remain to be studied, especially at the southern margin of the Campine basin and the adjoining northern border of the Brabant Massif. In a similar way, the data from the former South Limburg coal-mining area still need a thorough revision.

6. BIOCLAST ECOZONES (P.J. Felder)

Already in the past century it was known that several widespread fossiliferous marker beds occur in the Upper Cretaceous. Examples are the "Belemnite Graveyard", the "Coprolith Bed", the "Dentalium Layer" and the "Bryozoan Beds". The fact that these can be traced throughout South Limburg and surrounding areas suggests extremely uniform depositional environments. And on the other hand, important changes in the mean depositional environment must have occurred in the course of that period since these layers are characterized by completely different fossil assemblages. Since fossil fragments or bioclasts frequently constitute the larger portion of the Upper Cretaceous and Early Tertiary (organoclastic) deposits, it has been tried to use variations in the composition of bioclast assemblages for correlation. To that purpose bioclasts between 1.0 and 2.4 mm (measures determined by mesh size of commercially obtainable sieves) have been picked out from the crushed and sieved sediment. These bioclasts include both small fossils (e.g. foraminifera and ostracodes) and fragments of large specimens. The number of bioclasts per kilogram and the quantitative composition of the bioclast assemblage (distinguishing five main groups and some twenty subgroups) are used to characterize the layer from where the sample has been taken.
Initially, vertical variations in the thus obtained values were used for local correlation (e.g. P.J. FELDER 1981, 1982). Subsequently, seven bioclast ecozones have been distinguished which can be traced from South Limburg into to eastern Campine (ROBASZYNSKI et al. 1985). For the present report , some 865 samples from twenty different locations have been analyzed (tables 6-25, figs. 6-35). These permit the recognition of eight ecozones, which are briefly described here.

6.1. REMARKS ON MAIN BIOCLAST GROUPS

<u>Foraminifera</u>. Only the large forms ($>$ 1.0 mm) are observed. Two groups can be distinguished: agglutinated and non-agglutinated forms. Agglutinated foraminifera are practically restricted to the bioclast ecozones 1, 2 and 4.
The group of non-agglutinated foraminifera is composed mainly by Lagenidae, Rotaliidae and Orbitoididae. The Lagenidae are common in the ecozones 1, 2 and 4. Orbitoididae (<u>Orbitoides</u>), and Calcarinidae (<u>Siderolites</u>) mark the top of ecozone 5 and/or ecozone 6. Rotaliidae (<u>Rotalia</u>) characterize the Early Tertiary Houthem Formation (coinciding with ecozone 7).

<u>Bryozoans, sponges and corals.</u> Sponge spicules are rare since these usually pass through the sieve. Coral remains are also rare. Only the stick-shaped (in ecozones 1 to 5) and club-shaped spicules (in ecozones 5 to 7) of the Octocorallia are a common element in several sections. In practice, this group of bioclasts is predominated by the bryozoans, which reach their maximum abundance in ecozone 6 ("Bryozoan Beds") and ecozone 7.

High numbers of bryozoans also occur in ecozone 2 (Merksplas, Turnhout, Poederlee), ecozone 3 (Nieuwerkerken, Kastanjelaan-2) and ecozone 5 (KS 22, Nieuwerkerken). This group tends to be rare or absent in ecozones 1, 4 and 8, where (glauconiferous) sand, silt or clay form the bulk of the sediment.

Molluscs and brachiopods. Several subgroups seem to have some ecostratigraphic value, such as fragments of belemnite guards, prisms of the prismatic layer of bivalve shells and the brachiopod family Thecideidae. High numbers of belemnite guard fragments characterize the ecozones 2 and 4, and sometimes also ecozone 1. Remnants of the prismatic layer of bivalve shells are common to abundant in the ecozones 1, 2 and 4. But locally, low numbers are frequent in ecozones 3, 5 and 6 (Nieuwerkerken, Kastanjelaan-2, Lanaye). Thecideidae occur in several bands in the upper portion of ecozone 3 (top of Gulpen Formation), and in ecozones 5, 6 and 7. These tend to be more common in the Maastricht facies than in the Kunrade facies of ecozones 5 and 6.

Echinoderms. Frequently, several subgroups may be distinguished (crinoids, ophiurids, asteroids, echinoids). However, this is not possible for all fragments. Echinoderm fragments tend to be predominant in the assemblages of chalk or marly sediments.

Rest group. This heterogeneous group includes a.o. arthropod remains, coproliths, serpulids and fish remains. Only serpulids tend to be common in some intervals, notably in ecozones 5 and 6.

6.2. REMARKS ON BIOCLAST ECOZONES

Bioclast ecozone 1. Roughly corresponding to the foraminifer zone A'-lower to lower half of A'-middle or equivalents (lower half of Vaals Formation in Walem). Characterized by the predominance of bivalves and/or belemnites, and foraminifera (Lagenidae). Bryozoans and serpulids are rare or absent. Echinoderm fragments become locally abundant in the Campine. The number of bioclasts per kilogram is usually low. The boundary with the overlying ecozones 2 or 4 is not always well-defined. Usually, this limit is placed at the top of an interval with high numbers of foraminifera. In practice, this corresponds with the upper limit of ostracode ecozone 1.

Bioclast ecozone 2. Corresponding to foraminifer zones A, B and lower half of C (Zeven Wegen, Beutenaken and lower part of Vijlen Members of Gulpen Formation). Characterized by frequent predominance of belemnite guard fragments ("Belemnite Graveyard") and remnants of the prismatic layer of bivalves. At intervals predominance of echinoderms. Near the base of this ecozone high numers of echinoderm spines mark the Zeven Wegen Member (foraminifer zone A).

High values of crinoid columnals (frequently with a characteristic diabolical shape) occur in the Beutenaken Member and lower half of the Vijlen Member. Local high number of agglutinated foraminifera match glauconiferous bands, possibly related to wash-in phenomena ? In Merksplas, Turnhout and to al less extend also in Poederlee, the upper portion of the Beutenaken Member and basal layers of the Vijlen Member yielded large amounts of bryozoans. Usually, the number of bioclasts per kilogram is distinctly higher than in ecozones 1 and 3. This ecozone yields the most diverse bioclast assemblages of the Upper Cretaceous in South Limburg and Campine.

Bioclast ecozone 3. Corresponding to foraminifer zones C-upper through F (upper part of Vijlen Member, Lixhe and Lanaye Members of Gulpen Formation). Characterized by the predominance of echinoderms. In the lower portion of this ecozone (only present in Nieuwerkerken, Kastanjelaan-2 and Halembaye) echinoid fragments are frequent ("Echinocorys Bed"). In the upper portion crinoid columnals (typically barrel-shaped, this in contrast to the diabolical-shaped forms in ecozone 2) and locally ophiurids abound. High values of molluscs plus brachiopods may occur. In the upper part of the ecozone a band with Thecideidae (T. papillata) occurs. Agglutinated foraminifera are practically absent (except near the base of the ecozone in Poederlee?). The number of bioclasts per kilogram decreases dramatically in the lower portion of this ecozone as compared to that in ecozone 2. Most curiously, this interval coincides with the occurrence of silicified fossils in Nieuwerkerken, Kastanjelaan-2 and Halembaye (same phenomenon also observed in the ENCI). Towards the upper part of the ecozone, the number of bioclasts per kilogram slightly increases and subsequently decreases again just below the top, except in Nieuwerkerken, Walem and possibly in Lanaye.

Bioclast ecozone 4. Corresponding to the Pre-Valkenburg strata in the eastern Campine. Characterized by the frequent predominance of belemnite guard fragments (possibly equivalent of "Belemnite Graveyard" ?) and remnants of the prismatic layer of bivalves. At intervals predominance of echinoderms, among which often barrel-shaped crinoid columnals, especially in the upper half of the ecozone. Local high amounts of agglutinated foraminifera match glauconiferous bands, notably one in the middle of the ecozone in BGD 169, KS 16, KS 17, KS 18, KS 19 and KS 20. This seems to be a marker band for local correlation in the eastern Campine. Noteworth is the frequent occurrence of low numbers of stick-shaped spicules of Octocorallia in BGD 168 and BGD 169, possibly indicating slightly different paleoecological conditions. Usually, the number of bioclasts per kilogram increases gradually towards the upper half of the ecozone, where much higher values are observed than in the overlying ecozones 5 (in the eastern Campine) or 3 (in Walem). The fossil assemblages in this ecozone show a remarkable resemblance to those of ecozones 1 to 3. Therefore, it has been suggested in ROBASZYNSKI et al. (1985) that these had been reworked into this ecozone from the Vaals and Gulpen Formations. However, this interpretation is not followed here.

Bioclast ecozone 5. Roughly corresponding to foraminifer zones G, H, J (pars) and O (pars). This interval more or less matches the lower portion of the Maastricht Formation comprising the Valkenburg Member at the base up to the layers immediately overlying the Romontbos Horizon (= base of Emael Member) in the ENCI. Characterized by the predominance of echinoderm fragments, notably echinoids and (locally) barrel-shaped crinoid columnals and ophiurids. Several layers with Thecideidae (T. papillata) occur ("Thecidea Beds"), as well as oyster beds, producing local peaks in the profiles for molluscs-brachiopods. Locally high numbers of bryozoans occur (KS 22, Nieuwerkerken, Kastanjelaan-2, Lanaye, Merksplas and Valkenburg). Foraminifera are rare. Locally, a few specimens of Orbitoides and/or Siderolites are present (BGD 168, KS 16, KS 17, KS 18, KS 19, KS 20, Kunrade).
The number of bioclasts per kilogram varies from area to area. In the eastern Campine, the values are generally low, the profiles showing a small peak in the central portion of the ecozone. In that area, the profile for the number of bioclasts per kilogram seems to be largely a perfect replica of those observed in ecozone 3 (including the lower portion of ecozone 5) along the southern border of the Campine Basin (Merksplas, Poederlee, Leopoldsburg), on the northern flank of the Brabant Massif (Nieuwerkerken) or in the Maastricht area (Kastanjelaan-2, ENCI, Halembaye/Lanaye, the latter being the type locality for the Lanaye Member at the top of the Gulpen Formation).
In Valkenburg (type locality for the Valkenburg Member at the base of the Maastricht Formation) the profile for the number of bioclasts per kilogram in this ecozone essentially matches the profiles in the eastern Campine. In Walem, the same profile in the ecozones 3 plus 5 matches the profile observed in ecozone 5 in Valkenburg and in the eastern Campine. The number of bioclasts per kilogram may increase in the upper portion of this ecozone (e.g. Merksplas, Turnhout, Poederlee, Leopoldsburg, BGD 168, KS 20 and KS 22). In some sections (Nieuwerkerken, Halembaye/Lanaye) the number of bioclasts per kilogram is high throughout the ecozone, but there this ecozone is underlain by ecozone 3 showing low values for the number of bioclasts per kilogram.

Bioclast ecozone 6. Roughly corresponding to foraminifer zones I, J (pars), K to M, and O (pars). This matches the upper half of the Maastricht Formation (Emael Member except for basal layers, Nekum and Lixhe Members). Characterized by alternating predominance of echinoderms (echinoid fragments: "Hemipneustes Bed" in the Nekum Member), serpulids (in the Emael Member and in the "Dentalium Bed" of the Nekum Member), foraminifera (Orbitoides and Siderolites in the Meerssen Member) and bryozoans ("Bryozoan Beds" in the Meerssen Member). In the western Campine, a Thecidea band occurs in the lower portion of this ecozone (Merksplas, Turnhout, Poederlee). This band has also been recognized in Kastanjelaan-2 in South Limburg, and in BGD 168 in the eastern Campine. The number of bioclasts per kilogram is very high. Usually, the boundary with the underlying ecozone 5 is arbitrarily placed at the base of an increased value for the Rest Group (serpulids).

Bioclast ecozone 7. Corresponding to the foraminifer zones P, Q and R (Houthem Formation, Early Tertiary). Characterized by high numbers of foraminifera (notably Rotalia and Valvulammina), especially in the upper portion of the ecozone. Echinoderms (echinoids) are predominant. Molluscs and brachiopods are rare. Locally, a bed with Thecideidae (Lacazella longirostris) occurs (e.g. Kastanjelaan-2). But this is easily distinguished from the Thecideidae-bearing bands with T. papillata in ecozones 3, 5 and 6. The number of bioclasts per kilogram is generally high, but exceptions are known (e.g. Kastanjelaan-2). The lower boundary of this ecozone coincides with the appearance of Rotalia and Valvulammina.

Bioclast ecozone 8. Corresponding to the Zwartberg Clay, Orp Sand and Gelinden Marl (Paleocene). Characterized by predominance of molluscs (bivalves and gastropods) in the Zwartberg Clay and (part of) Orp Sand. Locally, foraminifera (KS 20, KS 22) or arthropod remnants (KS 18, KS 20) predominate in the higher portion of this interval (notably in the Gelinden Marl). The number of bioclasts per kilogram is variable, but tends to be extremely low in the Gelinden Marl.

6.3. CONCLUSIONS

The (lithologic) boundaries between the Upper Cretaceous and Early Tertiary Formations (Vaals, Gulpen, Maastricht, Houthem) match the boundaries between bioclast ecozones. The coincidence between lithologic and ecostratigraphic boundaries is not surprising, since formations are usually distinguished by different lithologies presumably representing different depositional environments. Comparison of the sections in figures 25-34 shows that within each timespan rather uniform conditions throughout the area considered have controlled not only the composition of the bioclast assemblages, but also the relative amount of bioclasts per kilogram. For an easy comparison of the profiles, the base of the Maastricht Formation is used as a datum line. Below this line are shown either (in descending order) the Gulpen and Vaals Formations, or the Pre-Valkenburg strata and the Vaals Formation. Originally, these Pre-Valkenburg strata had been included in the lower portion of the Maastricht Formation (ROBASZYNSKI et al. 1985).

In the present report, the base of the Valkenburg Member as defined in the Valkenburg area by W.M. FELDER (1975) is taken as the lower boundary of the Maastricht Formation. In sections where the Valkenburg Member seems to be absent (usually in sections where the Lanaye Member of the Gulpen Formation is present), the top of the Lanaye Member as defined in the Lanaye area by W.M. FELDER (1975) is taken as the boundary between the Maastricht and Gulpen Formation.

Careful analysis of the bioclast profiles in figures 25-34 readily learns that the (lithologic) boundary between the Maastricht and Gulpen Formations doesn't match the (lithologic) boundary between the Maastricht Formation (base of Valkenburg Member) and the Pre-Valkenburg strata. This is best shown in the profiles for the number of bioclasts per kilogram and for the molluscs and brachiopods.

The profiles for the number of bioclasts per kilogram can be subdivided into three main intervals as far as ecozones 1 to 7 are concerned. The lower interval is characterized by medium to high values for the number of bioclasts. The middle interval consists either of ecozone 5 (in sections where the Maastricht Formation is underlain by the Pre-Valkenburg strata) or of ecozones 3 and 5 (where the Gulpen Formation occurs below the Maastricht Formation). This interval shows two minima in the number of bioclasts which are separated by a small peak in the central portion. The upper interval shows very high values for the number of bioclasts per kilogram.
There, where the Valkenburg Member seems to be completely developed (Valkenburg and eastern Campine), this middle interval is situated entirely above the lithologic base of the Maastricht Formation. But in cases where the Lanaye Member of the topmost Gulpen Formation seems to be more or less complete, this interval is partly occurring below the lithologic boundary between the Maastricht Formation and Gulpen Formation (western Campine, Nieuwerkerken, Kastanjelaan-2, Halembaye/Lanaye). A mixt situation is observed in Walem.

The profiles for molluscs and brachiopods show high values in ecozones 1 and 4, or 1 and 2. Values generally decrease in ecozones 3 and 5. Also here, one must conclude that the profiles of ecozone 3 in the uppermost part of the Gulpen Formation closely resemble the basal part of profiles in ecozone 5 in the basal portion of the Maastricht Formation in the eastern Campine.
Therefore, it is suggested here that the interval of the ecozones 3 and 5 in the western Campine (Merksplas, Turnhout, Poederlee, Leopoldsburg), in Nieuwerkerken and in the Maastricht area (Halembaye/Lanaye, Kastanjelaan-2, ENCI and Walem) match the ecozone 5 in the eastern Campine and in Valkenburg. Note also that these intervals show about the same thickness! This implies that the lower portion of the Maastricht Formation in the eastern Campine and in Valkenburg is at least in part the ecostratigraphic equivalent of the upper portion of the Gulpen Formation in the western Campine, in Nieuwerkerken and in the Maastricht area, insofar as this upper portion belongs to the bioclast ecozone 3 (upper part of Vijlen Member, Lixhe and Lanaye Members). Presupposing that the ecostratigraphic boundaries within this area more or less are isochronous, this would mean that for example the Valkenburg Member at the base of the Maastricht Formation might be partly or entirely the time-equivalent of the Lanaye Member or even of the Lixhe Member or upper part of the Vijlen Member!
This interpretation contradicts the "classical" idea that the complete Gulpen Formation is older than the Maastricht Formation (an opinion repeated again and again, e.g. KUYL 1980, W.M. FELDER & BOSCH 1984, ROBASZYNSKI et al. 1985).

Accepting this ecostratigraphic correlation as a time-equivalent one implies that some of HOFKER's (1966) foraminifer zones for the upper portion of the Gulpen Formation (zones C, E, F) are partly or entirely time-equivalent to those of the basal part of the Maastricht Formation (e.g. zones G and part of J).
In that case these foraminifer zones might merely represent different paleoenvironments, as had been accepted already by Hofker (1966) for the foraminifer zones in the Maastricht Formation, where different zonations have been established for the Maastricht facies and the Kunrade facies.

In a similar way, the interval consisting of ecozones 1 and 2 seems very similar to (and of about the same thickness as) that formed by ecozones 1 and 4. This in not surprising if we remember that it was believed initially that the bioclasts of ecozone 4 had been reworked in part from ecozone 2 (and also from ecozones 1 and 3). The ecozones 2 and 4 regularly contain beds with abundant agglutinated foraminifera, and yield large amounts of belemnites and prismatic bivalves. Differences in the bioclast assemblages might be attributed to differences in the paleoecologic conditions, since the sediment of ecozone 2 is largely a fine-grained (marly) chalk, whereas that of ecozone 4 consists of glauconiferous sandy to silty marls.
Ecozone 4 has also been recognized in Walem in an interval assigned to the Vaals Formation by the Geological Survey of the Netherlands (because it yielded foraminifera of HOFKER's zone A'). There, this ecozone 4 corresponds to part of the foraminifer zone A'-middle and part of the zone A'-upper, which are placed in the Campanian. In KS 22, the foraminifer assemblage halfway ecozone 4 suggests a Campanian age. In KS 16, KS 17 and KS 18, the foraminifer assemblages of ecozone 4 indicate a Campanian age for the lower half to two-third of the ecozone, and a (Lower) Maastrichtian age (foraminifer zone B) for the upper portion of the same.

In ecozone 2, the foraminifer assemblages of the lower portion (Zeven Wegen Member, foraminifer zone A) indicate an Upper Campanian age, whereas those of the middle portion (Beutenaken Member, foraminifer zone B) suggest a Lower Maastrichtian age. The foraminifera in the upper part of ecozone 2 (Lower Vijlen Member, lower part of foraminifer zone C) suggest an Upper Maastrichtian age.
This means that ecozone 4 matches biostratigraphically and ecostratigraphically the lower to middle portion of ecozone 2 (Zeven Wegen and Beutenaken Members of Gulpen Formation). In Walem, ecozone 4 might correspond biostratigraphically to the lower portion of ecozone 2 (Zeven Wegen Member of Gulpen Formation).
A summary of the correlations between the different sections based on the bioclast ecostratigraphy is shown in figure 35.

7. PLANKTONIC FORAMINIFERA FROM MERKSPLAS AND POEDERLEE (F. Robaszynski)

In Merksplas and Poederlee, the base of the Cretaceous succession is marked by a relatively great abundance of planktonic foraminifera belonging to the family Globotruncanidae. At Merksplas numerous planktonic forms were found between 976 and 1005 m depth whereas at Poederlee it was between 764 and 774 m.
At a first sight, the associations observed are quite the same, with the dominance of specimens attributed to the genus *Archaeoglobigerina* (*A. cretacea* and *A. blowi*, two species well known in the Boreal realm). However, there are some representants, although relatively rare, of the genus *Globotruncana* (*G. bulloides* and *G.* gr. *arca*, species more frequent in the Tethyan realm).

The main criteria to separate this forms at a species level are as following:
Archaeoglobigerina cretacea (d'ORBIGNY, 1840). Test low trochospiral coiled, nearly symmetrical; chambers rounded, non-truncated, with two spaced faint keels (sometimes very faint) on each of the five to six globular chambers of the last whorl; equatorial periphery lobulate, sutures radial and depressed on the umbilical side. Tegilla structure in the umbilicus not preserved in the specimens studied.

Archaeoglobigerina blowi PESSAGNO, 1967. Same characters as *A. cretacea* except: four to five chambers in the last whorl, increasing rapidly in size; faint keels only on the early chambers of the last whorl.

Whiteinella baltica DOUGLAS & RANKIN, 1969. The genus *Whiteinella* differs from *Archaeoglobigerina* essentially by having portici instead of tegilla in a rather large umbilicus (these structures being visible only on very well preserved specimens, that is not the case for the present material). However the species *W. baltica* can be determined by the aspect of the four to five chambers of the last whorl which are rounded without keels.

Globotruncana arca (CUSHMAN, 1926). Low trochospire, nearly symmetrical, moderately spiroconvex, two spaced keels on the five to eight chambers of the last whorl; outline lobate, chambers crescent-shaped to petaloid on the spiral side, increasing slowly in size; umbilical keel, sutural ridge and adumbilical keel forming a horse-shoe shaped pattern.

Globotruncana bulloides VOGLER, 1941. Profile symmetrical with chambers convex on either sides and generally inflated, two widely spaced keels on all the six to seven chambers of the last whorl; umbilical sutures generally curved and depressed.

7.1. PLANKTONIC FORAMINIFER CONTENT OF THE SAMPLES STUDIED

7.1.1. Merksplas

976-981 m (2 specimens): Hedbergella delrioensis (1) and Whiteinella cf. baltica (1).

981-986 m (9 specimens): Archaeoglobigerina sp. (1 + 1 juvenile), Globotruncana cf. bulloides (2), Globotruncana arca (1), Globotruncana arca close to G.orientalis (2).

986-990 m (55 specimens): Archaeoglobigerina cretacea with very faint keels (46), Archaeoglobigerina blowi (5), Whiteinella cf. baltica (3), Globotruncana arca (1).

990-995 m (40 specimens): Archaeoglobigerina cretacea (35), Archaeoglobigerina blowi (2), Globotruncana arca (1), Globotruncana intermediate between G. arca and G. orientalis (1), Globotruncana cf. ventricosa? (1).

995-999 m (207 specimens): Archaeoglobigerina cretacea (190), Archaeoglobigerina blowi (9), Globotruncana bulloides (7), Globotruncana arca (1).

999-1005 m (98 specimens): Archaeoglobigerina cretacea (70), Archaeoglobigerina blowi (5), Globotruncana bulloides (18), Globotruncana arca (5).

7.1.2. Poederlee

764-769 m (106 specimens): A. cretacea (80 + 10 juvenile forms), A. blowi and intermediate forms between A. blowi and A. cretacea (11), G. bulloides (3), G. arca (2).

769-774 m (81 specimens): A. cretacea (61 + 8 juvenile forms), A. blowi (2), G. bulloides (8) and G. cf. bulloides (2), G. arca (2).

7.2. REMARKS

7.2.1. Paleoecology

At Merksplas as at Poederlee, the basal samples contain a much higher content of double - keeled forms as Globotruncana whereas the upper samples are dominated by globular forms with faint double-keels belonging to the genus Archaeoglobigerina. Strongly keeled forms are generally linked to a greater sea-depth whereas globular forms are more frequent in relative shallow waters (CARON 1983). Following this concept, the basal Cretaceous sediments of the two boreholes should have been deposited in a deeper sea than the strata immediately above.

7.2.2. Biostratigraphy

Archaeoglobigerina cretacea is known from Coniacian to Lower Maastrichtian in the Tethyan realm and in the Campanian in the Boreal chalks. In the Paris basin, chalks of uppermost Santonian to Lower Campanian sometimes contain relative floods of A. cretacea (MONCIARDINI, personal communication).

Globotruncana arca appears at the base of the Campanian and is known throughout the Maastrichtian in the Tethyan realm, more frequent in the Campanian to basal Maastrichtian in the Boreal Province.
Globotruncana bulloides extents from the uppermost Santonian to the basal Maastrichtian in the Tethyan realm and is known in the Boreal realm principally in the lower to middle part of the Campanian. Thus, the associations of planktonic foraminifera suggest a Campanian age, more probably early Campanian.

8. BENTHIC FORAMINIFERA (J.P.M.Th. Meessen)

Samples from the Lower Tertiary and Upper Cretaceous of the boreholes KS 16, KS 17, KS 18, KS 22, Leopoldsburg, Merksplas, Nieuwerkerken and Poederlee have been investigated on their benthic foraminifer contents.
The foraminifera were identified according to the criteria of HOFKER (1957, 1966) and dated according to HOFKER's 1966 foraminifer zonation.
The dating of a part of the samples is also based on the orthogenesis of the Bolivinoides strigillata-decorata-australis-gigantea gens as described in detail by HOFKER (1958, 1961).

8.1. KS 16 (table 26)

329, 333 and 345 m: Paleocene, Zone R. Characteristic species: Vacuovalvulina keyzeri, Rotorbinella corrugata, Rotorbinella mariei, Pararotalia tuberculifera, Rotalia perovalis, Rotalia saxorum, Rotalia trochidiformis and Valvulammina globularis.

365 m: no foraminifera.

370 and 375 m: Maastrichtian, Zone O. Characteristic species: Siderolites laevigata, Daviesina fleuriausi, and Orbitoidae.

380, 385, 390 and 405 m: no foraminifera.

410, 415, 420 and 430 m: Maastrichtian, Zone J. Characteristic species: Gavelinopsis involuta, Nonionella troostae and Allomorpha halli.

435 m: Maastrichtian, Zone J. Characteristic species: Gavelinopsis involuta and Gaudryina supracretacea.

440 and 445 m: Maastrichtian, Zone B? Important species are only Stensiöina pommerana and Eponides beissili. The range of Stensiöina pommerana is in South Limburg from Upper A' to halfway Zone C and of Eponides beisseli from Upper A' to Zone E. Both species occur in KS 18 (450 m) together with Bolivinoides australis with a mean number of pustules on the last chamber of 4.3. This value is within the range between 4 and 5 pustules, which HOFKER (1966) considered characteristic for Bolivinoides australis in Zone B.

Herewith a Zone B age for the samples 440 and 445 m seems likely.

455, 460 and 465 m: no characteristic species encountered.

470 and 475 m: Campanian. A characteristic species is Globorotalites micheliniana. This points to a Campanian age.

485, 490, 505, 510, 515, 520, 525 and 530 m: no characteristic species encountered.

535, 540, 545, 550, 555 and 560 m: Campanian, Lower A'. Characteristic species: Gavelinella clementiana (with dorsal ornamentation) and Lenticulina multinodosa.

8.2. KS 17 (table 26)

350 and 355 m: Paleocene, Zone R. Characteristic species: Vacuovalvulina keyzeri, Rotalia saxorum, Rotalia trochidiformis, Rotalia perovalis, Pararotalia tuberculifera and Rotorbinella corrugata.

360 and 365 m: Paleocene, Zone Q. Characteristic species: Rotalia trochidiformis and Rotalia saxorum.

370, 375 and 380 m: Paleocene, Zone P. Characteristic species: Protelphidium brotzeni, Sigmomorphina paleocenica and Robulus discus.

385, 390, 395, 400 and 405 m: Maastrichtian, Zone O. Characteristic species: Siderolites laevigata, Mississippina binkhorsti, Daviesina fleuriausi and Orbitoidae.

410 and 415 m: no foraminifera

420, 425 and 430 m: Maastrichtian, Zone J. Characteristic species: Gavelinopsis involuta, Nonionella troostae and Allomorphina halli.

435 and 440 m: Maastrichtian, Zone J. Characteristic species: Gavelinopsis involuta, Nonionella troostae, Allomorphina halli and Gaudryina supracretacea.

445, 450, 455, 460 and 465 m: no characteristic species encountered.

470, 475 and 480 m: Maastrichtian, Zone B? Important species are Stensiöina pommerana and Eponides beisseli. The range of Stensiöina pommerana is in South Limburg from Upper A' to halfway Zone C. That of Eponides beisseli from Upper A' to Zone E.

Both species occur in KS 18 (450 m) together with Bolivinoides australis with a mean number of pustules on the last chamber of 4.3. This value is within the range between 4 and 5 pustules, which HOFKER (1966) considered characteristic for Bolivinoides australis in Zone B.

Herewith a Zone B age for the samples 470, 475 and 480 m seems likely.

485, 490, 495, 500, 505, 510, 515, 520, 525, 530 and 535 m: Campanian. A characteristic species is only Globorotalites micheliniana. This points to a Campanian age.

540, 545, 550, 555, 560 and 565 m: Campanian, Lower A'. Characteristic species: Gavelinella clementiana (with dorsal ornamentation) and Lenticulina multinodosa.

8.3. KS 18 (table 26)

380, 385, 400, 405, 410 and 420 m: Maastrichtian, Zone J. Characteristic species: Gavelinopsis involuta, Nonionella troostae and Allomorphina halli.

425, 430 and 435 m: no characteristic species encountered.

450 m: Maastrichtian, Zone B. Characteristic species: Eponides beisseli, Stensiöina pommerana, Spiroplectammina laevis, Verneuillina limbata, Praebulimina laevis and Bolivinoides australis with a mean number of pustules on the last chamer of 4.3.

This value is within the range between 4 and 5 pustules, which HOFKER (1966) considered characteristic for Bolivinoides australis in Zone B.

460, 465, 470, 475, 480, 485 and 490 m: Campanian. A characteristic species is only Globorotalites micheliniana. This points to a Campanian age.

505, 520, 525 and 530 m: no characteristic species encountered.

535, 540 and 550 m: Campanian, Lower A'. Characteristic species: Gavelinella clementiana (with dorsal ornamentation) and Lenticulina multinodosa.

8.4. KS 22 (table 27)

439.11-439.20 m: Maastrichtian, Zone G. Zone G is a mixture of the foraminifera of Zone J and reworked forms of older zones (HOFKER 1966). Encountered as foraminifera of Zone J are: Cymbalopora radiata, Mississippina binkhorsti, Gavelinopsis involuta, Nonionella troostae, Gaudryina supracretacea and as reworked forms: Gavelinopsis monterelensis, Stensiöina pommerana and Globorotalites micheliniana.

473.85-473.90 m: Campanian. Characteristic species are: Globorotalites micheliniana and Bolivinoides decorata. These suggest a Campanian age.

488.50-488.55 m: no characteristic species encountered.

8.5. LEOPOLDSBURG

502-504 m: Paleocene, Zone Q. Characteristic species: Rotalia trochidiformis, Rotalia saxorum, Gavelinella danica, Valvulammina limbata and Rotorbinella corrugata.

515 and 522 m: Paleocene, Zone P. Characteristic species: Protelphidium brotzeni, Gavelinella danica and Globulina hantkeni.

528 m: Maastrichtian, Zone J. Characteristic species: Gavelinopsis involuta and Allomorphina halli.

545, 550, 562, 575, 584, 588 and 597 m: no foraminifera.

608, 620, 645, 652.57-655.42 and 670.74-671.19 m: the only characteristic species recognized is Stensiöina pommerana. The range of this species in South Limburg is from Upper A' to halfway Zone C.

675-678 and 690.14-691.8 m: Campanian, Zone A. Characteristic species: Globorotalites micheliniana, Stensiöina pommerana, Gavelinopsis monterelensis, Gavelinella clementiana and Praebulimina cushmani.

701.51-701.71 and 712.12-716.49 m: Campanian. A characteristic species is only Globorotalites micheliniana. This points to a Campanian age.

729.22-731.77 m: Campanian, Lower A' ? In the sample were only two species of Gavelinella clementiana with dorsal ornamentation.

8.6. MERKSPLAS (table 28)

695-753.59 m: no characteristic species encountered.

733.59-738.58 m: Maastrichtian, Zone J. Characteristic species: Gavelinopsis involuta and Gaudryina supracretacea.

738.58-785.94 m: no characteristic species encountered.

785.94-795.43 m: Maastrichtian, Zone F. Characteristic species: Orbignyna frankei, Eponides frankei and in the sample 791.70-795.43 m Bolivinoides gigantea with a mean number of pustules on the last chamber of 7.1. This value is within the range between 7 and 9 pustules, which HOFKER (1966) considered characteristic for Bolivinoides gigantea in Zone F.

795.43-800.19 m: no characteristic species encountered.

800.19-844.03 m: Maastrichtian, Zone C. Characteristic species: Flabellammina compressa, Praebulimina kickapooensis, Bolivina incrassata, Eponides beisseli and Bolivinoides australis with a mean number of pustules on the last chamber between 5.3 and 5.2. These values are within the range between 5 and 6, which HOFKER (1966) considered characteristic for Bolivinoides australis in Zone C.
Remarkable is the occurrence of Bolivinoides draco in the samples 804.95-809.70 m and 839.23-844.03 m. In South Limburg Bolivinoides draco is in this zone till now only known from one horizon (KIMPE et al. 1978).

844.03-919.25 m: Maastrichtian, Zone B. Characteristic species: Orbignyna aragonitica, Eponides beisseli, Praebulimina laevis, Osangularia lens and Bolivinoides australis with a mean number of pustules on the last chamber between 4.8 and 4.3. These values are within the range between 4 and 5 pustules, which HOFKER (1966) considered characteristic for Bolivinoides australis in Zone B.
Remarkable is the occurrence of Bolivinoides draco in the samples 861.85-866.62 m and 875.16-880.95 m. Till now, Bolivinoides draco is in South Limburg not known from Zone B.

919.25-967.12 m: Campanian, Zone A. Characteristic species: Globorotalites micheliniana, Stensiöina pommerana, Gavelinopsis monterelensis, Gavelinella clementiana and in sample 928.79-933.22 m Bolivinoides decorata with a mean number of pustules on the last chamber of 3.8. This value is within the range between 3 and 4 pustules, which HOFKER (1966) considered characteristic for Bolivinoides decorata in Zone A.

972.12-1005.20 m: Lower Campanian. Characteristic species: Globorotalites micheliniana, Stensiöina exculpta, Gavelinella clementiana with dorsal ornamentation and Bolivinoides strigillata.
After HILTERMANN (1963) and KOCH (1977) the range in NW Germany of Stensiöina exculpta is Coniacian-lowermost Upper Campanian; of Gavelinella clementiana with dorsal ornamentation Lower Campanian and of Bolivinoides strigillata Upper Santonian-Lower Campanian.

8.7. NIEUWERKERKEN

129-131 m: Maastrichtian, Zone F. Characteristic species: Orbignyna frankei, Orbignyna rimosa, Eponides frankei, Coleites reticulosus and Bolivinoides gigantea with a mean number of pustules on the last chamber of 7.3. This value is within the range between 7 and 9 pustules, which HOFKER (1966) considered characteristic for Bolivinoides gigantea in Zone F.

159-161 m: Maastrichtian, Zone E. Characteristic species: Praebulimina aspera, Allomorphina bullata and Bolivinoides australis with a mean number of pustules on the last chamber of 6.4. This value is within the range between 6 and 7 pustules, which HOFKER (1966) considered characteristic for Bolivinoides australis in zone E.

8.8. POEDERLEE (table 29)

535-601 m: no characteristic species encountered.

606-621 m: Maastrichtian, Zone C-F ? A few broken specimens of Bolivinoides australis-gigantea characterize this interval. These do not allow a more precise dating.

625-673 m: Maastrichtian, Zone C. This age is based on the occurrence of Stensiöina pommerana, which in South Limburg ranges until halfway Zone C, and on Bolivinoides autstralis with a mean number of pustules on the last chamber of 5.1 in sample 673 m. This value is within the range between 5 and 6 pustules, which HOFKER (1966) considered characteristic for Bolivinoides australis in Zone C. Bolivinoides draco is encountered in the sample 625 m.

678-705 m: Maastrichtian, Zone B. Characteristic species: Spiroplectammina laevis, Orbignyna aragonitica, Eponides beisseli, Praebulimina laevis and Bolivinoides australis with a mean number of pustules on the last chamber between 4.5 and 4.2. These values are within the range between 4 and 5 pustules, which HOFKER (1966) considered characteristic for Bolivinoides australis in Zone B. Bolivinoides draco is encountered in sample 701 m.

710-751 m: Campanian, Zone A. Characteristic species: Globorotalites micheliniana, Gavelinopsis monterelensis, Gavelinella clementiana, Stensiöina pommerana and Bolivinoides decorata with a mean number of pustules on the last chamber between 3.7 and 3.4. These values are within the range between 3 and 4 pustules, which HOFKER (1966) considered characteristic for Bolivinoides decorata in Zone A.

756-764 m: no characteristic species encountered.

769-774 m: Lower Campanian. Characteristic species: Globorotalites micheliniana, Gavelinopsis monterelensis, Stensiöina exculpta, Gavelinella clementiana with dorsal ornamentation and in the sample 769 m Bolivinoides strigillata with a mean number of pustules on the last chamber of 2.5.

After HILTERMANN (1963) and KOCH (1977) the range in NW Germany of Stensiöina exculpta is Coniacian-lowermost Upper Campanian; of Gavelinella clementiana with dorsal ornamentation Lower Campanian and of Bolivinoides strigillata Upper Santonian-Lower Campanian.

9. OSTRACODE ECOZONES (M.J.M. Bless)

9.1. INTRODUCTION

A biostratigraphic subdivision of the Upper Cretaceous to Lowermost Tertiary deposits in South Limburg and neighbouring parts of Belgium has been proposed by DEROO (1966), who distinguished seven ostracode zones, of which the fourth one (comprising the Lanaye Chalk of the Gulpen Formation and the Maastricht Formation at the ENCI quarry) could be subdivided into four subzones. DEROO did not designate a special zone for the Vaals Formation because ostracodes from that deposit had practically not been studied by him. ROMEIN et al. (1977) studied the ostracodes of the Kunrade Chalk at Benzenrade near Heerlen. But they were unable to correlate these assemblages exactly with one of the subzones of DEROO. In fact, their study showed that the stratigraphic range of some species is longer than suggested by DEROO (1966). This is not surprising if we compare DEROO's data with those obtained in Northern Germany (e.g. HERRIG 1966, CLARKE 1982, 1983). Also the present investigation has shown that the stratigraphic range of some species may need revision.

These observations suggest that the presence or absence of ostracode species is at least in part facies-controlled. The influence of the depositional environment on the quantitative composition of ostracode assemblages was studied by BLESS et al. (1983). These authors distinguished between "nearshore" assemblages (characterized by more than 20% ostracode specimens with an ornamented carapace) and "shallow marine offshore" assemblages (with more than 80% smooth-shelled ostracode specimens).

In order to get a repeatable method, lists were made of "smooth-shelled" and "ornamented" ostracode genera. It was realized, of course, that the assignment of a genus to either one of these categories is purely subjective. The reasoning for the distinction between smooth-shelled and ornamented ostracode assemblages was the following. It is believed that smooth-shelled ostracodes are characterized usually by a somewhat thinner and more fragile carapace that might favour a low-energy environment. And on the other hand, ornamented ostracodes frequently possess a thicker test that is better adapted to a relatively high-energy facies. Furthermore, it was presumed that the water-energy in "nearshore" facies may be relatively higher than in "offshore" environments.

A preliminary investigation on a reduced number of samples proved that coarse-grained deposits, such as the (marly) sands of the Vaals Formation and the calcarenites of the Kunrade Chalk in the Maastricht Formation (which are presumed to have been laid down in a relatively high-energy, nearshore environment), yield much higher number of ornamented ostracode specimens than the fine-grained calcilutites of the Gulpen Formation (which are supposed to represent a calm, offshore facies).

A more extended study on some 180 samples from nine sections (ROBASZYNSKI et al. 1985) enabled the distinction of fifteen ostracode ecozones for the Upper Cretaceous to Lowermost Tertiary deposits, which alternatingly are characterized by either ornamented or smooth-shelled specimens. These ecozones can be followed from one section into another. Correlations based upon the ostracode assemblages closely match those based upon bioclasts, foraminifera and lithologic properties. Thus, we may conclude that these ostracode ecozones have a certain stratigraphic value, at least for regional investigations.
In the course of the actual study, some 450 ostracode assemblages from twenty sections have been investigated. Another hundred samples did not yield ostracodes. The latter came either from the Maastricht Formation (Merksplas, Poederlee, Turnhout, Leopoldsburg, boreholes in eastern Campine) or from the Gulpen and Vaals Formations (Turnhout, Leopoldsburg). In the latter case, this may be due to problems in the preparation of the relatively old (consolidated) samples. For the Maastricht Formation this may be either due to preparation problems or to the real scarcity or absence of ostracodes. The relatively poor assemblages from Turnhout and Leopoldsburg are not further considered here, although it may be stated that the results are vaguely comparable to those obtained from other boreholes (Merksplas, Poederlee) in the same region. Moreover, the frequently very rich and diverse assemblages from the Houthem Formation are not taken into account here. The quantitave composition of the ostracode assemblages in the Vaals, Gulpen and Maastricht Formations (identified by means of the lithology and/or the bioclast assemblages) is shown in figures 36, 37 and 38. The data are summarized in figures 39 and 40.

9.2. REMARKS ON OSTRACODE ECOZONES

Ostracode ecozone 1. Roughly corresponding to the lower and middle portion (foraminifer zone A'-lower to A'-middle) of the Vaals Formation. Frequently very high numbers of ornamented ostracodes (up to 82% of assemblage in Beut.8 of Beutenaken section). Only occasionally less than 20% ornamented specimens. Characteristic are Veenia (V. foersteriana), Cythereis and Pterygocythere (P. laticristata), whereas Pterygocythereis, Curfsina and Cytherelloidea occur irregularly. Smooth-shelled ostracodes include Cytherella, Bairdia and less common Asciocythere and Sphaeroleberis. Isolated occurrence of Xestoleberis bidentata in KS 18 (520 m).

Ostracode ecozone 2. Presumably corresponding to the basal portion of the Pre-Valkenburg strata, in Walem corresponding to the foraminifer zone A'-middle to A'-upper. Originally, in ROBASZYNSKI et al. (1985), the lower portion of this ecozone in Walem had been included in ecozone 1. But correlation of the sections

rather suggests that this was incorrect (fig. 36 and 37). In Merksplas and Poederlee, this ecozone is present in marly sand, this in contrast to the other sections where glauconiferous, marly sands and silts occur. Also the foraminifer assemblage is different from that occurring elsewhere. However, the foraminifera are definitely of Lower Campanian age, and therefore may be of the same age as those of the zone A'-middle as suggested by the ecostratigraphical correlation. The number of ornamented ostracodes is usually low (less than 20%) to extremely low (between 0 and 10%) near the base and the top of this ecozone. The highest percentages of ornamented ostracode specimens occur in the middle part of the ecozone (occasionally more than 20% in KS 17, KS 16 and Walem). Characteristic is the regular occurrence of Veenia (V. foersteriana), Cythereis and Pterygocythere laticristata in low numbers, and sometimes of Curfsina and Cytherelloidea. Smooth-shelled ostracodes include Cytherella, Sphaeroleberis, Asciocythere and Bairdia. The upper portion of this ecozone may also yield Xestoleberis (X. bidentata in a.o. KS 18).
The upper portion of this ecozone has only been identified in Walem, where it bears Cythereis and P. laticristata. This is the only sequence unquestionably correlated with foraminifer zone A'-upper.

Ostracode ecozone 3. Roughly corresponding to the base of the Gulpen Formation, base of Zeven Wegen Chalk (= "Craie glauconifère" in DEROO 1966). This ecozone is marked by relatively high numbers of ornamented ostracodes (up to 35%), notably Cytherelloidea, Bythoceratina and Curfsina. In Merksplas and Poederlee, this ecozone also includes Mosaeleberis sp. gr. 1 (M. rutoti). Veenia, Cythereis and Pterygocythere have not been recognized, but DEROO (1966) mentioned the presence of P. laticristata in the "Graie glauconifère". Apparently, these genera may occur here occasionally in very low numbers. Smooth-shelled ostracodes predominate (Bairdia, Cytherella and Krithe).
The Bolivinoides assemblages in this ecozone (e.g. Poederlee and Halembaye) show different values for the mean number of pustulae on the last chamber. This suggests slight differences in age or possibly a condensed sequence for this very thin ecozone.

Ostracode ecozone 4. Roughly corresponding to lower part of Gulpen Formation, Zeven Wegen Chalk and lower half of Beutenaken Chalk (foraminifer zones A and lower portion of B). This ecozone is characterized by very high numbers of smooth-shelled ostracodes (more than 80% to occasionally 100% in upper portion of ecozone). Smooth-shelled ostracodes include notably Cytherella and/or Bairdia. Regularly, low numbers of ornamented ostracodes occur, especially Cytherelloidea, Bythoceratina, Curfsina and/or Mosaeleberis sp. gr. 1 (M. rutoti).

Ostracode ecozone 5. Roughly corresponding to middle portion of Beutenaken Chalk (middle portion of foraminifer zone B, mean value of pustulae on last chamber of Bolivinoides between 4.5 and 4.7). This ecozone is characterized by relatively high numbers of ornamented ostracodes (up to 37% in Beutenaken-2) in Beutenaken. Lower percentages have been observed in Merksplas (881 m, 13%) and in Poederlee (678 m, 22%). Smooth-shelled ostracodes include Bairdia, Cytherella, Asciocythere and Sphaeroleberis. Ornamented ostracodes include notably Cytherelloidea, Bythoceratina and Curfsina, occasionally Schizocythere and Eucytherura dorsotuberculata, and an isolated occurrence of Pterygocythere laticristata in Merksplas.

Ostracode ecozone 6. Roughly corresponding to top of Beutenaken Chalk to lower half of Lanaye Chalk (top of foraminifer zone B to lower half of foraminifer zone F). Very high numbers of Cytherella. Bairdia and Krithe are common amongst smooth-shelled ostracodes. Irregular occurrence of ornamented ostracodes, notably Curfsina, and also Schizocythere and Aversovalva.
Isolated occurrences of Pterygocythere (P. laticristata) in Turnhout and Kastanjelaan-2, of Eucytherura dorsotuberculata in Vijlen Chalk of Halembaye, and of Mosaeleberis sp. gr. 1 (M. rutoti) in Vijlen Chalk of Kastanjelaan-2.
Presumably, the top of this ecozone also occurs in Walem, where it yielded Mosaeleberis sp. gr. 2 (M. macrophthalma).

Ostracode ecozone 7. Corresponding to upper half of Lanaye Chalk (upper half of foraminifer zone F). This ecozone is characterized by high numbers of ornamented ostracodes (sometimes over 50%), notably Mosaeleberis sp. gr. 2, Veenia, Pterygocythere (P. alata), Pterygocythereis and Limburgina. Smooth-shelled ostracodes include Cytherella, Bairdia, Sphaeroleberis, etc.

Ostracode ecozone 8. Corresponding to the middle to upper portion of the Pre-Valkenburg strata in the eastern Campine coal-mining area. This ecozone is characterized by very high numbers of smooth-shelled ostracodes, notably Cytherella and Bairdia. Remarkable is the presence of rare specimens of Xestoleberis bidentata in the lower portion of this ecozone in a.o. KS 18. Ornamented ostracodes are rare and occur irregularly, notably Curfsina. Note the isolated occurrence of Mosaeleberis sp. gr. 2 in the top of the ecozone in BGD 169 and KS 16, of Pterygocythere laticristata in KS 17, of Veenia foersteriana (contamination from higher level?) in KS 20, of Pterygocythere alata (contamination from higher level?) in KS 20, and of Mosaeleberis sp. gr. 1 (M. cf. lerichei) in KS 16, KS 18 and KS 22.

Ostracode ecozone 9. Roughly corresponding to lower portion of Maastricht Formation, lower half of Valkenburg Chalk. This interval corresponds to the basal portion of foraminifer zone J in the Nekami, to foraminifer zone G and the basal portion of zone J in Valkenburg, KS 16 and KS 17. The ecozone is characterized by high numbers of ornamented ostracodes, notably Mosaeleberis sp. gr. 2, Veenia, Pterygocythere (P. alata), Pterygocythereis and Limburgina. Smooth-shelled ostracodes include Cytherella, Bairdia, Sphaeroleberis, etc.

Ostracode ecozone 10. Roughly corresponding to upper portion of Valkenburg Chalk in ENCI, Nekami and Valkenburg, and to basal portion of Kunrade Chalk in Kunrade. However, in Kastanjelaan-2 corresponding to topmost part of Gulpen Formation! This interval corresponds to foraminifer zone H in the ENCI, to foraminifer zone J in Nekami, Valkenburg and KS 16, to foraminifer zone G and/or J in Walem, to foraminifer zone J or O in Kunrade and to foraminifer zone F in Kastanjelaan-2. The ecozone is characterized by the same ostracodes as ecozone 9. But the percentage of ornamented specimens is markedly lower, usually below 20%.

Ostracode ecozone 11. Corresponding to the strata between the St.-Pieter Horizon and the Romontbos Horizon (Gronsveld Chalk and Schiepersberg Chalk) in Lanaye, ENCI, Nekami and Valkenburg. In Nieuwerkerken corresponding to the interval between the Lichtenberg Horizon and Romontbos Horizon (Valkenburg Chalk to Schiepersberg Chalk). In Kunrade corresponding to the middle portion of the Kunrade Chalk. This interval corresponds to foraminifer zone H in Lanaye and ENCI, to foraminifer zone J in Kastanjelaan, Nekami and Valkenburg, and to foraminifer zone O in Kunrade. This ecozone is characterized by the same ostracodes as ecozone 9 and 10. The numer of ornamented specimens is comparable to that observed for ecozone 9, and may be well over 50%.

Ostracode ecozone 12. Corresponding to the basal portion of the Emael Chalk, directly overlying the Romontbos Horizon, in the ENCI, Nekami, Valkenburg and Kastanjelaan, and to the herewith correlated interval in Kunrade. This interval corresponds to foraminifer zone H/I in the ENCI, to foraminifer zone J in Nekami and Kastanjelaan, and to foraminifer zone O in Kunrade. This ecozone contains the same ostracode genera as ecozone 9, 10 and 11. The number of ornamented specimens is lower than in ecozone 11.

Ostracode ecozone 13. Corresponding to the middle to upper portion of the Emael Chalk, Nekum Chalk and Meerssen Chalk in Lanaye, ENCI, Nekami, Valkenburg, Kastanjelaan and Nieuwerkerken, and to the upper portion of the Kunrade Chalk in Kunrade and the boreholes in the Campine coal-mining area (e.g. KS 16, BGD 169). This ecozone is roughly characterized by the same ostracode genera occurring in ecozones 9 to 12, but the percentage of ornamented specimens is well over 20%, sometimes over 50%.

9.3. CONCLUSIONS

It should be noticed that the original criterion for the distinction between these alternatingly "ornamented" and "smooth-shelled" ostracode ecozones was the cut-off value of 20% ornamented ostracode specimens (ROBASZYNSKI et al. 1985). In the present study, this criterion has been followed with some exeptions, where higher values have been occasionally incorporated within the smooth-shelled ecozones because of the overall pattern of the percentage curves.

Furthermore, it should be remembered that the lower or upper boundaries of the ecozones never cross the boundaries between the Vaals, Gulpen and Maastricht Formations as identified by lithologic, biostratigraphic (usually benthic foraminifer zones) or ecostratigraphic (bioclast assemblages) criteria, or by a combination of the same. This explains the apparently arbitrary limit between ecozones 1 and 2 in the boreholes in the eastern Campine, where the boundary between the Vaals and Maastricht Formation (ROBASZYNSKI et al. 1985) was placed at the base of usually slightly marly, glauconiferous sands and silts of what has been called in this report "Pre-Valkenburg strata". This name has been chosen since these deposits underly the easily recognizable Valkenburg Chalk.

The Pre-Valkenburg strata had been included in the Maastricht Formation (ROBASZYNSKI et al. 1985) because of the fact that the bioclast assemblages (bioclast ecozone 4) presumably contained high amounts of fossil debris reworked from the Gulpen Formation and more especially from the lower half (Zeven Wegen Chalk, Beutenaken Chalk, lower portion of Vijlen Chalk) of that formation. On lithologic arguments, however, the Pre-Valkenburg strata show a close resemblance to the upper portion of the Vaals Formation as identified in Walem (compare fig. 8 in ROBASZYNSKI et al. 1985). Unfortunately, the foraminifer assemblages from this interval were not conclusive, suggesting either an upper A' or a G zone as the most likely. This interpretation has been revised in the present report (see chapter on benthic foraminifera). The lower and middle part of the Pre-Valkenburg strata belong to the Campanian, the upper portion seems to represent the Lower Maastrichtian (HOFKER's zone B).

According to this interpretation, it has to be accepted that important sedimentary gaps occur in South Limburg and Northeastern Belgium between the Vaals Formation and the Gulpen Formation (Loën or Zeven Wegen Horizon), between the Gulpen and Maastricht Formations (Lichtenberg Horizon), and between the Vaals and Maastricht Formations (unnamed horizon).

On the other hand, the hypothesis that the Pre-Valkenburg strata should be included within the upper portion of the Vaals Formation would only increase the sedimentary gap between the Vaals and Gulpen Formations.The Lichtenberg Horizon would still represent an important gap between the Gulpen and Maastricht Formations. And eventually, the sedimentary gap between the Vaals and Maastricht Formations would have remained the same, comprising the total Gulpen Formation.

Whatever might have been the correct solution, it was never questioned if the biostratigraphic zonation of HOFKER (1966) might be interpreted in a different way. "Per definition" his foraminifer zone A' had to be older than A, and so on. In the past, this belief has been one of the causes for readjustments in the correlation of strata and in the end for readjustments in the limitations of the actual formations. As an example of this way of thinking, the fact has been quoted in our introduction that KUYL (1983) stated that the "upper part of the Gulpen Formation" in the Schin op Geul area "certainly belongs to the Maastricht Formation" because this yielded benthic foraminifera of HOFKER's zone G.

However, accepting the supposition that formation boundaries have not "ipso facto" a chronostratigraphic value, and also that this is true for biostratigraphic boundaties (as suggested by e.g. the lateral and vertical distribution of HOFKER's zones H, I, J and O), one might as wel argument that ecostratigraphic boundaries are not necessarily worse than those provided by lithostratigraphic or biostratigraphic methods, at least within a small area as here considered.

Comparison of the sections studied thus far shows that the ostracode ecozones 7 and 9 never occur in the same sequence, nor do the ecozones 4/6 and 8. And furthermore, where the ecozone 2 is extremely thick (in Walem), the ostracode ecozones 4/6 or 8 are (practically) absent. Moreover, it can be observed that the thickness of the ecozones 7 and 9 is very similar. The same holds for the "smooth-shelled" interval of the ecozones 4/6, 2/8 and the interval 2/6 in Walem.

If we wish to explain this phenomenon, we must accept an intricated history of block movements of the subsurface and of paleoecologic factors which produced sequences of comparable ostracode assemblages and comparable thicknesses all through the region. This will be very difficult to explain. Moreover, the ostracode ecozone 2 is marked by Cythereis hallembayensis and Pterygocythere laticristata, two species originally described by DEROO (1966) from the lower portion of the Gulpen Formation (respectively Zeven Wegen Chalk, and Zeven Wegen Chalk to base of Vijlen Chalk).

Ostracode ecozone 8 occasionally yielded ostracodes which are known from the lower half of the Gulpen Formation (Zeven Wegen Chalk to Vijlen Chalk) in its middle portion. And the top of the same ecozone occasionally yielded ostracodes known from the top of ostracode ecozone 6 or from ostracode ecozones 7 and 9 to 13. And finally, the ostracode contents of ecozone 7 is completely comparable to that of ostracode ecozone 9.
Therefore, it is suggested here, that the ostracode ecozones 4 to 6 in e.g. Halembaye/Lanaye and Kastanjelaan-2 represent the same period of deposition as ostracode ecozones 2 to 8 in the boreholes of the eastern Campine, and as ostracode ecozone 2 plus ecozone 6 in Walem. This suggestion doesn't exclude the possibility of important sedimentary gaps in these sequences. For example, in Halembaye and Kastanjelaan, the ecozone 5 is absent (as well as the top of 4 and the base of 6) because the Beutenaken Chalk is missing. This means, that the foraminifer zone A'-upper corresponds partly or entirely to the foraminifer zones A to the lower half of F ! It should be noticed in this connection that the foraminifer assemblages of zone A'-upper and A are practically similar.
This also means that the marly silts and sands occurring in this interval in the eastern Campine and in Walem represent the lateral silty to sandy equivalent of the Gulpen Formation, in a similar way as the Kunrade Chalk is the lateral equivalent of the Maastricht Chalk (fig. 40).

And also, it is suggested here, that the ostracode ecozone 7 in e.g. Nieuwerkerken, Lanaye, ENCI and Kastanjelaan-2 represents the same period of deposition as ostracode ecozone 9 in the Nekami and Valkenburg and in the eastern Campine. This means that the upper portion of foraminifer zone F corresponds to the basal portion of foraminifer zone J in the Nekami, and to foraminifer zones G to basal J in Valkenburg and the Belgian Campine.
This also means, that the lower portion of the Valkenburg Chalk represents the lateral equivalent of the upper portion of the Lanaye Chalk.

Accepting that these interpretations are correct, the ecostratigraphic history (based on ostracodes) of the Upper Cretaceous deposits can be subdivided into three main periods, A, B and C (fig. 39). Periods A and C are characterized by a predominance of "ornamented" ostracode assemblages, suggesting an overall "shallow marine" depositional environment. Period B is marked by predominantly smooth-shelled ostracode assemblages, suggesting an overall deepening of the depositional environment. Period C can be subdivided into three subperiods C1, C2 and C3. Deposits containing assemblages of period C2 (ecozone 10) are absent in Nieuwerkerken and Halembaye/Lanaye and extremely thin in ENCI and Kastanjelaan.

This suggests that the Lichtenberg Horizon in these sections occurring on top of ecozone 7 (or 10 in Kastanjelaan-2 ?) represents a period of erosion, non-sedimentation or condensed sedimentation. In Lanaye, this period seems to have continued during part of the deposition of ecozone 11. In the ENCI, also the top layers of ecozone 7 seem to have been affected by non-sedimentation or erosion. Following this interpretation, the Lichtenberg Horizon may not be present as such in Nekami and Valkenburg, nor in the Campine coal-mining area.

If the above conclusions are correct, a new scheme of correlations between the existant formations and foraminifer zones has to be made (fig. 40). Of course, this scheme is new only insofar as the correlations are concerned which had been proposed by e.g. ROMEIN (1962), HOFKER (1966) and W.M. FELDER (1975). However, one should keep in mind that "in earlier days" the "upper Gulpen Chalk" was "always incorporated in the Kunrade Chalk" (ROMEIN 1962, p. 84). And also, that the top of the Vaals Formation around Kunrade (there formerly named the Benzenrade Chalk) was once included in the Kunrade Chalk (VAN RUMMELEN 1923). This concept seems to have gained now (mutatis mutandis) a new value and a new contents.

It should be noticed also that the scheme in figure 40 doesn't account for possible or known sedimentary gaps. This has been done in order to simplify the overall correlation scheme. However, such gaps are known for the Vaals Formation in e.g. Halembaye and Cadier, for the Gulpen Formation in e.g. Halembaye and Cadier, and for the Maastricht Formation in Lanaye and ENCI. And these are presupposed to exist in the Pre-Valkenburg strata of the Campine, and in the upper portion of the Vaals Formation of the Walem borehole.

Acceptance of this scheme may have far-reaching consequences for the interpretation of changes in the lithology. For example, in that case it might be concluded that some faults as suggested on the cross-sections of the geological map of KUYL (1980) in fact match facies changes (e.g. unnamed fault between boreholes 62B-768 and 62B-665 in cross-section A-A', and Schin op Geul Fault in cross-section B-B' of KUYL 1980). Being aware of these possible consequences, it seems wise to consider the above conclusions only as tentative ones, which should stimulate a careful revision of all data, as well as more extended eco- and biostratigraphic investigations.

9.4. REMARKS ON SOME OSTRACODES

Genus <u>Pterygocythere</u> HILL 1954 (figures 41 and 42).

Two species have been recognized: <u>P. laticristata</u> (BOSQUET 1854) and <u>P. alata</u> (BOSQUET 1847). These are distinguished by the relatively shorter base of the alae in P. laticristata, which have a more massive, plumper appearance than those of P. alata. Moreover, the posterior portion of the carapace is usually more slender in P. alata than in P. laticristata.

Otherwise, there is a little difference in the size of the species (length of P. laticristata between 0.83 and 1.09 mm; length of P. alata between 0.90 and 1.12 mm).

P. laticristata is common in ostracode ecozones 1 and 2 where it occurs in association with Cythereis spp. and Veenia foersteriana (BOSQUET 1847). The species occurs occasionally in the Gulpen Formation (Zeven Wegen Chalk, Beutenaken Chalk, Vijlen Chalk?), in ecozone 8 in KS 17, and in the upper portion of the "Vaals Formation" (ecozone 2) in Walem. DEROO (1966) recognized the species in the Vaals Formation ("Smectite"), Zeven Wegen Chalk ("Craie glauconifère" and "Craie blanche") and Vijlen Chalk ("Craie grise") of the Maastricht-Halembaye area, and in the "Craie de Nouvelles" and "Craie de Spiennes" of the Mons Area.

P. alata occurs in the ostracode ecozones 7 and 9 to 13 (roughly corresponding to the upper portion of the Lanaye Chalk and to the Maastricht Formation). DEROO (1966) mentioned this species from the "Calcaire de Kunrade" and from the "Tuffeau de Maestricht". A single specimen of P. alata in ostracode ecozone 8 (Pre-Valkenburg strata) of KS 20 may be explained by contamination from a higher level because of its markedly different preservation.

Genus Mosaeleberis DEROO 1966 (figure 43).

Two species groups are distinguished. Mosaeleberis sp. gr. 1 is characterized by a rather swollen carapace, practically smooth and without distinct median costa, but usually with (subdued) subcentral tubercle. M. sp. gr. 1 includes M. lerichei DEROO 1966, M. pergensi (VAN VEEN 1936) and M. rutoti DEROO 1966. Mosaeleberis sp. gr. 2 is characterized by a well-developed median costa on each valve and/or by a reticulate ornament. This species group comprises M. interrupta (BOSQUET 1847), M. interruptella DEROO 1966, M. interruptoidea (VAN VEEN 1936), M. macrophthalma (BOSQUET 1847), and M. propinqua (BOSQUET 1854).

M. sp. gr. 1 has been recognized occasionally in ostracode zones 3 (Merksplas, Poederlee) and 4 (Merksplas, Poederlee, Halembaye), in strata corresponding to the Zeven Wegen Chalk. A single occurrence is known from the top of ostracode ecozone 2 in Merksplas (possible contamination from a higher level?) and from the base of ecozone 6 (base of Vijlen Chalk) in Kastanjelaan-2. In all these cases, it concerns M. rutoti, a species cited by DEROO (1966) from the Zeven Wegen Chalk ("Craie blanche") of Halembaye, and from the "Craie de Nouvelles", "Craie de Spiennes" and "Poudingue de Cuesmes"of the Mons area. Rare specimens of M. sp. gr. 1 (M. cf. lerichei) occur about halfway ostracode ecozone 8 (Pre-Valkenburg strata) of boreholes KS 16 and KS 22.

M. lerichei has been identified by DEROO (1966) in samples from the Vijlen Chalk ("Zone du hard ground" and "Craie grise") of Halembaye, North and Wahlwijlre.
Occasionally, M. sp. gr. 1 also occurs in the Maastricht Formation. In all cases, it concerns M. pergensi.
M. sp. gr. 2 is common in ostracode zones 7 and 9 to 13 (roughly corresponding to the upper portion of the Lanaye Chalk (Gulpen Formation) and Maastricht Formation). This species group also occurs in the upper portion of ostracode ecozone 6 (corresponding to the lower portion of the Lanaye Chalk) at Walem, and in the top of ostracode ecozone 8 (Pre-Valkenburg strata) in BGD 169 and KS 17. A single occurrence halfway ostracode ecozone 8 in KS 16 may be explained as contamination from a higher level because of the quite different preservation of this specimen. DEROO (1966) described specimen belonging to this species group from the Lanaye Chalk ("Craie grossière") of North and from the Maastricht Formation of South Limburg, and also from the "Craie de Spiennes" to "Poudingue de la Malogne" of the Mons area.

10. LOG CORRELATIONS (R. Demyttenaere and M. Dusar)

10.1. GENERAL GUIDELINES

Log subdivisions and hence correlations are based either on the recognition of hardgrounds, normally characterised by a sharp peak in the gamma-ray curve, often asymmetrical at the junction of different lithologies, or on the recognition of lithofacies changes, e.g. change from a chalk to a marl unit characterised by a jump in the gamma-ray value and a drop in the resistivities. However, some limits (such as the Maastricht-Gulpen Formation boundary) between different lithostratigraphic units, vary even between adjoining localities, whereas other limits such as the Houthem-Maastricht Formation boundary are arbitrarly placed at one particular hardground horizon out of a series of successive and rather similar hardground horizons.

The upper limit of the Cretaceous and calcareous lower Paleocene always can be recognized by a sharp increase in resistivity; the lower limit also by a sharp increase of the gamma-ray curve in the underlying more consolidated formations.

Stratigraphic log correlations including biostratigraphic limits and interval thicknesses are listed on tables 30-33.

10.2. CAMPINE MINING DISTRICT-EAST (type log: KS 19, fig. 44)

This area is already quite fault-affected and situated close to the border of the Rur Valley Graben. The studied consequences are overlain by continental lower Paleocene Zwartberg Clay and underlain partly by a Permo-Triassic sequence covering Westphalian C-D deposits (fig. 1). Correlations are mainly based on the gamma-ray logs as the resistivity measurements generally showed a poor resolution.

10.2.1. Aachen Formation

This formation can be recognized by its relative lower value of the gamma-ray compared to the underlying Carboniferous or Triassic and the overlying Vaals Formation. It is usually not more than 20 m thick. The thickness varies between zero (in KB 161 possibly on a Bunter Sandstone swell) and 21 m (in KB 169).

The formation has no typical log respons, only the limits can be correlated.

10.2.2. Vaals Formation

The Vaals Formation is always directly recognizable on the gamma-ray logs showing a fairly constant value. It may be subdivided into an upper and a lower part, the latter having a slightly higher gamma-ray value.

The top of this formation is characterised by a fairly distinct gamma-ray peak. The total thickness of this formation varies between 56 m (KS 17) and 79 m (KB 146).

10.2.3. Pre-Valkenburg strata (Gulpen Formation) (type log: KS 19, fig. 44 and 45)

This unit is highly variable in log response.

A very striking feature of this interval is the high gamma-ray peak marker horizon that can be seen on KS 17, KS 18, KS 19 and KS 25. This peak, correlated to a wider zone with high gamma-ray values in the other boreholes, is probably related to the "Beutenaken Marl" of the Gulpen Formation, and corresponds with a foraminifer peak (cf. figures 8 and 9).

At the lower part of this formation, the equivalent of the Zeven Wegen Member can be recognised over a thickness of about 30 m, characterised by lower gamma-ray values though not as low and distinctive as in the other district. The upper limit of the formation is placed at a considerable drop on the gamma-ray. The total thickness of the formation varies between 49 m (KS 22) and 92 m (KB 146).

10.2.4. Maastricht Formation

The gamma-ray shows different patterns in this interval which however can be correlated between all sections.

Towards the top there is a series of peaks continuing into the overlying Houthem Formation which probably correspond with hardgrounds. The highest peak has been taken as the upper limit of the formation in accordance with bio- and ecostratigraphic data.

The thickness varies between 49 m (KB 146) and 88 m (KS 22). The resistivity and sonic logs seem to respond to the presence of silicified beds in the lower part of this formation.

10.2.5. Houthem Formation

This formation shows similar features as the upper part of the Maastricht Formation. Because of the presence of hardgrounds, the gamma-ray is variable from well to well. Although few correlations can be made within this formation, its limits however are very clear.

The Zwartberg clay overlying the Houthem Formation in this area can easily be distinguished as it has a much higher gamma-ray.

The upper limit also can be detected by a strong resistivity decrease at the transition from porous tuffaceous limestone to clay.

The thickness of this formation varies between 26 m (KS 18) and 41 m (KB 161).

10.3. CAMPINE MINING DISTRICT-WEST (type log: KS 1, fig. 44)

This area is farther removed from the Rur Valley Graben and thus less fault-affected. It is mainly overlain by transgressive Paleocene Orp Sands as the Zwartberg Clay is gradually wedging out towards the west. It is underlain partly by some Triassic sandstones covering Westphalian A-B deposits (fig. 1).

10.3.1. Aachen Formation

The thickness of this formation varies considerably from 8 m (in KS 1) to 29 m (in KS 9). The limits are easily detected by an increase of the gamma-ray towards both underlying and overlying formations. It can be subdivided in two parts, the lower part having a higher gamma-ray value, which probably corresponds with a more lithified sandstone unit.

10.3.2. Vaals Formation

This formation bears a good resemblance to the Vaals Formation in the eastern part of the Campine Mining District. It was equally possible to distinguish two parts within this formation, especially on the resistivity curves. The thickness varies between 48 m (KS 1) and 77 m (KS 13).

10.3.3. Gulpen Formation

Zeven Wegen Member

This member is recognizable because of a drop in the gamma-ray. Sometimes a distinct gamma-ray peak, characteristic for a hardground, is included within the upper part of the formation. The resistivity is relatively high, and separation between the deep and the shallow resistivity increases.

Thickness: 14 m (KB 174) and 36 m (KS 11).

Beutenaken Member, "Beutenaken" Marl

This interval shows an important increase on the gamma-ray, which corresponds with the higher clay content. The resistivity is relatively low. The gamma-ray from KS 13 however shows a totally different pattern, which yet cannot be explained.

Thickness: 10 m (KS 12 and KS 14) and 21 m (KB 174).

Beutenaken Member, "Beutenaken" Chalk

The gamma-ray has a much lower value comparing to the "Beutenaken Marl" part. A further drop on the gamma-ray defines the upper limit and corresponds with a lithology change (clay disappearing). Also the resistivity of this unit is lower than in the "Beutenaken Marl".

The thickness varies between 7 m (KS 5) and 24 m (KS 12).

Vijlen - (Lanaye ?) Members

This unit is characterised by a constant and low gamma-ray and a fairly smooth resistivity, compared to the overlying formation. The thickness varies from 35 m (KB 174) to 51 m (KS 5).

10.3.4. Maastricht Formation

The base of this formation shows a slight increase on the gamma-ray curve (as well as in velocity, density and resistivity). As in the eastern part of the Campine Mining Disstrict the sonic and the resistivity curves show a very rapid succession of high and low values which problaby reflect the presence of silex beds. Although the underlying units, (assigned to the Gulpen Formation or its Pre-Valkenburg equivalent) may be of very different lithologies, the base of the Maastricht Formation can be easily distinguished.

The gamma-ray shows towards the top several distinct peaks though less in number than in the eastern mining district. These probably correspond with hardgrounds. The highest peak is designated as the base of the Houthem Formation. The thickness is very constant varying between 46 m (KS 12) and 56 m (KS 5).

10.3.5. Houthem Formation

As in the eastern Campine Mining District, this formation shows similar features as the Maastricht Formation. Few intraformational correlations are possible. The top is recognised by a drop in the resistivity value and a sudden increase on the gamma-ray. The thickness varies between 16 m (KS 11) and 31 m (KS 10).

10.4. ANTWERP CAMPINE (type log: Merksplas-1, fig. 44)

This area is no longer influenced by the Rur Valley Graben tectonics. However discontinuous faults and subsidence zones may occur above karstic collapse zones in the Dinantian (DREESEN et al. in press).

The studied sequences are overlain by Paleocene Orp Sands and overly Namurian to Westphalian A deposits (fig. 1). They rapidly increase in thickness from South (edge of Brabant Massif) to North (centre of Campine-Brabant Basin).

10.4.1. Aachen Formation

There are no continental deposits, attributed to this formation, left.

10.4.2. Vaals Formation (fig. 46)

As in the former areas the Vaals Formation can easily be detected. The interval subdivision is here very striking however. Furthermore the characteristics of the logs are different, due to the higher clay content in this area. The lower part has also the higher gamma-ray value, but the difference between both parts is more pronounced, as can also be seen on the other logs shown on fig. 44.

The thickness of this formation varies between 25 m (Poederlee) and 70 m (Meer).

10.4.3. Gulpen Formation

Log features of this formation are similar to those recognised in the western Campine Mining District. As a consequence no major difficulties were encountered when subdividing this formation. The differences on the gamma-ray curve are however much smoother and it was easier to define these limits using other logs such as the neutron porosity, the density and the sonic. However the top part of the Gulpen Formation again is different and certainly more variable in this area. A distinct hardground peak is noticed towards the top. Based on bio-ecostratigraphical evidence this peak could correspond with the limit between the Vijlen-(Lixhe), and the Lanaye Members.

The Gulpen-Maastricht transition itself is less distinctive and corresponds with a decrease in the gamma-ray curve. The thickness of the individual units varies respectively:

- for the Zeven Wegen Member between 40 m (Turnhout) and 58 m (Meer, DZH 1 and DZH 4)
- for the "Beutenaken" Marl between 23 m (Poederlee) and 42 m (Turnhout and Meer)
- for the "Beutenaken" Chalk between 27 m (Poederlee) and 51 m (DZH 5)
- for the Vijlen (-Lixhe) Member between 33 m (Poederlee) and 77 m (Turnhout)
- for the Lanaye Member between 90 m (Poederlee) and 19 m (Turnhout).

The Gulpen Formation recently has been subdivided into a lower Gulpen chalk, corresponding to the Zeven Wegen Member, a middle Gulpen marl, corresponding to the "Beutenaken" Marl, and an upper Gulpen chalk, corresponding to the "Beutenaken" Chalk and (Lixhe)-Vijlen Members (VANDENBERGHE & DUSAR 1985). The designation "upper Gulpen chalk" was made independently, irrespective of meaning of this term elsewhere.

10.4.4. Maastricht Formation

The characteristics of this formation can be compared with those in the western mining district. However, a perspicious hardground peak occurs in the middle of this formation on all logs. Bio-ecostratigraphic correlations suggest that this horizon occurs at a similar level as the Lava Horizon in South Limburg.

The thickness of this formation varies between 58 m (Turnhout) and 90 m (Meer).

10.5. RUR VALLEY GRABEN BORDER ZONE

Towards the northeastern margin of the eastern Campine Mining District, separated by the Dilsen and Heerlerheide Faults (fig. 1), some boreholes have intersected a very reduced Lower Paleocene - Upper Cretaceous sequence. The Aachen, Vaals, Gulpen (in its Pre-Valkenburg facies) and lower half of the Maastricht Formations are rapidly disappearing due to the Upper Cretaceous uplift of the graben floor (PATIJN 1963; LEGRAND 1961). However, the remaining part of the Maastricht Formation and the Houthem Formation is similar to the eastern Campine Mining District.

10.6. COVER OF THE NORTHERN PART OF THE BRABANT MASSIF AND ITS EASTERN SPUR IN SOUTH LIMBUG

This area includes the classical exposures along the Meuse Valley. Subdivisions in logged wells on the Brabant Massif (Velm, Nieuwerkerken) closely match those of the type area.

10.7. SYNTHETIC DESCRIPTION OF THE FORMATIONS

10.7.1. Aachen Formation

This formation, although limited in thickness is easily recognisable in the Campine Mining District, but is wedging out towards the South (Brabant Massif) and the West (Antwerp Campine). It mainly consists of sand (or sandstone) and clay with lignite; glauconite is altogether absent. The gamma-ray is usually lower than in the Vaals Formation, but sometimes shows considerable peaks. The logs indicate much variation even between adjoining wells, as can be expected from the heterogeneous lithology. A sandstone lens can be followed throughout the western mining district.

10.7.2. Vaals Formation

This formation can always be detected on all the logs. It normally can be subdivided into a lower and an upper part, of comparable thickness. The lower part has a higher gamma-ray value (fig. 46). In the Campine Mining District this difference is sometimes very small, and the Vaals Formation may be considered as a homogeneous sequence consisting of glauconite - rich sands and silts, partly lithified.

In the Antwerp Campine the separation in two parts is however more distinct, due probably to the higher clay content in this area which is possibly related to a more open marine environment. It should be noted that this subdivision has been established independently from bio- and lithostratigraphic subdivisions made elsewhere.

In the eastern Campine Mining District, the transition to the overlying formation is somehow more gradual and the limit arbitrarily placed at the top gamma-ray peak which is still in line with the underlying sequence.

10.7.3. Pre-Valkenburg strata (Gulpen Formation, fig. 45)

This facies characterises the eastern part of the Campine Mining District, but it laterally corresponds with the Gulpen Formation. This lateral persistence of the Gulpen Formation could already be deduced from comparison of seismic sections in the Campine. The gamma-ray is variable, a three-fold succession characterised by a low, high and again lower gamma-ray curves can be recognised. A distinct peak, though not always present, can be recognised in the middle part (Opglabbeek area). This peak shows characteristics of a hardground separating different lithologies: at the bottom there's a gradual increase, but the top jump is very abrupt.

The lower part, with the low gamma-ray value probably corresponds with the Zeven Wegen Member of the Gulpen Formation. The middle part up to the high gamma-ray peak could be correlated with the "Beutenaken Marl". Where this peak is present it is overlain by a relatively low gamma-ray sequence possibly corresponding to the upper part of the Vijlen-Lanaye sequence. Where this peak is missing but replaced by a longer sequence characterised by a higher gamma-ray value, the Vijlen-Lanaye sequence may be mostly missing.

10.7.4. Gulpen Formation

This formation was recognised in its typical development in the western part of the Campine Mining District and in the Antwerp Campine. It can be subdivided in three major parts characterised on the gamma-ray curve by a low, high and again lower gamma-ray value, going from bottom to top.

Zeven Wegen Chalk Member

The lower part corresponds to the Zeven Wegen Chalk Member, and is characterised by a low and relatively constant gamma-ray curve. Sometimes however a distinct peak (hardground type) can be noticed in the upper part which could not yet be correlated to known hardgrounds. The resistivity also is rather constant and relatively high, and the difference between the shallow and the deep resistivity curves increases, which corresponds to an increase in effective porosity.

Beutenaken Member

This member can be divided in two parts, the lower part having the highest gamma-ray, which corresponds with a higher clay content. This part was provisionally named the "Beutenaken Marl" although it rather forms a clay instead of a marl (e.g. the gamma-ray can reach 65 cps in well KS 5, which is the highest value observed in the whole Cretaceous in that well).
The upper part, with lower gamma-ray and higher resistivity values, is the more chalky part of the member, and was therefore named provisionally the "Beutenaken Chalk".
The gamma-ray values decrease towards the Antwerp Campine which probably corresponds with a decrease in clay content of this member.

Vijlen (Lanaye) Members

The logs show for this members a constant gamma-ray curve in the western part of the Campine Mining District, but in the Antwerp Campine the Lanaye Member is overlying a perspicious hardground. This may indicate that the Lanaye Member could be absent in the Campine Mining District (interpretation based on bio-ecostratigraphic data). The differences between the two areas are probably due to slight facies changes. The lithology in general consists of clear sandy chalk.

10.7.5. Maastricht Formation

This formation is present everywhere, but the log pattern is variable. Especially in the upper part several inconsistent gamma-ray peaks were observed. These peaks probably correspond with hardgrounds or zones with a higher glauconite content, which both indicate a delay in the rate of sedimentation. Most of these hardgrounds are laterally inconsistent as is demonstrated by a lack in lateral persistence of the individual peaks. A distinct peak however could be correlated throughout the Antwerp Campine and was tentatively identified as the Lava Horizon equivalent. The Maastricht Formation mainly consists of a "tuffaceous" chalk with a high porosity which can be deduced from the bigger separation between the shallow and the deep resistivity. In the lower part silicified beds are frequent influencing the resistivity respons.

10.7.6. Houthem Formation

This formation was found in the Campine Mining District and in the Rur Valley Graben. It has the same characteristics as the Maastricht Formation as well on the logs as in lithology. The limit was tentatively placed at a particular and more prominent hardground on the basis of bio-ecostratigraphical information. It was however not always possible to make a clear distinction between this hardground, and the frequent adjoining hardgrounds.

10.8. CONCLUSIONS

Within the Campine basin five formations could be recognised on petrophysical log correlation (fig. 47). The subdivision was based on comparison with bio-ecostratigraphical zonations. Intraformational lithofacies variations, which occur frequently in the Campine Cretaceous, do not hamper lateral correlations too much. It was noticed that distinct geographical areas are also reflected by differences in the Cretaceous sequence.

The main characteristics of the Campine Cretaceous can be summarised as follows.

The Aachen Formation is persistent in the Campine Mining District, but wedges out toward the Antwerp Campine.

The Vaals Formation is very homogeneous in the Campine Mining District, but becomes more clayey and open marine, especially in the lower half, in the Antwerp Campine.

The Gulpen Formation shows a variable lithology and stratigraphic gaps may occur in the upper part. Subdivisions of the lower part of the Gulpen Formation are consistent throughout, even when they are different in petrophysical value. The Zeven Wegen and Beutenaken Members could even be identified within the Pre-Valkenburg facies. The upper part shows gaps, generally increasing from West to East. In the eastern Campine Mining District a more transitional facies occurs, provisionally named, the Pre-Valkenburg Strata.

The Maastricht Formation has variable characteristics: a finely cyclic sequence dominated by silicified beds characterises the lower part, towards the top the number of hardgrounds increases.
The Houthem Formation could only be recognised in the mining district and the graben, having similar characteristics as the Maastricht Formation.
In the Rur Valley Graben only the upper half of the Maastricht Formation and the Houthem Formation are present, in similar thicknesses as outside the graben. The transition is stepwise along faults, the gap at the base of the Cretaceous is stratigraphically rising towards the graben.

11. CONCLUSIONS

The foregoing chapters show that indiscriminate use of lithostratigraphic, biostratigraphic and chronostratigraphic terms has been made in the past. This has yielded contradictory results in the naming of the Upper Cretaceous to Early Tertiary strata in Northeastern Belgium and South Limburg (figures 2-5). This problem was met by W.M. FELDER (1975) in creating a new lithostratigraphic subdivision for the Maastricht area. This lithostratigraphic zonation could be compared with HOFKER's (1966) foraminifer zonation (table 1). The present study suggests that (mutatis mutandis) these lithostratigraphic and foraminifer zonations also can be used in Northeastern Belgium. In the eastern Campine (and possibly also in the coal-mining area of South Limburg) however, the lithology of the strata in between the Vaals and Maastricht Formations is different from that in the Maastricht area. Therefore, the term Pre-Valkenburg Strata is proposed for that interval. For a correlation of the lithostratigraphic units four different methods have been used:

1 - Bioclast assemblages
2 - Benthic and planktonic foraminifer assemblages
3 - Ostracode assemblages
4 - Borehole logs.

In a restricted number of sections two or more of these methods have been applied for calibration of the different techniques (tables 2, 3 and 4, figures 6-24).
Initially, the bioclast and ostracode ecozonations had been established in the Maastricht area and in the eastern Campine. The Pre-Valkenburg Strata in the latter area were attributed to the lowermost Maastricht Formation, this in the assumption that these beds contained large amounts of material reworked from the Vaals and Gulpen Formations. Furthermore, the (in the recent literature widespread) concept was followed that the lithostratigraphic units had chronostratigraphic value (cf. ROBASZYNSKI et al. 1985).
However, correlation of the Upper Cretaceous rocks by ecostratigraphic methods strongly suggests that this opinion should be revised. There is ample evidence that the Valkenburg Chalk ("per definition" included in the basal Maastricht Formation) partly or entirely matches the Lanaye Chalk ("per definition" included in the uppermost Gulpen Formation). In a similar way, the Pre-Valkenburg Strata seem to be the ecostratigraphic equivalent of a large part of the Gulpen Formation (at least of the Zeven Wegen and Beutenaken Members, and possibly of some portion of the higher members of this formation). And finally, the upper part of the Vaals Formation (characterized by benthic foraminifera of the A'-upper zone and possibly a part of the A'-middle zone) may be the ecostratigraphic equivalent of the lower portion of the Gulpen Formation (Zeven Wegen Member).

The ecostratigraphic correlation closely matches the correlation by petrophysical borehole logs. Exceptions are: KS 22 (base of Pre-Valkenburg Strata at 500 m according to logs, at 520 m according to bioclasts, at 515 m according to ostracodes), Turnhout (base of Lanaye Member and of Maastricht Formation according to logs quite different from that according to - poor - bioclast assemblages); and Poederlee (base of Vijlen Member according to logs at 649 m, base of Zone C according to benthic foraminifera at 673 m). However, in the last case the foraminifer zone C should not necessarily match the Vijlen Member as suggested by W.M. FELDER (1975).

Acceptance of the ecostratigraphic/borehole log zonations as parachronostratigraphic ones implies that the correlation of the lithostratigraphic units of W.M. FELDER (1975) and of the foraminifer zones of HOFKER (1966) needs revision. The final result may be an intricate jigsaw puzzle of terms as shown in figures 48 and 49. Eventually, this scheme suggests that the lateral and vertical variations in the Upper Cretaceous depositional environment have been much more complicate than had been accepted before. Because of the reduced number of sections studied thus far it seems premature to establish a more simplified subdivision of the Upper Cretaceous rocks in the area considered.

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13. FIGURES 1 - 49

Figure 1

Locality map of the Upper Cretaceous and Early Tertiary deposits in described boreholes and sections, showing the edge of the Brabant Massif as indicated by the Dinantian subcrop.

The mentioned faults bordering the Rur Valley Graben are directly influencing the Cretaceous deposits. The limits splitting the Campine Mining District and separating the Antwerp Campine to the west follow important fault paths but cannot be associated with a single fault. However it is clear that active epeirogenetic movements occurred along these faults and influenced the paleogeographical distribution of the sediments.

Typical log columns are shown illustrating the thickness variation of the successive formations (H = Houthem, M = Maastricht, G = Gulpen, P = Pre-Valkenburg (lateral equivalent of Gulpen), V = Vaals, A = Aachen, Sl = Cambro-Silurian, Ca = Carboniferous, Tr = Triassic).

Figure 2

Upper Cretaceous and Early Tertiary deposits in boreholes to the South of the main faults of the coal-mining area in South Limburg. Comparison of these sections suggests inconsistent description of the lithology (after KIMPE in: PATIJN & KIMPE 1961) and the lithostratigraphic interpretation of the same.

Lithostratigraphic interpretation:

DB 77: after KIMPE in: PATIJN & KIMPE 1961.

DB 76: Paleocene and Kunrade/Maastricht after KIMPE in: PATIJN & KIMPE 1961. Vaals/Herve and Aachen after JONGMANS & VAN RUMMELEN 1942.

DB 112: Paleocene and Kunrade/Maastricht after KIMPE in: PATIJN & KIMPE 1961. Kunrade/Maastricht and Vaals/Herve after JONGMANS & VAN RUMMELEN 1942.

DB 52: after KIMPE in: PATIJN & KIMPE 1961.

SM XLIII: after JONGMANS & VAN RUMMELEN 1942 and KIMPE in: PATIJN & KIMPE 1961.

DB 48: after JONGMANS & VAN RUMMELEN 1942 and KIMPE in: PATIJN & KIMPE 1961.

SM LXVII: after KIMPE in: PATIJN & KIMPE 1961.

DB 26: after JONGMANS & VAN RUMMELEN 1942 and KIMPE in: PATIJN & KIMPE 1961.

DB 113: after JONGMANS & VAN RUMMELEN 1942 and KIMPE in: PATIJN & KIMPE 1961.

SM LXIII: after KIMPE in: PATIJN & KIMPE 1961.

SM LIX: after JONGMANS & VAN RUMMELEN 1942 and KIMPE in: PATIJN & KIMPE 1961.

Figure 3

Upper Cretaceous and Early Tertiary deposits in boreholes and coal-mine shaft (Emma II) in South Limburg. Comparison of these sections suggests inconsistent description of the lithology (after KIMPE in: PATIJN & KIMPE 1961, except Kastanjelaan-2 after BLESS et al. 1981) and of the lithostratigraphic interpretation of the same.

Lithostratigraphic interpretation:

Kastanjelaan-2: after BLESS et al. 1981.

DB 105: symbols to the left after JONGMANS & VAN RUMMELEN 1942. Symbols to the right after KIMPE in: PATIJN & KIMPE 1961.

DB 24: Symbols to the left after KIMPE in: PATIJN & KIMPE 1961. Symbols to the right after JONGMANS & VAN RUMMELEN 1942.

SM LXIX: after KIMPE in: PATIJN & KIMPE 1961.

DB 28: after KIMPE in: PATIJN & KIMPE 1961.

SM LVI: after KIMPE in: PATIJN & KIMPE 1961.

DB 40: after JONGMANS & VAN RUMMELEN 1942 and KIMPE in: PATIJN & KIMPE 1961.

Emma II: after KIMPE in: PATIJN & KIMPE 1961.

Figure 4

Upper Cretaceous and Early Tertiary deposits in some boreholes in the Campine. Comparison of these sections suggests inconsistent lithostratigraphic interpretation of the same. Vertical hatching = Aachen Formation.

Lithostratigraphic interpretation:

KS 16: this report.

BGD 24: after H. FORIR in: Anonymus 1903.

BGD 32: after Anonymus 1903.

BGD 49: after Anonymus 1903.

Figure 5

Comparison of lithostratigraphic interpretation of Upper Cretaceous and Early Tertiary deposits in some boreholes in the Campine and South Limburg, suggesting inconsistent use of lithostratigraphic terminology. Vertical hatching = Aachen Formation.

Lithostratigraphic interpretation:

BGD 169: this report.

BGD 40: after X. STAINIER in: Anonymus 1903.

BGD 6: H. FORIR et al. in: Anonymus 1903.

KS 16: this report.

BGD 20: after Anonymus 1903.

BGD 45: after Anonymus 1903.

Figure 5 - continued

BGD 53: after Anonymus 1903.

DB 77: after JONGMANS & VAN RUMMELEN 1942 and FRANCKEN 1947.

DB 76: after JONGMANS & VAN RUMMELEN 1942 and FRANCKEN 1947.

DB 112: after JONGMANS & VAN RUMMELEN 1942 and FRANCKEN 1947.

DB 52: after JONGMANS & VAN RUMMELEN 1942 and FRANCKEN 1947.

SM LVII: after JONGMANS & VAN RUMMELEN 1942 and FRANCKEN 1947.

Figures 6 - 24

Stratigraphic columns of Upper Cretaceous to Early Tertiary rocks in Northeastern Belgium and South Limburg, showing correlation of (from left to right): profile of number bioclasts (1.0 - 2.4 mm) per kilogram, boundaries based on borehole logs (indicated by numbered asterisks), formations (A = Aachen Fm., V = Vaals Fm., G = Gulpen Fm., P = Pre-Valkenburg strata, M = Maastricht Fm., H = Houthem Fm., Z = Zwartberg Clay, Orp Sand and Gelinden Marl), foraminifer zones (also indicated in some sections mean number of pustules on last chamber of Bolivinoides), ostracode ecozones, depth in boreholes, quantitative composition of bioclast assemblages (For = foraminifera, Bry = bryozoans, sponges, corals, Mo-Br = molluscs, brachiopods, Ech = echinoderms, Rest = other bioclasts).

Figure 6	KS 16
Figure 7	KS 17
Figure 8	KS 18
Figure 9	KS 19
Figure 10	KS 20
Figure 11	KS 22
Figure 12	BGD 168
Figure 13	BGD 169
Figure 14	Cadier en Keer
Figure 15	ENCI
Figure 16	Halembaye - Lanaye
Figure 17	Kastanjelaan-2
Figure 18	Leopoldsburg
Figure 19	Merksplas
Figure 20	Nieuwerkerken
Figure 21	Poederlee
Figure 22	Turnhout
Figure 23	Valkenburg
Figure 24	Walem

Figures 25 - 34

Comparison of bioclast profiles and bioclast ecozones.

Figures 25 - 26	Number of bioclasts (1.0 - 2.4 mm) per kilogram.
Figures 27 - 28	Percentage of foraminifera in bioclast assemblages.
Figures 29 - 30	Percentage of bryozoans, sponges and corals in bioclast assemblages.
Figures 31 - 32	Percentage of molluscs and brachiopods in bioclast assemblages.
Figures 33 - 34	Percentage of echinoderms in bioclast assemblages.

Figure 35

Cartoon showing tentative correlation of Upper Cretaceous to Early Tertiary Formations (excluded Aachen Formation) in South Limburg and Campine, based on bioclast ecozones (not to scale!). Also the correlation of HOFKER's foraminifer zones A', A to R is based on the bioclast ecozones 1 to 7. It should be noticed that the bioclast assemblages of the Vaals Formation at Kunrade (including in its upper portion the Benzenrade Chalk of STARING 1860) have not been studied thus far! However, by inference it is suggested that the Vaals Formation at Kunrade may be partly the lateral equivalent of the Gulpen and/or basal Maastricht Formations. This suggestion doesn't exclude the possible presence of (important) sedimentary gaps. The same holds for the other formations. Diagonal hatching indicates presence of known or possible sedimentary gaps.

Figure 36

Relative percentage of ornamented ostracode specimens in the ostracode assemblages of the Vaals and Gulpen Formations of Northeastern Belgium (Merksplas, Poederlee, Halembaye/Lanaye) and South Limburg (Kastanjelaan-2, Cadier en Keer, Walem). The datum line represents the base of the Maastricht Formation. The distribution of some characteristic ostracodes is shown, as well as the ostracode ecozones.

Figure 37

Relative percentage of ornamented ostracode specimens in the ostracode assemblages of the Vaals and Gulpen Formations and in the Pre-Valkenburg strata of Northeastern Belgium (BGD 169, KS 19, KS 17, KS 18, KS 20, KS 22, KS 16) and South Limburg (Walem). The datum line represents the base of the Maastricht Formation (in Walem) or the base of the Valkenburg Chalk. The distribution of some characteristic ostracodes is shown, as well as the ostracode ecozones.

Figure 38

Relative percentage of ostracode specimens in the Gulpen Formation (only partly shown in Nieuwerkerken, Halembaye/Lanaye, ENCI and Kastanjelaan-2), in the Pre-Valkenburg strata (only partly shown in KS 16) and in the Maastricht Formation (represented in all sections) of Northeastern Belgium (KS 16, Nieuwerkerken, Halembaye/Lanaye) and South Limburg (ENCI, Kastanjelaan-2, Nekami, Valkenburg, Kunrade). The datum line represents the Romontbos Horizon. The distribution of the ostracode ecozones is shown.

Figure 39

Compilation of data on ostracode ecozones 1 to 13 as presented in figures 36 to 38. Note regular thicknesses for each ecozone (except in Merksplas, Poederlee and BGD 169), and comparable thicknesses for ecozones 4-6, 8 and 2 (in Walem) on the one hand, and for ecozones 7 and 9 on the other. Moreover, note comparable relative position (compared to datum line of Romontbos for ecozones 7 and 9, and compared to datum line of base of Valkenburg Chalk for ecozones 4-6, 8 and 2 (in Walem) of smooth-shelled and ornamented ostracode ecozones. To the right, three main ecostratigraphic periods are distinguished. During periods A and C, high numbers of ornamented ostracode specimens in the assemblages suggest very shallow marine environments, possibly above wave base. During period B, low numbers of ornamented ostracode specimens suggest an overall (shallow ?) marine environment below wave base.

Note that this figure doesn't account for (partly known) sedimentary gaps!

Figure 40

Tentative correlation of Upper Cretaceous Formations (excluding Aachen Formation) in South Limburg and eastern Campine, based on ostracode ecozones (not to scale!). Also the correlation of HOFKER's foraminifer zones A', A to O is based on the ostracode ecozones 1 to 13. It should be noticed that the ostracode assemblages of the Vaals Formation at Kunrade (including in its upper portion the Benzenrade Chalk of STARING 1860) have not been studied thus far! However, by inference it is suggested that the Vaals Formation at Kunrade may be partly the lateral equivalent of the Gulpen and/or basal Maastricht Formations. This suggestion doesn't exclude the possible presence of (important) sedimentary gaps.The same holds for the other formations. Diagonal hatching indicates presence of known or possible sedimentary gaps.

Figure 41. Pterygocythere (Ostracodes)

1 - 5 Pterygocythere laticristata (BOSQUET 1854)

1 KS 17, 480 m, Pre-Valkenburg strata.
1a: left view, 1b: interior view

2 Turnhout, 815.89 m, Gulpen Formation, Vijlen Chalk.
2a: dorsal view, 2b: left view.

3 Merksplas, 880.95 m, Gulpen Formation, Beutenaken Chalk.
3a: dorsal view, 3b: right view.

4 Merksplas, 933.22 m, Gulpen Formation, Zeven Wegen Chalk.
4a: left view, 4b: dorsal view, 4c: interior view.

5 Merksplas, 942.48 m, Gulpen Formation, Zeven Wegen Chalk.
5a: right view, 5b: dorsal view, 5c: interior view.

Figure 42. Pterygocythere (Ostracodes)

1 - 4 Pterygocythere laticristata (BOSQUET 1854)

1 Merksplas, 995.66 m, Vaals Formation.
1a: right view, 1b: dorsal view.

2 BGD 169, 685 m, Vaals Formation.
2a: right view, 2b: dorsal view.

3 Walem, 39.40 m, Vaals Formation.
3a: left view, 3b: dorsal view, 3c: interior view.

4 Kastanjelaan-2, 157.2 m, Vaals Formation.
4a: right view, 4b: dorsal view, 4c: interior view.

5 Pterygocythere alata (BOSQUET 1847)
Kunrade, K 4, Maastricht Formation, Kunrade Chalk.
5a: left view, 5b: dorsal view, 5c: interior view.

Figure 43. Mosaeleberis (Ostracodes)

1 - 4 Mosaeleberis sp. gr. 1

1 Mosaeleberis interruptoidea (VAN VEEN 1936)
Valkenburg, V 10, Maastricht Formation, Valkenburg Chalk.
1a: left view, 1b: interior view.

2 Mosaeleberis sp.
BGD 169, 562 m, Pre-Valkenburg strata.
Left view.

3 - 4 Mosaeleberis macrophthalma (BOSQUET 1847)

3 Nieuwerkerken, 126 m, Gulpen Formation, Lanaye Chalk.
3a: right view, 3b: dorsal view.

Figure 43 - continued

4 Walem, 8 m (Walem 11), Gulpen Formation, Lanaye Chalk.
4a: left view, 4b: interior view.

5 - 8 Mosaeleberis sp. gr. 2

5 Mosaeleberis cf. lerichei DEROO 1966.
KS 22, 480 m, Pre-Valkenburg strata.
5a: right view, 5b: dorsal view.

6 - 8 Mosaeleberis rutoti DEROO 1966.

6 Kastanjelaan-2, 128.8 m, Gulpen Formation, Zeven Wegen Chalk.
6a: right view, 6b: dorsal view.

7 Merksplas, 957.45 m, Gulpen Formation, Zeven Wegen Chalk.
7a: right view, 7b: dorsal view.

8 Merksplas, 947.89 m, Gulpen Formation, Zeven Wegen Chalk.
8a: left view, 8b: interior view.

Figure 44

Gamma ray log correlation of representative sections in the Campine Basin (Merksplas-1 in Antwerp Campine, KS 1 in western Campine coal-mining area, KS 19 in eastern Campine coal-mining area).

Figure 45

Characteristics of Pre-Valkenburg strata (Gulpen Formation equivalent) in Campine Basin.

Figure 46

Characteristics of Vaals Formation in Merksplas-1 (Antwerp Campine).

Figure 47

Correlation of Upper Cretaceous and Early Tertiary deposits in the Campine Basin based on petrophysical borehole logs.

Figure 48

Correlation of Upper Cretaceous and Early Tertiary zonations in Northeastern Belgium and South Limburg. Marly to sandy equivalents of Gulpen Formation (Pre-Valkenburg strata in eastern Campine and upper portion of Vaals Formation in South Limburg) are punctated.

Figure 49

Cartoon showing proposed chronostratigraphic relationship of principal lithologic facies in Northeastern Belgium and South Limburg. Punctated are presumed nearshore deposits containing large amounts of clastics (sand, silt, clay) and frequently being glauconiferous. In fact the Campanian and Maastrichtian deposits always can be subdivided into an offshore shelf facies and a nearshore shelf facies. Offshore shelf conditions for the Vaals Formation (Lower Campanian) have been distinguished in the Antwerp Campine where rich planktonic foraminifer assemblages occur. Also the Gulpen Formation s.s. and the Maastricht Facies of the Maastricht Formation can be considered as offshore shelf. Presumably, the influx of clastics ceased when inversion of the Rur Valley Graben came to an end.

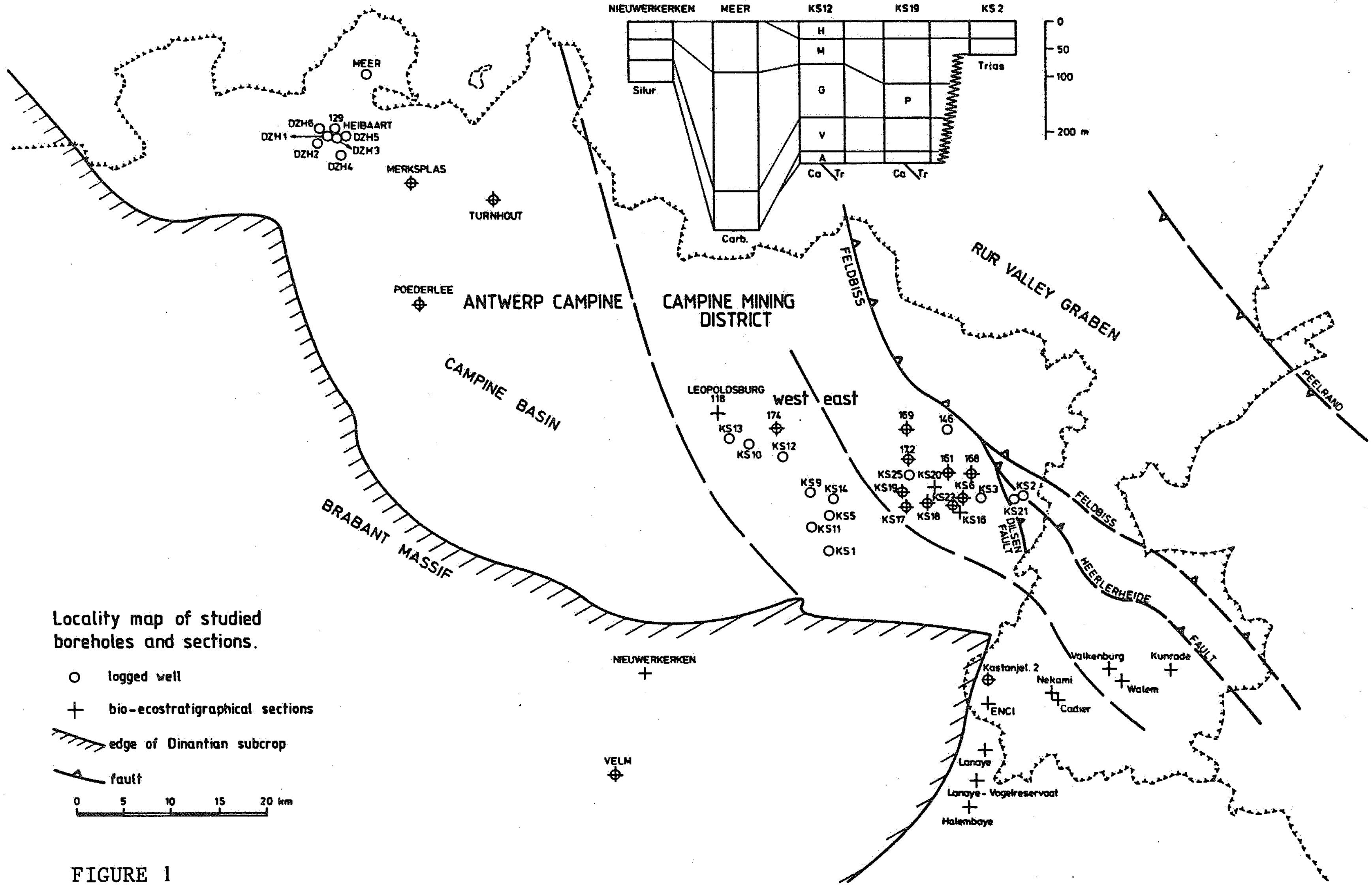

NIEUWERKERKEN
MEER
KS12
KS19
KS 2
H
M
G
V
A
P
Silur.
Trias
Carb.
Ca
Tr
0
50
100
200 m
MEER
DZH6
129
HEIBAART
DZH1
DZH5
DZH2
DZH3
DZH4
MERKSPLAS
TURNHOUT
POEDERLEE
ANTWERP CAMPINE
CAMPINE MINING DISTRICT
CAMPINE BASIN
BRABANT MASSIF
RUR VALLEY GRABEN
FELDBISS
PEELRAND
HEERLERHEIDE FAULT
DILSEN FAULT
LEOPOLDSBURG 118
west
east
174
KS13
KS10
KS12
169
146
172
161
168
KS25
KS20
KS6
KS3
KS2
KS19
KS22
KS21
KS17
KS18
KS16
KS9
KS14
KS5
KS11
KS1
Kastanjel. 2
Valkenburg
Kunrade
Walem
Nekami
Cadier
ENCI
Lanaye
Lanaye - Vogelreservaat
Halembaye
NIEUWERKERKEN
VELM
Locality map of studied boreholes and sections.
logged well
bio-ecostratigraphical sections
edge of Dinantian subcrop
fault
0
5
10
15
20 km

FIGURE 1

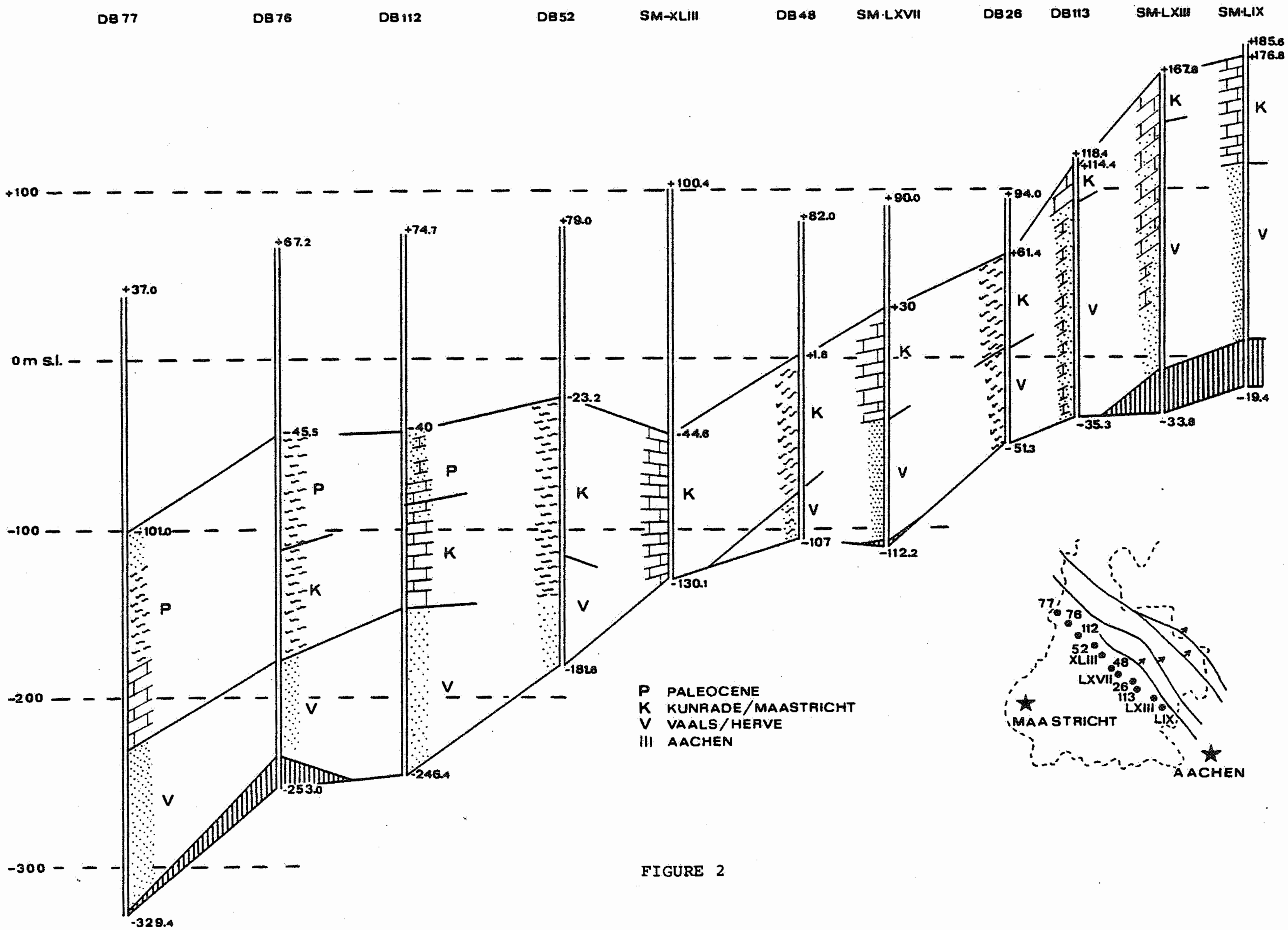
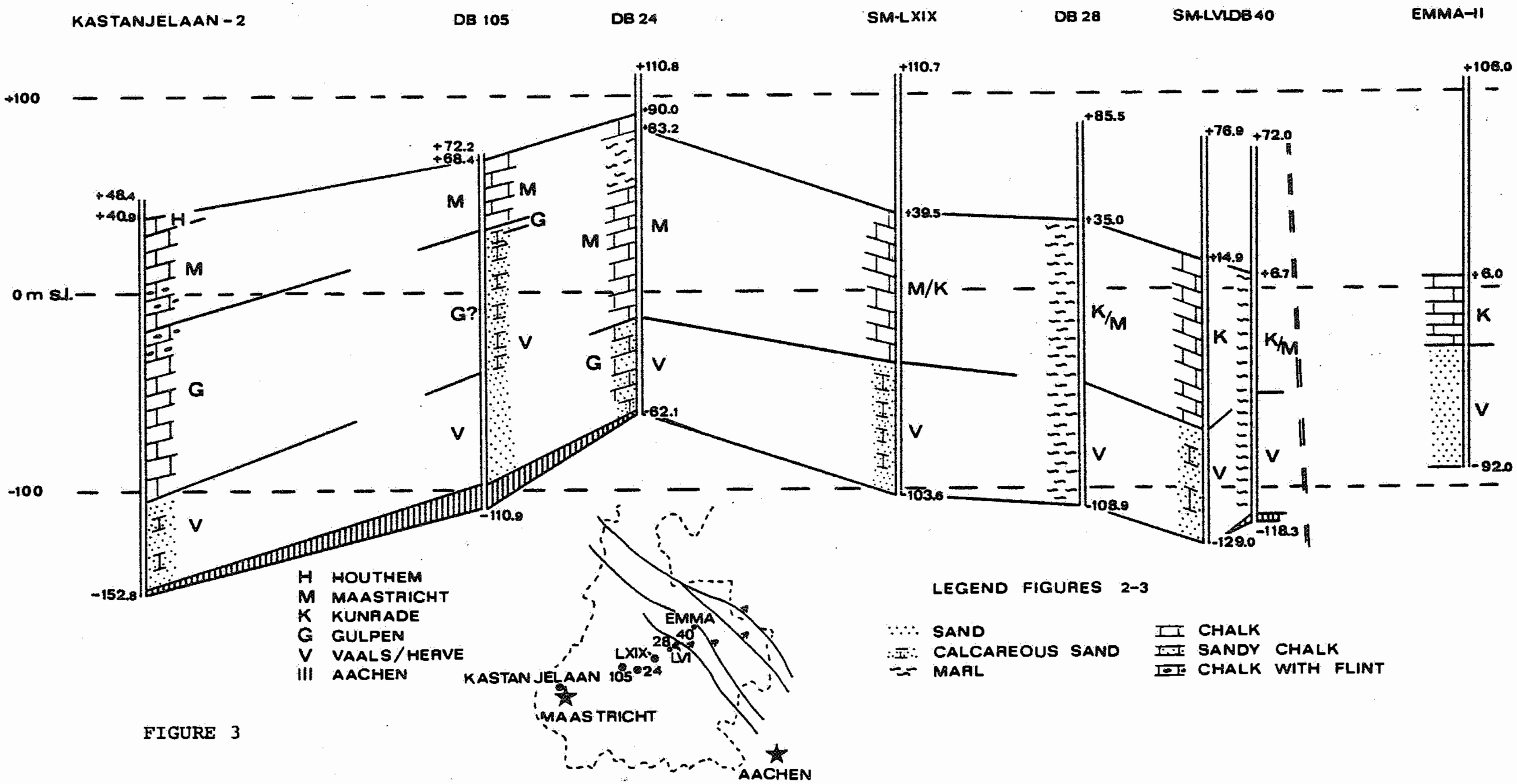

DB 77
DB 76
DB 112
DB 52
SM-XLIII
DB 48
SM-LXVII
DB 26
DB 113
SM-LXIII
SM-LIX
+100
0 m s.l.
-100
-200
-300
P PALEOCENE
K KUNRADE/MAASTRICHT
V VAALS/HERVE
III AACHEN
MAASTRICHT
AACHEN

FIGURE 2



KASTANJELAAN - 2
DB 105
DB 24
SM-LXIX
DB 28
SM-LVI
DB 40
EMMA-II
+100
0 m s.l.
-100
+48.4
+40.9
-152.8
+72.2
+68.4
-110.9
+110.8
+90.0
+83.2
-62.1
+110.7
+39.5
-103.6
+85.5
+35.0
-108.9
+76.9
+14.9
-129.0
+72.0
+6.7
-118.3
+106.0
+6.0
-92.0
H HOUTHEM
M MAASTRICHT
K KUNRADE
G GULPEN
V VAALS/HERVE
III AACHEN
EMMA
LXIX
28
40
LVI
KASTANJELAAN
105
24
MAASTRICHT
AACHEN
LEGEND FIGURES 2-3
SAND
CALCAREOUS SAND
MARL
CHALK
SANDY CHALK
CHALK WITH FLINT

FIGURE 3

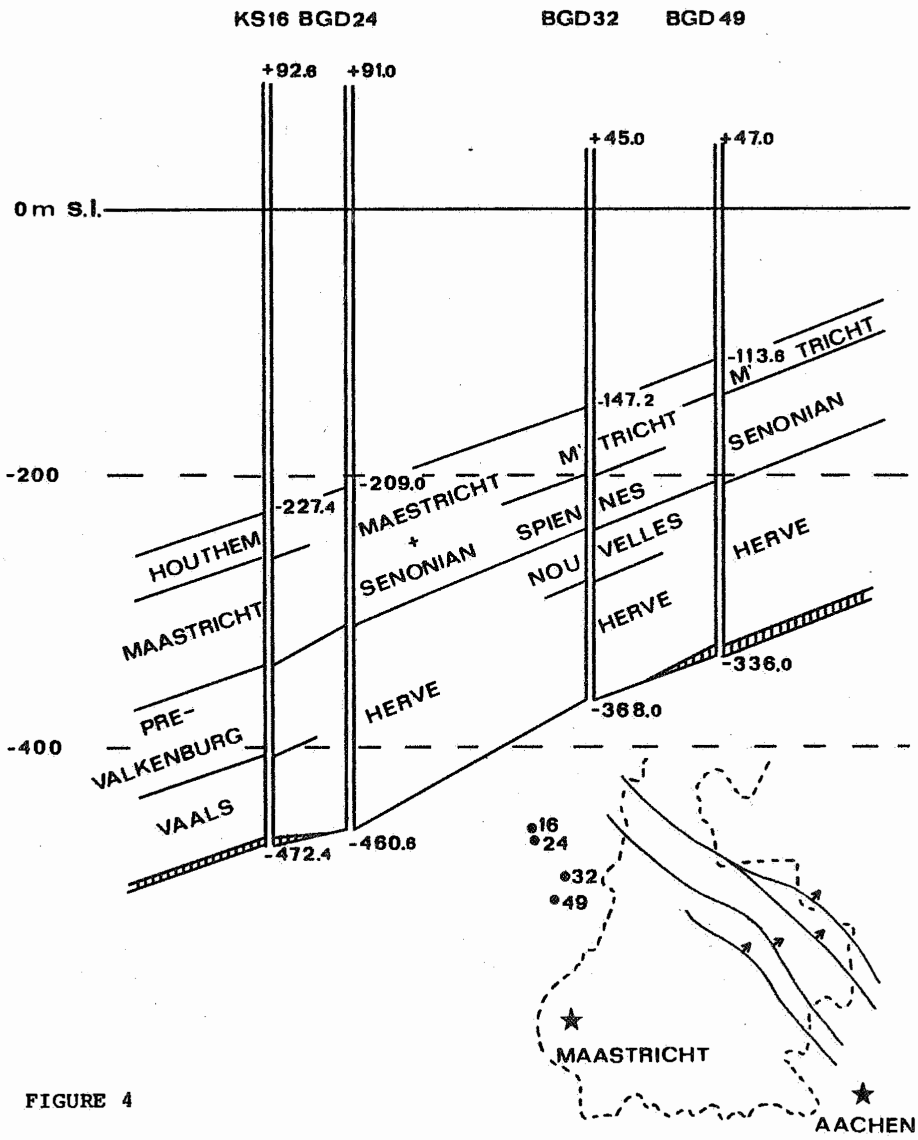

KS16 BGD24
BGD32
BGD49
+92.6
+91.0
+45.0
+47.0
0 m s.l.
-200
-400
-113.6
TRICHT
M'
-147.2
M'
TRICHT
SENONIAN
-209.0
MAESTRICHT
+
SENONIAN
-227.4
SPIEN
NES
NOU
VELLES
HERVE
HOUTHEM
MAASTRICHT
PRE-
VALKENBURG
VAALS
HERVE
HERVE
-336.0
-368.0
-460.6
-472.4
16
24
32
49
MAASTRICHT
AACHEN

FIGURE 4

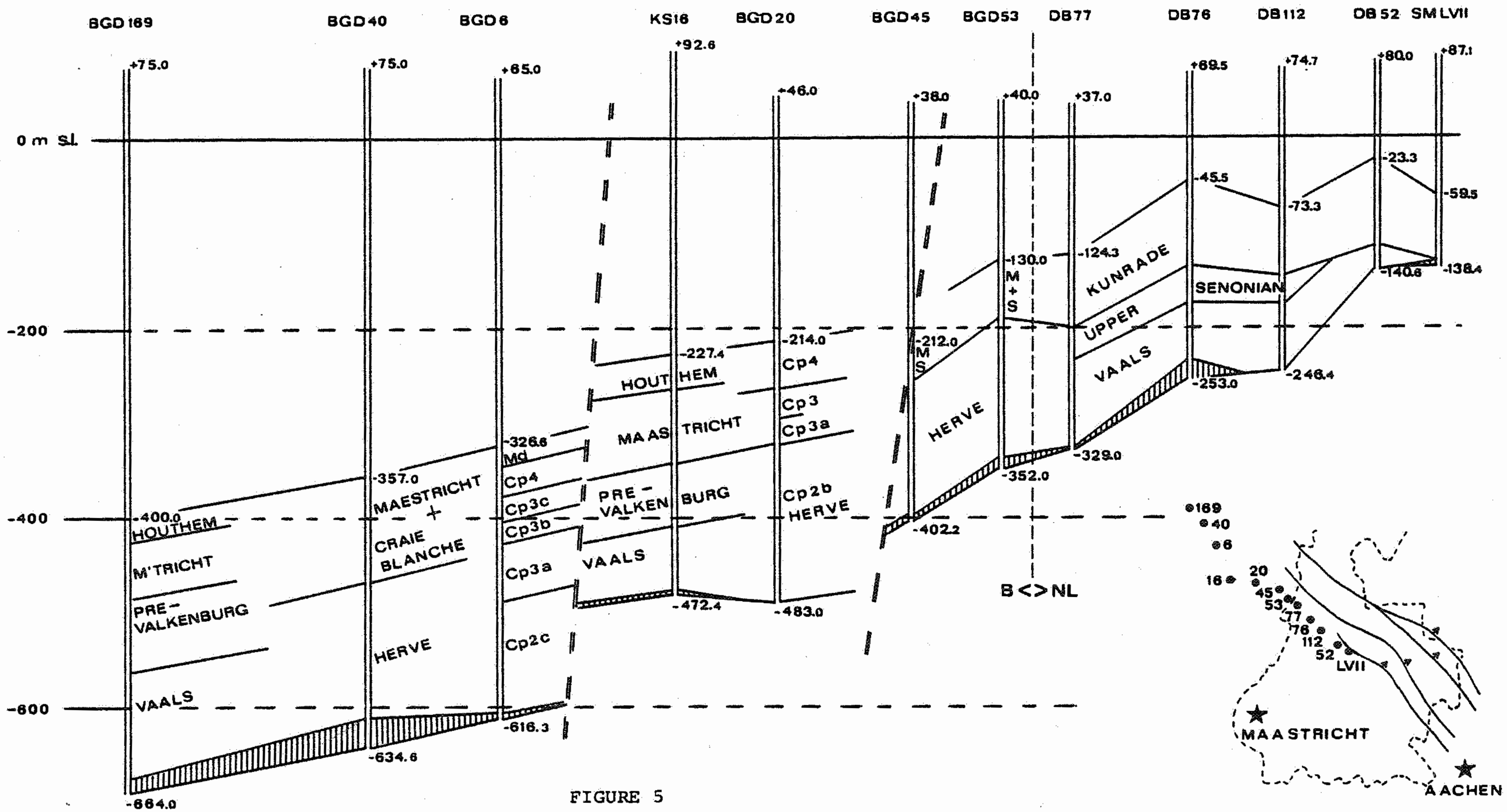
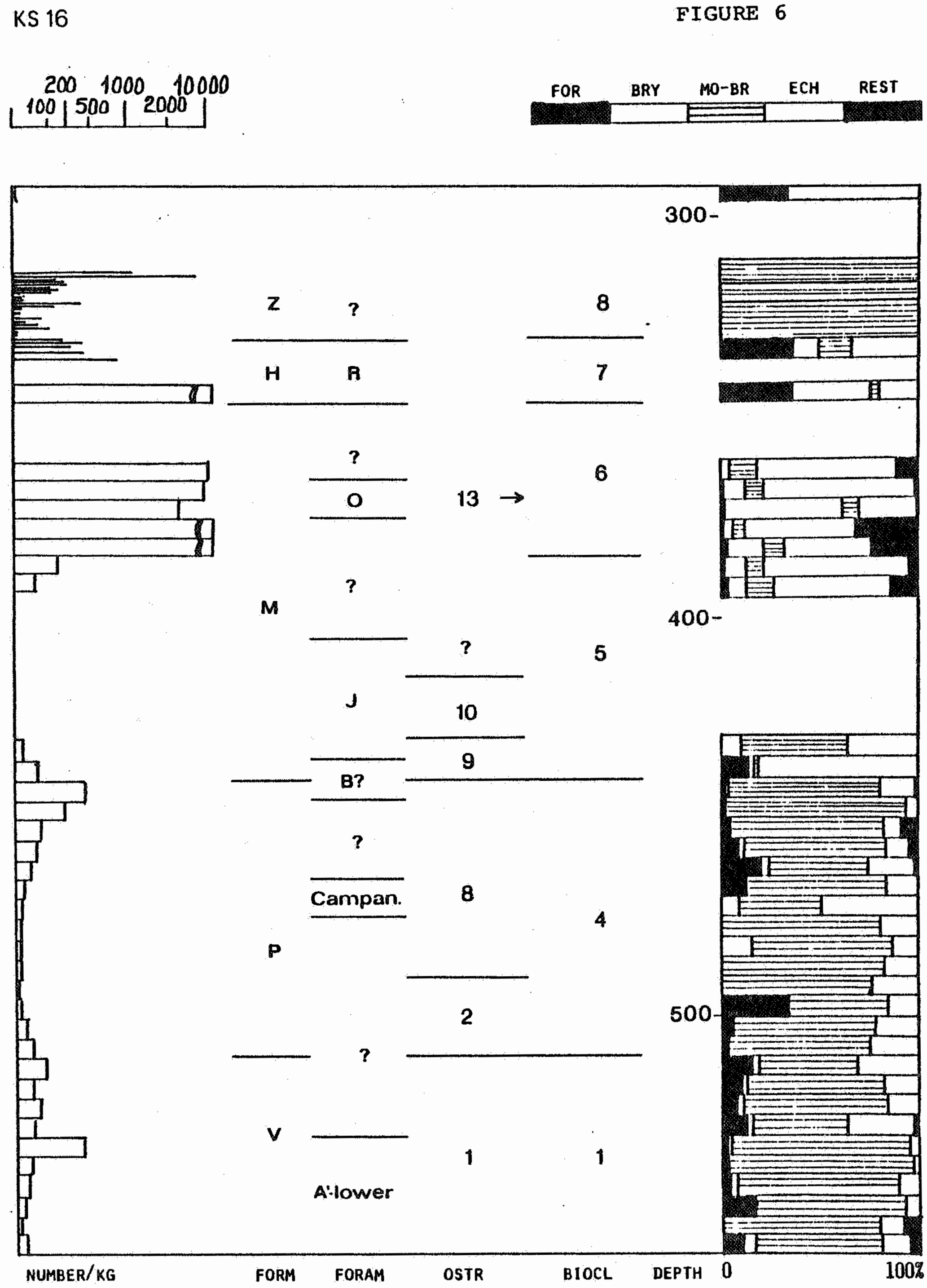

BGD 169
BGD 40
BGD 6
KS 16
BGD 20
BGD 45
BGD 53
DB 77
DB 76
DB 112
DB 52
SM LVII
0 m sl.
-200
-400
-600
+75.0
+75.0
+65.0
+92.6
+46.0
+38.0
+40.0
+37.0
+69.5
+74.7
+80.0
+87.1
-45.5
-73.3
-23.3
-59.5
-130.0
-124.3
-140.6
-138.4
-227.4
-214.0
-212.0
-253.0
-246.4
-326.6
-357.0
-352.0
-329.0
-400.0
-402.2
-472.4
-483.0
-616.3
-634.6
-664.0
HOUTHEM
M'TRICHT
PRE-
VALKENBURG
VAALS
MAESTRICHT
+
CRAIE
BLANCHE
HERVE
Md
Cp4
Cp3c
Cp3b
Cp3a
Cp2c
HOUT HEM
MAAS TRICHT
PRE -
VALKEN BURG
VAALS
Cp4
Cp3
Cp3a
Cp2b
HERVE
M
S
HERVE
M
+
S
KUNRADE
UPPER
VAALS
SENONIAN
B <> NL
169
40
6
16
20
45
53
77
76
112
52
LVII
MAASTRICHT
AACHEN

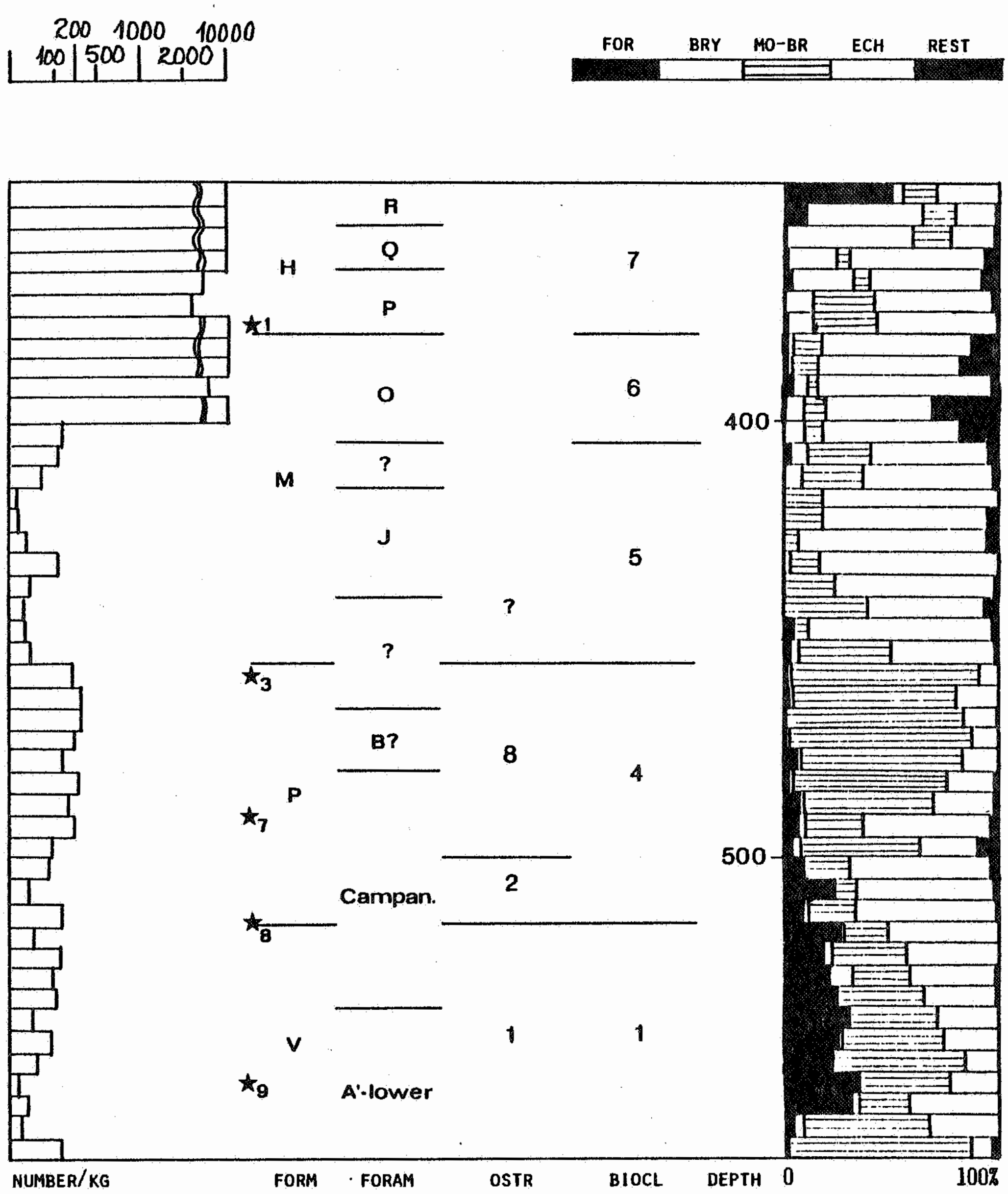
FIGURE 5

FIGURE 6


KS 16
200 1000 10000
100 500 2000
FOR BRY MO-BR ECH REST
300-
400-
500-
Z ? 8
H R 7
? 6
O 13 →
M ?
? 5
J 10
9
B?
?
Campan. 8
4
P
2
?
V
1 1
A'-lower
NUMBER/KG FORM FORAM OSTR BIOCL DEPTH 0 100%

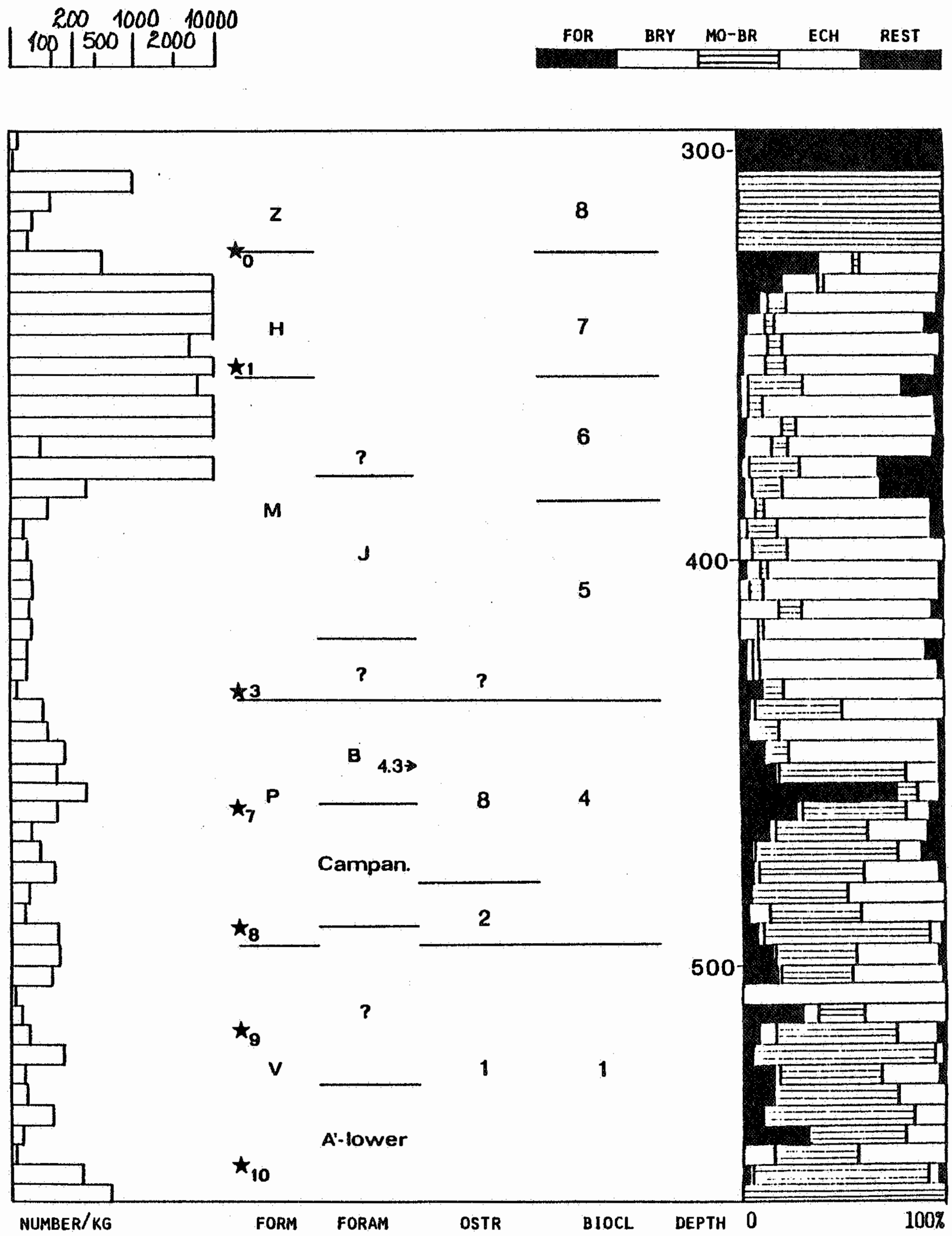
KS 17

FIGURE 7

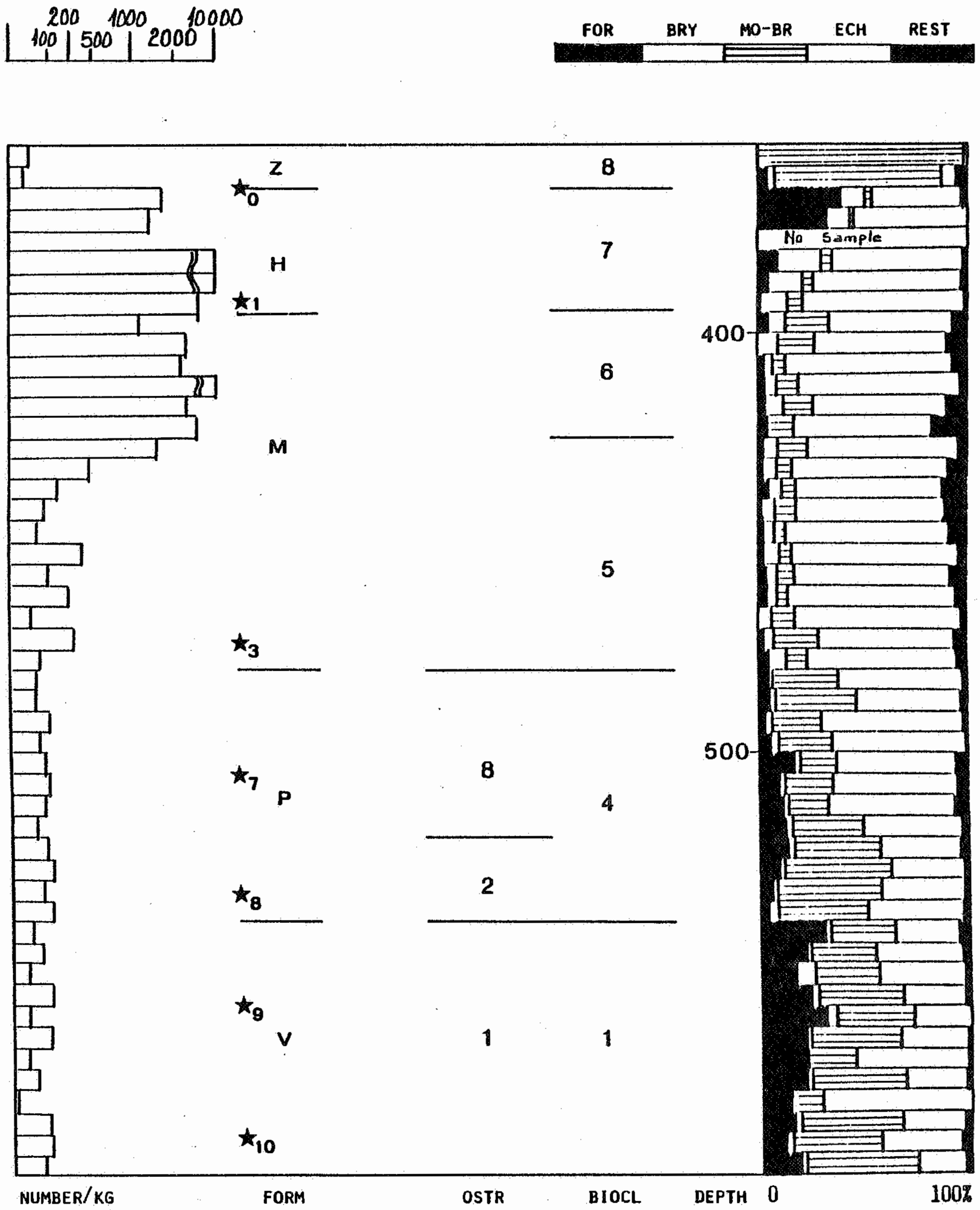


KS 18

FIGURE 8

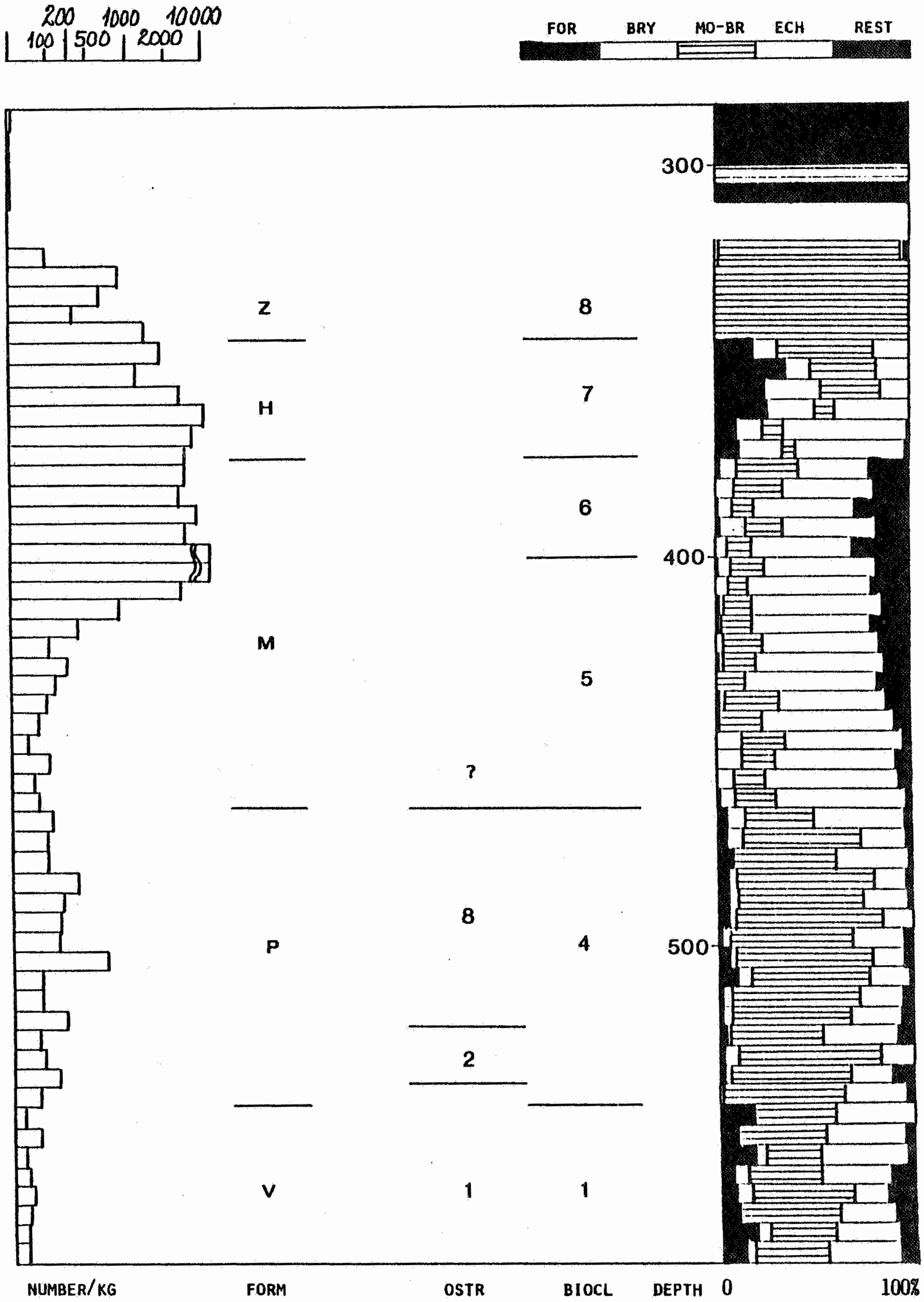


KS 19 FIGURE 9



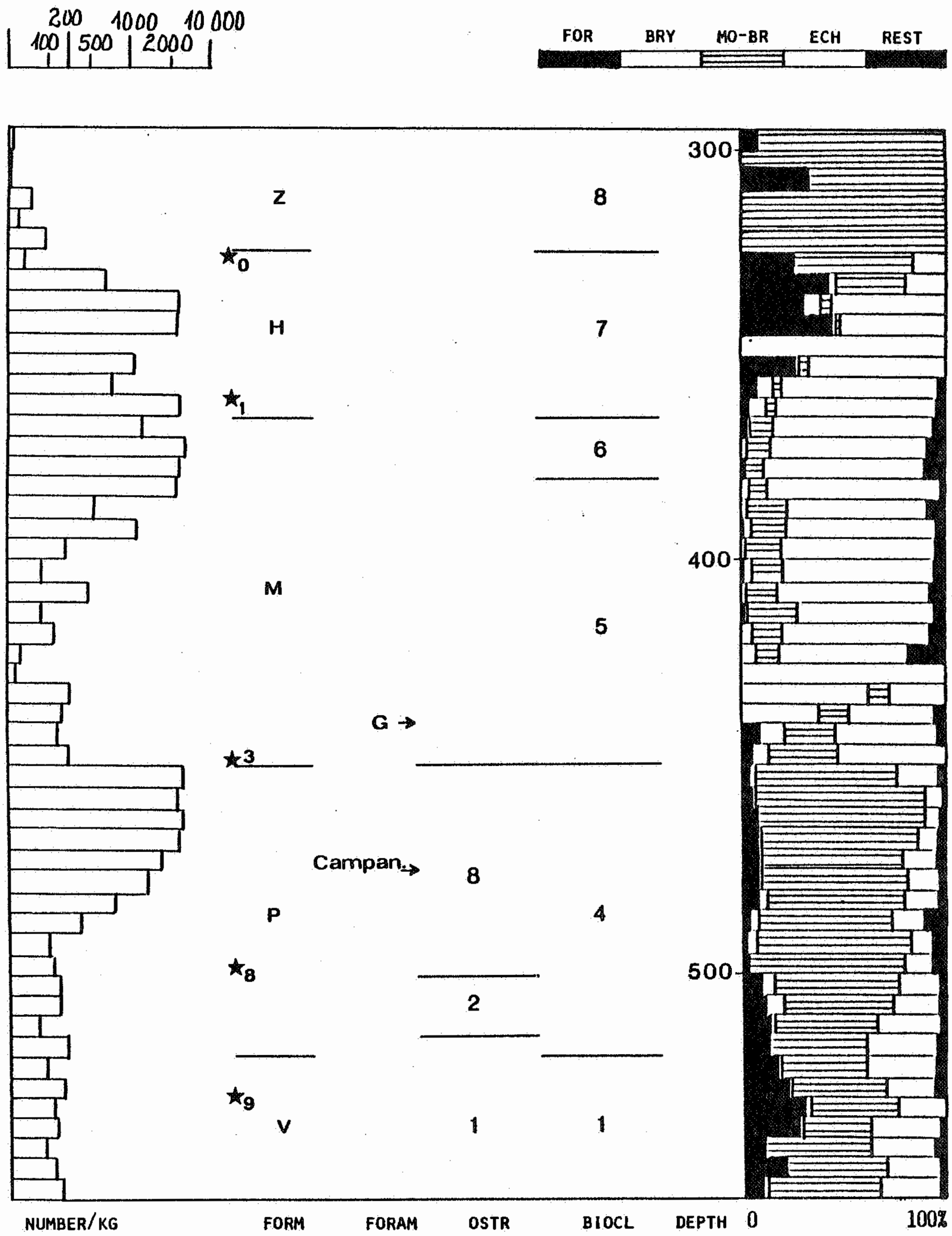
KS 20

FIGURE 10



KS22

FIGURE 11



BGD 168

FIGURE 12

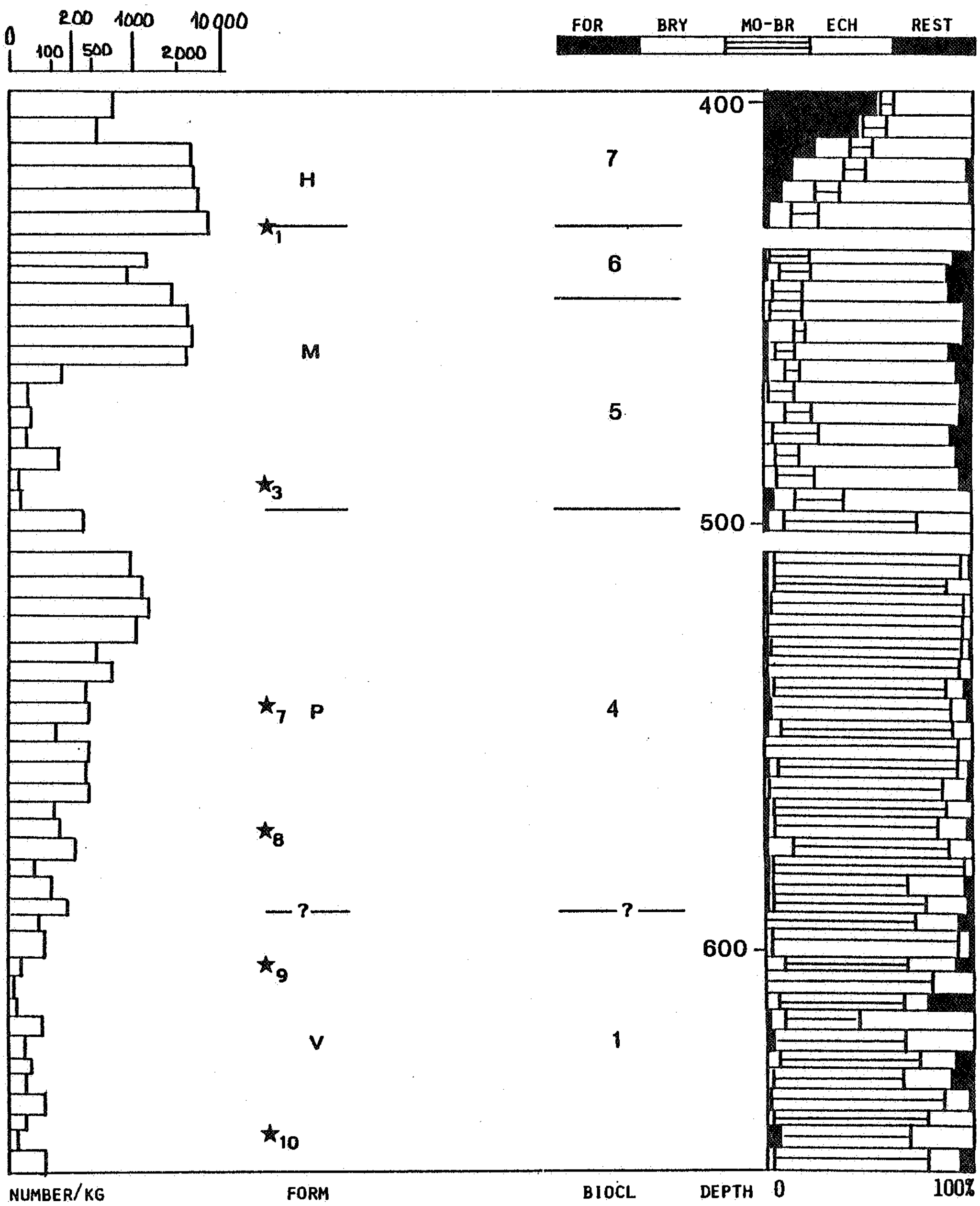
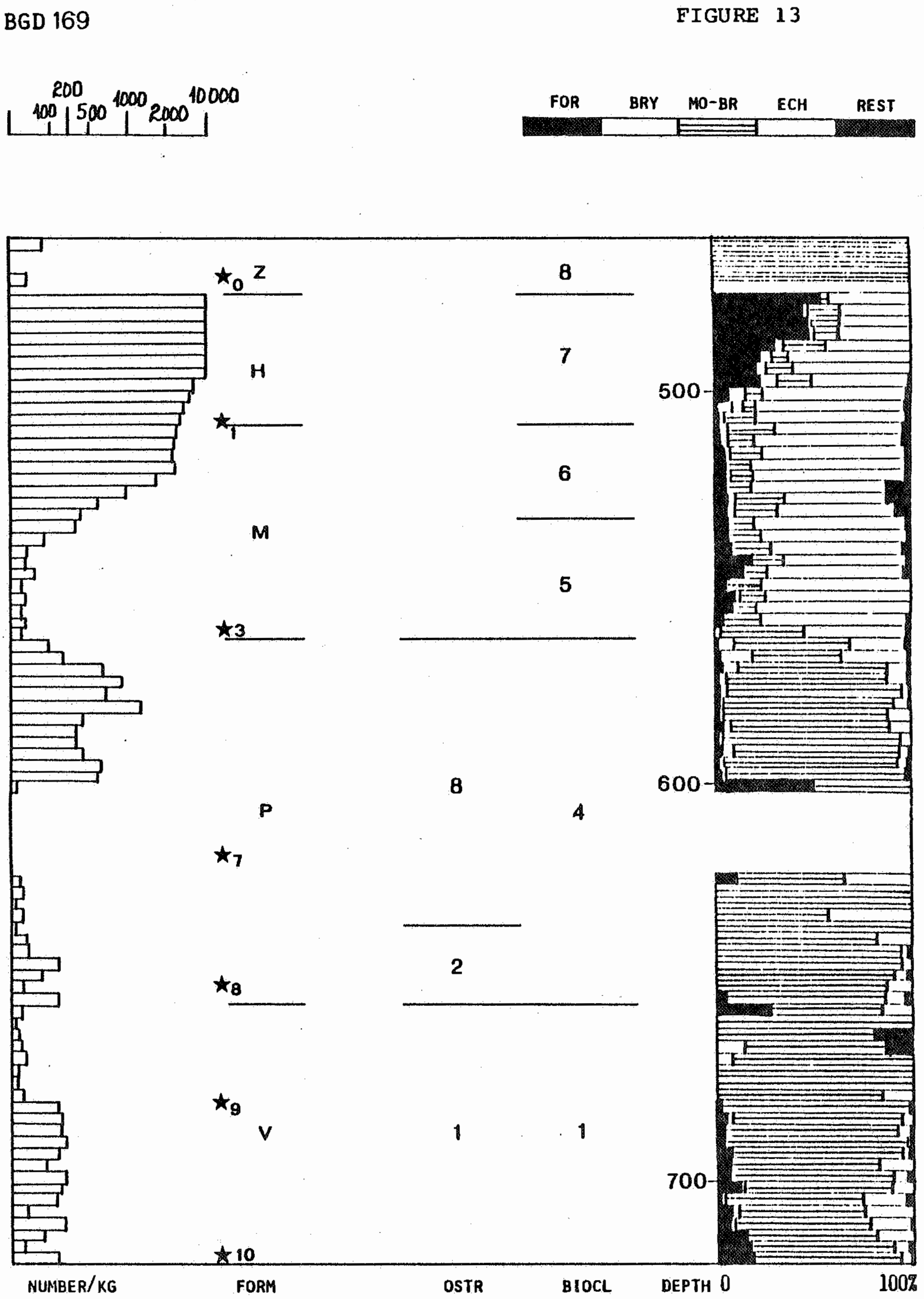
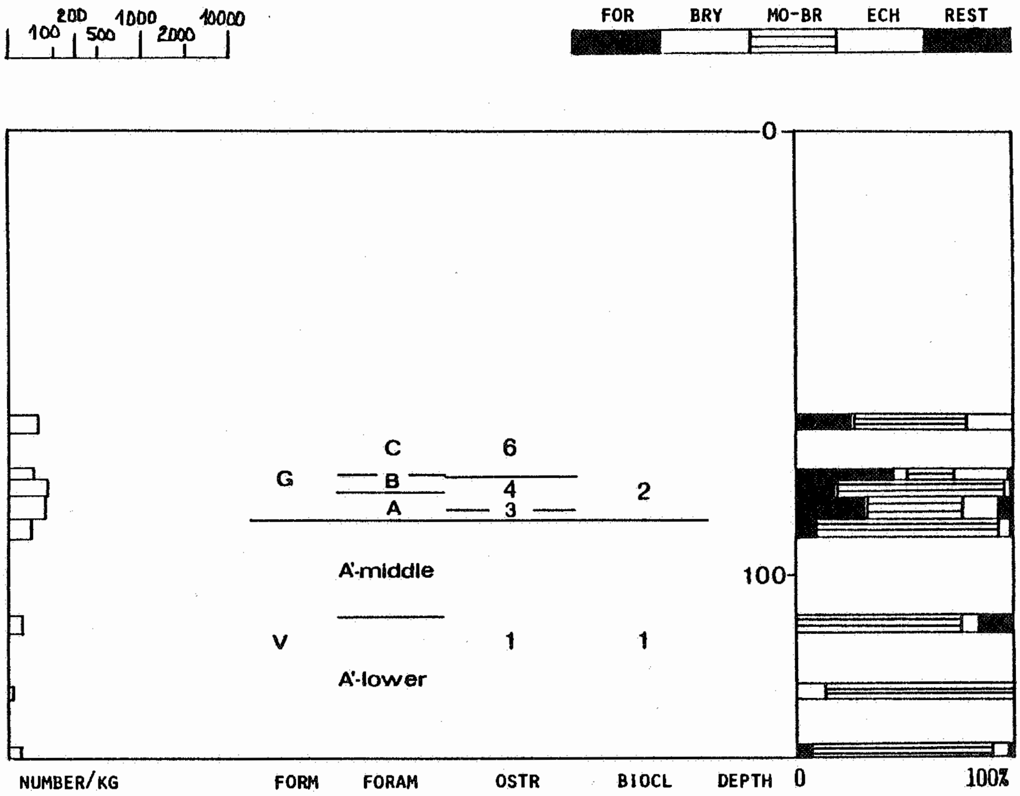


FIGURE 13


BGD 169
200
100
500
1000
2000
10000
FOR
BRY
MO-BR
ECH
REST
Z
H
M
P
V
8
7
6
5
4
2
1
1
500
600
700
NUMBER/KG
FORM
OSTR
BIOCL
DEPTH
0
100%

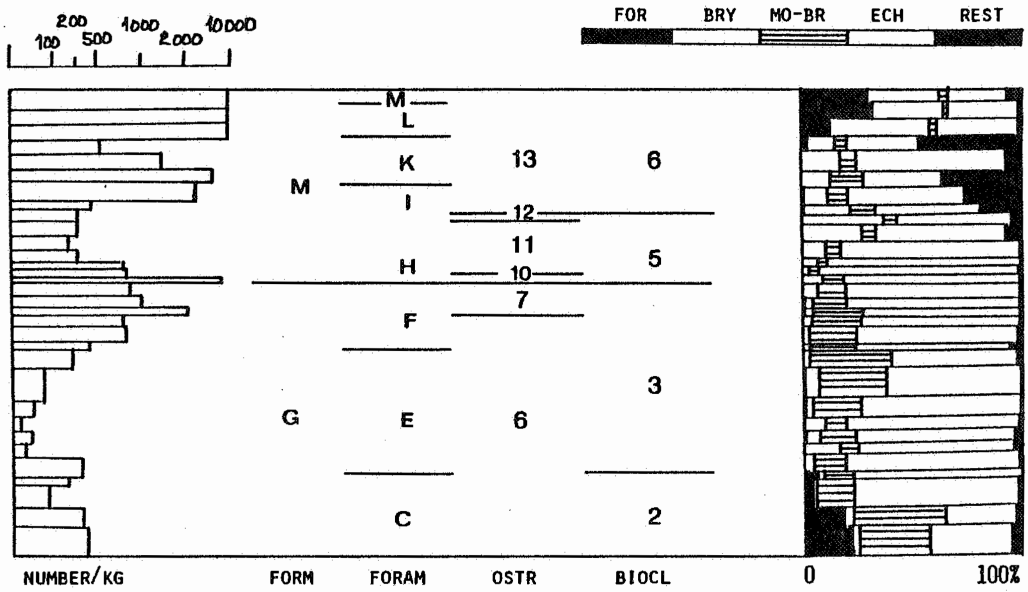
CADIER EN KEER

FIGURE 14



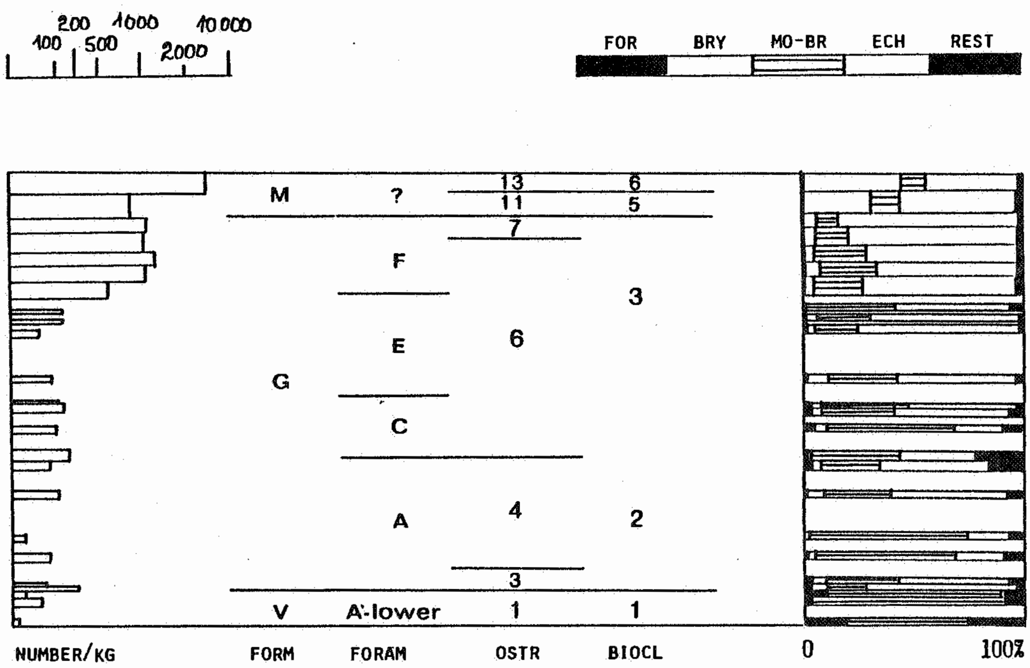
ENCI

FIGURE 15



HALEMBAYE - LANAYE

FIGURE 16



KASTANJELAAN-2

FIGURE 17

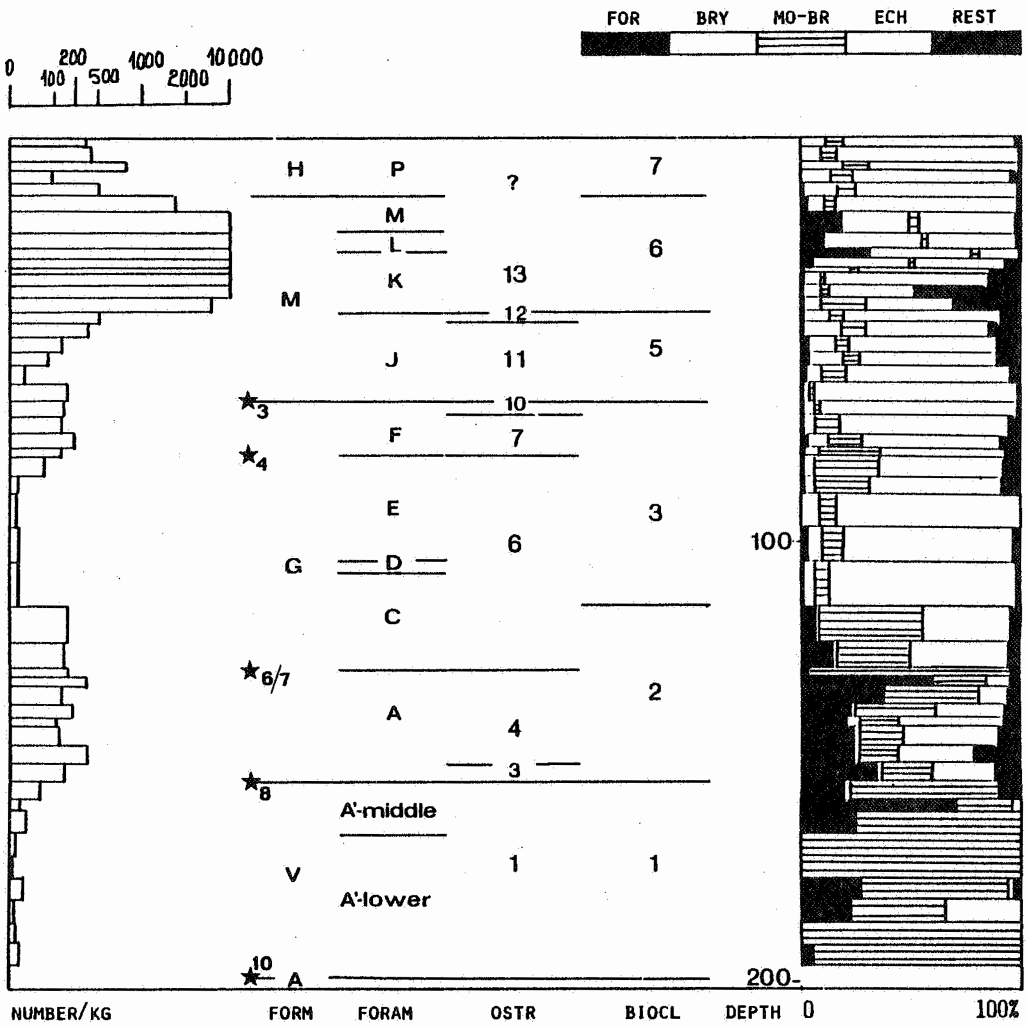
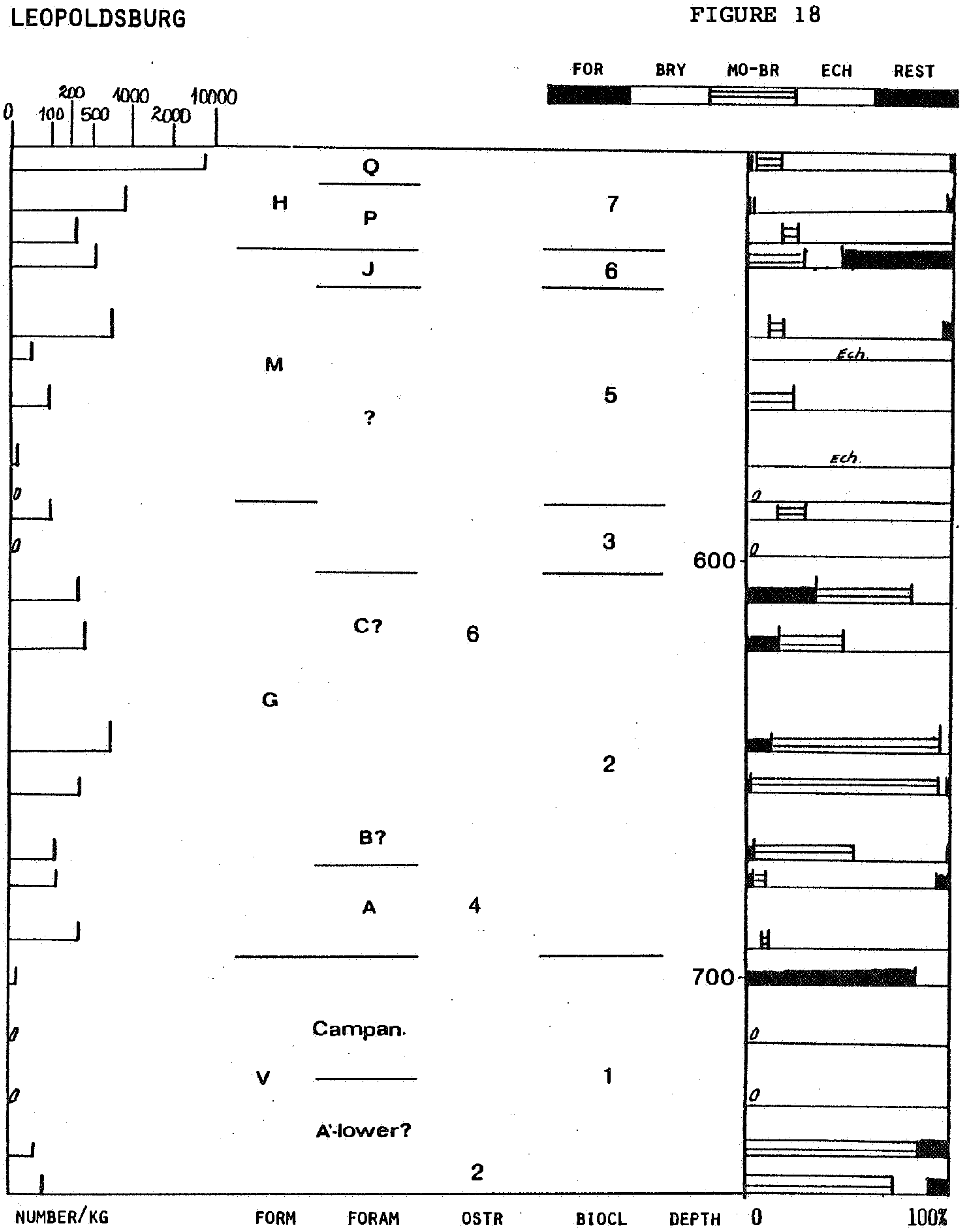
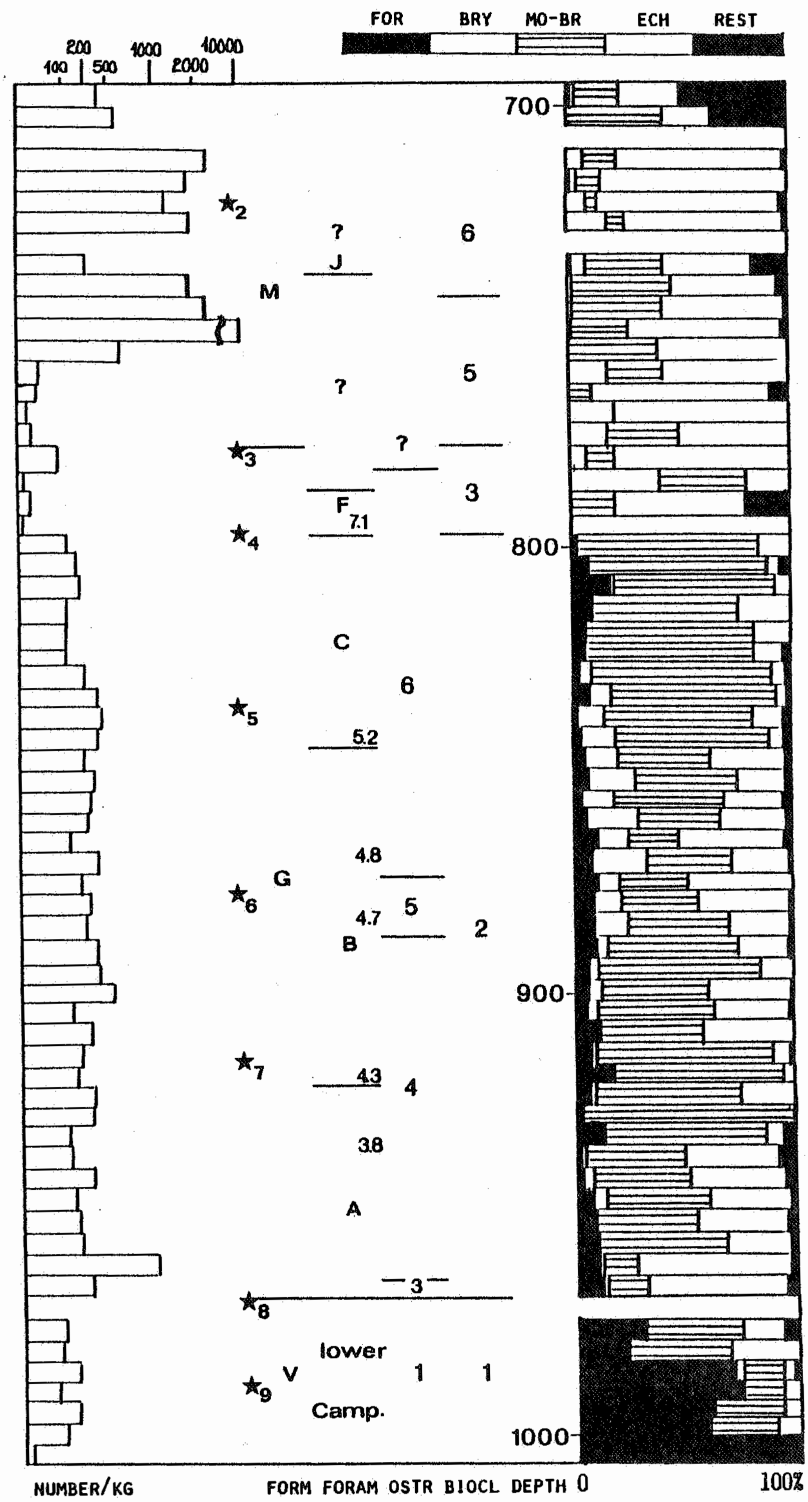


FIGURE 18


LEOPOLDSBURG
FOR
BRY
MO-BR
ECH
REST
0
100
200
500
1000
2000
10000
Q
H
P
7
J
6
M
5
?
Ech.
Ech.
3
600
C?
6
G
2
B?
A
4
700
Campan.
V
1
A'-lower?
2
NUMBER/KG
FORM
FORAM
OSTR
BIOCL
DEPTH
0
100%

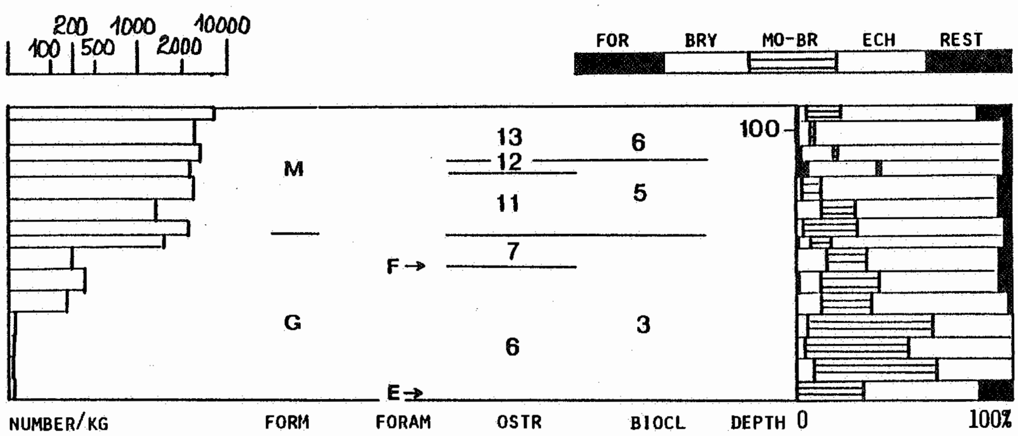
MERKSPLAS

FIGURE 19



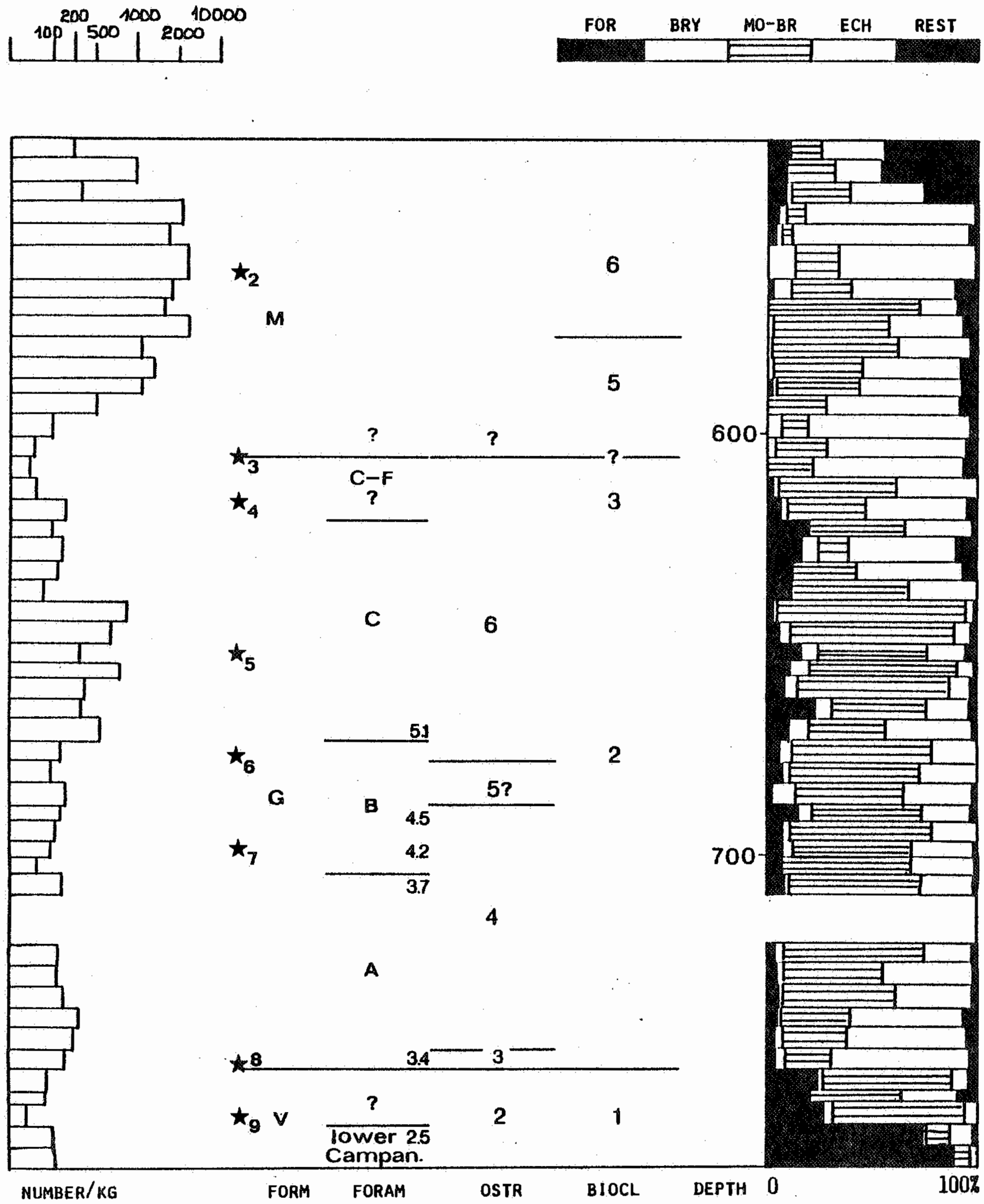
NIEUWERKERKEN

FIGURE 20



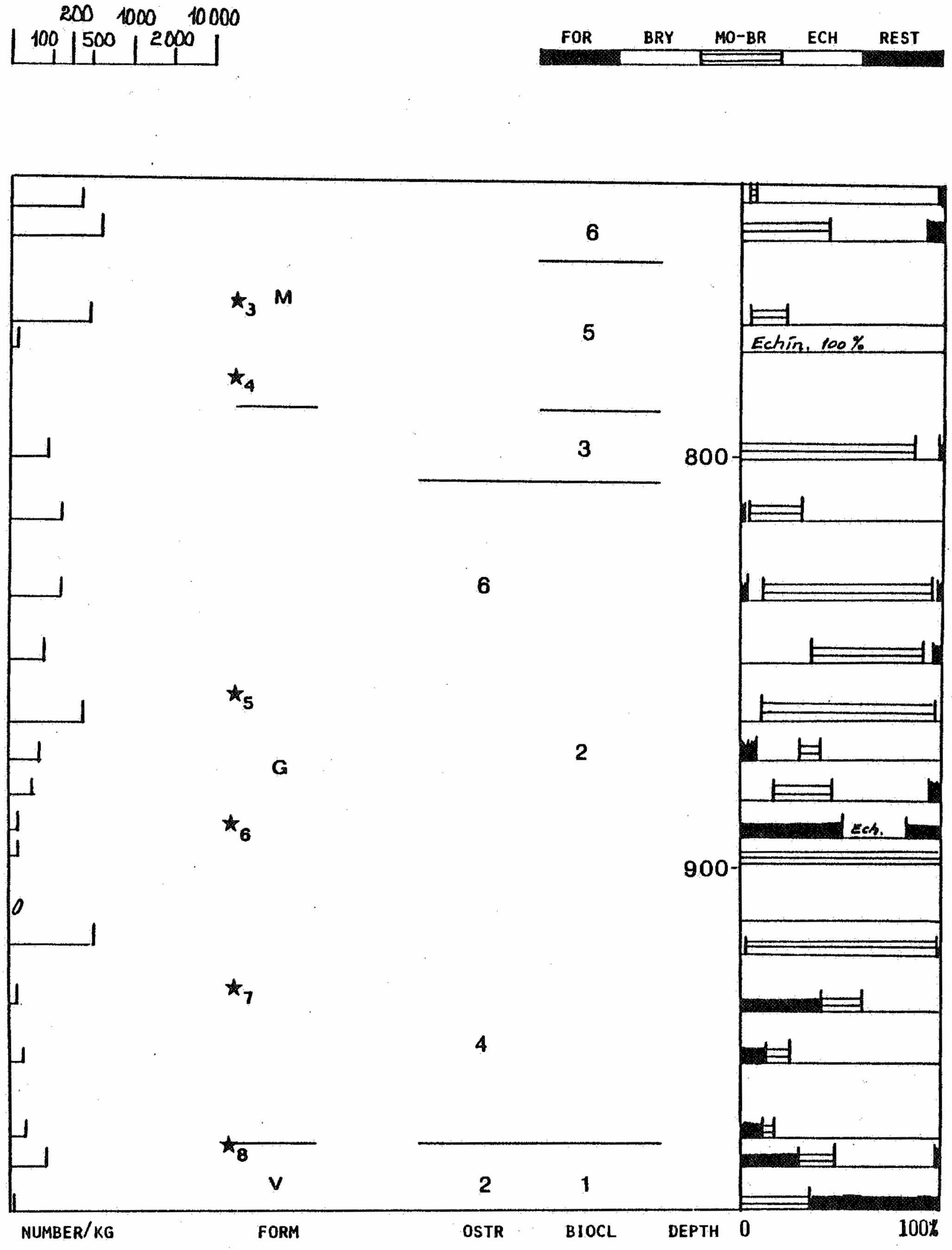
POEDERLEE

FIGURE 21



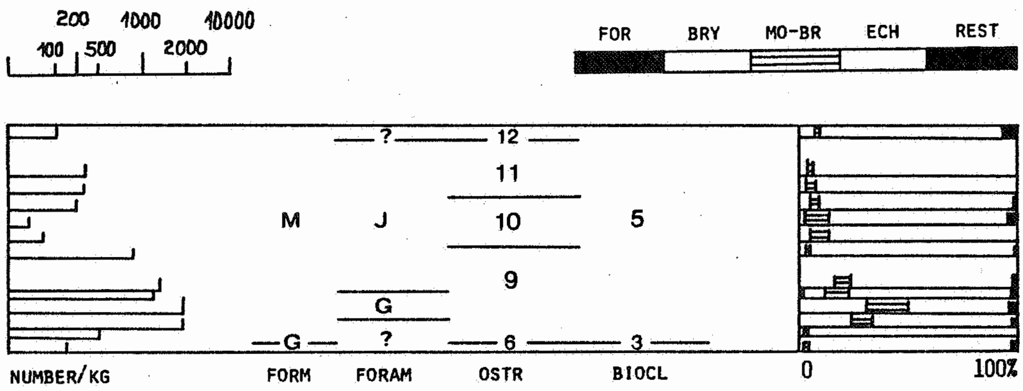
TURNHOUT

FIGURE 22



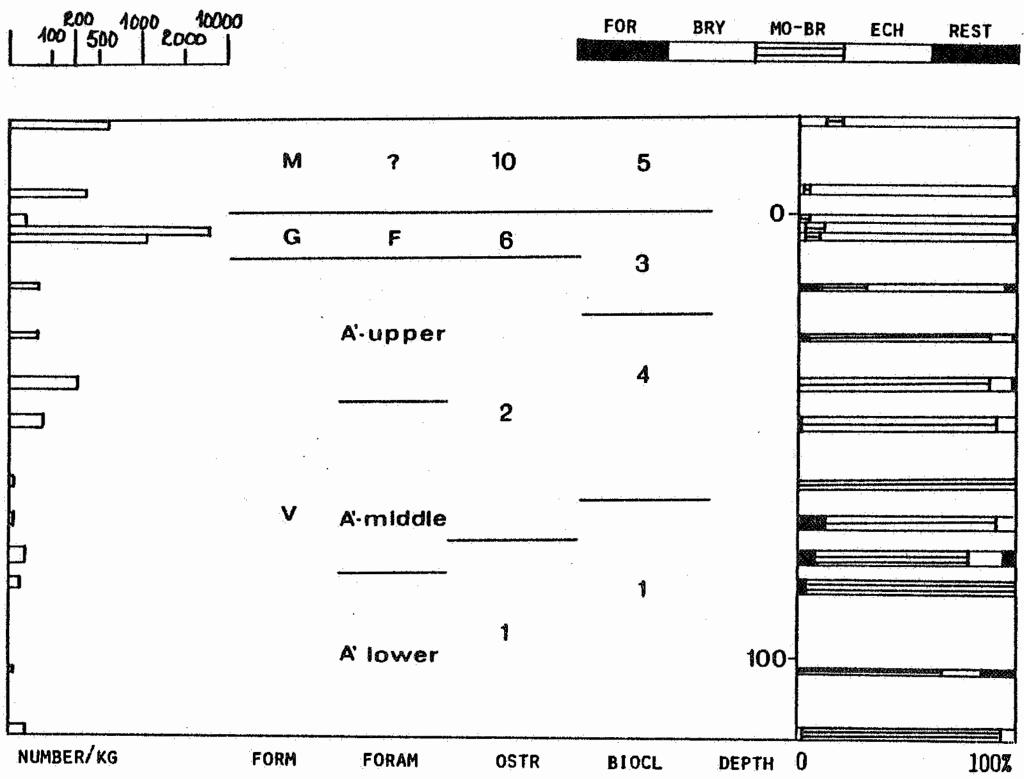
VALKENBURG

FIGURE 23



WALEM

FIGURE 24



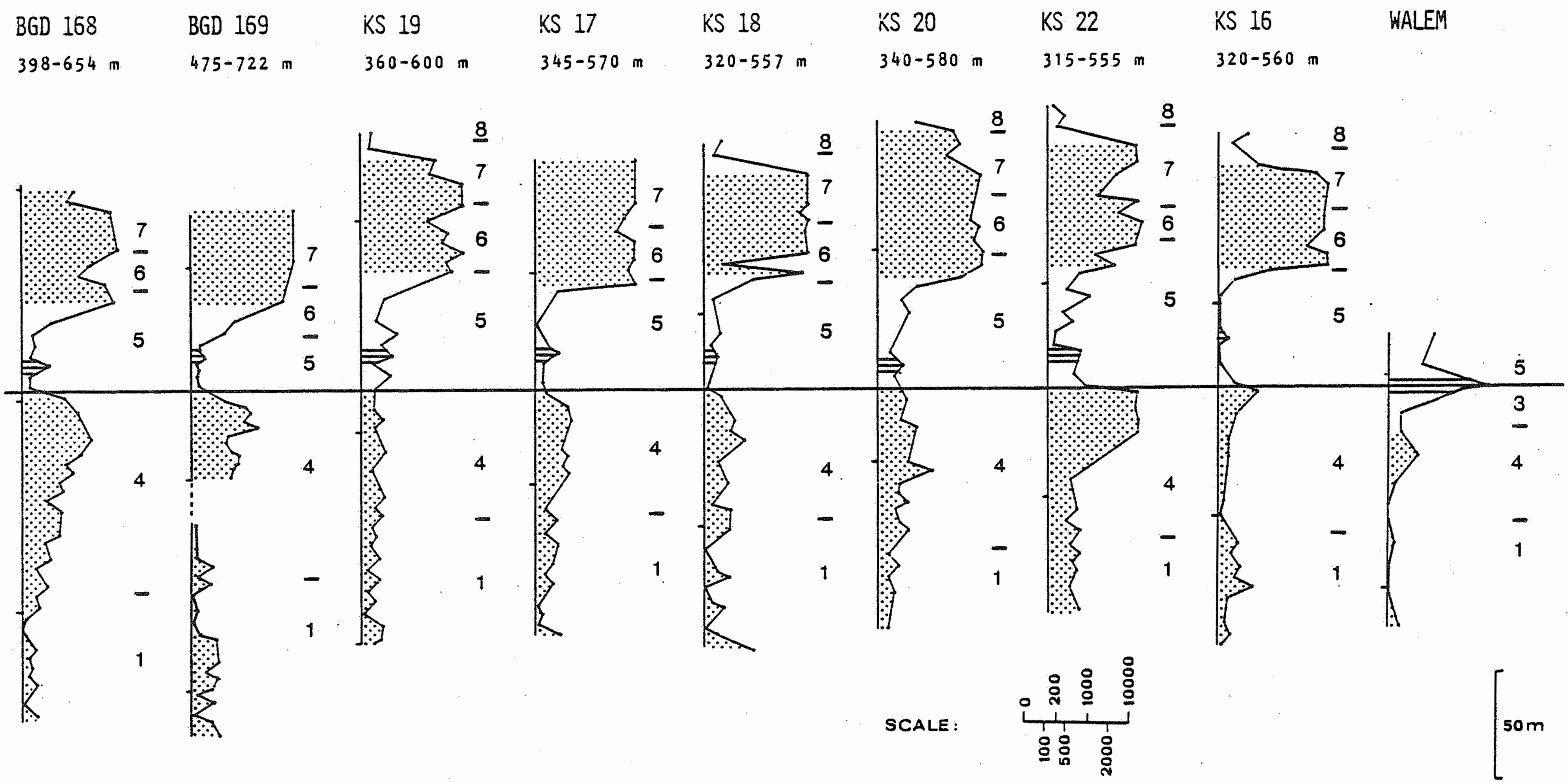


FIGURE 25

BIOCLASTS 1-2,4mm NUMBER/KG

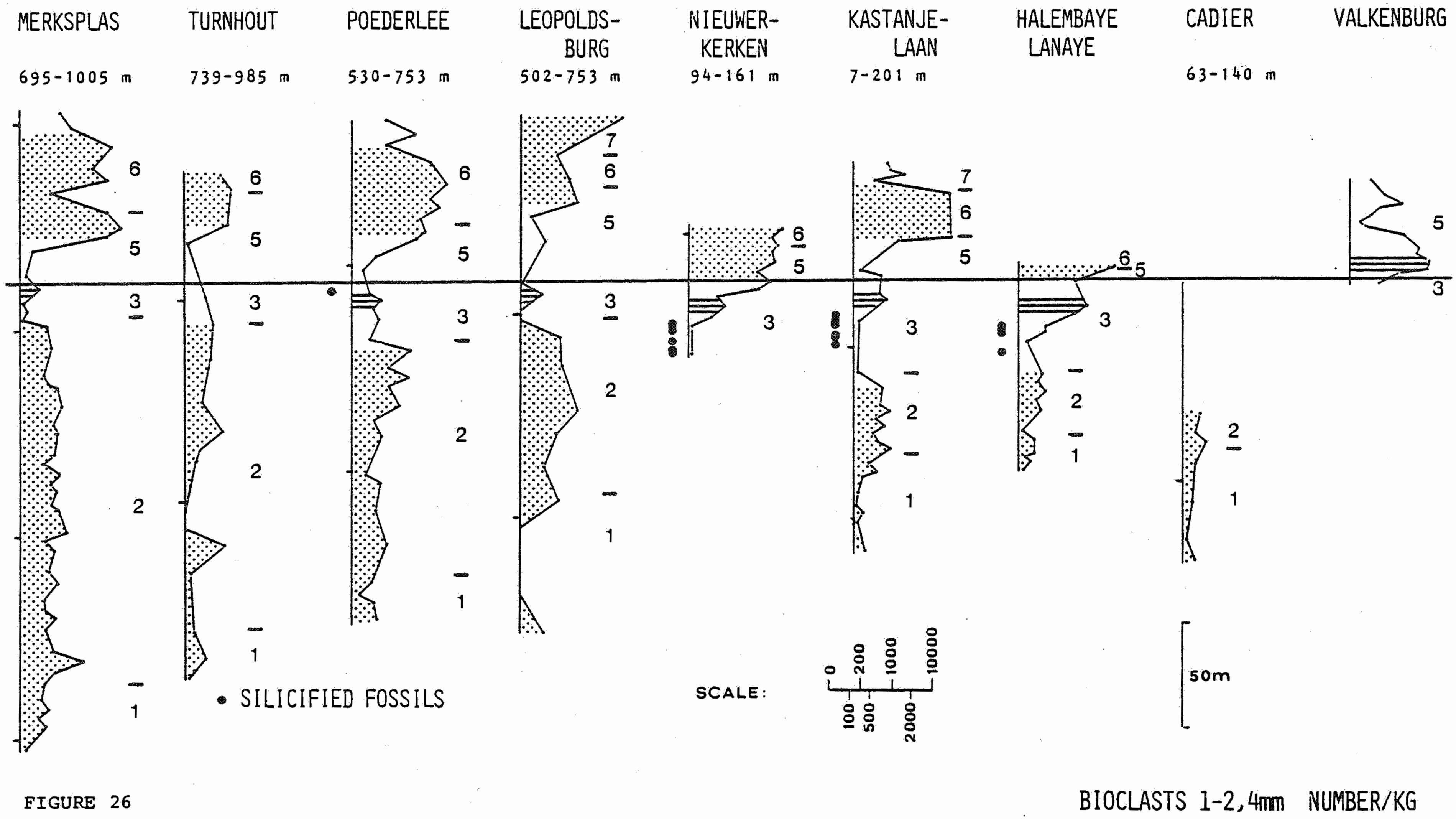

MERKSPLAS
695-1005 m
TURNHOUT
739-985 m
POEDERLEE
530-753 m
LEOPOLDS-BURG
502-753 m
NIEUWER-KERKEN
94-161 m
KASTANJE-LAAN
7-201 m
HALEMBAYE LANAYE
CADIER
63-140 m
VALKENBURG
• SILICIFIED FOSSILS
SCALE:
0
200
1000
10000
100
500
2000
50m
BIOCLASTS 1-2,4mm NUMBER/KG

FIGURE 26

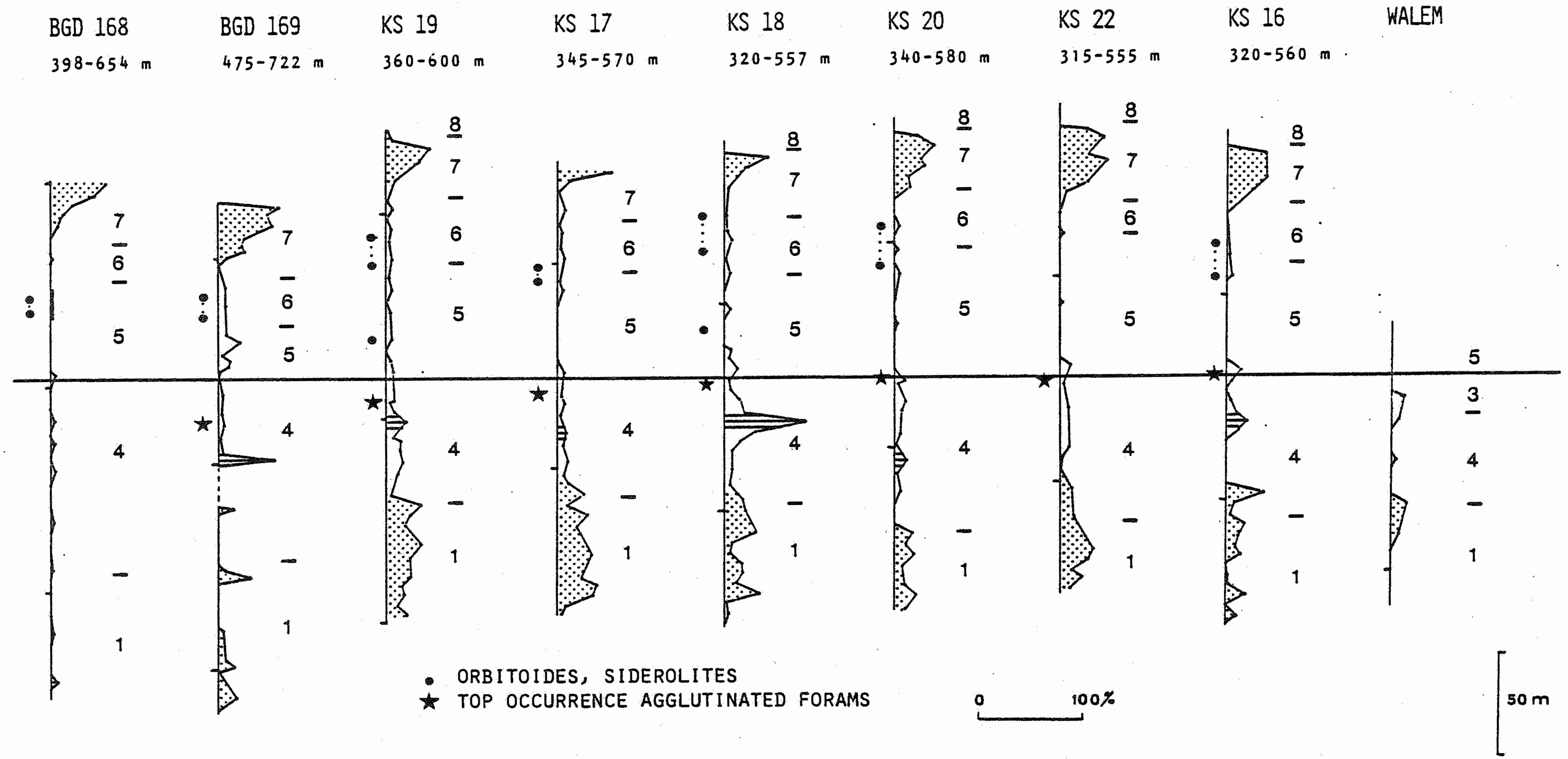


FIGURE 27

FORAMINIFERA

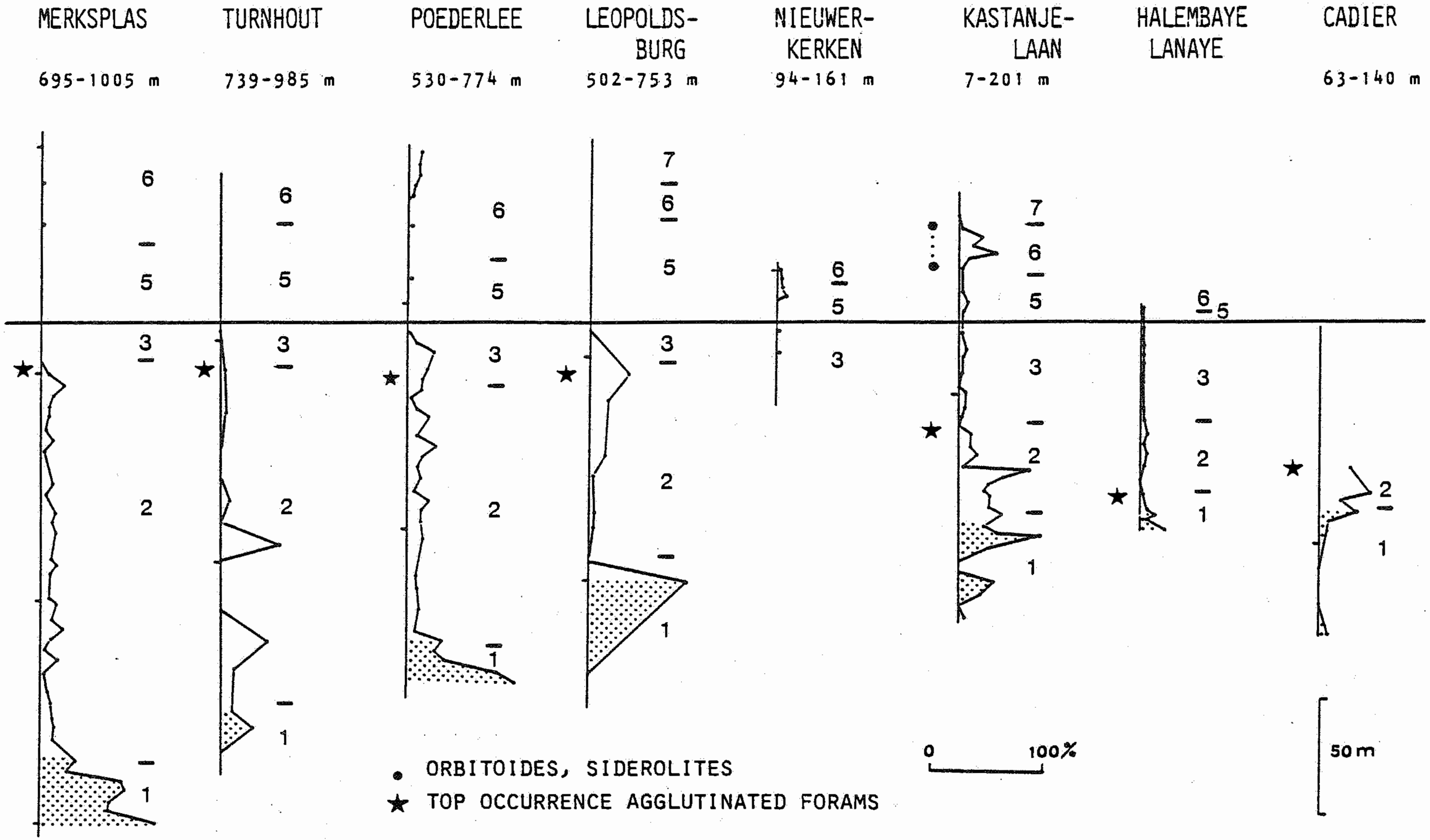


FIGURE 28

FORAMINIFERA

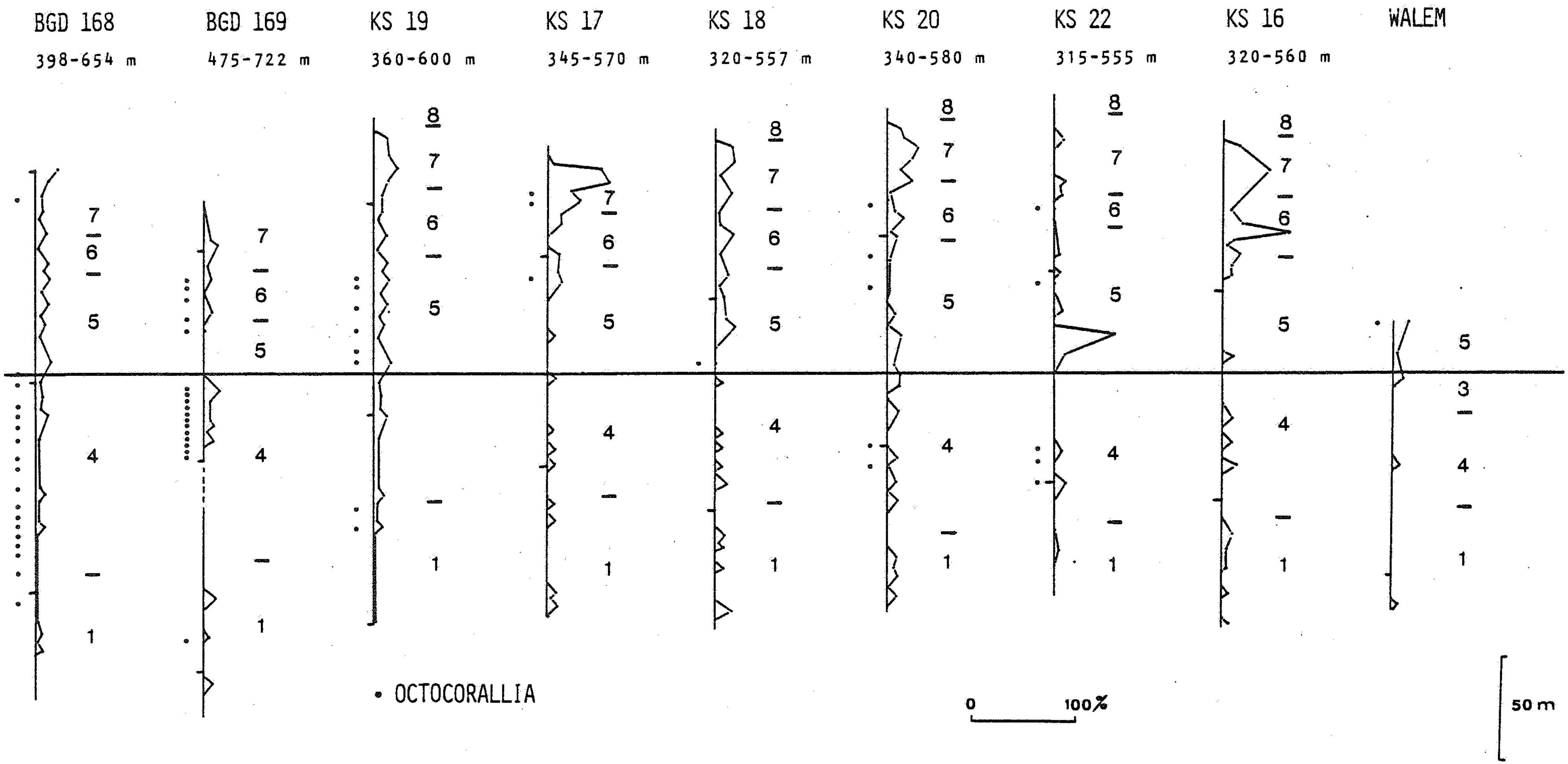


FIGURE 29

BRYOZOANS, SPONGES, CORALS

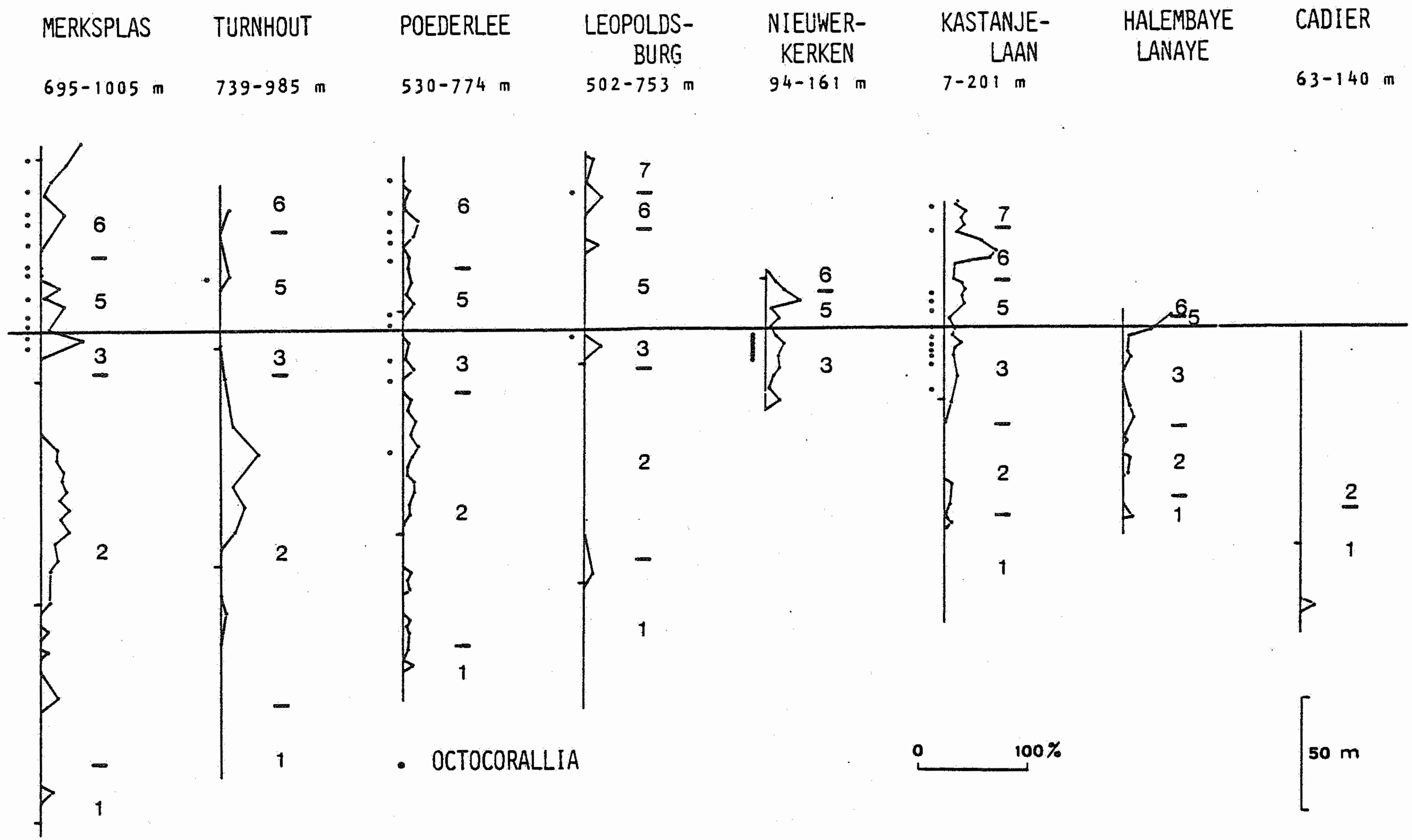


FIGURE 30

BRYOZOANS, SPONGES, CORALS

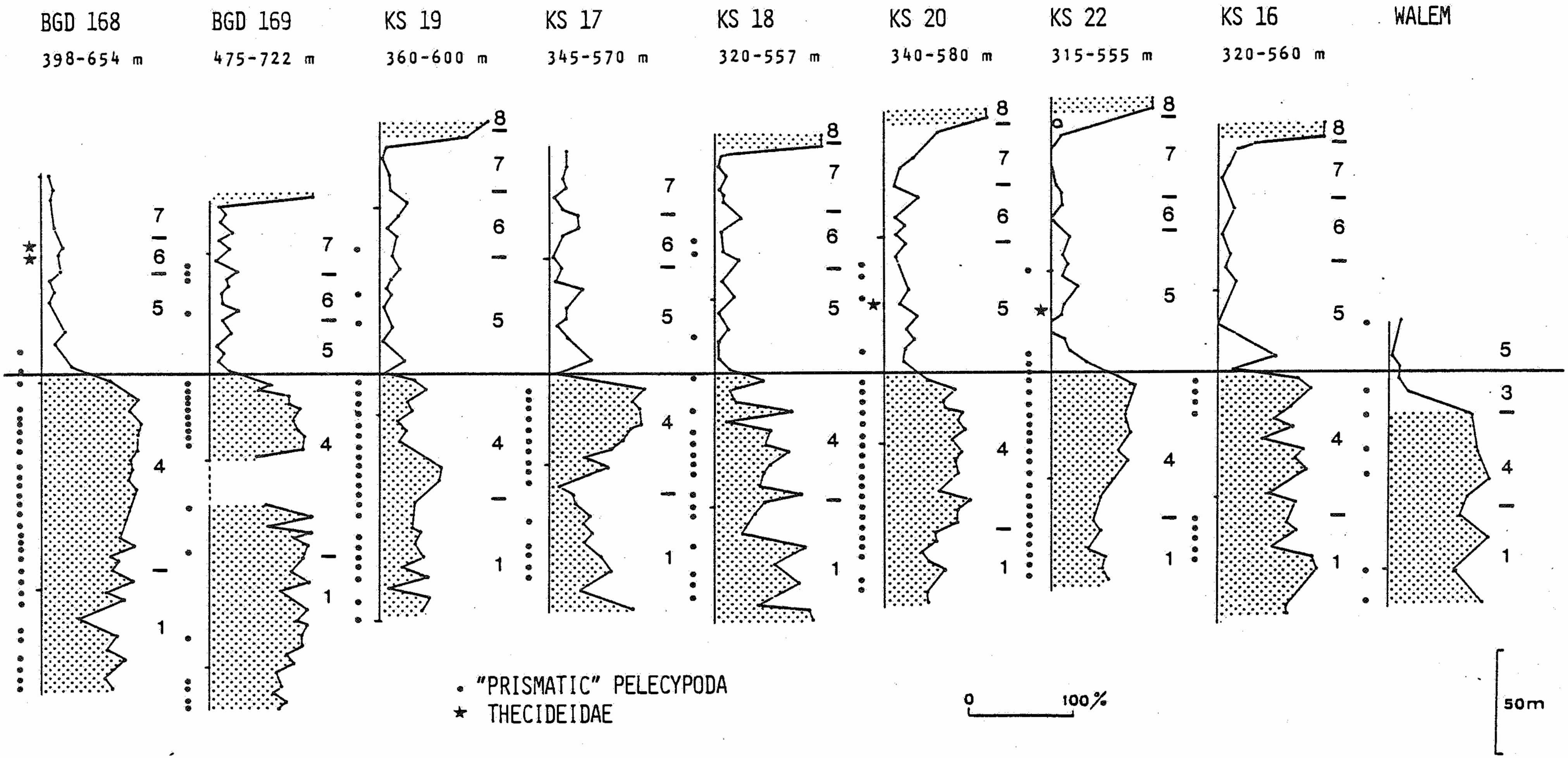


FIGURE 31

MOLLUSCS, BRACHIOPODS

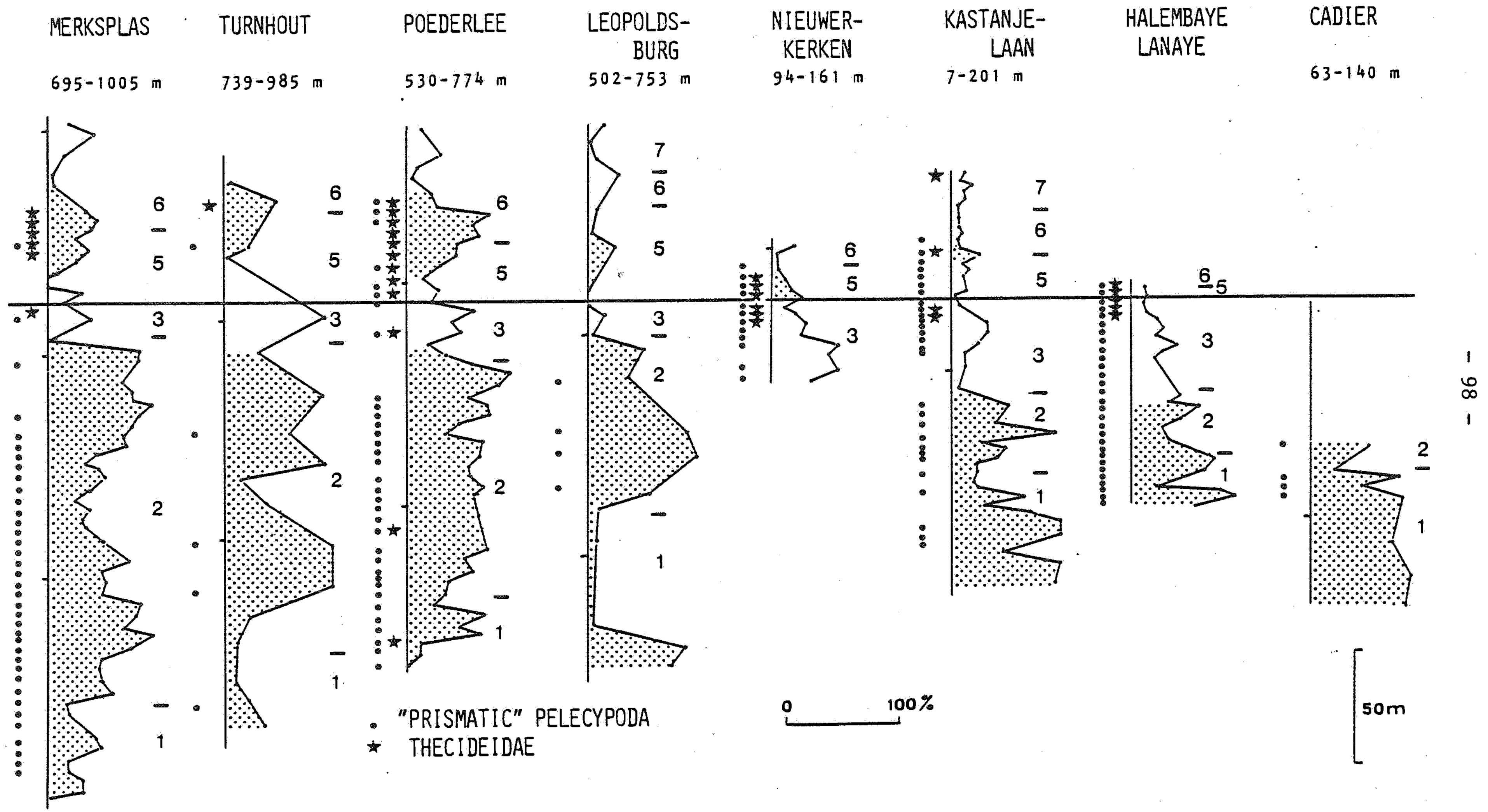


FIGURE 32

MOLLUSCS, BRACHIOPODS

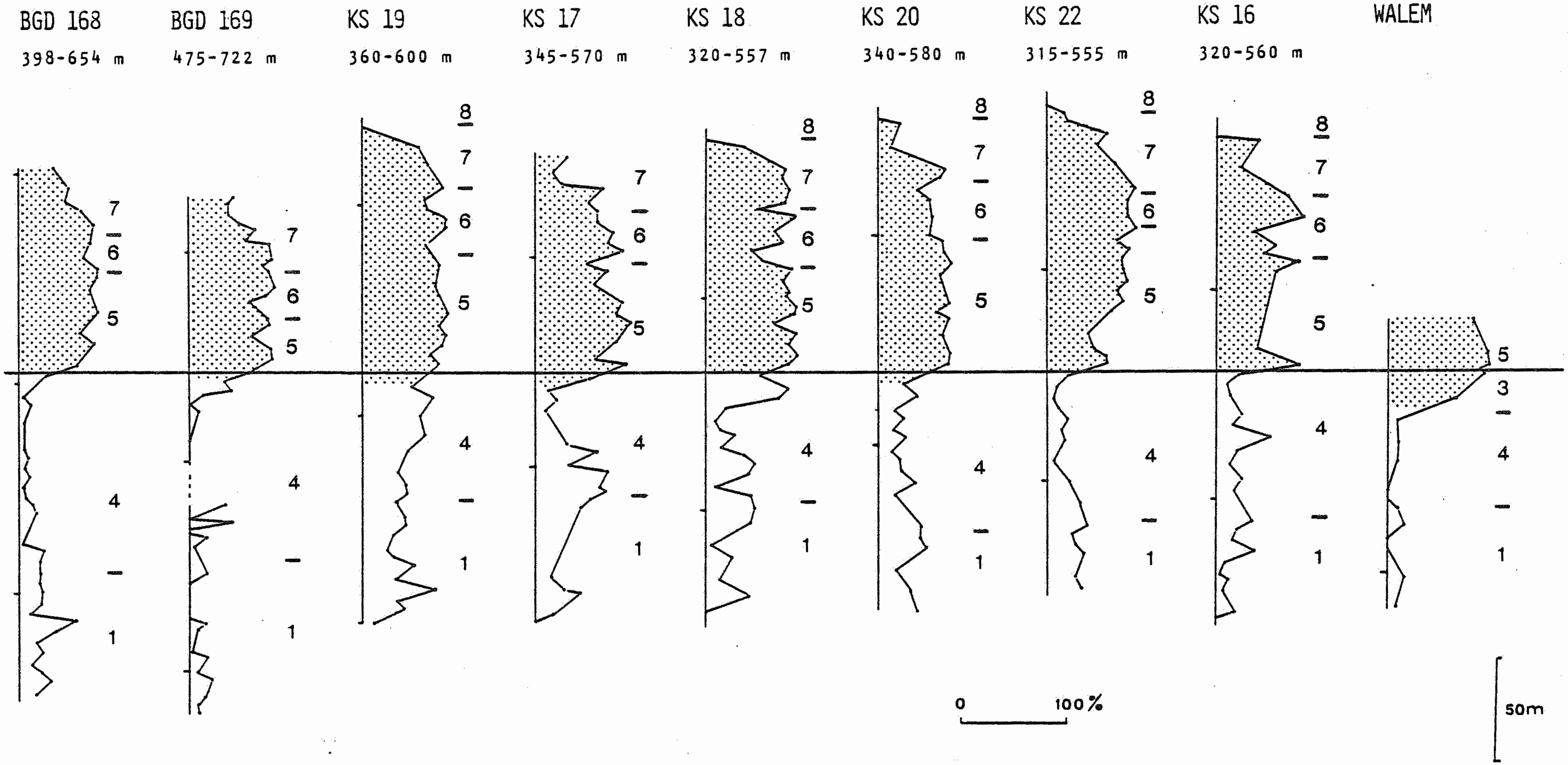


FIGURE 33

ECHINODERMS

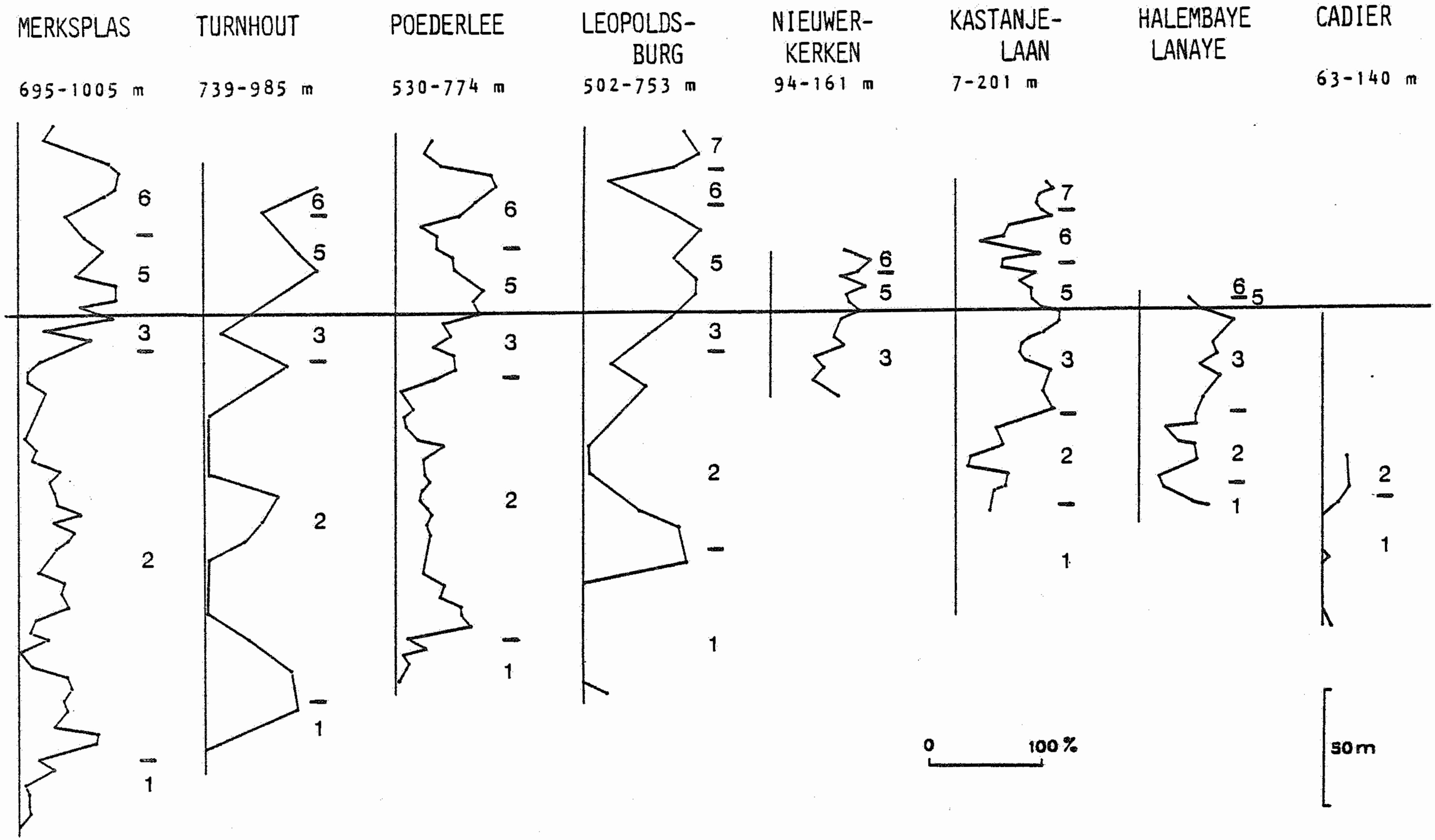


FIGURE 34

ECHINODERMS

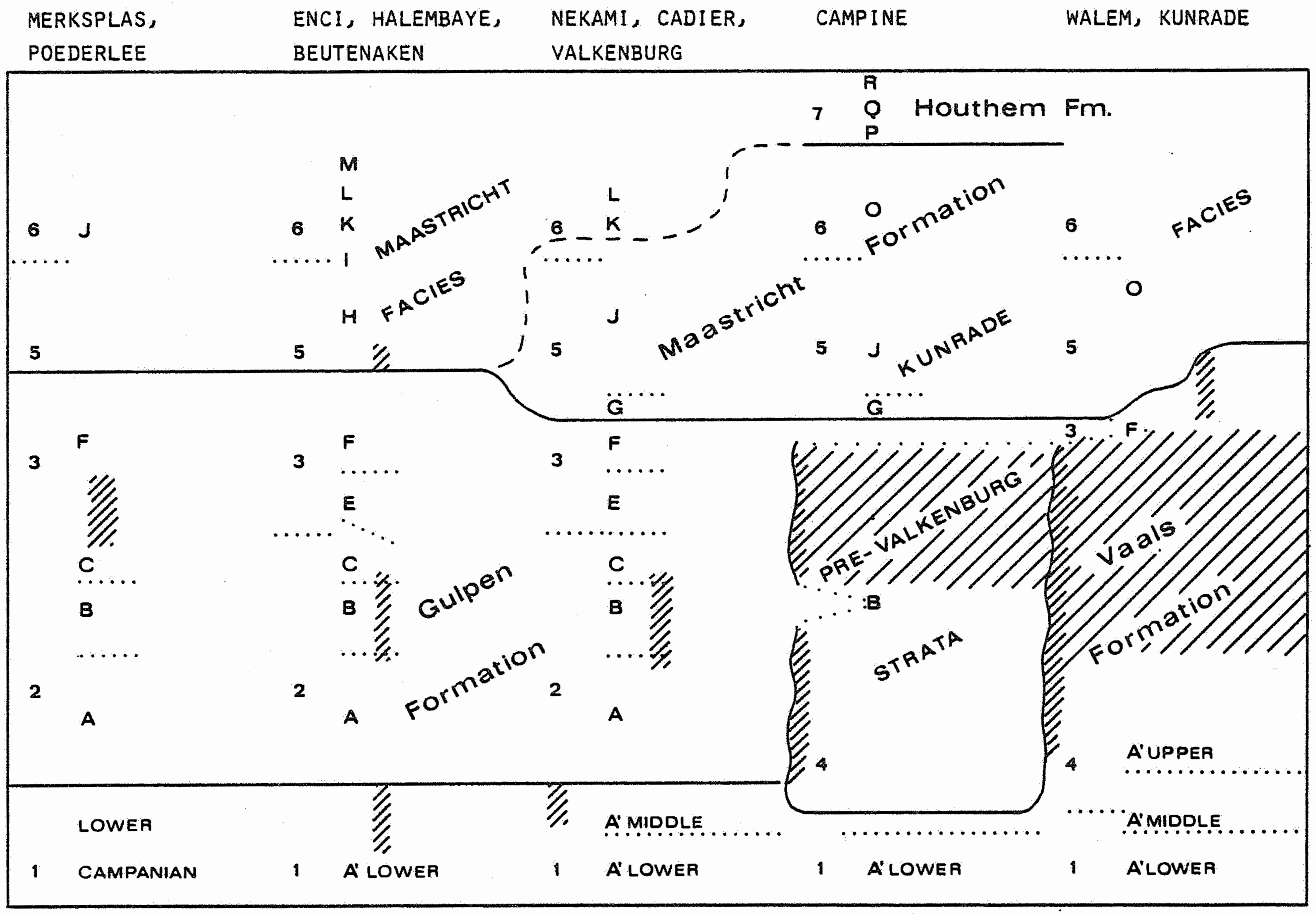

MERKSPLAS, POEDERLEE
ENCI, HALEMBAYE, BEUTENAKEN
NEKAMI, CADIER, VALKENBURG
CAMPINE
WALEM, KUNRADE
7
R
Q
P
Houthem Fm.
M
L
K
I
H
MAASTRICHT FACIES
Maastricht Formation
KUNRADE FACIES
6
5
3
2
4
1
J
O
G
F
E
C
B
A
Gulpen Formation
PRE-VALKENBURG STRATA
Vaals Formation
A' UPPER
A' MIDDLE
A' LOWER
LOWER CAMPANIAN

FIGURE 35

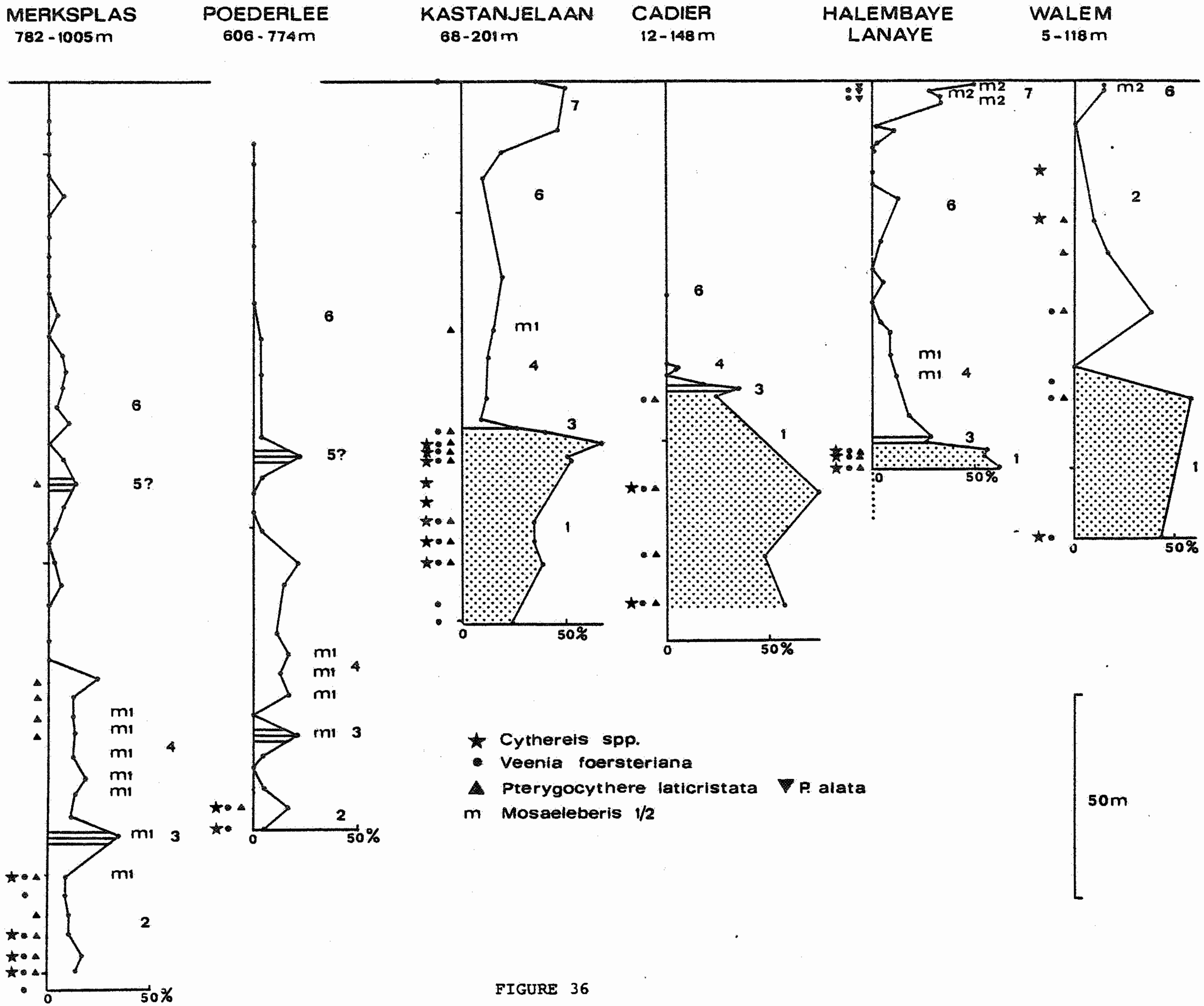
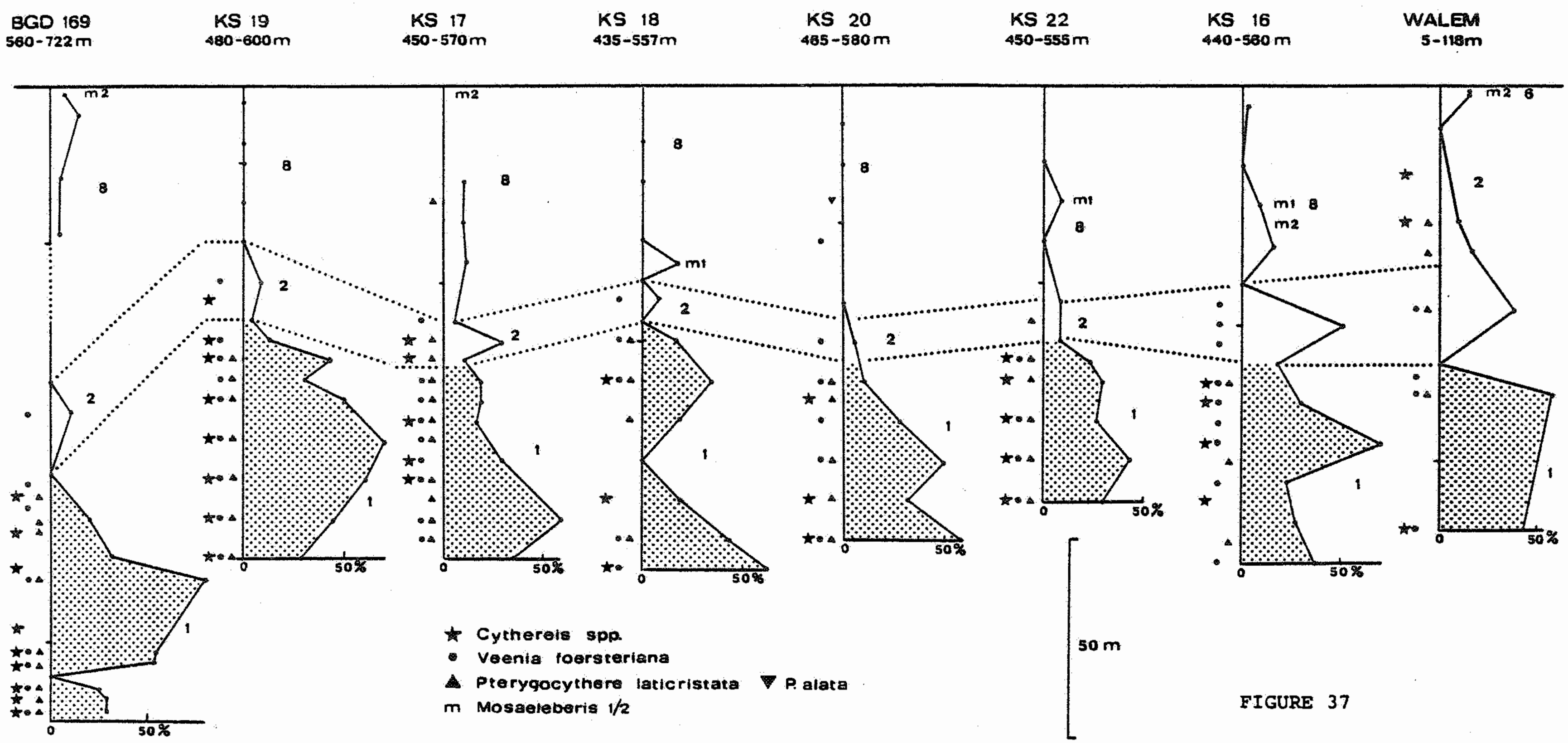

MERKSPLAS
782 - 1005 m
POEDERLEE
606 - 774 m
KASTANJELAAN
68 - 201 m
CADIER
12 - 148 m
HALEMBAYE
LANAYE
WALEM
5 - 118 m
★ Cythereis spp.
● Veenia foersteriana
▲ Pterygocythere laticristata
▼ P. alata
m Mosaeleberis 1/2
50 m
0
50 %

FIGURE 36



BGD 169
560-722 m
KS 19
480-600 m
KS 17
450-570 m
KS 18
435-557 m
KS 20
485-580 m
KS 22
450-555 m
KS 16
440-560 m
WALEM
5-118m
50 %
50 m
★ Cythereis spp.
● Veenia foersteriana
▲ Pterygocythere laticristata ▼ P. alata
m Mosaeleberis 1/2

FIGURE 37

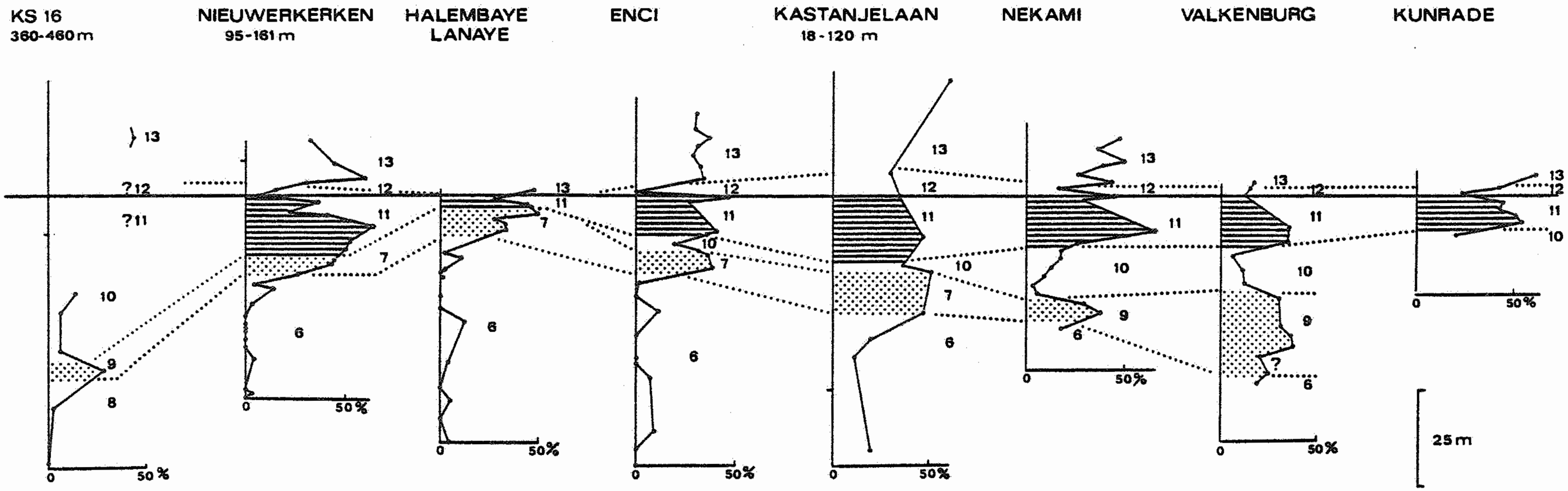

KS 16
360-460 m
NIEUWERKERKEN
95-161 m
HALEMBAYE
LANAYE
ENCI
KASTANJELAAN
18-120 m
NEKAMI
VALKENBURG
KUNRADE
50 %
25 m

FIGURE 38

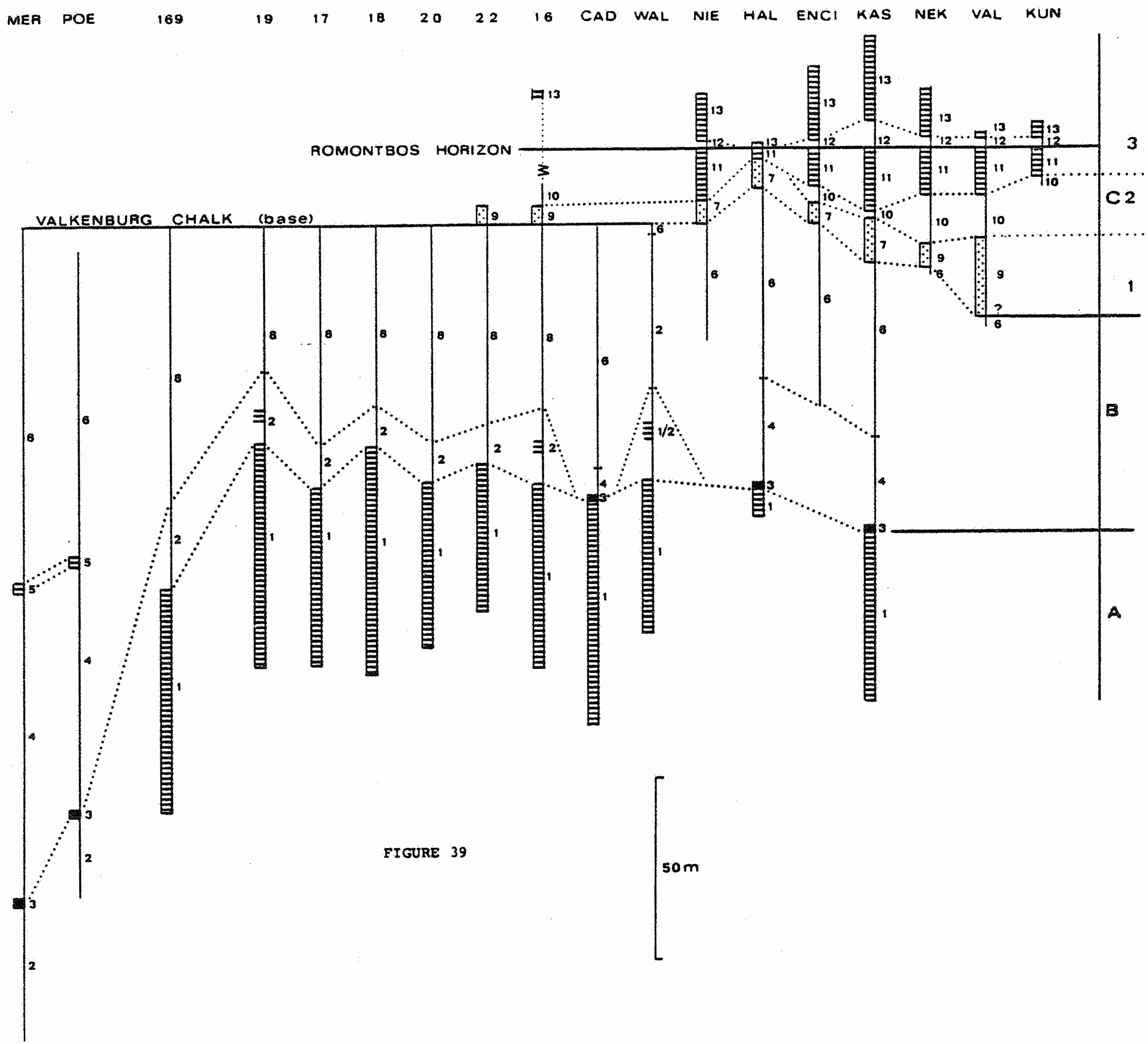

MER POE 169 19 17 18 20 22 16 CAD WAL NIE HAL ENCI KAS NEK VAL KUN
ROMONTBOS HORIZON
VALKENBURG CHALK (base)
3
C2
1
B
A
50m

FIGURE 39

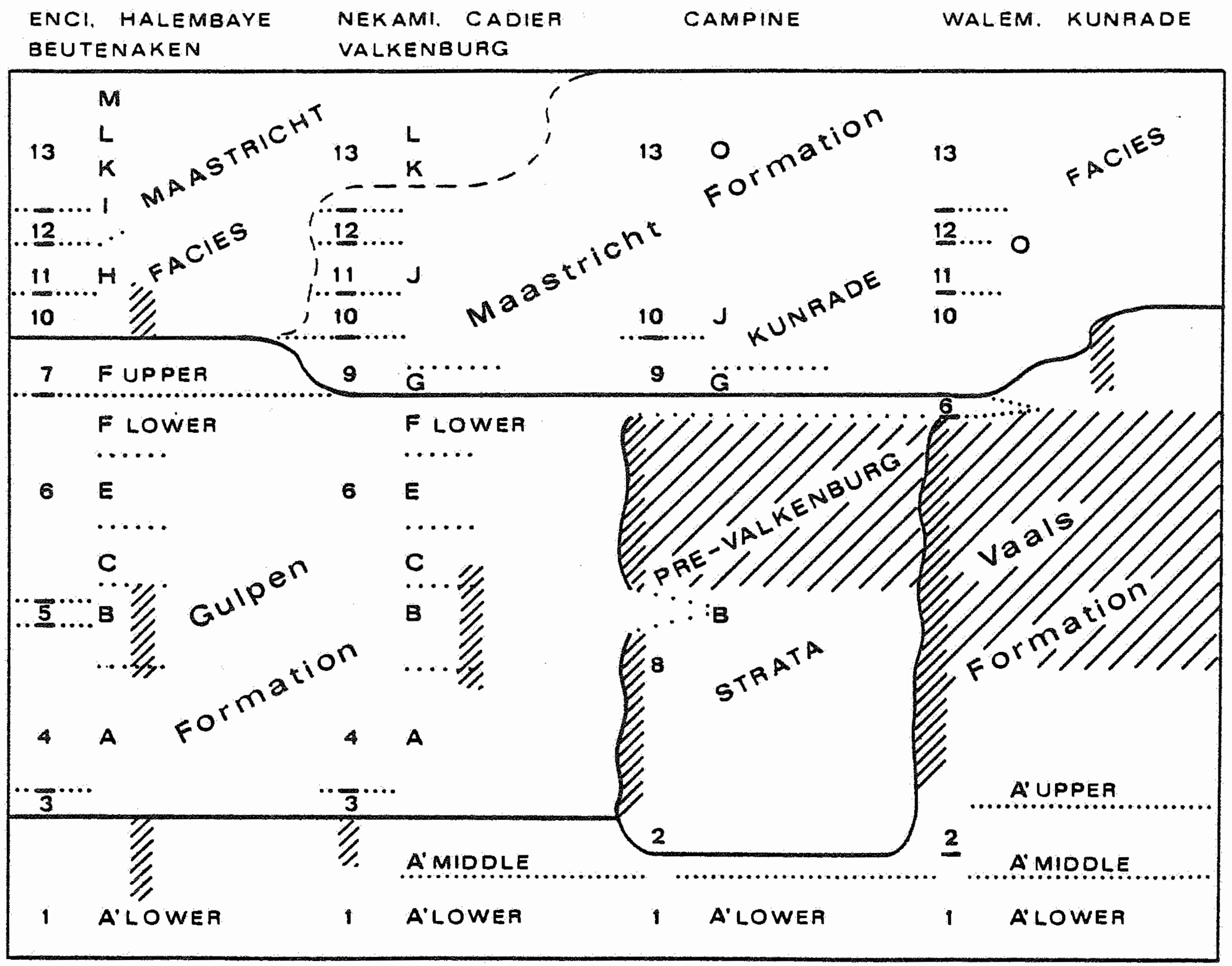

ENCI, HALEMBAYE
BEUTENAKEN
NEKAMI, CADIER
VALKENBURG
CAMPINE
WALEM, KUNRADE
MAASTRICHT FACIES
Maastricht Formation
KUNRADE FACIES
F UPPER
F LOWER
Gulpen Formation
PRE-VALKENBURG STRATA
Vaals Formation
A' UPPER
A' MIDDLE
A' LOWER

FIGURE 40

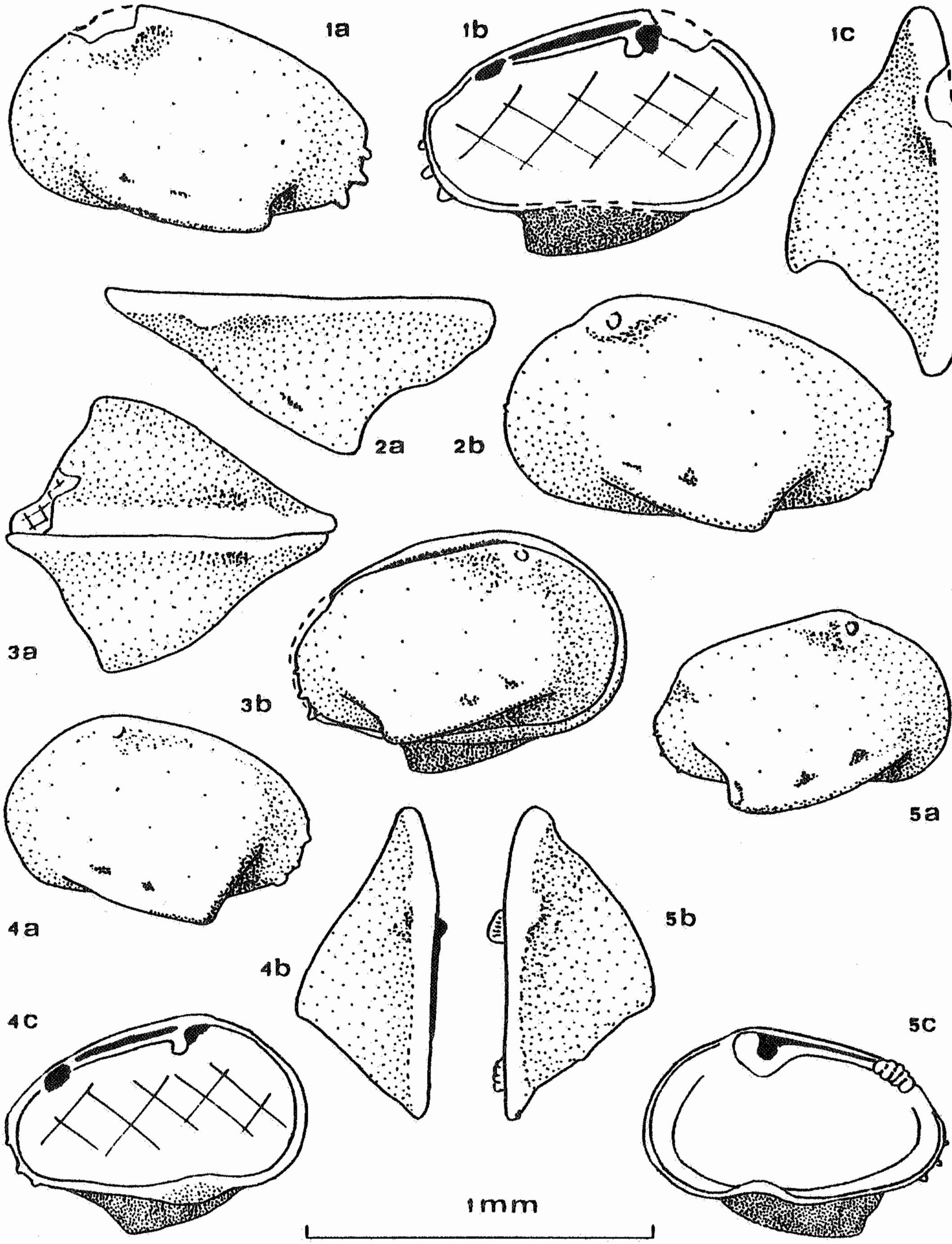


FIGURE 41

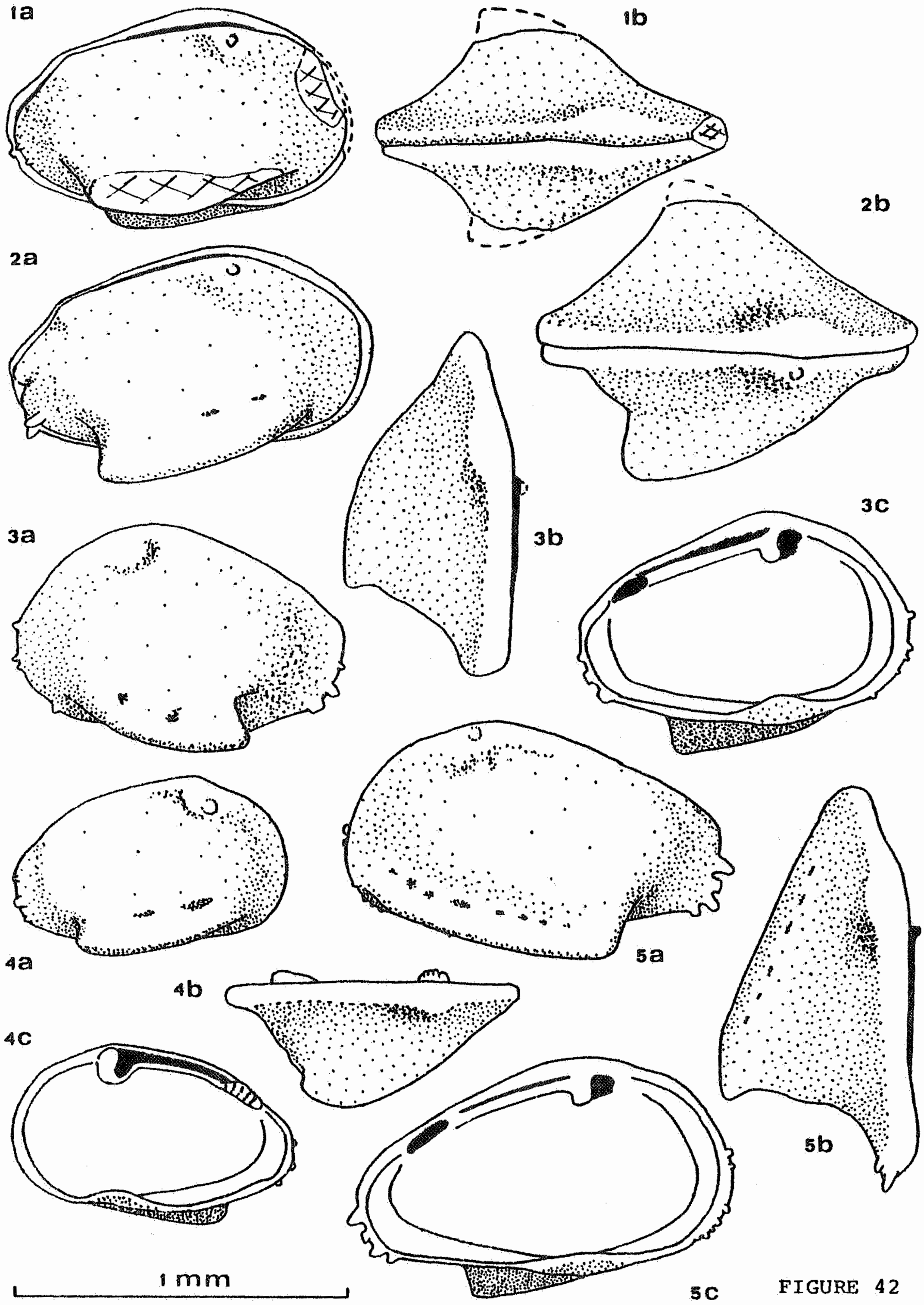


FIGURE 42

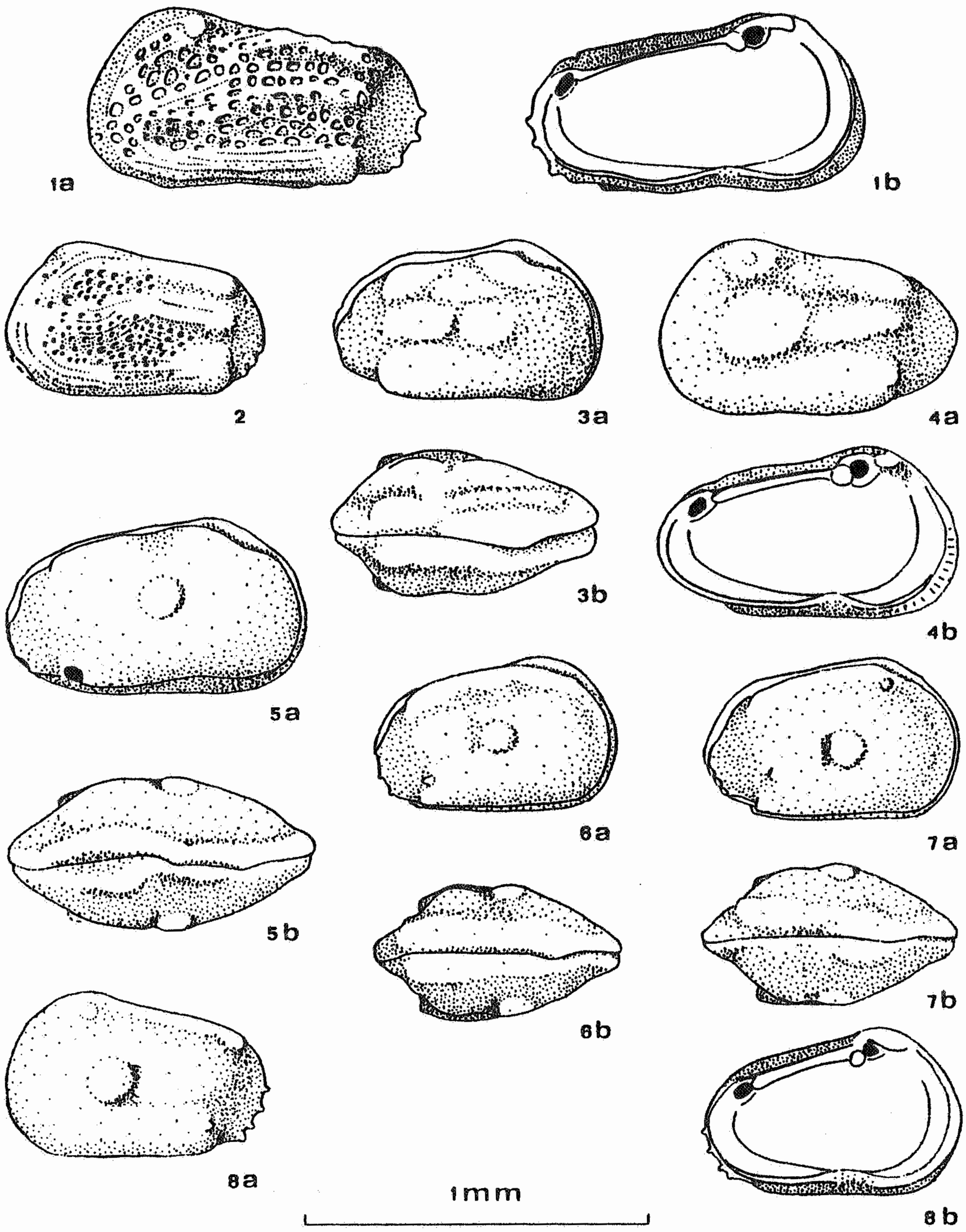
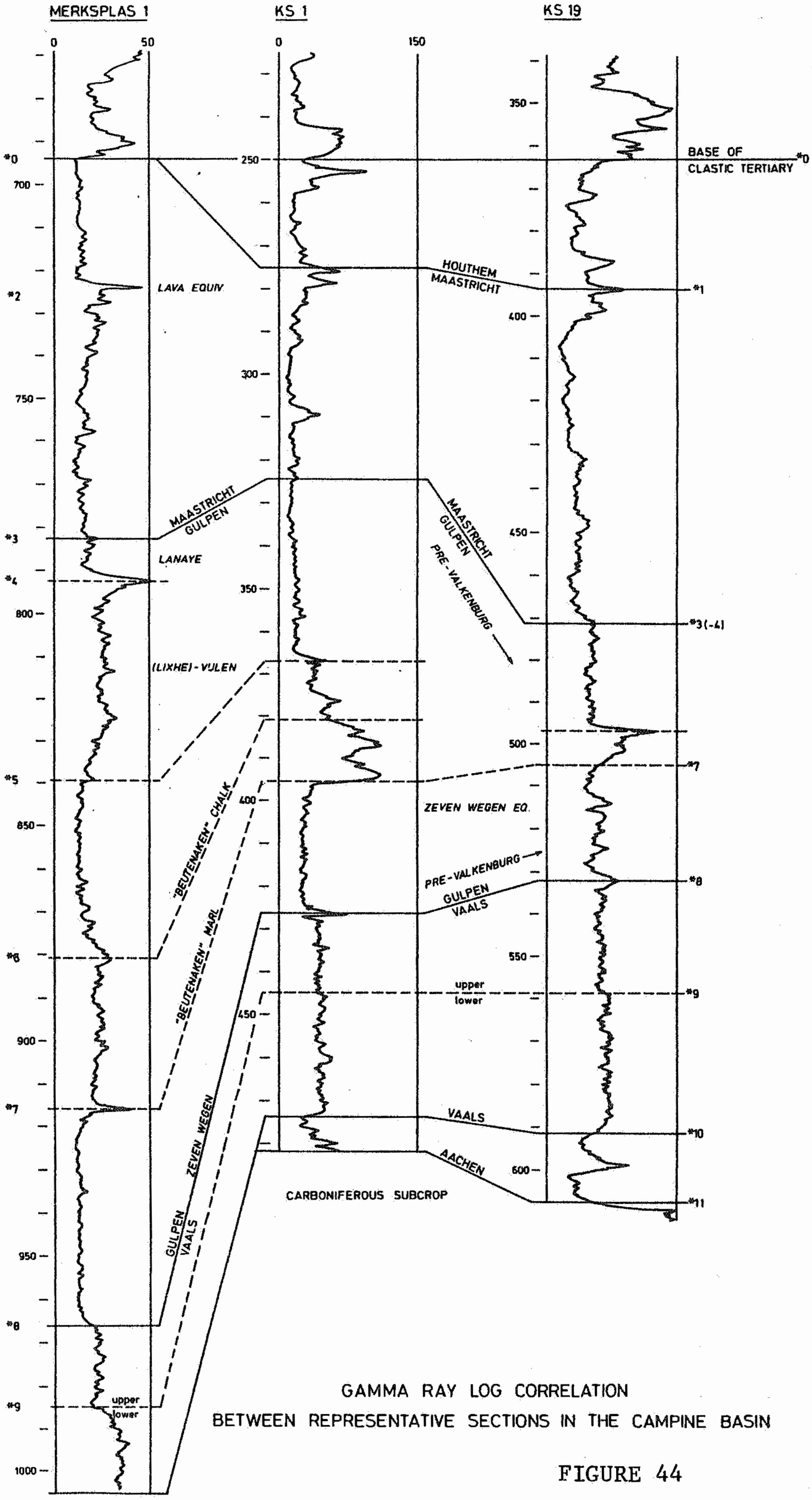
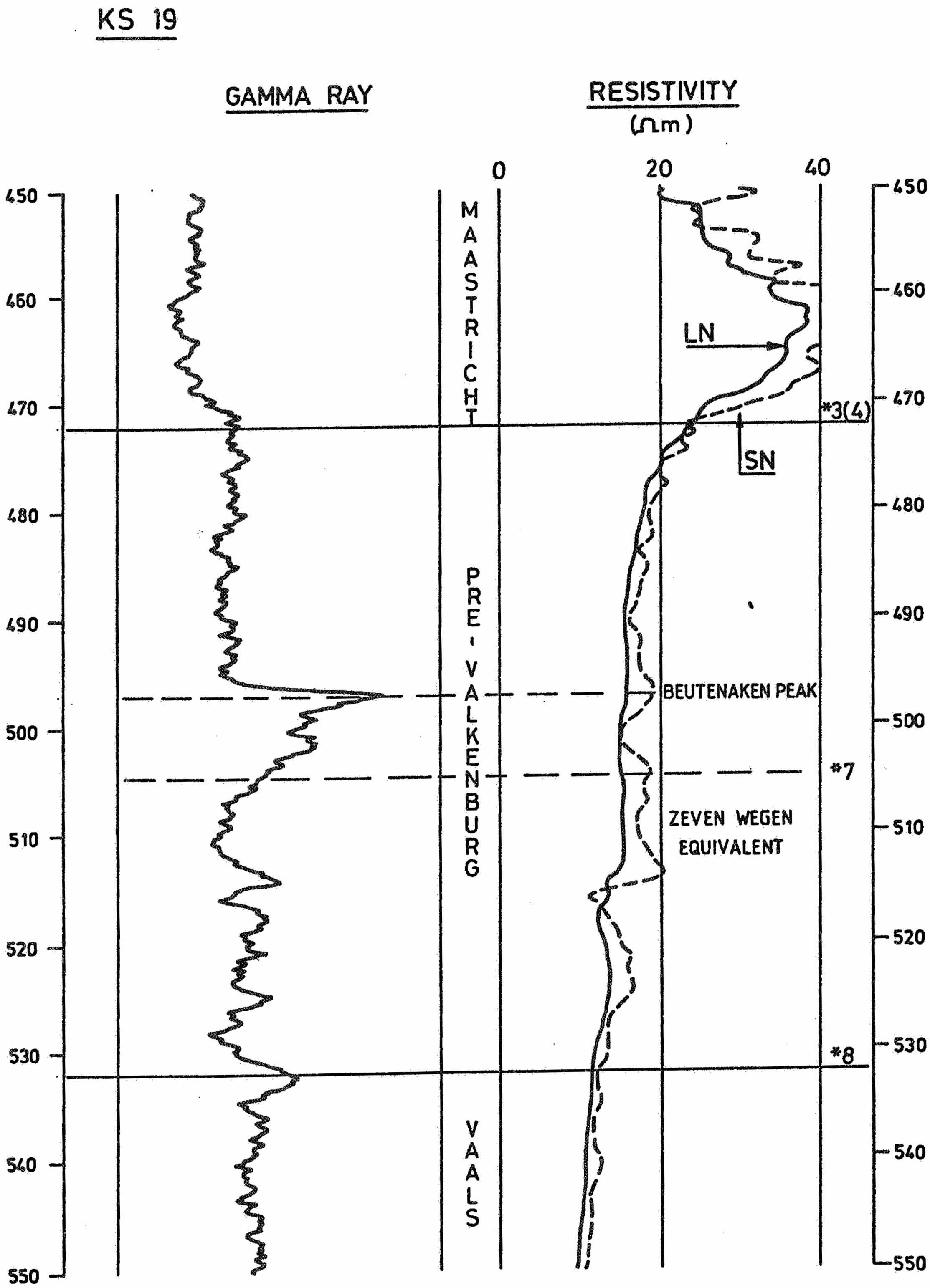


FIGURE 43



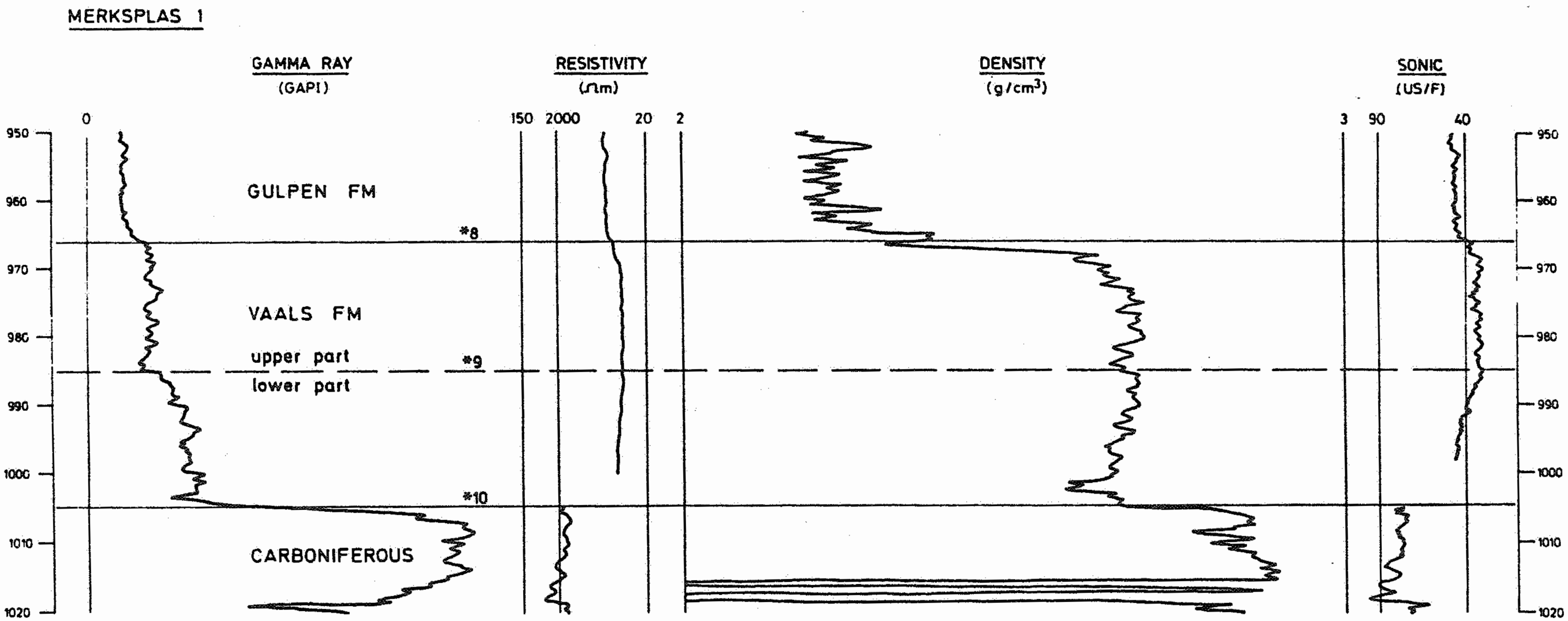
GAMMA RAY LOG CORRELATION
BETWEEN REPRESENTATIVE SECTIONS IN THE CAMPINE BASIN

FIGURE 44



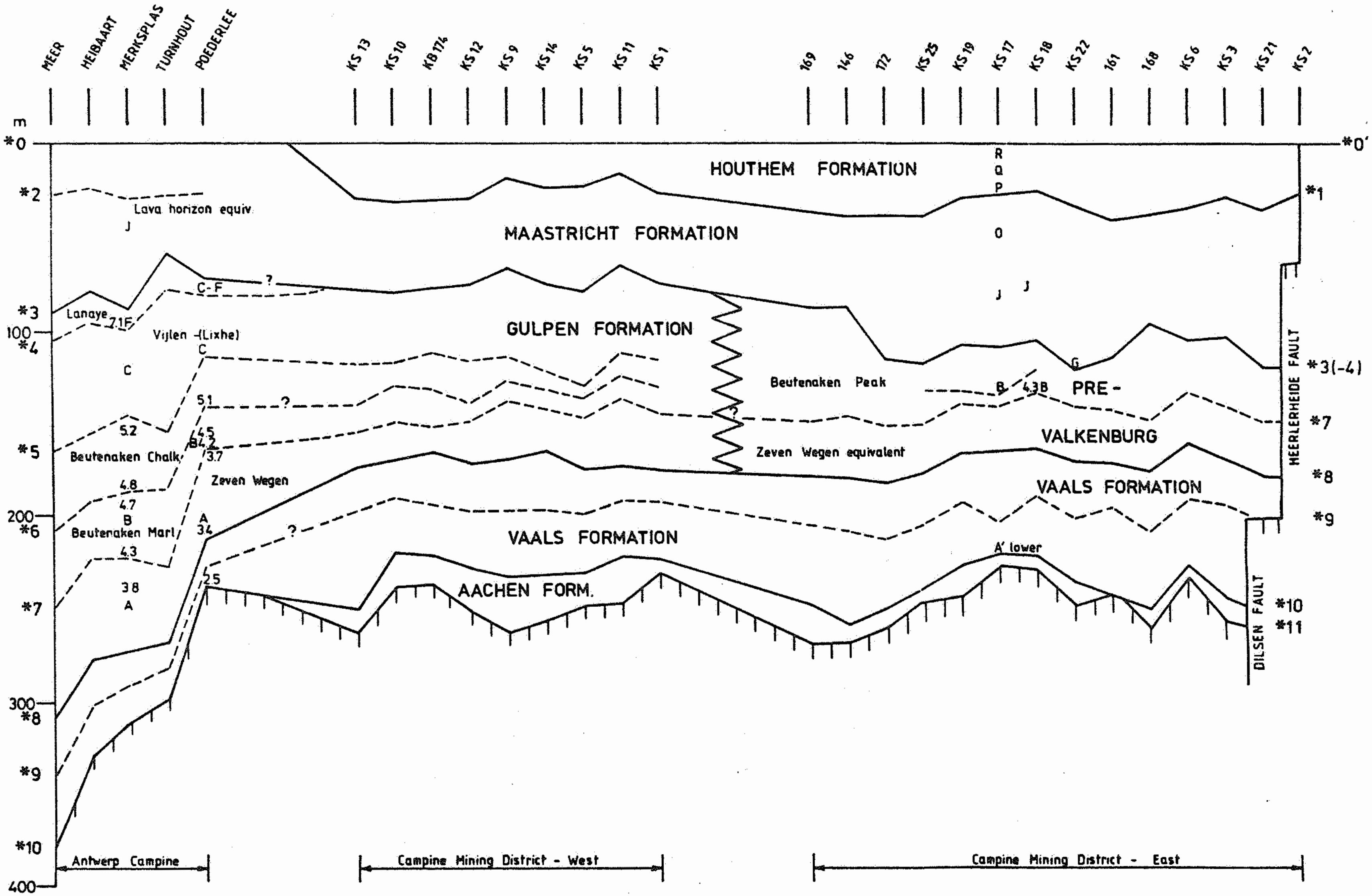
CHARACTERISATION OF PRE-VALKENBURG FACIES (GULPEN FM EQUIVALENT) IN BOREHOLE KS 19 (EASTERN CAMPINE MINING DISTRICT)

FIGURE 45



CHARACTERISATION OF VAALS FORMATION IN MERKSPLAS-1 WELL (ANTWERP CAMPINE)

FIGURE 46



CAMPINE BASIN - LOG CORRELATIONS

FIGURE 47

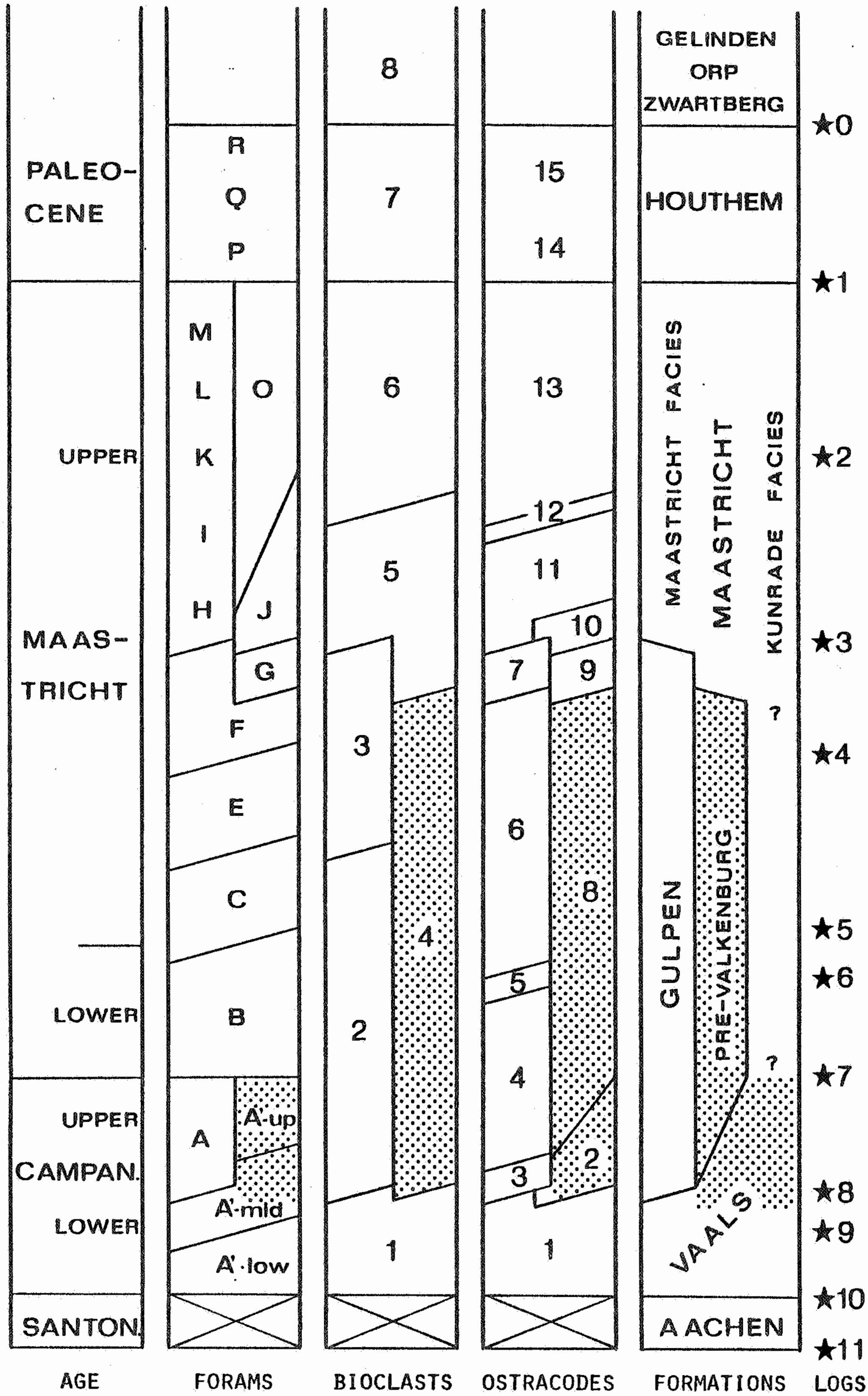

GELINDEN
ORP
ZWARTBERG
PALEO-
CENE
R
Q
P
8
7
15
14
HOUTHEM
★0
★1
M
L
K
I
H
O
J
G
6
13
12
11
10
5
7
9
UPPER
MAAS-
TRICHT
MAASTRICHT FACIES
MAASTRICHT
KUNRADE FACIES
★2
★3
F
E
C
B
3
4
2
6
8
5
4
?
★4
★5
★6
LOWER
GULPEN
PRE-VALKENBURG
UPPER
CAMPAN.
LOWER
A
A-up
A-mid
A-low
3
2
1
1
?
★7
★8
★9
VAALS
SANTON.
AACHEN
★10
★11
AGE
FORAMS
BIOCLASTS
OSTRACODES
FORMATIONS
LOGS

FIGURE 48

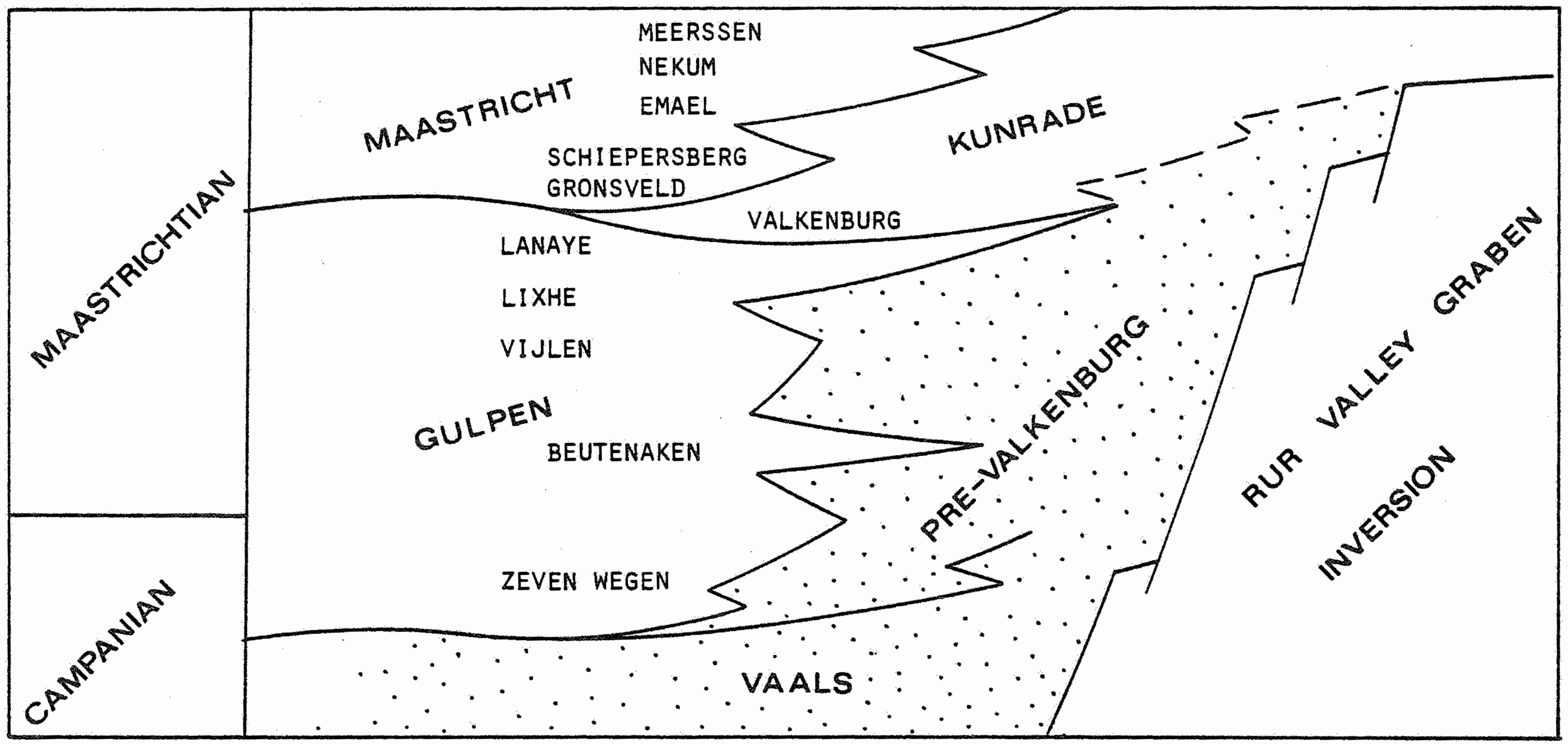

MAASTRICHTIAN
CAMPANIAN
MEERSSEN
NEKUM
EMAEL
MAASTRICHT
SCHIEPERSBERG
GRONSVELD
KUNRADE
VALKENBURG
LANAYE
LIXHE
VIJLEN
GULPEN
BEUTENAKEN
PRE-VALKENBURG
ZEVEN WEGEN
VAALS
RUR VALLEY GRABEN
INVERSION

FIGURE 49

14. TABLES 1 - 33

Table 1

Lithostratigraphic subdivision of the Upper Cretaceous and Early Tertiary in South Limburg and neighbouring areas of Belgium and the Federal Republic of Germany (from W.M. FELDER 1975).

Table 2

Subdivision of the Upper Cretaceous in Northeastern Belgium according to Algemeen Stratigrafisch Register van de Uitvoerige Aardkundige Kaart van België 1932.

Table 3

Boreholes with Upper Cretaceous rocks in Northeastern Belgium which have been studied for this report.

Table 4

Boreholes with Upper Cretaceous rocks in South Limburg which have been studied for this report.

Table 5

Outcrops with Upper Cretaceous rocks in Northeastern Belgium and South Limburg which have been studied for this report.

Tables 6 - 25

Bioclasts (1.0 - 2.4 mm) occurring in Upper Cretaceous and Early Tertiary of boreholes and outcrops in Northern Belgium and South Limburg. Abbreviations: za = agglutinated foraminifera; ka = non-agglutinated foraminifera; po = sponges (Porifera); oc = octocorallia; br = bryozoans; be = belemnites; pr = remnants of the prismatic layer of bivalves; la = bivalves and non-identified brachiopods; br = identified brachiopods others than Thecideidae (e.g. *Trigonosemus*, *Terebratula*); Th = Thecideidae; cr = crinoids; op = ophiurids; as = asteroids; ec = echinoids; st = echinoderm spines; re = non-identified echinoderms; ar = arthropods; se = serpulids; pi = fish (Pisces); tot = total number of counted bioclasts (including not separately mentioned coproliths; not to be mistaken with calculated number of bioclasts per kilogram!); ec-strat = bioclast ecozones.

Table 6	KS 16
Table 7	KS 17
Table 8	KS 18
Table 9	KS 19

Tables 6 - 25 - continued

Table 10	KS 20
Table 11	KS 22
Table 12	BGD 168
Table 13	BGD 169
Table 14	Cadier en Keer
Table 15	Halembaye
Table 16	Kastanjelaan-2
Table 17	Lanaye
Table 18	Lanaye - Vogelreservaat
Table 19	Leopoldsburg
Table 20	Merksplas
Table 21	Nieuwerkerken
Table 22	Poederlee
Table 23	Turnhout
Table 24	Valkenburg
Table 25	Walem

Table 26

Distribution of some foraminifera in KS 16, KS 17 and KS 18.

Table 27

Biostratigraphic range of foraminifera in sample 439.11 - 439.20 m, KS 22, HOFKER's foraminifer zone G. At least part of the foraminifera in this zone have been reworked (or might be restricted to more clastic substratum?).

Table 28

The orthogenesis of the Bolivinoides decorata-australis-gigantea gens in Merksplas.

Table 29

The orthogenesis of the Bolivinoides strigillata-decorata-australis-gigantea gens in Poederlee.

Table 30

Stratigraphic log correlations (limits and thicknesses) on the Heibaart Dome.

Table 31

Stratigraphic log correlations (limits and thicknesses) in the Antwerp Campine.

Table 32

Stratigraphic log correlations (limits and thicknesses) in the western Campine coal-mining area.

Table 33

Stratigraphic log correlations (limits and thicknesses) in the eastern Campine coal-mining area.

Formatie		Eenheid	Oost	West	Horizont	Uhlenbroek (1912)	Hofker (1966)
			van de Maas		Horz. van Lutterade		
Formatie v. Houthem		Kalksteen van Geleen	Vc				R
					Horz. van Geleen		
		Kalksteen van Bunde	Vb				Q
					Horz. van Bunde		
		Kalksteen van Geulhem	Va	XIw			P
					Horz. van Vroenhoven		
Formatie v. Maastricht	Boven	Kalksteen van Meerssen	IVf	Xw		Md	N M L
					Horz. van Caster		
		Kalksteen van Nekum	IVe	IXw	Horz. van Kanne	Mc	K
					Horz. van Laumont		
	Onder	Kalksteen van Emael	IVd		Horz. van Lava		I
					Horz. van Romontbos		
		Kalksteen van Schiepersberg	IVc			Mb	H
					Horz. van Schiepersberg		
		Kalksteen van Gronsveld	IVb	VIIIw			
					Horz. van St. Pieter		
		Kalksteen van Valkenburg	IVa				G
					Horz. van Lichtenberg		
Formatie v. Gulpen	Boven	Kalksteen van Lanaye	IIIg	VIIw		Cr4	F
					Horz. van Nivelle		
		Kalksteen van Lixhe 3	IIIf	VIw			
					Horz. van Boirs		
		Kalksteen van Lixhe 2	IIIe	Vw	Horz. van Halembaye 2	Cr3c	E
					Horz. van Halembaye 1		
		Kalksteen van Lixhe 1	IIId	IVw		Cr3γ	
					Horz. van Wahlwiller		
	Onder	Kalksteen van Vylen	IIIc	IIIw			D C
					Horz. van Bovenste Bos		
		Kalksteen van Beuteneken	IIIb			Cr3b	B
					Horz. van Slenaken		
		Kalksteen van Zeven Wegen	IIIa	IIw		Cr3a	A
					Horz. van Zeven Wegen		
Formatie v. Vaals	Boven	Zand van Terstraeten	IIf				
					Horz. van Terstraten		
		Zand van Beusdal	IIe				
					Horz. van Beusdal		
	Onder	Zand van Vaalsbroek	IId		Horz. van Vaalsbroek		
					Horz. van Overgeul		
		Zand van Grenspaal 7	IIc	Iw		Cr2	A'
					Horz. van Grenspaal 7		
		Zand van Cottessen	IIb				
					Horz. van Cottessen		
		Zand van Raren	IIa				
					Horz. van Raren		
Formatie v. Aken		Zand van Aken	Ib			Cr1	
					Horz. van Schampelheide		
		Klei van Hergenrath	Ia				
					Horz. van Hergenrath		

TABLE 1

GROUPE MÉSOZOÏQUE

(SECONDAIRE)

SYSTÈME CRÉTACIQUE

Le système crétacique affleure ou se trouve à faible profondeur dans le Tournaisis, le bassin de la Haine, la Hesbaye et le Pays de Herve. Il existe en couches continues, recouvertes par les terrains tertiaires, dans toute la partie septentrionale du Royaume, sauf sur le plateau primaire du Brabant et du Nord du Hainaut. Sur ce plateau, de même qu'au Sud de la Sambre-Meuse et de la Vesdre, on en rencontre des lambeaux isolés, des témoins de peu d'étendue ou des vestiges résiduels.

Dans le Hainaut, le Crétacique débute par une formation continentale rapportée au Wealdien, que surmonte une série transgressive d'étages marins allant de l'Albien supérieur au Maestrichtien, continuée par une série régressive que couronnent les dépôts continentaux du Montien supérieur. Plusieurs régressions locales, avec dénudation et lacunes stratigraphiques, interrompent ces séries.

Dans la partie orientale du pays, le système présente à sa base des dépôts continentaux, avec intercalations marines sénoniennes, et se continue par le Sénonien supérieur et le Maestrichtien, que surmontent des dépôts continentaux rapportés au Montien.

ÉTAGE MONTIEN (*Mt*).

Mtc. (1) Marne grise ou blanche; calcaire argileux compact; argile noire ou bariolée; lignite.
Physa montensis, Paludina Lamberti, Chara.

Mtb. Calcaire grossier, blanc jaunâtre ou gris bleu, friable ou plus ou moins cohérent (CALCAIRE DE MONS).
Briartia Veluini, Potamides montensis, Turritella montensis, Crassatella montensis, Corbis montensis, Pectunculus Duponti.

Mta. Calcaire finement grenu, blanc, jaunâtre ou gris bleu, friable ou plus ou moins cohérent, à silex gris clair (TUFFEAU DE CIPLY).
Campanile maximum, Nautilus.
A la base, conglomérat de cailloux phosphatés, à fossiles maestrichtiens et sénoniens remaniés (POUDINGUE DE LA MALOGNE *proparte*).

ÉTAGE MAESTRICHTIEN (*M*).

Hainaut.	Campine, Hesbaye et Plateau de Herve.
Ma. Tuffeau de Saint-Symphorien. A la base, conglomérat de cailloux phosphatés (POUDINGUE DE LA MALOGNE). *Trigonosemus pectiniformis, Thecidea papillata* abondants.	*Mb.* Alternances de tuffeau friable, de tuffeau caverneux et de tuffeau massif, avec lits à Bryozoaires. Bancs de calcaire cristallin blanc. *Belemnitella mucronata, Mosasaurus giganteus* (*M. Camperi*). *Ma.* Craie grossière, à silex gris. Localement, à la base, lit graveleux à *Thecidea papillata*.

(1) Il se peut que l'assise *Mnc* soit représenté en certains points du Limbourg par des argiles grises, bigarrées de rouge.

ÉTAGE SÉNONIEN (*Cp*).

Assise de Spiennes, a *Trigonosemus Palissyi* (*Cp4*).

Hainaut.	Campine, Hesbaye et Plateaux de Herve
Cp4b. Craie phosphatée, glauconifère au sommet (CRAIE DE CIPLY). Localement, à la base, poudingue (POUDINGUE DE CUESMES). *Pachydiscus neubergicus, P. colligatus, Ostrea lunata, Pecten pulchellus.* *Cp4a.* Craie grossière à silex gris ou bruns (CRAIE DE SPIENNES).	*Cp4.* Craie grossière, phosphatée, à silex bruns ou noirs.

Assise de Nouvelles, a *Magas pumilus* (*Cp3*).

Hainaut.	Campine, Hesbaye et Plateaux de Herve
Cp3bc. Craie blanche à *Magas pumilus* (CRAIE DE NOUVELLES). *Cp3a.* Craie blanche, souvent à silex noirs (CRAIE D'OBOURG). A la base, conglomérat à *Belemnitella mucronata*, avec *Actinocamax quadratus* remanié.	*Cp3c.* Craie blanche, à silex noirs. *Cp3b.* Craie blanche, sans silex. Craie grossière, à silex gris rudimentaires. *Cp3a.* Craie glauconifère à *Belemnitella mucronata*. Craie grossière glauconifère, à silex gris rudimentaires et *Belemnitella mucronata*. A la base, lit graveleux et glauconie grossière. *Note.* — Dans les vallées de la Petite-Gette et de la Méhaigne, l'assise est représentée par des faciès gréseux (TUFFEAU DE FOLX-LES-CAVES et GRÈS DE SÉRON).

Assise de Trivières ou de Herve, a *Actinocamax quadratus* et *Belemnitella mucronata* (*Cp2*).

Hainaut.	Campine, Hesbaye et Plateaux de Herve
Cp2. Craie blanche, sans silex (CRAIE DE TRIVIÈRES). A la base, conglomérat. *Belemnitella mucronata, Actinocamax quadratus, Inoceramus balticus.*	*Cp2.* Marne glauconieuse. Sable glauconieux, passant localement au grès calcareux. A la base, gravier. *Belemnitella mucronata, Actinocamax quadratus, Inoceramus balticus, Gyrolites Davreuxi.*

Assise de Saint-Vaast ou d'Aix-la-Chapelle, a *Actinocamax verus* (*Cp1*).

Hainaut.	Campine, Hesbaye et Plateaux de Herve
Cp1. Craie blanche à silex bigarrés (CRAIE DE SAINT-VAAST). Glauconie (GLAUCONIE DE LONZÉE). *Inoceramus involutus. Actinocamax verus.*	*Cp1.* Graviers, sables, grès et argiles à végétaux terrestres (SABLES D'AIX-LA-CHAPELLE).

TABLE 2

Table 3

NAME	LOCALITY	PURPOSE	GEOL.SURVEY FILES	LAMBERT COORD. X	Y	Z	T.D.	BASE CLASTIC TERTIARY	BASE CRETACEOUS	LOGS (CRETACEOUS)	BIO / ECO (CRETACEOUS)
KB 118	Leopoldsburg Kamp	coal	47W 251	214.054	200.885	57.75	1754.10	495	752	---	+
KB 120	Turnhout Zwemdok	geothermics	17E 225	190.573	223.829	29.63	2705.55	701	1001	Schlumberger	+
He-1 bis	Heibaart	hydrocarbons	7E 178 (KB 129)	173.343	231.025	23.4	1631.70	722	1052	Schlumberger	---
DZH 1	Loenhout - Heibaart	in-situ storage	7E 196 (KB 135)	173.185	230.809	21.8	1399	710	1038	Schlumberger	---
KS 1	Genk Schemmersberg	coal	77E 300 (KB 136)	225.504	186.415	69.64	805	250	482	Schlumberger	---
KS 5	Houthalen Hengelhoef	coal	62E 266 (KB 137)	225.585	190.195	80.90	1023.70	328	576	T.N.O.	---
KS 3	Dilsen Driepaal	coal	63E 217 (KB 139)	241.571	192.162	90.68	1188.40	341	599	T.N.O.	---
KS 2	Dilsen Koeweide	coal	64W 259 (KB 140)	246.140	192.340	39.36	1027	400	462	T.N.O.	---
DZH 2	Loenhout	in-situ storage	7E 198 (KB 141)	172.131	229.884	23.0	1353.50	694	1006	Dresser	---

Table 3 - 2

DZH 3	Loenhout	in-situ storage	7E 199 (KB 142)	174.090	230.496	22.6	1350	710	1038.5	Schlumberger	---
DZH 4	Loenhout	in-situ storage	7E 200 (KB 143)	174.617	228.569	26.9	1351	685.5	1008	Dresser	---
DZH 5	Loenhout	in-situ storage	7E 201 (KB 144)	175.150	230.732	25.3	1350	722.5	1073	Schlumberger	---
DZH 6	Loenhout	in-situ storage	7E 202 (KB 145)	172.384	231.445	20.5	1352	717.5	1049	Dresser	---
KB 146	Neerglabbeek	coal	48E 248	238.259	199.321	71	1357	462 m	730 m	T.N.O./ Schlumberger	---
KS 6	Opoeteren Dornerheide	coal	63E 216 (KB 147)	239.743	192.154	87.12	1075.50	348	587 m	T.N.O.	+
KB 149	Meer	geothermics	7E 205 (KB 149)	177.378	237.303	13.22	2517	808	1185	Schlumberger	---
KS 11	Houthalen De Teut	coal	62E 269 (KB 151)	223.740	189.100	78.20	925.30	305	553 m	T.N.O.	---
KS 10	Koersel 't Fonteintje	coal	62W 302 (KB 152)	217.195	197.820	66.80	982.40	482	720.50	T.N.O.	---
KS 9	Houthalen Hoevebos	coal	62E 270 (KB 153)	223.635	192.660	77.50	830	367	629.50	T.N.O.	---
KS 14	Houthalen De Hutte	coal	63W 212 (KB 154)	226.179	192.027	81.60	1111.30	357	614.45	T.N.O.	---

Table 3 - 3

KS 12	Houthalen Witte Bergen	coal	62E 272 (KB 155)	220.800	196.441	74.36	994.90	445	697.40	T.N.O.	---
DZH 11	Loenhout	in-situ storage	7E 213	173.323	231.075	25.86	1336 (dev.)	716	1045	Schlumberger	---
DZH 101	Loenhout	in-situ storage	7E 214	173.195	230.734	20.97	1310 (dev.30°)	699	1025	Schlumberger	---
KS 13	Koersel Hemelbrug	coal	47W 260 (KB 159)	215.225	198.303	59.12	1200.30	455	716	T.N.O.	---
KS 16	Opoeteren Heuvelsven	coal	63E 219 (KB 160)	239.428	190.662	92.64	1245.16	± 325	571	---	+
KB 161	Opglabbeek Louwelsbroek	coal	63E 218	238.212	194.690	62.33	1342	377	622	T.N.O.	+
KS 17	Opglabbeek Grote Hei	coal	63W 214 (KB 162)	233.658	191.229	85.20	1213.40	348	577	T.N.O.	+
KS 18	Opglabbeek Hoefkant	coal	63E 220 (KB 163)	235.900	191.512	73.50	1252.60	319	556	T.N.O.	+
KS 19	Opglabbeek Industriepark	coal	63W 215 (KB 164)	233.422	192.708	86.38	1228	357	611	T.N.O.	+
KB 165	Merksplas 1	geothermics	17W 265	181.938	225.856	33.93	1760	694	1005	Schlumberger	+
KS 20	Opglabbeek Biersbeemden	coal	63E 221 (KB 166)	236.950	193.190	66.92	1304.60	± 345	590	---	+

Table 3 - 4

KS 22	Opoeteren Ruwmortels-heide	coal	63E 222 (KB 167)	238.787	191.238	92	1236	328	577	Schlumberger	+
KB 168	Opoeteren Den Houw	coal	63E 223	240.546	194.697	78.85	1264.72	391	653	T.N.O./B.P.B.	+
KB 169	Gruitrode Muisvenner-bemden	coal	48W 185	233.846	199.436	72.31	1371	468	739	T.N.O.	+
DZP 1	Poederlee	in-situ storage	30W 371 (KB 170)	182.667	212.654	15.51	1690	535	773	Welex	+
KS 21	Dilsen- Oude Baan	coal	64W 266 (KB 171)	245.150	192.020	38.38	1137	256	457	T.N.O.	—
KB 172	Gruitrode Ophovender-heide	coal	63E 224	234.022	196.268	77.73	1599	420	681	Welex	+
KB 174	Hechtel-Hoef	coal	47E 196	220.085	199.406	69.15		492	729	Welex	+
N.M.W.	Nieuwerkerken	water	91E 405	207.214	173.150	33.76	161	93	—	—	+
N.M.W.	Velm	water	105E 411	203.825	162.750	62	96	43	—	T.N.O.	—
KS 25	Opglabbeek Reyndersstraat	coal	63E 225 (KB 173)	234.083	194.450	84	872.60	402	648	T.N.O.	—

NAME	LOCALITY	PURPOSE	MAP	COORDINATES x	COORDINATES y	NAP	TD	BASE OF QUATERNARY	BASE OF CRETACEOUS	LOGS CRETACEOUS	BIO / ECO
Cadier en Keer KB 423	Margraten	Mapping	62A	182.490	315.835	+ 96.5	151.63	3.8	149.5	-	x
Kastanjelaan-2 61F-296	Maastricht	Water	61F	175.595	318.530	+ 51.5	500.5	7.5	201.2	Schlumberger B.P.B.	x
Walem KB 408	Valkenburg	Mapping	62A	188.915	318.880	+ 88.2	140.85	0.5	138.5	-	x

TABLE 4

NAME	LOCALITY	MAP	COORDINATES x	COORDINATES y	THICKNESS CRETACEOUS exposed	THICKNESS CRETACEOUS borehole	BIO / ECO
Halembaye 61H-9	Haccourt	61H	174.000	306.000	83.5		x
Lanaye Vogelreservaat 61H-49	Lanaye	61H	175.400	309.700	9.2		x
Lanaye 61H-36	Lanaye	61H	176.180	311.600	18.7		x
ENCI 61F-19	Maastricht	61F	176.000	315.000	84.0	19.6	x
NEKAMI 62A-7	Margraten	62A	182.500	315.500	35.0	20.0	x
Valkenburg	Valkenburg	62A			49.0		x
62A-170			188.130	319.040			
62A-84			188.070	318.900			
62A-4			187.700	318.850			
Walem 62A-481	Valkenburg	62A	188.850	318.675	18.0	138.5	x
Kunrade 62B-9	Voerendaal	62B	194.440	320.200	20.0		x

TABLE 5

Table 6

KS 16, Opoeteren, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	Eco-strat.
298		2											4			1			7	
303																		1	1	8
308																		1	1	
314								1000											1000	
319								120											120	
324								25											25	
328								9											9	
333		55	1		20			24			3	5	18	10	15	1			152	
345		60			62			5	2			3	23	4	5	1			165	7
365					5			19					63		27	1	16		131	
370		2			18			16					91		37		6		170	
375		2			92			12					15		38		1		150	6
380		1			7			8					12		67	1	48		144	
385		3			27			13			1		15	1	44	1	33		138	
390		1			13			9				1	24	2	52		5		107	
395		1			4			5					11		23		6		40	
400																			0	
405																			0	5
410																			0	
415															4				4	
420																			0	
425																			0	
430																			0	
435					1			6		2					2				11	
440	1	6			1			1						6	39				54	
445		2			1	42	9	236		2			3		9	1	1	2	308	
450	1					37	6	93				2		2	5				146	
455	2					12	1	34						2	3	6			60	
460	4				1	6	3	32		2	1				3	3			54	
465	2	4			1	3		13			1		2		5	1			32	4
470	2							12				1			2				17	
475					1			7					2	1	5				16	
480						6		6					3						15	
485					2	7		3							2				14	
490						4		5			1				1				11	
495						2		1							1				4	
500		2						3							1				6	
505		1				1		15							5				22	
510	1				1	4	1	24				3		1	6				39	
515		10			3	1	1	43		2		2	1	1	18				72	
520		4			1		5	26				2			6				44	
525		4			2	11	1	34					2		8				62	
530		5			1	1	1	19		5		1	1		8	1			43	1
535	1	2			3	1		251			1	5			9				277	
540		1						31					1						34	
545		1			1	1		21		1		1			1				27	
550		2						10					1						13	
555								8							1		1		10	
560		2			1	1		12							3		1		20	

Table 7

KS 17, Opglabbeek, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
350		50			5			18			1	4	11	6	10				110	
355		11			67			17	3			1	12	1	7		1		120	
360		1			162			48		1	1	1	35	2	10	4			265	
365		1			33			7				5	61	8	10		6		134	
370		3	2	1	34			11					62	4	6		8		134	7
375				3	20		2	42	5		1		35	1	66		6		180	
380		2			14			32	2			1	45	5	14		1		116	
385		2			4			33					41		136	2	32		250	
390		2			2			16		2			41		40		23		126	
395		4			11			7		1			27	2	101		4		157	
400		1			9			14					23	1	33		39		120	6
405					12		1	11			1		13	3	68		24		133	
410		2		1	9			36				3	35		28		6		120	
415					5	1		18					6		37		1		68	
420								2		2		1			7				12	
425						1		2		1		2	3	1	5		1		18	
430								2		9	3	1	3		15		1		35	
435					2	5		9		12	4		2	1	81				116	5
440						2		7	1	3			2	1	26				43	
445						4		6		2			2		10		1		26	
450								2		5			4		20		1		33	
455		1			1	1		19		1			4	1	17		1		46	
460	1				2	120	32	16		2		2	4		6				185	
465	1	4			3	77	66	30		30		2			11		1		227	
470	2	1				102	69	11		11			2		23		1		223	
475	1	2			2	82	57	18		11			1	8	5				188	
480	1	7			1	52	39	11		14		1	5	1	5				138	4
485	1	7			3	96	13	38		4		3	8		35	2	1		212	
490	7	4			2	63	23	12		7			10		29		4		161	
495	9	3			8	25	15	10		28			10		77		10		195	
500	2	2			3	42	1	11		2			3	1	19	3	6		94	
505	1	7				11	3	3				4	2		47	2	1		81	
510	1	11				3		2		1		9	2		19		1		49	
515	1	12			3	21		7		6		23	2		61		2		140	
520	1	12			1	3		7		1		6	2		19				52	
525		24			3	30	4	12		3		6			52				134	
530	1	18			9			24		6		2	3		25		1		90	1
535		25				17	3	19		7		1	2		24		1		99	
540		15				10	1	9		2			1		12				50	
545		22			1	23	2	18		5			1		18				90	
550		13				6	2	29		2					8				60	
555		7				7		1							4				19	
560		12			1	3		6				5	1		11				39	
565		1			1	4		9						1	6				22	
570		2				28	5	68					1		8		4	1	121	

Table 8

KS 18, Opglabbeek, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
300																15			15	
305																7			7	
310								990											990	8
315		1						97								1			99	
320								54											54	
325								48											48	
330		61			25			5			4	4	8	7	41	1	1		157	
335		28			23			3	1		2		43	3	23	1			127	
340		12			5			10			1	2	57	1	18		2		108	7
345		6			14			7	1		2	3	58	5	36		13		145	
350		4			11			8		2		7	60	4	12		1		109	
355		2			15			12			1	7	68	5	13		8		129	
360		1			7	2		41					57	1	16		35		158	
365		1			6			11				1	84		63		6		172	
370		6			29			9	3		1		47	1	65		4		164	6
375		2			10		1	4					11		34		4		66	
380		1			4		6	22				1	27		14		37		113	
385		2			3			17			2	1	40		11		36		112	
390		2			3			4			1		57		8		6		81	
395					1	1		3					9		12		2		28	
400					2	1	1	4					15	2	11				34	
405		1			3			1			1		17		19	1			43	5
410					2			3		3			19	1	18		1		47	
415					7			4		2			11	1	11	1	1		38	
420					4		1			3	6		6	1	21				42	
425		1			1			1		1		2	6		18	1	2		33	
430		1		1				7		5			4	1	11		1		31	
435		1						1		1			1		5				9	
440	1	2			1	1	12	17		14				3	21				72	
445		3						13		3	6	4	2		52	2			85	
450	11	6				4		13		27				1	95	3			150	
455	17	4			1	50	6	9		3	1	3			10		3		107	
460	200	1			1	22		9		3			6	1	16		1	1	265	
465	30	2			3	15	2	38					5	1	6		9		109	4
470	4	2			1	5	1	13		2				2	7		3		41	
475	2	2			1	35	1	8		1			2		3	1	6		62	
480	3	4			3	30	4	24					7	6	27		2	1	111	
485	1	1				9	1	8				2		1	12	3			38	
490		1	1		2	6		7				1	4		6				28	
495	1	8			2	23	17	61		4		2			2			2	122	
500		19			1			51				5		3	43		4		127	
505		17	2			3	1	32		2		4			39	1			101	
510																	1		1	
515		8	1		1			6		1					10				27	
520		4			4		3	25		1	1	1	1		5	2			47	
525		8				59		92				1			5	1			167	
530		5	1			1		15				2			7	1			32	
535		5				10	3	10		1			2		6				38	
540		10				2	1	68		1		3	4	1	6				96	1
545		8					1	12			1				4				25	
550					1			3							3				7	
555		11			2	9		266		9		3	1	1	6	2	6	2	318	
557								700											700	

Table 9

KS 19, Opglabbeek, Bioclasts 1.0 - 2.4 mm

in m	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest			Tot.	Eco-strat.
	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.		
360								55							1				56	8
365		2			1			37					1		2	3			46	
370		47			13			2					20	2	30	3			117	
375		46			17			2			5	3	21	2	37				133	7
385		16			34			9			3	3	25	5	64				163	
390		8			23			8			1	3	19	5	75		5		147	
395		1			18			9			1	1	10	7	85		2		134	
400		7			13	1		27				1	16	3	57		10		135	
405					14			30		2		3	38	11	45		20		164	
410		5			5			12		2			52	11	77		16		181	
415		4			7			12	1				33	6	60		5		128	6
420		5			13		1	20		1	1		32	3	59		14		149	
425		2			4			16					23	2	50		21		118	
430		3			10			17	2				35	5	60		7		139	
435		2		1	9			9			1		32	8	76		17		155	
440		13		2	10			18		1	1	3	42	15	120		31		256	
445		1			9	1	1	11		1		4	25	3	62		16		134	
450		4		1	7			7	1	7	1	4	20	17	77		13		163	5
455		4			8			6		3		4	14	5	90		8		142	
460		4		1	11		1	14		4	1	5	26	9	93		18		187	
465		6			8	1		8		3	2	2	25	14	90		12		171	
470				1	3	1		6		2	1		13	4	35		2		68	
475		3		2	5			31			2	3	16	14	68		10		154	
480		6			9			11		2	2	2	6	10	52		7		107	
485		4			1		21	12		1			15	6	44		2		106	
490	1	5			3	1	31	24		11			5	1	54	3	2		141	
495		4			6		27	8		11			15	4	71	2	3		151	
500		8			5	2	14	19		8	1	2	17	4	64		1		145	
505	18	6			3	11	8	7		1	3	1	13	2	68	1	7		150	
510	7	8			3	15	6	19		3	1	4	14	2	68	1	8		153	4
515	6	6			2	12	7	6		1		1	19	5	52	2	7		127	
520	11	3			3	12	9	18		3		3	7	3	43		2		117	
525	11	9			3	18	15	27		6	2	1	14	1	31	1	2		146	
530	6	6			1	49	11	11		2		4	9	5	30		2	1	137	
535	6	2			1	48	13	11				2	10	2	47		3		145	
540		6			6	51	9	18		3		1	6	5	66		4	1	176	
545	1	37		1	2	15	2	20				5	1		36	3	3		126	
550	11	25			3	29	8	20				7	3	4	58	2	3		173	
555	1	13		3	4	3		21		3			4	2	24		2		80	
560	8	22			4	17	2	34		3		2	3	1	30		3		129	
565	1	15			2	4	3	12				1	4		9				51	
570	2	26			1	32	1	28					4	4	40	2	1		141	
575	2	12				4	2	18		1				1	32	1			69	
580	2	8			1	7	1	15		2			3	2	10	1			53	
585		1						1							5				7	1
590	1	17			4	18	2	38		1			5	1	28	3		1	119	
595	1	15			5	18		42		4			5	4	40	6	1		141	
600	7	12			1	18	1	44				1	8	4	16		3		115	
605		6			5	14	4	93		3		3	7	2	5	1	2		144	
610		6			2	6	2	41		1		2	2	1	7	1	2		74	
615		1			1	9	1	34							7	1	1		55	

Table 10

KS 20, Opglabbeek, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda					Echinodermata						Rest				
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.	Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	Eco-strat.
290		1															6			7	
295		1																		1	
300																	1			1	
305								1												1	
310																			1	1	8
325		1						80							1				3	85	
330								890												890	
335								600												600	
340								210												210	
345								1400												1400	
350		23			14			56				1		17	3	2				116	
355		44			15			42					1	13	1	6				121	
360		36			40			43					3	20	1					143	7
365		33			30			13				2	2	32	5	5				122	
370		15			17			14					3	75	1	13		1		139	
375		18			31			11						72	4	9	2	1		148	
380		2			10			37				1		37	1	6		25		119	
385			1		14			40			1	3		53		18		30		160	
390		1			12			17	1				2	63	4	14	3	42		159	
395		2			15			23						43	1	13		20		117	6
400					10			25	1		1			82		19	2	58		198	
405		1			12			30				1	1	75	3	21		32		176	
410			1		6			14						57	3	32		30		143	
415		2			2		2	20				1		73	2	21		21		144	
420		1			1		1	19				1	1	28		47		25		126	
425			1		2			18			1		1	19		33		15		90	
430		1			4		4	25				1	3	41	2	75		24		185	5
435					17			16		1				26	4	51		21		120	
440		1			2			22			1		2	16	1	23		11		79	
445					1			14			2	1		8	3	31		7		67	
450					5			6	3		1			7		17		2		41	
455					11		2	11	2		3	1	3	9	1	28	1	8		90	
460					4			8			1	5	3	11		13	1	4		50	
465		1			5			11			4	4	1	12		17		1	1	57	
470	1	3			8	9	3	21						7	1	37		3		93	
475	2	2			7	11	3	36			4	2		2		11		1		83	
480	2	3			1	7	6	34			6	1		5		22		1		88	
485	2	10			6	28	12	123	1		10			7		37		6		233	
490	4	4			7	26	8	64			4	1		5	2	28			1	155	
495	4	2			4	10	10	74			4	1		3		13				125	
500		1	2		4	18	5	51			2			4	3	22		3		118	4
505	3	3			4	25	8	57			4	2		1	1	16		3	3	130	
510	1	4	1		3	12	3	22			3			8	1	3			1	62	
515		1			4	16	1	33			3	2	2	3		7		2	1	76	
520		1			10	39	6	50			3	1	2	14	1	18	2	2	7	156	
525	1	1			1	9	1	18				1	2	8	1	11	1	1	4	59	
530		1			6	14	3	39			3			2	1	7	1			83	
535		2			4	28	4	45			2			9		14	4	9	4	125	
540					1	10	2	23					2	5		12		2		57	
545		4				4	3	3						3		7				24	
550		6				14	3	14						2		27		2	1	69	
555		4			1		1	6			2		1	1		7		1		24	
560		2			2	3		10			3		1			8		3	2	34	
565		3			3	7	1	14					1	3	1	4	2	4	4	43	1
570		3				5	1	11								9		3	1	33	
575		6			2	5		6			1			3		7		3		33	
580	1	3			1		1	11					3	3		6				32	

Table 11

KS 22, Opoeteren, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
300		1						12											13	
305								2											2	
310		1						2											3	8
315								31											31	
320								17											17	
325								103											103	
330		8						17					5						30	
335		72			4			58			1		24	1	9				169	
340		51			12			8				8	47	8	29				163	
345		60			1			3				21	19	4	23				131	7
355		32			1			6			2	6	24	8	37				116	
360		11			9			5				8	41	9	46		5		134	
365		6			15			6	2	1	1	6	66	2	52		7		164	
370		8		1				16	1	3		3	98		23		11		164	
375					4	1		14		1		1	95		16		16		148	6
380					2			11					82	3	20		15		133	
385					5	1		13				3	107		22		4		155	
390					4			22	1		5		50		22		11		115	
395		1			5			22	1		1	1	85		15		7		138	
400					2		3	13	1	1		4	57		14		4		100	
405	1			1	2			11					38		18		4		75	
410					2			17	2				72		24		10		127	5
415		1			2			29				6	38	3	33		7		119	
420					6			19	1			2	39	2	51		8	1	129	
425					1			2					8		2		3		16	
430													9						9	
435					47			6	1	2			10		9				75	
440					47	1	2	14		4	7	2	14	4	14		5	1	125	
445		7			10	3	2	15					4		35	2	2		80	
450		4			8	2	9	30					5		43				92	
455	2	3			3	24	13	68		1	1	1	6		23		4	1	152	
460	3	4			1	17	1	113		1			1		12		3		156	
465	6	6				20	3	112	1	3			1		8		1	1	166	
470	6	5			1	22	8	94	1		1		2		15	1	2	1	161	
475	9	3			1	12	2	91		2	1		5		19		5		151	
480	8	2			2	16	3	93		1			1	1	23		2		151	
485	5	9		1	5	23	5	92		1				1	30		5	2	179	4
490	3	2		2	3	41	3	42		1		3	5	1	10	1	3	11	131	
495		1			4	30	2	37	1					1	11		3	3	93	
500		1				16	2	22			1				6		3	1	52	
505	4	6		1	6	19	3	53		2		3	11	1	13		2	1	128	
510	4	10			11	13	6	51				5	4	3	18		4	1	129	
515	1	9			1	13	5	21		1		2	9	4	10		2		78	
520		18			1	6	6	60		1	1	13	3	6	31	2	4	1	153	
525	1	14			1	4	6	30		1		3		2	25	2	2	1	92	
530		25			2	2	2	47	1	2		6	2	2	15	2	4		112	
535	1	27			2	2	3	34		1	1	5		3	14				94	
540		24			1	4	1	26		2		2	7	4	18		1		91	1
545		11				5	3	49	1			7	2		27	2	4	1	112	
550	2	5				2	1	14					4	1	4		1		34	
555		8			2	6		62		3		6	2	1	12		2		104	

Table 12

Opoeteren, BGD 168, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda					Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.	Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
403		63			2			6				1	1	21	2	21				117	
408		56			2			13					3	12	4	34				124	
413		32		1	23			15				1	2	14	4	52				134	7
418		17			32			14						39	4	30		3		129	
423		13			23			18					5	44	5	37		1		146	
429		2			12			12	3			4	2	66	3	16				120	
438		1			1			25		1				57	4	31		14		134	
442		2			6			16		2			2	61	4	10		15		118	6
447					4			21					2	89	3	10		17		146	
452					4			22				1		109		8		7		151	
457		1			17			7				1		112		11		8		157	
461		1			5			10						67	3	18		12		116	
466		2			10			9					6	56	6	29		9		127	
471					1			4				1	1	24		3		2		36	
476					3	1		3				2		16		7		2		34	5
481					1			6					1	8		9		3		28	
486					5		1	9	1			1	7	50	5	14		8		101	
491					1			3						9	3			1		17	
496		1		2		2	1	2					1	1		12				22	
501		1		4	5	15	23	47			1			3		33				132	
512		1		2	2	11	29	108			1	1		4		6		1		166	
516		1		5	1	11	13	84							1	13				129	
521		2		1		17	23	96								9				148	
527				2		19	14	70								5				110	
531		2			1	15	16	74								5		1		114	
536				1		13	12	78						1		8				113	
541		2		1	3	5	16	89			1			1	2	7	3	2	1	133	4
546		3				15	8	81							2	9				119	
550		1		3	3	13	6	60							1	10				97	
555						11	9	90								8				118	
559		1		2	4	14	10	87			1					8		1	1	129	
564				1	2	30	18	93			2			5		16		3		170	
568		1		2	1	11	8	63						5		7				98	
573		1		2	2	13	10	62						2	1	16		3		111	
578		1		8	3	19	14	85						2		25				157	
582		1		1		7	14	28								3				54	
587		1			1	10	11	29					1	3		18	1	2	1	78	
591		1		2	3	24	18	80						3		29	5			165	
595						9	3	24						4		7	2	1	1	51	
601					2	22	10	28						3		2			1	68	
605				1	1	3	1	10						2		4		1	1	24	
610						2		6						1		1				10	
614					1			10						2			4			17	1
619		1			5	3	1	21						16	2	21				70	
624		1				3	3	12						6		4				29	
628					2	4		25						1		8	2	2		49	
633					1	6	1	15								9	1	2	1	36	
638					1	15	5	40			2			4		4			1	72	
642					1	3	3	15						1		6				29	
647					1		1	9							1	4				16	
652					3	8	1	48			1			5	2	5		4	1	78	
653						4	1	4												9	

Table 13

Gruitrode, BGD 169, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
466								72											72	8
472								43											43	
478		63						5					33		14				115	
481		68			4			25			5		15	4	24				145	
484		66			2			18	1		5	1	21	3	17				134	
487		139			5			33	3		7	3	54	10	31				285	
490		109			16			62	11		7		107	8	30				350	
493		36			8			11			4		59	4	23				145	7
496		32			8			19	3		3		52	5	26				148	
499		66			24			37	9		8	1	105	10	13		1		274	
502		22			32			24	3		6	5	175	18	35		6		326	
505		24			16			12	2		11	2	163	6	29	1	7		273	
508		9			9		2	47	5		9	1	210	10	38		8		348	
511		9			14		1	78	2		2	2	148	12	48		13		328	
514		11		3	8		1	52			4	2	209	6	55	1	18		370	
517		14		5	4			50		2	2	1	172	8	32		9		299	
520		20			5			31			1		174	2	44		10		277	6
523		20		1	5			35	1	2		1	191	6	66		13		341	
526		8			7			38	3		3		144	6	63		39		309	
529		19			6			69	1		3		80	9	54		37		278	
532		16		1	9		3	48		1	4	1	68	4	65		21		241	
535		11			2			26		1	5	6	74	13	56	1	4		199	
538		3		3	14						1	3	12	11	39		1		87	
541		3						7				1	1		23		2		37	
544		6						5				1		1	17		1		31	
547		10			1			7	1		1		11	3	34		3		71	
550		3						9					7	1	29				49	
553		4			1			5			1		4	2	21				38	5
556		3						4					8	4	13				32	
559		4				1		12					8	4	42		1		72	
562					1			16					5	2	12	1			37	
565		1		4	3	13	4	41			2		6	3	19		3		99	
568		5		14	10	23	7	44		3			18	6	26			1	158	
571		11		12	5	24	45	130			2		8	1	16		2	1	257	
574		7		10	5	47	116	107			1		12	4	18			6	333	
577		9		5	4	23	80	148				1	2	4	12		1		289	
580		2		4	2	22	94	129					8	2	13		1		281	
583		6		4	2	32	82	147	1			2	10	3	22				311	
586	5	6		4	5	22	77	85	2			2	4	2	13				227	
589	2	1		4	1	48	57	110	1				5	1	9				239	
592	5	7		14	1	62	71	125			1		7	3	5			1	302	4
595	1	5		3	4	37	61	157			1		1	3	9		4	3	290	
598	1	5		2	2	30	35	121						3	2		1		202	
601		1						1											2	
607						8	14				1		3		6		1		33	
625		1					1	4					4		2				9	
628						2		7	1										10	
631						2		1											3	
634						2		6					3	1	2				14	
637								3											3	
640						17		15										6	33	
643						16		31					1					1	49	
646						26		64			1		1	2					94	
649						24	1	29					2		2				59	

Table 13 - continued

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
652								6							1				7	
655		3				6		46				1			6			2	64	
658		2						4					1						7	
661								3											3	
664						1		3										1	5	
667					1	1		4										1	7	
670					1	4		10											15	
673								4											4	
676								4											4	
679								11					2						13	
682	1							60										1	62	
685	2	4		1	2	1		91				2		1	3				107	
688	1	2					1	80		2		2		1	1			1	91	
691	3				1	2		111							2			1	120	
694	2	4						74				2			1		2		85	1
697	2	1						39		1		5		2					50	
700	5	2				1		88				3	1		4		2	1	107	
703	4	8			1	2		71		1		1			10				101	
706	2				2	1		94		6		13		1	13		1	2	135	
709	2	2			2		1	35		1		5		4	5				57	
712		5			1		2	50		1		8		1	7			1	76	
715	3	10				1		60		2		8		3	5				92	
718	3	3					1	27		1					2			1	38	
721	20	3				2	4	86						1	6			1	123	
724	5	9			1	5	2	113		2		4		2	5		7	1	156	
727	3	5			3	19	2	202		1			1	4	1	1	6	1	249	
730	1	2				13	11	177		3		2	1		1		5	1	217	
733	3	3				4	2	45		1				1	5		1		65	
736	2	2				5	2	42		1			3	1	4		1		62	
739	2							33						1					36	

Table 14

Cadier en Keer (KB 423), Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
64.95	19	2			1		7	34					1	3	3				70	
66.75	23	5			1	29	8	23		1	1		10		26				127	
77.00	15	4			3			5	4			1			23		2		57	
78.00	30	4			4		1	13	1						5		1		59	2
78.95	10	3			3	80	30	17	4					1	4				152	
80.00	2	7				1	38	11					1						60	
81.00		3					25	12	1										42	
81.80	16	8					11	6						3					44	
82.00	2	1			2			39					4	5			3		56	
84.00	14	6						37		3			17	6		8	9		101	
85.05	12	5						12		2			1	1	9		6		48	
87.25	67	31			1	1		109		3			1	8	7		5		233	
88.10		6						56					2		1				65	
89.60		8					1	29		1		1	4		2				46	
91.15		10					6	126				1	1	1	1		2		148	
111.00								28				1	1			8			38	1
112.50								24		1		1				2		1	29	
126.25		1						7											8	
139.25	1	1						35						4					41	
140.15	1	2						30						1			2		36	

Table 15

Halembaye, CPL, 61H-9, Bioclasts 1.0 - 2.4 mm

Sample	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
H82-13					1		3	75		15	1		85		9	2	6		204	
H82-18		2			16		10	46	15	6			169	6	20			1	294	3
H82-12		1			7		3	23		10			79	2	15				142	
H82-11		1			16		12	22	9		26		28	1	27	2	1	2	147	
H82-15		4			9		5	33	44		2		85	12	7		3		207	
H82-10		7			11		8	63	11	3		1	101	19	15		6	1	254	
H82-9		9			11		7	101	12	2	5	4	9	10	14	13		2	204	
H82-8		2			1		2	108		1	3	3	76	9	7			1	273	
H82-7		6			6	15	7	22	3	37	2		12	12	24	7	17	4	174	
H82-6		1		1	19		1	70		51	4	5	26	17	25		15	1	236	
H82-5					1		13	21					6	2	1	1		2	47	
H82-14		1			2		1	101		7	4		23	6	1		12	1	159	2
H82-4	4	1		2	6	2		47		6	1	6	55	5	9	2	4	2	152	
H82-3	5	1	11		21		1	55	8	30	2	6	177	26	38	2	1	4	389	
H82-2		5						44		1								6	56	
H82-16		3						108								8		2	121	1
H82-1		3					1	8										3	16	

Table 16

Kastanjelaan-2, Maastricht, Bioclastst 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda					Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.	Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
9.0					37			17		3			4	223	2	2	5	4		297	
12.0					38			31					8	326	7	32	3	4		449	7
13.5				3	143			82				3	15	402	23	95	15	2	1	784	
17.5					13			8					8	43	7	7	1	4		92	
20.3		4			35			16						146	10	9	1	3		224	
24.8		28		1	79			48			1			854	1	37	3	15		1067	
29.8		114			189			26						252	3	10		13		607	
32.8		74			316			17			5	1		263		16		19		711	
34.8		134			192			17						66		14		3		426	6
36.8		34			283			14			3			225	6	21		51		637	
37.8		2			39			5						99			1	25		171	
40.8		5			22			4			1		1	188	3	13	12	45		294	
43.8		1			12		4	3						53			4	71		148	
46.8		3			26			58			1	3	8	105	1	2	5	93		305	
49.8		2			65		6	23		1		17	9	404		4	1	56		588	
52.8		5		3	75		7	36				17	6	217	1	6	3	57		433	
56.8		17		4	53		5	24			2	15	7	263		17	2	65		474	5
59.8		11		3	38		1	16			2	7	1	137		15		29		261	
63.8		3			8		1	10			5	10		69	1	7	1	4		119	
67.8		5		5	17		1	15			56	78		424	6	18	4	5		634	
70.8		1		18	1		7	8			179	12	11	137	8	41		6		430	
74.8		5		4	23		14	25	21	4	179	1	2	145	4	25	2	21		465	
77.8		21		4	54		18	41	18	6	99	2		239	2	33	7	42		586	
79.8		1		1	18		2	67			73			61	6	7	2	19		257	3
84.8		4		4	17	3	13	77			101		1	61	5	34	11	20		354	
88.8		1			3		3	13			7			26	3	4	4	2		66	
95.8				1	10	1	5	3			7			29	2	66				124	
103.8		5			12	1		15			10	1		112		18	3	6		183	
105.8		1						3						28						32	
112.8					8	1		2			1			81	1	7	1	2	1	107	
117.8	11	28			5	55	15	223			4	18		116	48	43	9	19		615	
121.8	20	6			2	173	17	102			2	15	4	142		106		26	1	768	
127.8	98	12			1	101	71	107				21		193	1	167	19	26		817	
128.3	3	1				144		5						2				1		156	
131.8	347	131			2	68	21	112			3			26	39	19	14	19	1	602	
135.2	75	118			2	51	72	98			5		1	37	13	7	2	22	1	505	2
138.2	16	95			9	38	12	139			6			102	33	13	12	28	1	503	
140.2	22	23			11	4	1	32			21	5	1	42	14	16	6	12	1	211	
145.2	52	83			15	10		88			68	8	2	84	18	69	22	26		549	
149.2	161	51			22	5	12	137			32	11	3	160	44	59	13	171		881	
153.2	170	37			15	68		70			46	5	2	75	25	48	3	53		618	
157.2	5	45			5	20	4	140			13			3	2	32		3		274	
158.2		47			2	1		97			2									149	
161.2		23				3		5						1						32	
166.2		9						27												36	
171.2						8	1	8												17	
176.2							1	1												2	1
181.2		11					1	24						1					1	38	
186.2		2						4						3						5	
191.2								12												12	
196.2		2						42												44	

Table 17

Lanaye 61H-36 Lanaye Chalk, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda					Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.	Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
18.70		2			27		41	32	2		97	17		547	13	23	1	8		810	
18.20		2		5	126		11	87	3	9	185	5	6	1437	8	60	2	15		1961	
16.55		4		6	28		10	45	20	71	115		1	791	12	43		23		1170	
15.20		3		5	22		2	121	11	3	59		19	320	25	15		18		626	
14.50				35	50		8	140	11		47		26	736	41	13	3	15	3	1128	
13.60				13	46		8	49	5		31		20	679	27	19	2	1		900	
12.70		2		17	78		19	319	19		91	4	11	1237	7	76		61	2	1944	
12.00				16	52		18	152	20		200		8	695	52	12	4	12	1	1242	
11.40		5		4	106	1	11	281	90		422		30	668	24	59	3	21	1	1726	
10.80		3		2	56		34	131	166		79		7	775	9	14	9	61		1347	3
9.30		1			83		17	177	103		109			634	12	18	7	12		1173	
8.50		3		3	20		44	151	26		173		24	670	29	20	4	6		1173	
7.50		5		1	33		38	91	1		100		2	369	23	6		30		698	
6.65		8			40		14	126	2		20		3	232	6	4	6	2		463	
5.70		7			33		36	119			4		3	374	24	3		7		610	
5.15		10			72		29	164			12	1		248	10	9	3	5		563	
4.90		2		3	38		20	161			31	2	5	585	17	10	3	19		897	
3.70		11		1	61		15	268			146	2		774	27	29	8	26		1369	
3.40		4			36		7	111			50		3	387	3	2	4	10		617	
2.80		4		1	9		5	127			156	2	1	223	5	14	3	10	1	563	
1.40		5			19		14	144	1		87	1	2	275	9	10	20	23	1	612	
0.80				4	1		12	84	3		47	1	1	128	7	15	8	2		313	
Nivelle Horizon																					

Table 18

Lanaye Vogelreservaat, 61H-49, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
+0.60		3		1	153	20	41	1		2	10	1	303		15	2	4	1	559	6
+0.20		1		11	408	48	35			1	29	1	116		28	6	14	2	705	
Romontbos																				
+4.80		5		1	410	5	45	2		2	20		186	1	62	6	9		756	
+4.50		1		4	287	2	52	1		4	14	3	170		21	6	23	2	590	
+4.16		3		23	527	15	163	5	1	14	18	13	379	1	31	9	80		1282	
+3.81		1		3	183	7	62	1	3		6	1	217	1	10				495	
+3.31		2		2	154	3	44		11		3	2	415	11	16				662	
+3.11				3	205	5	69		27		3	2	332	22	4		4		676	
+2.71				4	115	10	71	1	31	3	5	1	290	17	7	4	5		563	5
+2.44				4	151	18	68	8	6		7	4	290	1	12	2	7		578	
+2.21		2		7	100	14	25	13	18		1	3	218		17	2	12	1	433	
+1.91		1		7	143	18	36	6	14	1	3		489	5	14		10	2	748	
+1.67		4		5	255	7	35	3	60		10	8	227		10		33		657	
+1.17		5		2	178	11	70	2	9	3	6	1	545	3	15		8	1	859	
+0.67				18	61	7	9	2	1		5	1	340	2	10		6	1	463	
+0.23		1		4	109	15	64	5	51		5	4	419	2	5	1	17		702	
Lichtenberg																				
-0.20				1	79	3	27	69	234		4	1	160	1	7	1	27	1	615	
-0.50		1		1	84	8	37	3	58	1	4		439	3	6	1	12		661	
-0.92		1		2	83	11	50	3	4	1	9	1	447		9	1	24		646	
-1.12		1			116	13	120	5	44	9	11	3	323	4	14	2	9		674	
-1.30				2	71	5	52	4	57	18	9	1	249	5	22	13	18		525	
-1.42					26	6	35	1	2	33	16		351	23	15		22	1	528	
-1.92		1			46	23	31		7	29	6	1	330	26	24	3	15		543	3
-2.17		2			54	17	21			130	12	1	249		17	6	6		515	
-2.47					44	6	21			211	6		325		28	1	11		653	
-2.68					41	3	33	2	1	139	9	8	294		20	3	7		560	
-2.92					31	5	8	1	4	75	2	4	404	1	7	1	13		567	
-3.47		3		1	49	7	14	14	3	60	8	6	494		5	1			665	
-3,82				3	13	1	8		3	53	2	5	132	2	12				234	

Table 19

Leopoldsburg, BGD 118, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
504		1			2			12					3	30	52	2			102	
515		1						1				3	59	8	6		2		80	7
522				2				1					1	1	7				12	
528								9					2		3		17		31	6
545					6			3					11		36		3		59	
550													2	1	1				4	
562								1	1						7				9	5
575															1				1	
588				1		1				1			3		1				7	3
608	5	1				5		3		2					1				17	
620	2	2				3	2	3		3				1	10				26	
645	5					35	1	3							2				46	
655.42	1						40								2		1		44	2
671.19	3						2	27							27			1	60	
678		1						2							29		2		34	
691.80					3			1							35				39	
701.71		5													1				6	
743.85								16								1		2	19	1
752.72						1		12		1				2				2	18	

Table 20

Merksplas, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda					Echinodermata						Rest				Eco-strat.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.	Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pi.	Tot.	
700.1		1		2				18					6	7		11	2	42		89	
704.9								53	1					6		18	1	42		121	
714.4				1	8			16	2			3	3	38	2	48		4		125	6
719.26		1			3			14				3		46	4	41		1		115	
724.25				11	1			6	1		2	4	3	28	7	61		4		128	
728.8				28	2			10				3	2	19	33	60		3		160	
738.58		1		8		1		47		1	2	1		14	4	31	1	22		133	
743.36					2	1		53	11	19				31		63	1	8		188	
748.13				2		1		18	28	17		1	1	43		42		2		155	
752.97				1	1		1	14	14	12				50	4	61		4		163	
757.68						1		9	26	14		1	1	33	1	38				124	
762.23				2				3					1	1		5				12	5
766.79								1								9		1		11	
771.57				1												4				5	
776.36				1		2								1	1	1				6	
781.50				1	1	2		1		1	10			5	2	8				31	
785.94				1	1		1	1						1						5	
791.70								1								3		1		5	3
795.43																2				2	
800.19	1					1		45			2		1	3		3				56	
804.94	3	3				2	1	71							1	4				89	
809.70	14				1	4		59			3				1	2				84	
815.45	4							33					1	1		10				49	
820.2	3					4		37			3			3	2	2				54	
824.96	1	2				9		30					2	2	2	2		2		52	
829.50	4				8	15	3	99						5	1	5		2		142	
834.43	13	1			16	15		127			1	2		3		5		2		195	
839.23	4				25	29	6	100						25	1	7		7		204	
844.03	6	1			36	14	5	138				3		6	2	6		5		222	
848.69	4	1			15	2	2	35			4		1	9	3	18		2		96	
853.35	7	3			34	22	5	52			2		1	20	2	11		3		162	
857.06	4	1			24	9	6	65			5	3	1	21	4	12		5		160	
861.85	8				32	19	4	24			6	3	3	14	3	13		3		132	
866.62	7	1			10	4	8	5			12	12		7	4	14		1		76	2
871.38	11	2			37	45	4	21			6	8	2	16	5	6		1		154	
875.16	8	1			8	16	5	6			14	2	2	4	5	14				85	
880.95	9				12	22	1	9			9		2	4	3	19		1		91	
885.73	7	2			15	20	8	16			2		1	9	3	13		1		97	
890.51	17				9	36	55	9			7	1	1	11	4	16		3		169	
895.29	12	1			6	23	98	21			6	2	3	4	3	10				189	
900.06	14	1			15	63	62	23			14	5	5	15	20	63		2		302	
904.86	3				3	7	9	16			3			6	1	11				60	
909.66	3	3				5	15	9			2	3		10	5	2				52	
914.66	7	1			2	5	63	9			1	1	1	1	2	3		2		97	
919.25	13						56	2			1				1	2				75	
924.25	3	5			2	6	57	6							2	23				104	
928.79	2					2	85	6			1									96	
933.22	5					10	12	5							2	1		2		37	
938.31	1				2	6	17	8						13		15		6		68	
942.48	3	1			9	16	32	24			4	2	1	11	12	38		11		164	
947.89	1	4			5	4	4	36			5	1		10	6	12		2		90	
952.89	1	2			5	4	7	33			1	3	1	12	9	15		4		97	2
957.45	2	4			3	5	12	47			3			11	10	7		3		108	
962.45	7	7			2	7	7	7			11	2	7	25	10	46		4		142	
967.12	11	3			2	5	9	9			8		3	5	8	57		5		125	
976.66	6	7				8	1	10			1	1			2	3	2	1		43	
981.66	2	5				3	3	10			2			6		3				34	
986.26	28	7			1	4	3	2							2			1		48	
990.96	11	16				3	2	1							3					36	1
995.66	2	6				3		1								1				13	
999.80	3	3				2		1								1				10	
1005.2		1																		1	

Table 21

Nieuwerkerken, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda					Echinodermata						Rest				Eco-strat.
In m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.	Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
95					6			21					1	72		12		39		151	
96					7			18	1					121		13		39		199	
97					6			24				1		73		10		10		124	
98		2			7		1	27	3					82		9		11		142	
99					4			2					1	141	1	16		14		179	6
100					11			3			2		1	201		13		14		245	
102		6			10			4			3		2	237		35		5	1	293	
103					18			2			4			96		12		2		134	
104		2			19			4			3			127		14		1		170	
105		4			8			2			3			74		9	1	11		112	
106		4			26						2		2	176		11		16		237	
107		6			78		1	13			13		4	363		16	3			497	
108		6			53			1			2			39		21		2		124	
109		4			56						1			58		14		5		138	
110		6			29			1						66		15		8		125	
111		6			22			2						64		23	2	3		122	
112		1			3			12		1	7		1	86		26	3	1		140	
113					1			7		6				77		16		3		111	
114					3		2	5	3	1	1			72	2	17	1	12		119	5
115					4			5	1		8	1		97	1	7		11		137	
116					4		1	7			5			77	3	9		6		113	
117					15		2	12	1	7	4			77	1	12		7		139	
118					19	2	7	16	3			1		106	4	3	1	9		171	
119					12	1	5	7	2		1		1	102	1	5		5		132	
120					17		1	10	15					78	1	1		13		137	
121		1			2		2	5	7	10	1		1	93	2	7		1		133	
122					5		2	9	7	10		1		80	1	5	1	5		126	
123							1	5		36	2	1	1	53	4	12	2			117	
124					10		4	10	1	20	2	3		80	1	18		6		154	
125		1		1	11		1	13	1	1	13			100		19	1	8		170	
126		1		2	5	1		12		4	8	1	1	89		22		3		149	
127				3	4		3	4			58			36	1	11		1		122	
128				2	2			5		4	8			15		4		4		34	
129		3		2	18			24			20		2	33	8	15		11		136	
130				7	2		1	11			5		1	18	2	8		2		57	
131					1			1					1	1				1		5	
132				8	1	2	2	8		2	4			34	2	6	2	2		73	
133		1		1	13	3	2	16	4		24			44	1	13	4	7		133	
134				3	2	1	7	23			2		1	27	4		1			71	
135		2		1	12	2	6	16	2				1	53	1	8		12		117	3
136		1			8		7	41			1			66	4	10		12		151	
137		1		1	11	6	3	6	1		3			25	2	12		3		74	
138					2			9			4			12		6				33	
139					13	2	4	8			18			23		20	1	3		92	
140					1		2	5			8		1	7		8				32	
141					1						1			1		1				4	
142					8	2	6	16			17			11	1	9		1		71	
143						1		1			1			5						8	
144						2	2	2												6	
145								2												2	
146					1			1								1				3	
148														1						1	
151					1	6		6												13	
152																12				12	3
154																1				1	
156					1	3	1				1	1								7	
157								4						1						5	
159								1								1				2	
160								2						3				2		6	
161								1								3		1		5	

Table 22

Poederlee, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda					Echinodermata						Rest				Eco-stral.
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.	Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
535		8			16									26	1	6		47		105	
540		7		1				27	1		1			12	5	8		57		121	
545		12			4			49						23	1	35	1	45	1	171	
550		7			7			15				2	6	103	1	37		3		181	
555		5		2	2			9			1	6	6	54	5	71		5	1	167	6
563				7	13	1		30		3	4		5	35	15	52		2		167	
568		1		7	3		1	30		2	5	3	6	22	5	20		13		119	
572							1	56	5	24				15		6	1	12		120	
577				1	2		2	31	23	42		2	1	48	1	7	2	11		173	
582					1			22	20	32		1		37	1	5		4		123	
587					2	1		12	17	22				52	1	3		10		120	5
591		1			2		2	8	18	18			1	44		8	2	6		110	
596						1		11	7	15	10			50		18	3	8		123	
601				3		2	1	1	1	1	14			6		20		2		51	?
606				1			2	1	3	3	10			1	1	12		2		36	
611						2	2	2			8			2	1	11		2		30	3
616		1			1	17		6	2		2			6		9				44	
621	6			2		14	2	14	4	3	7		2	5	7	28		5		99	?
625	14	2				7		26	2		6				2	19		1		79	
631	5	3		1	3	2		5			3		5	6	2	11	1	4		51	
635	7					3		14			2	1		6	2	15		6		56	
640	4	1				14		9						1	1	13				43	
645	2	1			1	43		65	6						3	3	1	2		127	
650	5	2			6	19	2	84	5					9	2	2		6		142	
654	20	7			15	14	7	64	7		7	2		11	7	4	1	9		175	
658	18	2			20	10	2	128			1		1	4	2	9		3		200	
663	9	2		1	7	13	2	77				3		5	1	5		2		129	
668	24	6			10	14	2	42			6	5	3	4	4	4		5		129	
673	13	1			14	22	3	24			12	2	2	26	3	11		3		136	
678	2	4			5	30	2	30			5	2		10	3	1				94	
683	3	2			2	25		14	1		3			5	8	3				66	2
688	2	1			16	35	2	31	2		7	2	4	14	9	9		3		137	
692	8	6			5	25	5	17			2	1		16	2	10		1		90	
697	5	1			2	5	28	25					1	11	3	6				87	
701	6	2			4	14	25	16				1		13	6	9		1		97	
705	1	2				4	12	9			1	1	1	6		4		1		42	
710	7				3	14	20	12		1	3			7	6	4		3		90	
726	1	2			6	8	20	41	7		5	1	2	4	13	5		2		114	
731		4			4	8	18	9	16		5	1		13	18	12		2		110	
736	5	3			2	12	20	32	7		6	2	2	18	8	10		3		129	
741	5	1			3	7	16	16	2		10	6	3	11	7	30		9		126	
746	4	3			7	18	17	29			12	6	4	14	20	52		7	1	180	
751	4	2			6	7	6	12	5		21		5	10	12	42		4		137	
756	7	15			2	7	33	17			2	1			2	3		4		93	
759	3	10				11	8	7		1	1	2		7	3	5		6		64	
764	4	2			1	3	6	5						1						22	1
769	27	56			1	11		2						1	3	6		3		110	
774	29	83				5	1	1							3					122	

Table 23

Turnhout, BGD 120, Bioclasts 1.0 - 2.4 mm

	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda					Echinodermata						Rest				
in m	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.	Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	Eco-strat.
739.31					3			3						12	1	73		2		94	6
748.53								33	42	4				56	1	25		14		176	
768.77				5	1		6	25				5		19		118				179	5
775.01																4				4	
801.10								41								5		1		47	3
815.89	1				1			20						10	3	41				76	
635.00	2				4			52					1			1	1			62	
850.02					10		4	12								1		2		29	
864.00					9			80			1	1				1				92	
874.00	2				5			2			4		2	3	1	5				24	
883.16					3			5			1			1		6	1			17	2
892.87	3															2		1		6	
900.00							3													3	
922.00	3	1					259												1	264	
936.16		2						1								2				5	
949.00		1									1			2		3				8	
967.42	1	1						1						1	13	3				20	
974.00	3	8					1	6							2	21			2	42	
984.60								1										1	1	3	1

Table 24

Valkenburg, Bioclasts 1.0 - 2.4 mm

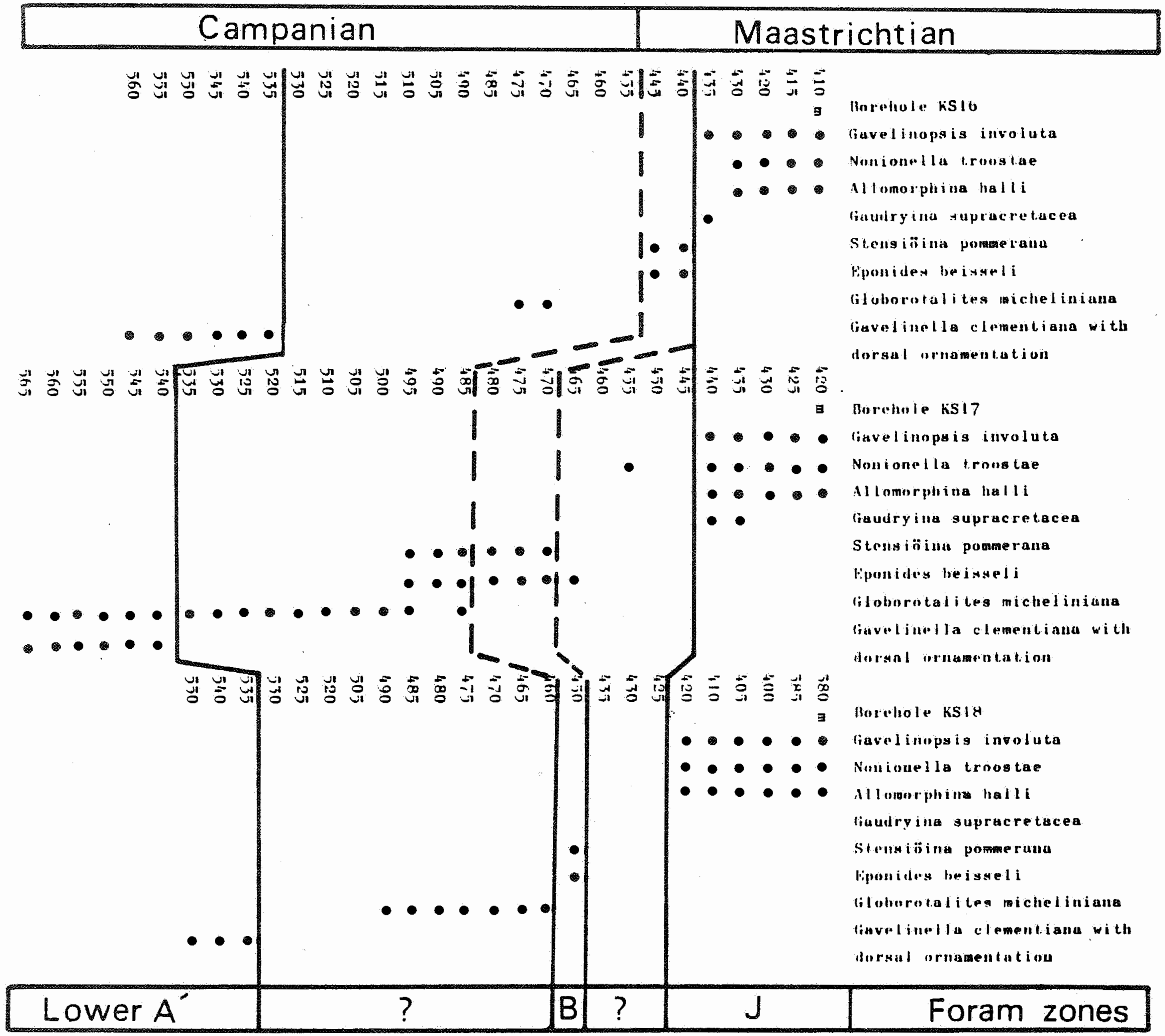
Sample	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
V 1					12		1				4	1	124		5	1	8		156	
V 2					7			4					192						203	
V 3					5		1	6			1		126						139	
V 4					7			8			1		152				1		169	
V 5					1			6					41				1		50	
V 6				1	4			8			1		97	1					131	5
V 7					4		1	1		1			143		2		1		153	
V 8					28			10		1	1		122	3	8		2		175	
V 9		1			15			10		1	1	1	102	1	3	2			137	
V 10				1	45			28		4	3		54	2	7		3		149	
V 11					38			15		5			84	6	10		4		162	
V 14					2			2		6			143	8	12				173	
V 15				1	3			4		7		1	136	2	16		4		180	3

Table 25

Walem (KB 408), Bioclasts 1.0 - 2.4 mm

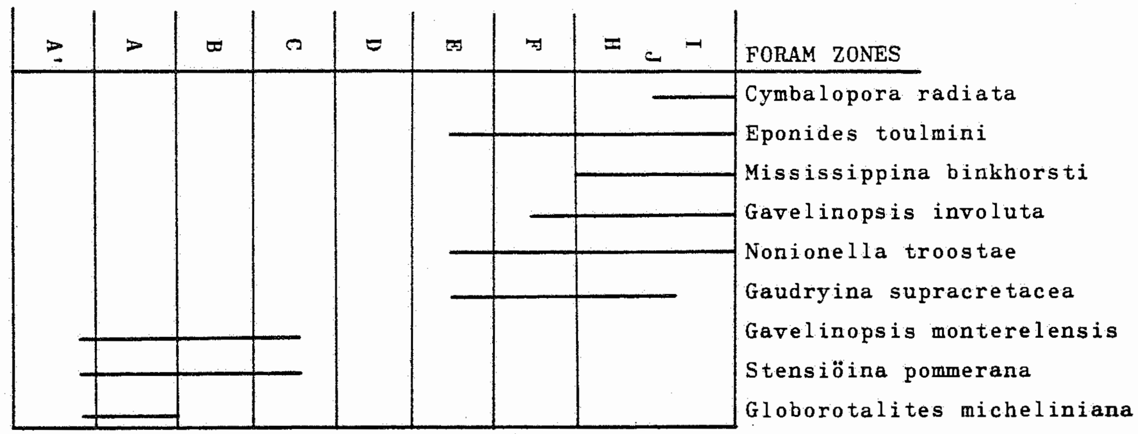
Sample/ in m	Forams.		Porifera-Bryozoa			Mollusca + Brachiopoda				Echinodermata						Rest				Eco-strat.
	Za.	Ka.	Po.	Oc.	Br.	Be.	Pr.	La.	Br.Th.	Cr.	Op.	As.	Ec.	St.	Re.	Ar.	Se.	Pl.	Tot.	
W 15				1	16		1	10		5	1		97	2	13				146	
W 14					4			4		8			134		16		2		168	
W 13								2	1	5			59		5				63	5
W 12					5			12	7	2			150	3	2		3		184	
W 11					5			4	6	7	1		130	3	9				165	
									KB 408											
17.00		7					2	14		11		1	9	2	24	2	2		74	3
28.00		2				2	3	38					1		4			1	51	
39.40		2					1	136					8	1	4		3		155	4
48.55		1					1	79					4	3					88	
61.85								8											8	
69.90		1						2					1						4	
71.40								5											5	
76.00								16											16	
79.05		3						11				2	4					3	23	
83.60		1						13											14	1
85.15								14											14	
103.45							1	3				1						1	6	
116.15							1	23					2						26	
117.70					1			13					1						15	

TABLE 26



Campanian
Maastrichtian
Borehole KS16
Gavelinopsis involuta
Nonionella troostae
Allomorphina halli
Gaudryina supracretacea
Stensiöina pommerana
Eponides beisseli
Globorotalites micheliniana
Gavelinella clementiana with dorsal ornamentation
Borehole KS17
Gavelinopsis involuta
Nonionella troostae
Allomorphina halli
Gaudryina supracretacea
Stensiöina pommerana
Eponides beisseli
Globorotalites micheliniana
Gavelinella clementiana with dorsal ornamentation
Borehole KS18
Gavelinopsis involuta
Nonionella troostae
Allomorphina halli
Gaudryina supracretacea
Stensiöina pommerana
Eponides beisseli
Globorotalites micheliniana
Gavelinella clementiana with dorsal ornamentation
Lower A´
?
B
?
J
Foram zones

TABLE 27


FORAM ZONES
A'
A
B
C
D
E
F
H
I
J
Cymbalopora radiata
Eponides toulmini
Mississippina binkhorsti
Gavelinopsis involuta
Nonionella troostae
Gaudryina supracretacea
Gavelinopsis monterelensis
Stensiöina pommerana
Globorotalites micheliniana

sample	number of pustules on last chamber 3	4	5	6	7	8	averages
791.70-795.43 m				1	11	2	7.1
815.45-824.96			10	4			5.3
839.23-844.03			8	2			5.2
861.85-866.62		2	11				4.8
875.16-880.90		5	10				4.7
914.66-919.25		9	3				4.3
928.79-933.22	5	15					3.8

Table 28 Bolivinoides - Merksplas

sample	number of pustules on last chamber 2	3	4	5	6	averages
673 m				7	1	5.1
692			9	8		4.5
701			12	3		4.2
710		6	12			3.7
751		9	6			3.4
769	6	7				2.5

Table 29 Bolivinoides - Poederlee

	Helbis	DZH1	DZH2	DZH3	DZH4	DZH5	DZH6	DZH11 Corr	DZH101 Corr
Base Clastic Tertiary	722	710	704	710	705	723	717	716	699
	22	22	12	24	13	26	25	23	24
Lava horizon equiv.	744	732	716	734	718	749	742	739	723
	56	55	56		54	55	55	56	53
Base Maastricht Fm	800	787	772		772	804	797	795	776
	16	15	10		10	15	15	16	17
Base Lanaye	816	802	782	805	782	819	812	811	793
	57	46	53		52	53	53	59	
Base (Lixhe)-Vijlen	873	848	835	855	834	872	865	870	?
	41	50	43		44	51	44	38	127
Base "Beutenaken"chalk	914	898	878		878	923	909	908	?
	30	30	26		26	28	31	31	?
Base "Beutenaken"Marl	944	928	904	932	904	951	940	939	920
	50	58	51		58	52	46	54	57
Base Zeven Wegen = Base Gulpen Fm	994	986	955	984	962	1003	986	993	977
	31	20	20		17	23	31	24	48
Base Vaals, upper part	1025	1006	975		979	1026	1017	1017	?
	27	32	20		25	28	31	28	?
Base Vaals Fm = Base Cretaceous	1052	1038	995	1038	1004	1054	1048	1045	1025
Total thickness Cretaceous	330	328	291	328	299	331	331	329	326

Table 30

	Meer	DZH 11	Merksplas	Turnhout	Poederlee
Base Clastic Tertiary	807	716	694	704	535
	27	23	29	30	26
Lava Horizon equiv.	834	739	723	734	561
	63	56	59	28	46
Base Maastricht Fm	897	795	782	762	607
	15	16	11	19	9
Base Lanaye	912	811	793	781	616
	60	59	47	77	33
Base (Lixhe)-Vijlen	972	870	840	858	649
	44	38	41	32	27
Base "Beutenaken" Chalk	1016	908	881	890	676
	42	31	36	42	23
Base "Beutenaken" Marl	1058	939	917	932	699
	58	54	49	40	49
Base Zeven Wegen	1116	993	966	972	748
= Base Gulpen Fm	30	24	19	14	14
Base Vaals, upper part	1146	1017	985	986	762
	40	28	20	16	11
Base Vaals Fm	1186	1045	1005	1002	773
= Base Cretaceous					
Total thickness Cretaceous	379	329	311	298	238

Table 31

	KS 13	KS 10	KB 174	KS 12	KS 9	KS 14	KS 5	KS 11	KS 1
Base Clastic Tertiary	455	482	492	445	367	357	328	305	250
	30	31	30	29	19	24	23	16	27
Base Houthem Fm	485	513	522	474	386	381	351	321	277
	48	48	47	46	48	51	56	50	48
Base Maastricht Fm	533	561	569	520	434	432	407	371	325
	39	38	35	40	47	46	51	46	41
Base Lanaye (Lixhe)-Vijlen	572	599	604	560	481	478	458	417	366
	23	12	19	24	13	12	7	13	15
Base "Beutenaken" Chalk	595	611	623	584	494	490	465	430	381
	14	20	21	10	11	10	11	12	15
Base "Beutenaken" Marl	609	631	644	594	505	500	476	442	396
	20	20	14	22	31	22	27	36	30
Base Zeven Wegen = Base Gulpen Fm	629	651	658	616	536	522	503	478	426
	23	22	29	27	28	32	25	19	17
Base Vaals, upper part	652	673	687	643	564	554	528	497	443
	54	30	27	31	37	35	32	31	31
Base Vaals Fm	706	703	714	674	601	589	560	528	474
	12	17	15	23	29	25	16	25	8
Base Aachen Fm = Base Cretaceous	718	720	729	697	630	614	576	553	482
Total thickness Cretaceous	263	238	237	252	263	257	248	248	232

Table 32

	168	146	172	KS 25	KS 19	KS 17	KS 18	KS 22	161	168	KS 6	KS 3	KS 21	KS 2
Base Clastic Tertiary	470	462	420	402	364	348	326	328	374	391	356	341	256	400
	37	39	39	39	29	28	26	34	41	38	34	28	36	27
Base Houthem Fm	507	501	459	441	393	376	352	362	415	429	390	369	292	427
	51	49	77	77	79	81	80	88	74	59	72	75	84	35
Base Maastricht Fm	558	550	536	518	472	457	432	450	489	488	462	444	376	462
	60	58	36	32	33	33	29	20	29	53	29	38	30	
Base "Beutenaken"	618	608	572	550	505	490	461	470	518	541	491	482	406	-
	30	34	31	26	27	24	29	29	28	27	27	29	30	
Base Pre-Valkenburg = Base Gulpen Fm	648	642	603	576	532	514	490	499	546	568	518	511	436	
	70	30	31	27	26	38	27	31	25	33	29	25	21	
Base Vaals, upper part	?	672	634	603	558	552	517	530	571	601	547	536	457	
		49	37	33	33	18	32	35	47	42	37	50		
Base Vaals Fm	718	721	671	636	591	570	549	565	618	643	584	586	-	
	21	9	10	10	16	7	7	12		10	6	13		
Base Aachen Fm = Base Cretaceous	739	730	681	646	607	577	556	577	-	653	590	599		
Total thickness Cretaceous	269	268	261	244	243	229	230	249	244	262	234	258	201	62

Table 33