THE WESTPHALIAN OF THE NETHERLANDS WITH SPECIAL REFERENCE TO MIOSPORE ASSEMBLAGES

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SUMMARY

The Westphalian in The Netherlands can be subdivided into six biostratigraphical miospore zones. Each zone is distinguished by an assemblage of several characteristic species, which individually are not restricted to a particular zone with the exception of *Radiizonates aligerens*. Top and base of each zone are characterized by the first or last (regular) occurrence of a particular diagnostic species.

In the Upper Westphalian A and Lower Westphalian C a distinct correlation exists between the microfloral and major lithological changes, which suggests that the Westphalian floras have been at least partly influenced by paleoecological factors.

1. INTRODUCTION

The Westphalian of The Netherlands, outside the mining district, has received special attention since the discovery of the Groningen gas field. The gas is thought to be derived from deeply buried Westphalian coal deposits (Patijn 1963). The discovery triggered extensive exploration activity both on- and offshore The Netherlands. Many wells have penetrated the Westphalian but in most cases not very deeply. A few wells with a longer Westphalian section (fig. 6) provide an important part of the information for this paper. The Westphalian stratigraphy of most exploration boreholes is at present based on palynology. The preference for palynology above macrofloral and -faunal age determinations is due to the economy of the method rather than any distinction in the quality of results. Palynological age determinations can be based on drill cuttings and, thus, time consuming coring operations can be avoided. The presented microfloral zonation for the Westphalian is developed on the basis of the macropaleontological stratigraphy. Macropaleontology is still occasionally used for comparison of results, and, as a check on the palynological method, if required. The application of palynology is not restricted to the Dutch part of northwestern Europe. Extensive monographs and numerous smaller papers have appeared which deal with the miospore assemblages from Great Britain (e.g. Smith & Butterworth 1967), the North of France (e.g. Loboziak 1969), the Campine (e.g. Somers 1971) and the Ruhr area (e.g. Grebe 1972).

The main purpose of the present report is to provide information on Westphalian miospores from The Netherlands in order to supplement the cover of northwestern Europe. In addition, the relation between the biostratigraphical miospore zonation and the lithostratigraphy has been studied. Both coal seams and clastic material have been investigated for their miospore content in order to reduce paleofacies influences.

Coalification is one of the most significant aspects of Carboniferous rocks, not only because it directly influences the state of preservation and the degree of translucency of the spores, but rather because it relates to the generation of natural gas. For the palynological preparation methods used we may refer to Bless & Meessen 1973.

2. WESTPHALIAN MIOSPORE ASSEMBLAGES

Some fifty miospore species, which might be useful for a biostratigraphical subdivision of the Westphalian in The Netherlands, have been selected. They are presented in photographs and briefly described in the chapter on systematics, with remarks on their occurrences. A more restricted number of species seems to occur regularly enough to be used for biostratigraphical purposes. These species and their ranges are indicated on figures 1 and 2.

Species belonging to genera such as *Calamospora, Leiotriletes, Granulatisporites, Verrucosisporites, Punctatisporites* and *Lycospora* have either been grouped or disregarded altogether in this study, as it was felt that they would hardly contribute to the knowledge of miospore assemblages. Species of these genera either occur too frequently or they are difficult to distinguish individually; alternatively, some may occur in extremely small quantities throughout the investigated sediments. Finally, we have deliberately disregarded some species as *Reinschospora triangularis* which may have a rather restricted range, but do not occur frequently enough to be considered of value.

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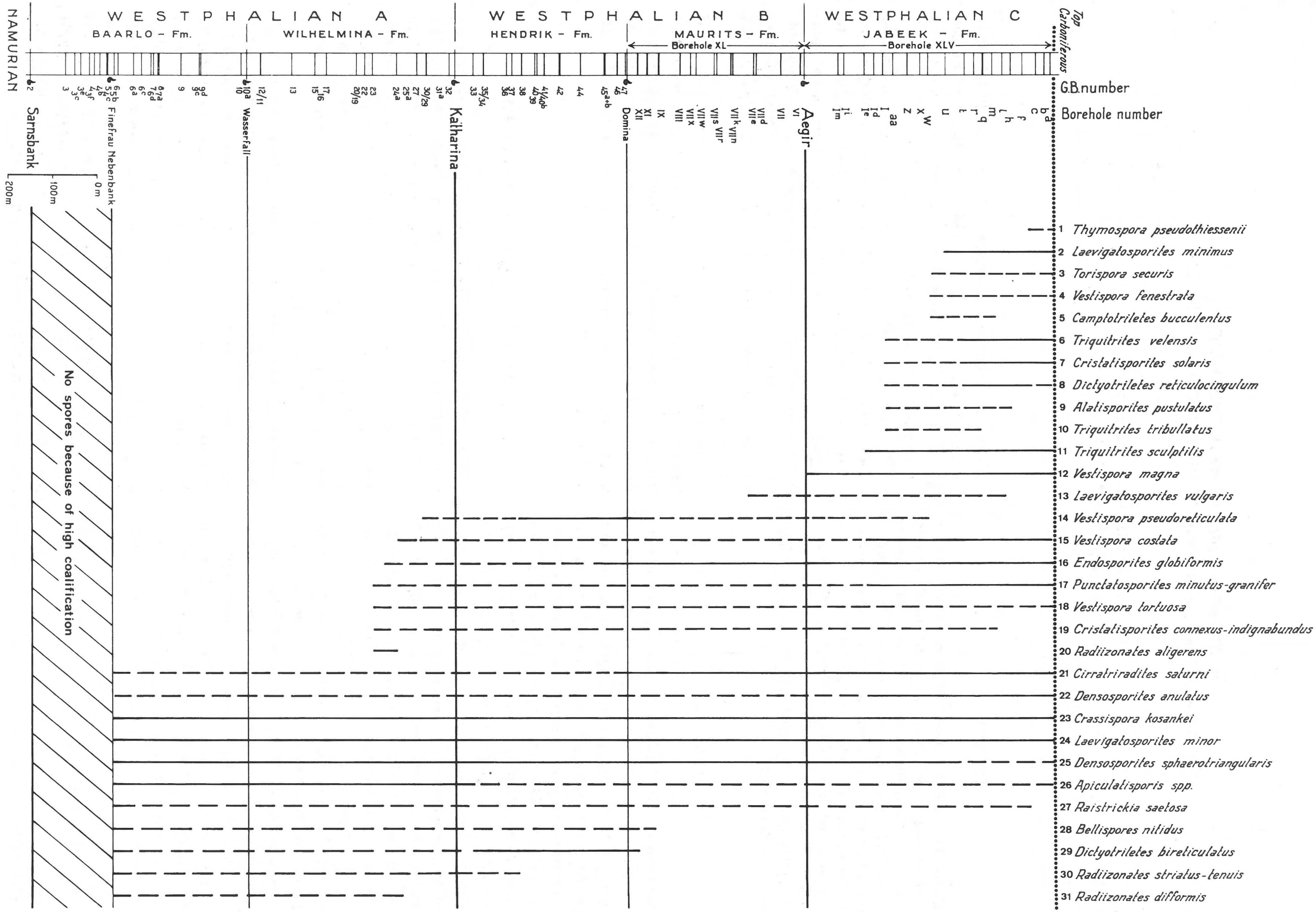


Fig. 1
Observed ranges of some selected miospore species in the Westphalian A-C of the mining district of Limburg.

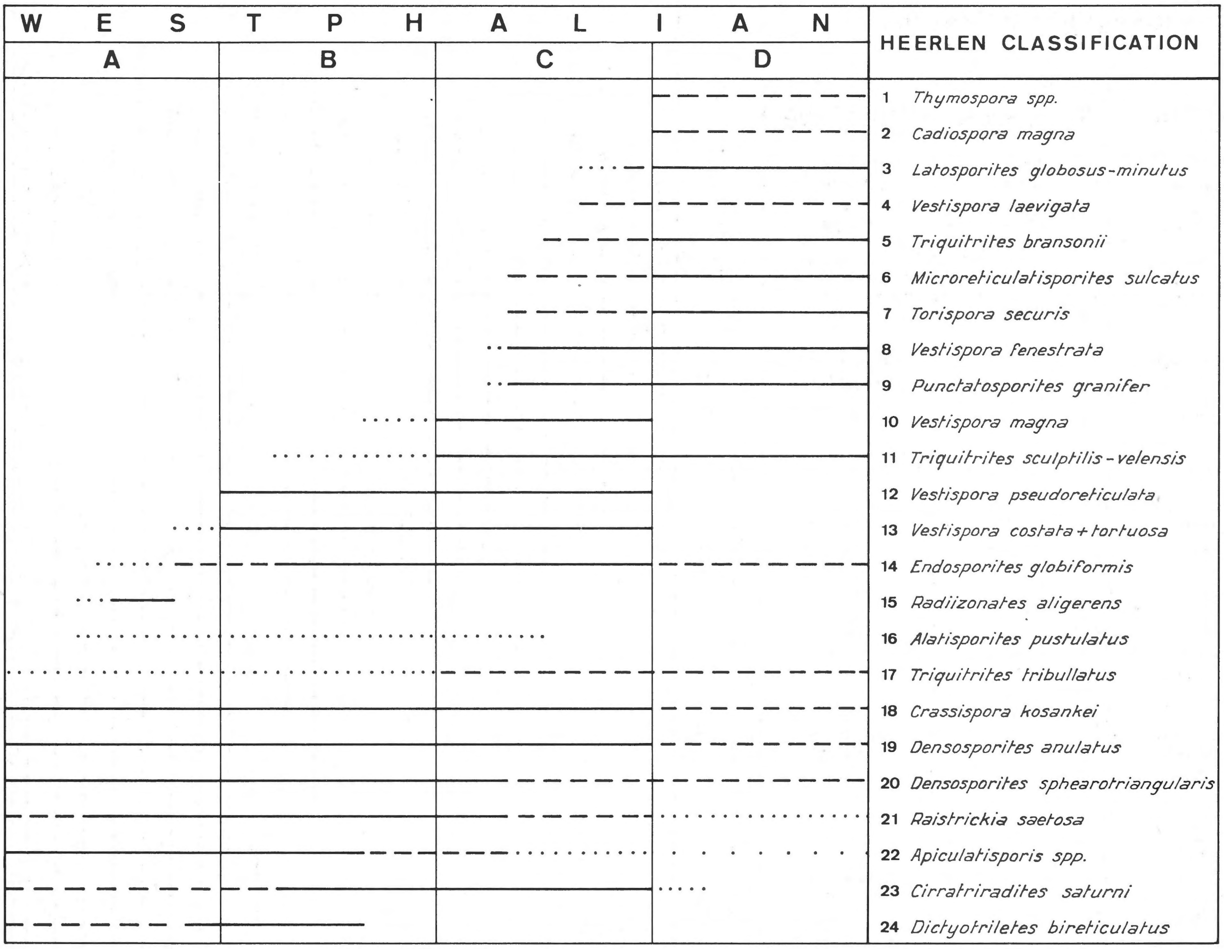


Fig. 2
Observed ranges of some selected miospore species in the Westphalian A-D of exploration boreholes in The Netherlands outside the mining district of Limburg. The subdivision of the Westphalian is based on macropaleontological evidence.

The following six miospore assemblages have been defined by reference to the main characteristics of their contents, and lower and upper limits. One should bear in mind, that in practice these are rather flexible limits, since several of them are based on the subjective observation of first and last "regular" occurrence. Nonetheless, our experience is that these miospore assemblages form a workable concept for biostratigraphical zonation in the Netherlands Westphalian.

We have treated separately the data from the mining district of Limburg (fig. 1) and those from exploration boreholes outside Limburg (fig. 2). The Limburg data are thoroughly checked by classic methods (marine bands, non-marine lamellibranchs, macroflora). The second group of data is only partly based on this classic framework due to its dependence on core sample material. Both figures show a good correlation, however, so that we may assume that we can rely on the method itself.

Figure 3 shows a composite range chart with the proposed zonation for The Netherlands compared to those for Great Britain and the Ruhr area. In figure 4 the subcrop of the Carboniferous below the Permian and Mesozoic formations is given. The Westphalian stages are mainly inferred from the miospore assemblages.

2.1. *Apiculatisporis* assemblage (Zone I)

Base: above last occurrence of *Schulzospora campyloptera* and *Densosporites spinifer.*
Top: below first occurrence of *Radiizonates aligerens.*
Age: Lower Westphalian A and base of Upper Westphalian A.

Main characteristics: Frequent occurrence of species of *Apiculatisporis, Densosporites anulatus, Densosporites sphaerotriangularis* and *Savitrisporites nux.* Rare occurrence of *Dictyotriletes bireticulatus, Florinites* spp. and *Cirratriradites saturni. R. difformis* is already present, but is rare to infrequent.

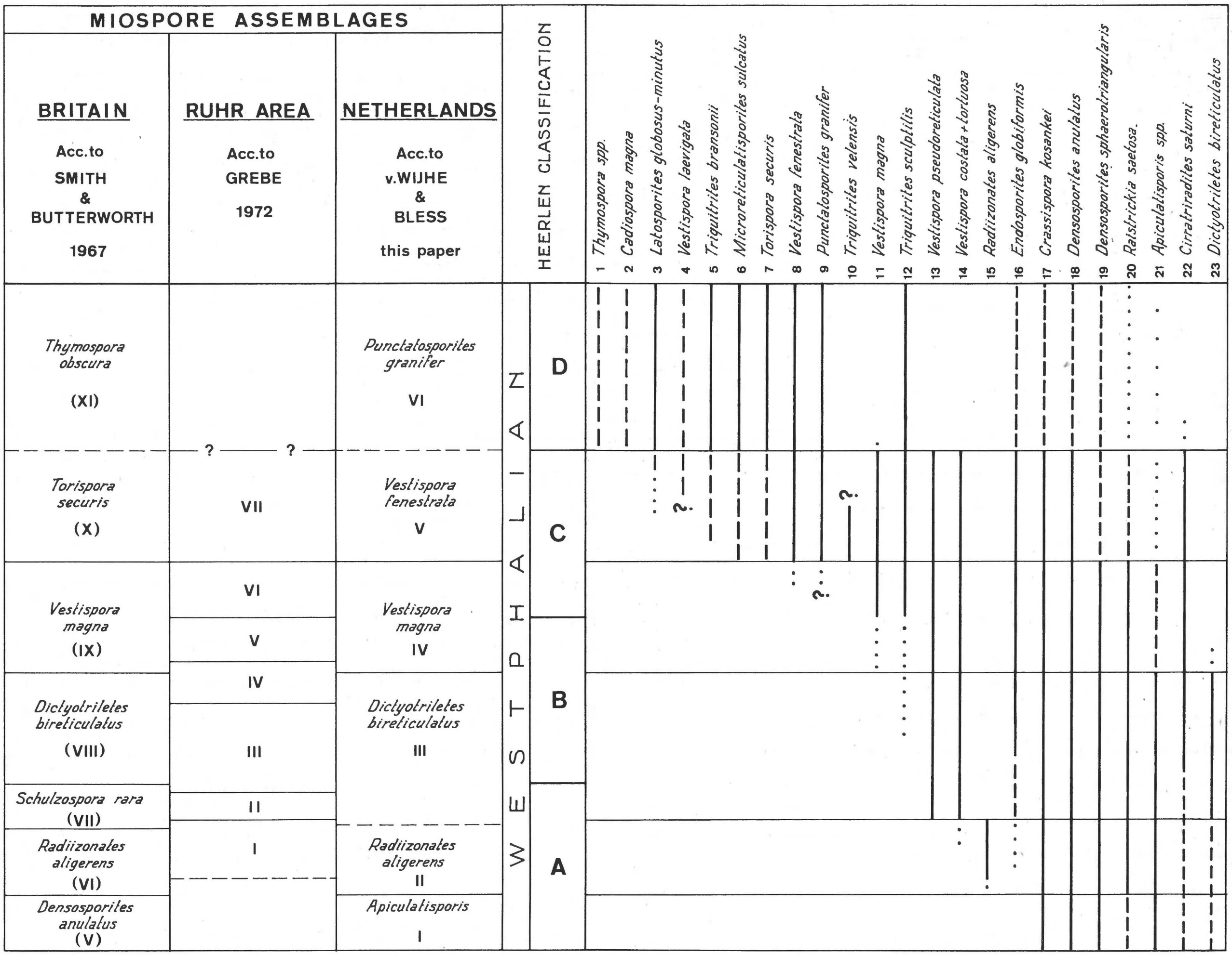


Fig. 3
Composite range chart of some selected miospore species in the Westphalian of The Netherlands, with proposed zonation into six miospore assemblages, which are compared to miospore zones in the Ruhr area and Great Britain.

Remarks: The recognition of this zone is often hampered by the poor preservation of the spores. This may be due in part to the high degree of coalification. Outside the mining district the *Apiculatisporis* assemblage has been only found in a few boreholes, of which the most important are Rijsbergen-1 (RSB1) and Tjuchem-2 (TJM2).

2.2. *Radiizonates aligerens* assemblage (Zone II)

Base: first occurrence of *Radiizonates aligerens.*
Top: last occurrence of *Radiizonates aligerens.*
Age: middle and upper part of Upper Westphalian A, except topmost beds of Westphalian A.

Main characteristics: *Radiizonates aligerens* occurs in low frequencies in the lower part of this zone and in moderate to occasionally high frequencies in the upper part. The species does not occur in all coal seams according to the analysis of the Limburg area. *Densosporites sphaerotriangularis, Raistrickia* spp. (especially *R. saetosa*), *Apiculatisporis* spp. *Florinites* spp. and *Laevigatosporites minor* occur regularly and are sometimes abundant. In the higher part of the zone the first occurrences of *Vestispora costata, V. tortuosa* and *Endosporites globiformis* have been recorded. *Ahrensisporites guerickei* and *Converrucosisporites armatus* are rare. *Schulzospora rara* is an extremely rare element in some boreholes, which cannot be used as it is seldomly found.

Remarks: This zone has been recognized in many off- and onshore boreholes of The Netherlands. Preservation of the spores in this zone is generally good. Laveine (1961) described erroneously one of the best and richest assemblages from the Zeddam-1 (ZED1) borehole as belonging to Westphalian B (table III).

2.3. *Dictyotriletes bireticulatus* assemblage (Zone III)

Base: first occurrence of *Vestispora pseudoreticulata.*

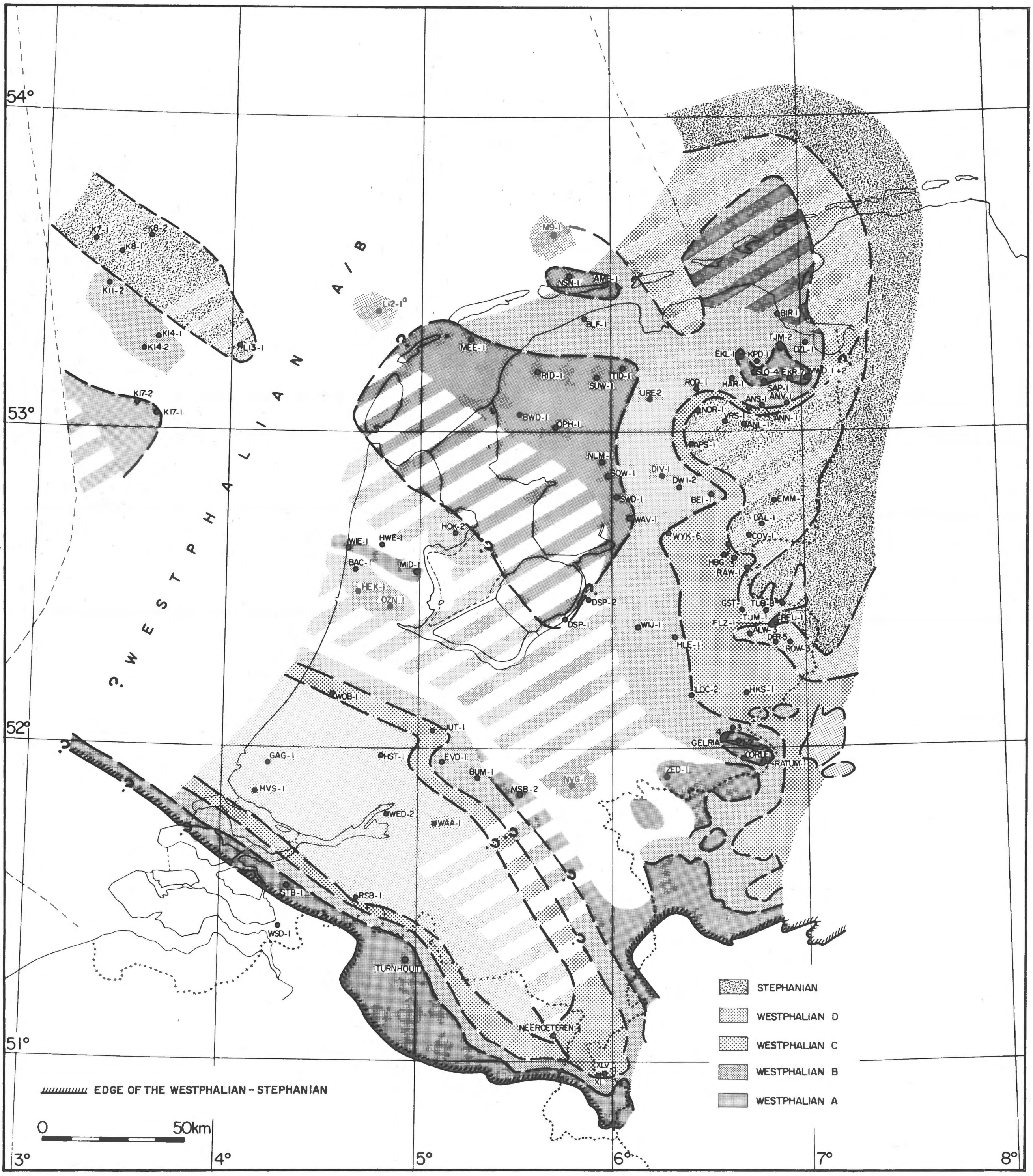


Fig. 4
The Carboniferous subcrop below Permian and Mesozoic formations.

Top: sudden quantitative decrease of *Dictyotriletes bireticulatus.*
Age: top of Westphalian A to base of Upper Westphalian B.

Main characteristics: Frequent occurrence of moderate quantities of *Dictyotriletes bireticulatus* and *Cristatisporites connexus-indignabundus.* Frequent occurrence of *Vestispora* *costata-tortuosa* and *V. pseudoreticulata* (especially in Limburg). *Endosporites globiformis* becomes common, especially in the higher parts of the zone.

Remarks: For a good understanding of the relative frequency of *D. bireticulatus* in this zone it is probably significant to note that usually no more than five to ten specimens of the species are found per slide. It is remarkable, however, that this low occurrence – much less than one percent – is recognized in practically all samples within the zone. Below and above this zone the species is extremely rare (one to two specimens per sample) and rather infrequent.

There may sometimes be a gap of some tens of metres between the top occurrence of *R. aligerens* and the base regular occurrence of *D. bireticulatus.*

2.4. *Vestispora magna* assemblage (Zone IV)

Base: above sudden quantitative decrease of *Dictyotriletes bireticulatus.*
Top: below first occurrence of *Vestispora fenestrata.*
Age: Upper Westphalian B and Lower Westphalian C.

Main characteristics: *Vestispora magna* may be extremely rare or even absent in the lower part of this zone. From the base of the Westphalian C upwards, *V. magna* becomes common to sometimes abundant. *Endosporites globiformis* and *Vestispora costata* are common. *Laevigatosporites vulgaris* is practically restricted to this zone, at least in Limburg. Transitional forms between *Punctatosporites minutus* and *P. granifer* are rare in the middle and upper parts of the zone. In the top of the zone *Vestispora fenestrata* may isolatedly occur, *Triquitrites sculptilis* becomes common.

2.5. *Vestispora fenestrata* assemblage (Zone V)

Base: first occurrence of *Vestispora fenestrata.*
Top: above last regular occurrence of *Cirratriradites saturni.*
Age: Upper Westphalian C.

Main characteristics: Regular occurrence in low frequencies of *Torispora securis* and *Vestispora fenestrata. Punctatosporites granifer* becomes common. *Cristatisporites solaris* replaces *C. connexus-indignabundus* and *Densosporites anulatus* predominates over *D. sphaerotriangularis. Microreticulatisporites sulcatus* and *M. nobilis, Cirratriradites saturni* and several species of *Vestispora (V. costata-tortuosa, V. magna, V. reticulata), Triquitrites (T. sculptilis, T. bransonii, T. tribullatus, T. velensis), Savitrisporites concavus* and *Laevigatosporites minimus* are regular elements in the flora. Isolated specimens of *Vestispora laevigata* and *Latosporites globosus* may occur.

2.6. *Punctatosporites granifer* assemblage (Zone VI)

Base: above last regular occurrence of *Cirratriradites saturni.*
Top: not defined (see remarks).
Age: Westphalian D (may be also including topmost Westphalian C).

Main characteristics: Monolete spores predominate, in particular *Punctatosporites granifer, Torispora securis, Latosporites globosus, L. minutus, Laevigatosporites minor* and *L. minimus.* Another monolete, *Thymospora* spp., and the trilete *Cadiospora magna* are rare to infrequent. *Crassispora kosankei, Endosporites globiformis, Densosporites anulatus* and *Triquitrites* spp. are less frequent than in the underlying zone. Apart from *Vestispora laevigata* and *V. fenestrata,* all other species of *Vestispora* show a remarkable decrease in this zone and are usually absent.

Remarks: The upper part of this zone is usually developed as a red bed sequence with practically no characteristic spores. We are unable to determine whether this zone comprises the complete Westphalian D since we have not recognized a clear contact with beds of Stephanian age. Moreover, since a Cantabrian stage has been introduced between Westphalian D and Stephanian A by the IUGS Subcommission on Carboniferous Stratigraphy, we suspect that the transition in microfloras between Westphalian D and Stephanian A is rather gradual, comparable to that described by Chateauneuf (1973) from northern Spain.

3. LITHOSTRATIGRAPHY

3.1. *South Limburg*

Over 3000 m of Westphalian sediments have been studied in detail in the Dutch coal mining district. The identification of rocks has been established here macroscopically. It appears that the distribution of sand and coal in the predominantly shale-siltstone sequence is both vertically and laterally far from uniform. Table I gives the sand and coal percentages of the Westphalian stages.

A systematic description of the lithological sequence allowed the recognition of three main cyclic developments in the Westphalian of Limburg (fig. 5):

I. Cycles with an open marine phase immediately overlying the coal and widespread sheet sands practically without erosional channels. This type predominated during the Lower Westphalian A and lower part of the Upper Westphalian A.

II. Cycles with a shallow marine to brackish or freshwater phase above the coal and isolated channel sands. The channels may have eroded one or more coal seams. Marine incursions are rare and reflected only by *Lingula* bands (Katharina, Domina). This type characterized the upper part of the Upper Westphalian A and Westphalian B. It represents a period of major regression relative to the first one.

III. Cycles with a non-marine phase immediately above the coal and widespread sheet sands alternating with channel sands. Brackish fossils are extremely rare and constitute a minor element. This type occurs in the Westphalian C in Limburg and most probably reflects tectonic uplift of a

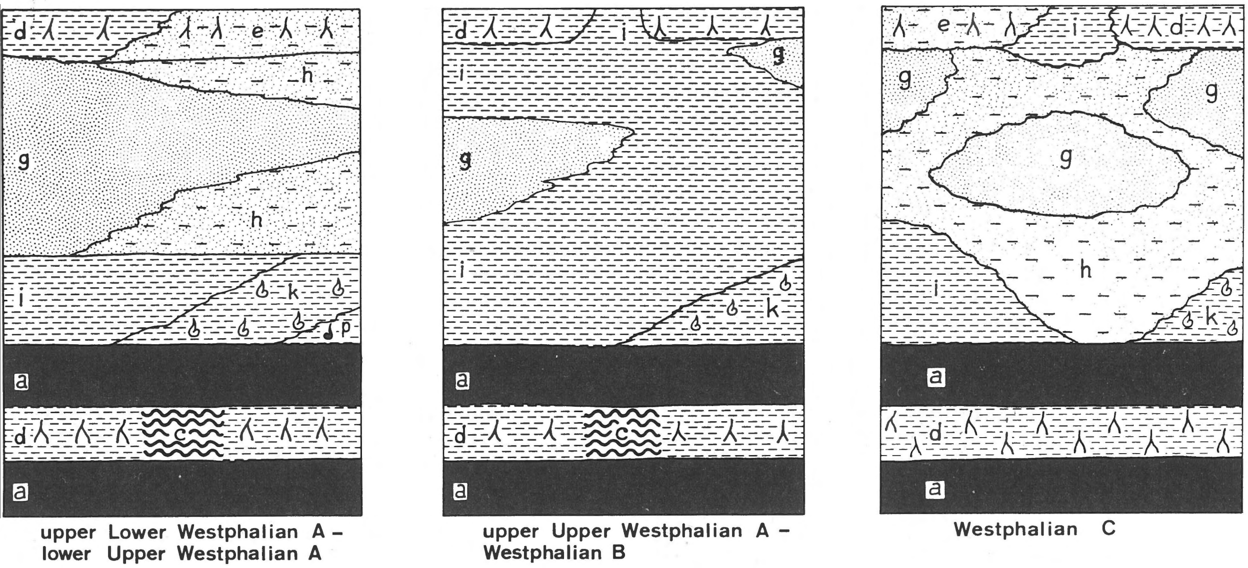


Fig. 5
Schematized cyclothems in Westphalian A-C of Limburg with simplified lithological classification adopted by Bless (1973); lithologies b, f, l, m and o are extremely rare and can be neglected in practice. Key to symbols: a = coal, b = pseudocannel coal, c = shale with coalstreaks, d = shales and siltstones with rootlets (including underclay), e = slightly sandy sediments with rootlets, f = sandy sediments with rootlets, g = sandy sediments, h = slightly sandy sediments (including striped beds), i = shales and siltstones, k = shales and siltstones with non-marine fauna, l = slightly sandy sediments with non-marine fauna, m = sandy sediments with non-marine fauna, o = conglomerate, p = shales and siltstones with marine fauna.

nearby area. This period is characterized by continuously diminishing marine influence.

Table I shows that coal seams make up only slightly more than one percent of the total thickness associated with the first period. We believe that they represent former coastal marshes with a relatively short lifetime due to frequent marine incursions and less favourable conditions of the substratum (salt groundwater?).

During the second period vast back swamps may have developed similar to those of the present Mississippi Delta. Table I shows that plant material had about three to four times more chance to accumulate in this environment than in the first period. The greater mean thickness of the coals suggests that these swamps persisted during a longer period than was the case in the first period.

The third period is marked again by a distinct drop of the coal percentage indicating that the mean distance to the shoreline – which still increased – did no longer favour the development of vast swamps. It is suggested here that the possibly dryer substratum, changing climate and relatively higher sedimentation rate on the fluvial plains indicate a transition into what may be termed a "hinterland" facies.

The basal Westphalian D, which occurs in two boreholes some kilometres from the Dutch frontier in the Campine (Pierart 1958, Bless, Calver & Josten 1972) marks here the beginning of the fourth period, characterized by the massive Neeroeteren Sandstones of thicknesses up to 50 m. These are intercalated with a few shaly sequences and isolated coal seams. We suppose that they also reflect the uplift of a nearby area which delivered the clastic material. Swamp vegetation became quite restricted because of further progression of unfavourable conditions.

TABLE I
Occurrence of coal and sandstone in the Westphalian A-C of Limburg and in the basal Westphalian D of the Campine. The given percentages have been computed from a number of selected sections. Overall percentages for the complete mining area may slightly differ from these.

	% sandstone	% coal	mean coal thickness in cm
Basal Westphalian D (Neeroeteren Sandstones)	75.00	1.69	not computed
Westphalian C (Jabeek Fm.)	16.00	1.56	11
Upper Westphalian B (Maurits Fm.)	7.92	4.30	24
Lower Westphalian B (Hendrik Fm.)	7.64	3.60	26
Upper Westphalian A (Wilhelmina Fm.)	14.26	4.51	21
Lower Westphalian A (Baarlo Fm.)	14.91	1.11	19

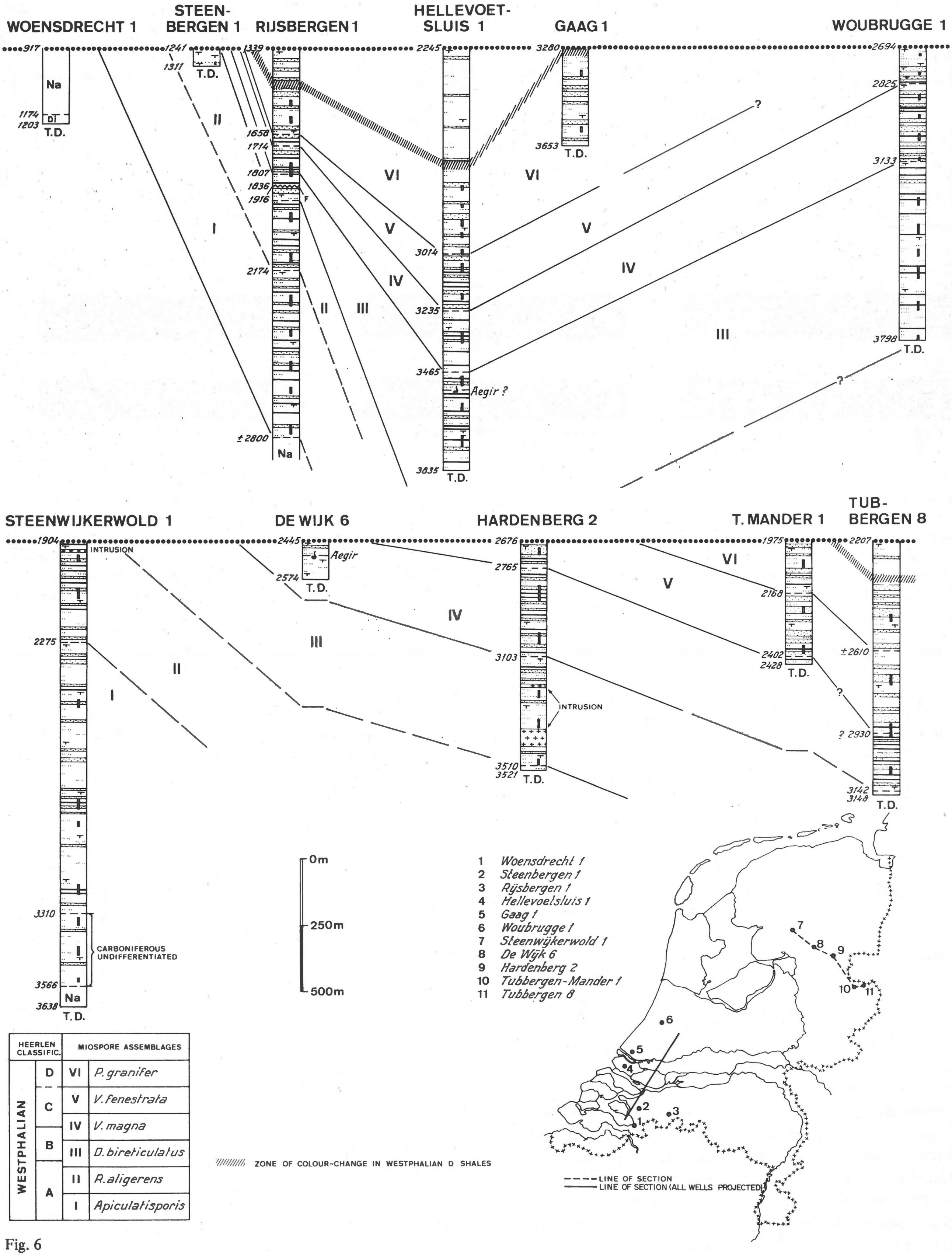


Fig. 6

Sections through the Westphalian in southwestern and eastern parts of The Netherlands showing biostratigraphical miospore zonation and lithology. Depths are given in metres subsea along borehole; top Carboniferous is indicated by dotted line. Key to symbols: Di = Dinantian, Na = Namurian.

TABLE II

Estimated coal and sandstone percentages in the Westphalian of some exploration boreholes in The Netherlands.

HEERLEN CLASSIFICATION		MIOSPORE ASSEMBLAGES		RIJSBERGEN 1		HELLEVOETSLUIS 1		WOUBRUGGE 1		EMMEN 7		TUBBERGEN 8		HARDENBERG 2		STEENWIJKERWOLD 1		TJUCHEM 2		HAARLE 1		ZEDDAM 1	
				COAL %	SAND %	COAL %	SAND %	COAL %	SAND %	COAL %	SAND %	COAL %	SAND %	COAL %	SAND %	COAL %	SAND %	COAL %	SAND %	COAL %	SAND %	COAL %	SAND %
WESTPHALIAN	D	VI P. granifer	RED	~.0	~20	~.0	~7.5			~.0	~17	~.0	~7										
	D	VI P. granifer	GREY	0.5	15	0.5	13			.0 B	44 B	<.5	49										
	C	V V. fenestrata		3.3 *	20 *	3.5	20	~	~			1.5	44	~2.0	~39								
	C/B	IV V. magna		4.0 *	17 *	4.0	8	3.5	32			3.5	30	3.5	14								
	B	III D. bireticulatus		F	F	4.0 B	5 B	3.5 ?B	9 ?B			+	+	1.5	8					~3.0 B	~11 B		
	A	II R. aligerens		2.5	9									+	+	~1.5	~10	~	~			~1.0	~18
	A	I Apiculatisporis		0.7	6											0.5	13	2.0	15			1.0 B	20 B

~: TRUNCATED B: BASE NOT REACHED *: INTERVAL VERY MUCH REDUCED F: INTERVAL REDUCED BY FAULTING

+: ONLY TOP OF ASSEMBLAGE PENETRATED

3.2. *Exploration Boreholes*

For the identification of the lithologies in boreholes outside Limburg use is made of electric, acoustic and radiation logs. This method does not of course permit the detailed lithological inspection that is possible in the mining district. It appears, however, that the major types of cyclic development, which are recognized in Limburg, are in a broad sense also recognizable in the boreholes. Estimated coal and sand percentages and the recognition of marine bands in cores, cuttings and logs seem to be sufficient for a general comparison.

Unfortunately the lithological development of the Westphalian outside the mining area is based on rather scattered information. Most boreholes which have reached the Upper Carboniferous have penetrated it less than a hundred metres. The few boreholes of considerably deeper penetration are located mainly in the northeastern, eastern and southwestern parts of the country where a maximum of Westphalian sediments has been preserved (fig. 6). In selecting representative sections, we have tried to avoid duplication of earlier information by T h i a d e n s (1963).

In the following paragraph, the Westphalian lithological development of the boreholes is summarized.

The basal part of the *Apiculatisporis* assemblage in the NE in Tjuchem-2 (TJM2) and Steenwijkerwold-1 (SWD1) (fig. 6) is developed as a sandy sequence which is the continuation of a similar sequence in the Upper Namurian. The middle part of the zone is predominantly shale while towards the top sand percentages increase again. The estimated overall coal percentages vary considerably viz.: from 2% in Tjuchem-2 to only 0.5% in Steenwijkerwold-1 (table II). The shales in Steenwijkerwold-1 are on the whole much sandier than in Tjuchem-2. The sand percentages are about 14% in both boreholes.

Dwingelo-2 (DWI2) shows a development which is comparable to Steenwijkerwold-1. The sand and coal percentages for the upper part of the *Apiculatisporis* assemblage in Zeddam-1 (ZED1) may not be representative since the lower part of this assemblage has not been penetrated in this borehole (table II).

In the SW, in Rijsbergen-1 (RSB1), the *Apiculatisporis* assemblage contains only 6% sandstones and approximately 0.5% coal. The sandstones are thin and the shales generally rather sandy. A stronger sand development is found here in the Upper Namurian, which is comparable to the adjacent Belgian Turnhout borehole. The lithology in the *R. aligerens* assemblage is similar to that of the upper part of the *Apiculatisporis* assemblage. The sand percentages remain the same or decrease slightly, whereas the number of coal layers increases. This development continues into the overlying *D. bireticulatus* assemblage. Local deviations from this general tendency may occur as for instance in the Hardenberg-2 borehole, where only 1.5% coal has been found. In the southwestern Netherlands, a rather sudden influx of sands occurs in the *V. magna* assemblage of Woubrugge-1 (WOB1). The same event is observed in the nearby Jutphaas-1 borehole (JUT1) at the equivalent stratigraphical level. In the SW in Hellevoetsluis-1 (HVS1) and near the Brabant Massif in Rijsbergen-1, the sand percentages increase also, but here no massive sandstones occur.

The base of the sequence of massive sandstones in the eastern Netherlands and adjoining German area appears to shift in time. In the German Ibbenbüren UB150 borehole (Osnabrück area, Federal Republic of Germany), the base of these sands was not reached at total depth in the lower part of the *V. magna* assemblage. In Tubbergen-8 (TUB8) it is found in the *V. magna* assemblage. In Hardenberg-2, the base of the sandy sequence coincides approximately with the base of the *V. fenestrata* assemblage. Table II shows also a strong decrease of the coal percentage from the *V. magna* to the *V. fenestrata* assemblage. In the eastern and southwestern Netherlands, the top of the sandy facies lies in the basal part of the *Punctatosporites granifer* assemblage. The colour of the shales in this basal part is predominantly grey. The sand percentages decrease gradually towards the top of the assemblage in Hellevoetsluis-1 and Emmen-7 (EMM7), which both penetrated over 700 m of sediments with this assemblage. The upper part of the assemblage is characterized by predominantly redbrown shales. The boundary between the grey and red zone is rather well marked (fig. 6).

3.3. *Discussion*

The overall lithological picture from the described boreholes (fig. 6, table II) appears comparable to that of the mining district of Limburg.

The diminishing marine influence from the Westphalian A onwards is difficult to establish directly, but the general tendency towards increasingly favourable conditions for the formation of peat deposits, starting in Upper Westphalian A and reaching its maximum in Westphalian B, has also been traced in the boreholes. The same holds for the minimum sand percentage in the *D. bireticulatus* assemblage (Westphalian B) as compared with that of the under- and overlying assemblages.

The strong increase in sand supply, which starts in boreholes in The Netherlands in Westphalian C, can be correlated with an event of the same type in Limburg. Even the contact of sandy sediments with overlying coal, which has been found in the Westphalian C of Limburg (fig. 5) has been observed on logs from boreholes.

Conditions for swamp development became less and less favourable during the Upper Westphalian C and this tendency continued into the Westphalian D. The change in climate in the Westphalian D (Hedemann & Teichmüller 1971) is reflected in increasingly unfavourable conditions for sporomorph preservation. In addition we may assume that during this stage the abundance of plant life which marked the Westphalian comes to an end.

In a few boreholes, the Stephanian (dated on macroflora) overlies the Westphalian D. Unlike the German boreholes, there is no evidence in The Netherlands that the Stephanian unconformably overlies sediments older than Westphalian D (Fabian 1971).

3.4. *Source of Sediments*

The supply of clastic material which in Germany has had a dominant NE-SW direction (Hedemann & Teichmüller 1971) may have had other directions notably in the Upper Westphalian.

Schröder (1971), in a study on the sedimentation of the Upper Carboniferous in northwestern Germany, favours a main sediment supply from the south(east). He found that the Upper Westphalian sandstone sequence becomes thinner from the Osnabrück area towards the north, while marine influences increase in the same direction.

The occurrence of additional supply is probably connected to the upheaval and folding of the southern Ruhr area. Hoyer & Pilger (1971) suggest in this connection that less Carboniferous overburden here can be inferred from the decrease in coalification from NW to SE in the Westphalian C (fig. 7). In The Netherlands a thickness reduction in younger Westphalian has been observed in the direction of the Brabant Massif (fig. 6). From Hellevoetsluis-1 (HVS1) to Rijsbergen-1 (RSB1) clear decrease in thickness of the assemblages IV, V and the lower part of VI can be noticed (the reduction of assemblage III is due to faulting). If we draw a conclusion from the above observation it would support the view that the Brabant Massif has been an area of less subsidence and intermittently probably even a source of clastic material. For the discussion on the genesis of the Brabant Massif we may refer to the review given by Bless (1973). In this paper Bless adds some arguments in favour of the hypothesis that the Massif was a positive element during the lower Westphalian A. He found evidence for sediment transport from the eastern spur of the Brabant Massif and for synsedimentary uplift of anticlinal structures during the Westphalian A and B in that area.

A reduction of Westphalian B and C in Hardenberg-2 (HBG2) and Tubbergen-8 (TUB8), at the edge of the Ems area, may indicate a degree of subsidence different from that in the centre of the Ems area. In this context, Schröder (1971) found the penetration of marine influence towards the south to be stronger in this area than in surrounding areas. This could be regarded as a prelude to the accentuated subsidence of the Ems Low during the Permo-Triassic.

4. COALIFICATION

The degree of coalification of the organic material in Carboniferous sediments is regularly so high that it directly influences the translucency of the miospores. In exceptional cases, these may become completely opaque. The use of an electron-scanning microscope is then required for identification of the spores (Bless & Meessen 1973).

In figure 7 the coalification data have been summarized, which have mainly become available over the past ten years. All determinations are based on vitrinite reflectance measurements, mostly on coals. In addition sporomorph translucency changes have been systematically recorded and are generally in good agreement with the vitrinite reflectance measurements. The translucency method is obviously not very

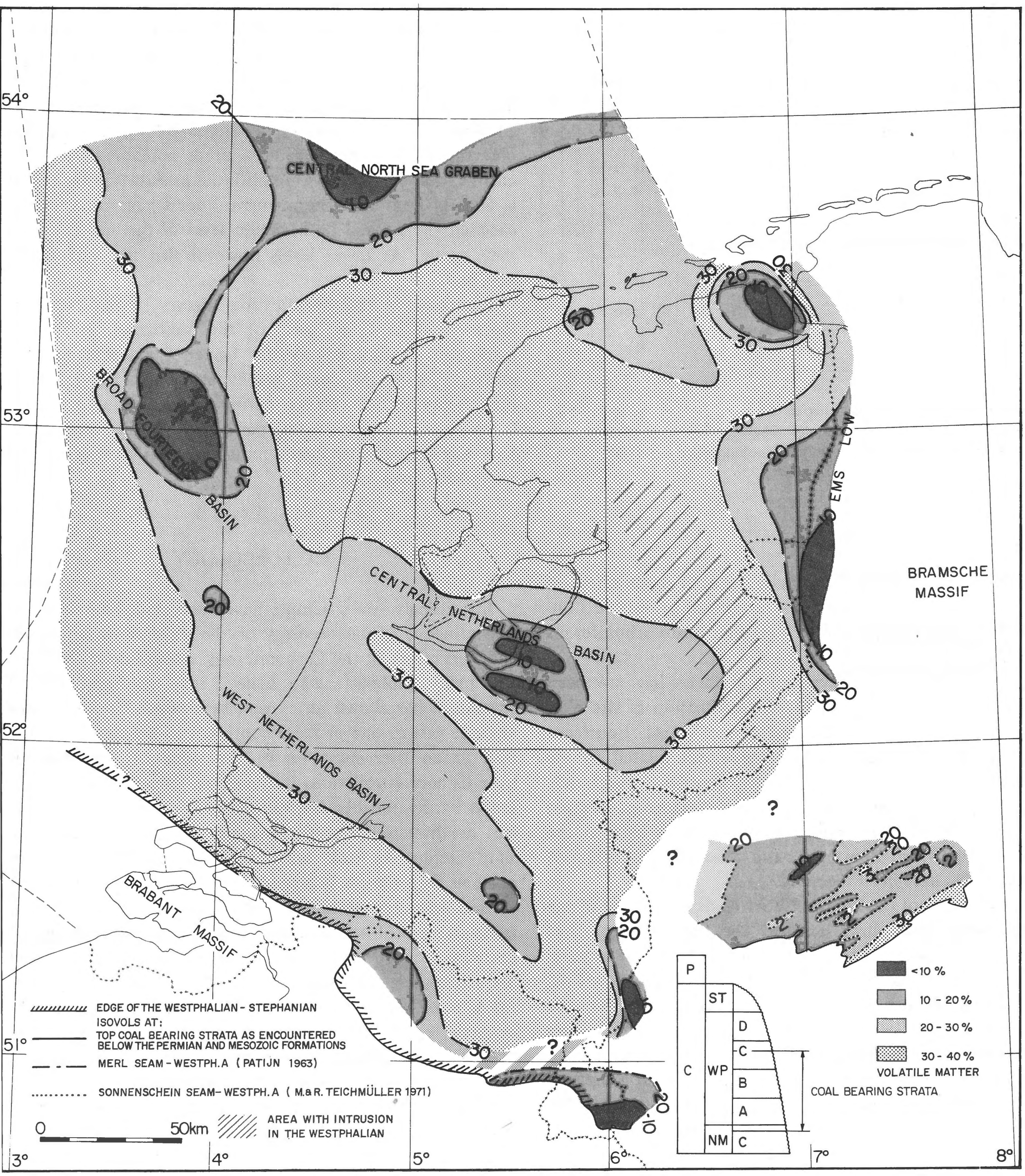


Fig. 7
Coalification map of top Carboniferous.

precise but proved useful for providing quick information during exploration drilling outside the Limburg-Ruhr mining districts. The iso-coalification lines have been sketched for data from below the eroded Carboniferous surface. This means that the data compared are not of equal age and do not always come from the youngest coal bearing strata. The reason for constructing the map as such is twofold. Firstly, the method of presentation has the advantage that factual

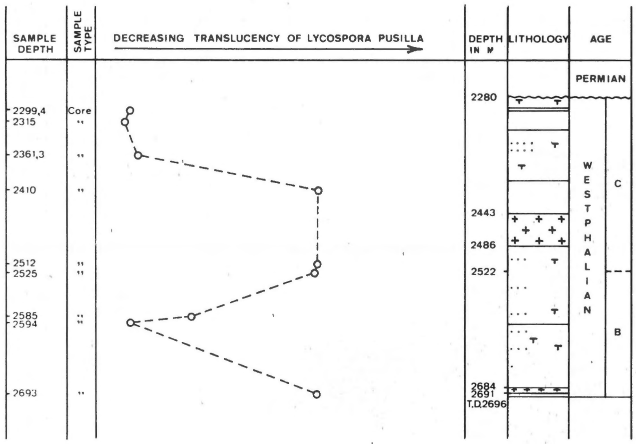


Fig. 8
Influence of intrusions on degree of coalification in enveloping sediments in De Wijk-7 borehole. Coalification here shown as a function of decreasing translucency of the miospore *L. pusilla.*

determinations are used. Secondly, and of greater importance, is the demonstration that coalification outside Limburg is primarily controlled by the post-Carboniferous overburden (Patijn 1963).

Assuming that paleo-temperature gradients have not been significantly higher, the degree of coalification in the West Netherlands-, Central Netherlands- and Broad Fourteens basins (Heybroek 1974) is clearly not related to the present overburden, but to the overburden, which was present up to and including the Lower Cretaceous. In areas where strong inversion movements took place such as the centre of the Broad Fourteens basin volatile matter values of less than 10% have been recorded.

In the centre of the Central Netherlands Basin none of the available boreholes have reached the Carboniferous, but strong coalification has been observed here from the Jurassic. In the southern part of the Central North Sea Graben, the high degree of coalification has been inferred from the present great depth of burial (Heybroek 1974; Top Carboniferous depth contour map).

In the Ems Low, the high degree of coalification is partly controlled by overburden and partly by the influence of the magmatically heated area of the Bramsche Massif (Boigk et al., 1971).

In the northeastern part of the Groningen Field a coalification anomaly exists which can not be related to either past or present overburden. The temperature gradients in this area as compared to those in the southeastern part of the field would also not explain this difference. The only possible link which can be recognized is with the occurrence of a magnetic anomaly in this area (Atlas of The Netherlands, Geophysic Map II-7). It is uncertain when this event occurred.

In the area roughly outlined by the boreholes Steenwijkerwold-1 (SWD1), Haarle-1 (HLE1), Corle-1, Hardenberg-2 (HBG2) and Dwingelo-2 (DWI2) (fig. 7) basic intrusions have been encountered in the Westphalian (Thiadens 1963). These intrusions seem to have had a rather local effect on the enveloping sediments as is illustrated by figure 8. Similar observations have been made in other boreholes. From the coalification data at top Carboniferous as shown in figure 7 it is not apparent that the intrusive bodies have considerably elevated the general coalification level of the area in which they occur. At lower levels however this may indeed be possible.

Summarizing the coalification history, it may be concluded that in those parts of the Mesozoic basins with maximum overburden to the Upper Cretaceous (Heybroek 1974) the coalification pattern was imprinted on the Carboniferous surface during the Late Jurassic-Early Cretaceous. In the remaining parts of the basins, and on the Late Kimmerian Highs, maximum coalification was reached only in the Quaternary.

5. PALEOECOLOGY

Surprisingly few attempts have been made to investigate the influence of paleoecology on the distribution of macro- and microflora in the Carboniferous. Accordingly, there are still many geologists who believe that the Carboniferous vegetation has shown an extremely uniform character over areas as vast as one or more continents. This conviction has lead to an overestimation of the value of the flora for long-distance correlations in the Upper Carboniferous, which seems hardly tenable. Even in a more or less closed area, as was northwestern Europe during the Westphalian and possibly Stephanian (our information on the Stephanian in northwestern Europe is very scanty), we recognize lateral and vertical changes within a few hundred kilometres. This correlation problem increases still further if we try to correlate northwestern European Westphalian and Stephanian stages with sequences in North America, Spain or the U.S.S.R. In this connection one might suspect that, for example, the Cantabrian stage between Westphalian D and Stephanian A represents merely a transitional facies (compare also Garcia-Loygorri 1974).

Small-scale paleoecological investigations on Westphalian miospore assemblages have been carried out during the past decade by a.o. Smith (1962), Hacquebard, Cameron & Donaldson (1965), Habib (1966), Habib, Riegel & Spackman (1966) and Habib & Groth (1967).

Smith (1962) gives an account of vertical changes in the miospore contents of four coal seams from the Westphalian A-C in Yorkshire (Great Britain). He decides that four miospore assemblages can be distinguished, of which the *Lycospora* and *Densosporites* assemblages are the most relevant.

An important minor element of the transitional phase ›etween these assemblages is *Dictyotriletes bireticulatus*, the .iagnostic element of our spore zone III. The principal onclusion in his paper, in the present context is that during he Westphalian A-B two main vegetation types existed. One lominated by arborescent Lycopods and a second in which ıerbaceous Lycopods, ferns and pteridosperms were imporant. Both vegetations characterize deltaic swamp areas; .ifferences between them are presumably caused by dif'erences in the water level.

The other authors have studied miospore assemblages 'rom the Westphalian D of Canada and the United States. Their studies are of interest to us, since H a c q u e b a r d et al. 1965) investigated miospore assemblages from a non-marine equence in Canada, and H a b i b and collaborators were :oncerned with the miospore assemblages in an area where ›aralic conditions prevailed.

H a c q u e b a r d et al. (1965) recognize two principal :nvironments, a forested moor with a mainly arborescent 'egetation and predominance of *Lycospora* and *Laevigato-porites*, and an open moor with a mainly herbaceous 'egetation, in which *Punctatosporites* and *Torispora* are :haracteristic elements. A transitional reed-moor environnent, without characteristic species, has been observed. The ›pen moor environment is believed to have been "dryer" han the forest moor.

H a b i b and collaborators (1966-1967) recognize two ›rincipal vegetations. Firstly a chiefly herbaceous vegetation vith *Densosporites, Cristatisporites* and *Punctatisporites* *›bliquus*. In this assemblage the number of counted species ›er slide is relatively low (20 to 28). The authors suggested hat the vegetation existed in a principally brackish environnent, the herbaceous plants having been salinity-tolerant. 'he second environment is dominated by arborescent Lyco›ods, *Lycospora* being the most common miospore species. 'he number of counted species per slide is higher than in the irst assemblage (25 to 35). Since this vegetation tends to .isappear when brackish or marine influences come in, it is ›elieved that it represents a back swamp, freshwater vegetaion.

Summarizing the above papers, it is concluded by the ›resent authors that there existed three main vegetation ypes during the Westphalian linked by numerous others of a ›robably more local significance.

The first is characterized by *Densosporites*, herbaceous .ycopods, ferns and pteridosperms. The number of species nay have been relatively low. This vegetation occurred nainly in brackish environments, under the influence of oastal conditions and persisted at least during the entire Vestphalian in paralic basins. It is absent in completely on-marine areas, such as the Westphalian D of Sydney 'oalfield (Canada).

The second vegetation type is dominated by *Lycospora*, he miospore of arborescent Lycopods, with *Laevigato-›orites* (Sphenopsida) often an important secondary element. The number of species seems to be higher than in the *Densosporites* vegetation. It occurs characteristically in wet, freshwater areas both in the delta and in the fluvial plains. Presumably it was the most common and widest-spread vegetation during the Westphalian.

The third type is restricted to non-marine, drier areas, probably the higher parts of the fluvial floodplains, or parts of the "hinterland". This was an open moor vegetation with herbaceous plants, monolete miospores such as *Punctato-sporites, Torispora, Latosporites* and, may be, *Thymospora* being predominant. No data exist for the number of species.

6. ANALYSIS OF RESULTS

A number of observations can be made from a consideration of the miospore assemblages in association with the main sedimentary facies prevailing in The Netherlands during the Westphalian.

The larger part of the Westphalian A is characterized by a paralic sedimentation and a relatively poor microflora in which two species of *Densosporites* played an important role.

During the Upper Westphalian A, there is a gradual change to a less paralic sedimentation pattern, in which presumably back swamp conditions prevailed. At about the same time the number of miospore species increases. This environment persisted during the Westphalian B.

In the Lower Westphalian C, there is again a major change in the sedimentary cycles, to a character which most likely reflects fluvial plain conditions. The number of miospore species increases again, although some characteristic genera as *Radiizonates* and *Dictyotriletes* tend to disappear or become rare. Some other genera, such as *Cirratriradites* (Lycopods), *Vestispora* (Sphenopsids) and *Triquitrites* (ferns) become important and are each represented by several species.

At the end of the Westphalian C and beginning of the Westphalian D, numerous miospore species disappear or become rare. Monolete spores are now the most important group. In the Westphalian D, the climate becomes increasingly arid resulting in a reduced vegetation cover.

In figure 9 an attempt has been made to illustrate the broad relation in time and space between the basin fill and the floral development. In this model a landscape with low relief is assumed in which environmental belts stretched out over vast areas. Alterations in a given situation, such as sea level fluctuations, may have had an influence on considerable parts of the basin, depending on their magnitude. Against this general setting, the observations in the Westphalian of The Netherlands have been interpreted.

The Westphalian A and B were characterized by coastal marsh and back swamp conditions. They were inhabited by respectively a *Densosporites* herbaceous vegetation in the coastal marshes and a transitional *Densosporites-Lycospora* vegetation in the back swamps. The occurrence of several species of *Radiizonates* and *Dictyotriletes* which seem to have flourished especially in the coastal marshes and back

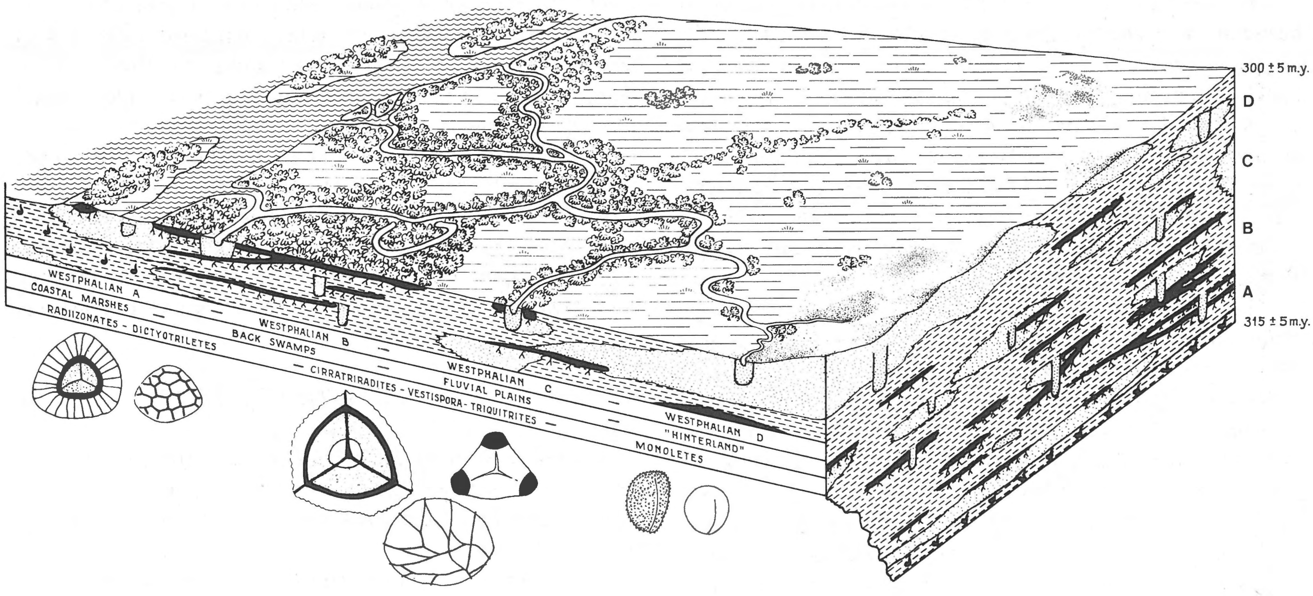


Fig. 9
Idealized relationship between sedimentary environment and vegetational pattern, in time and space, with indication of some characteristical miospore genera. One of the most significant aspects is, that each genus was represented by several species when it was most prolific. The genera are naturally not restricted to the indicated areas and time.

swamps (Upper Westphalian A and Westphalian B) is believed to be characteristic. It is remarkable that these forms are absent in a presumably non-marine basin, where such a transitional flora would not have existed. We think here of the Canadian basins. *Radiizonates* is unimportant in these basins and also in the Westphalian A-B of Spain (Neves 1964, Neves in: Moore, Neves, Wagner & Wagner-Gentis 1971). In this latter country, *Dictyotriletes bireticulatus* is an important element for the Namurian C, whereas it becomes more common in NW Europe in topmost Westphalian A and Lower Westphalian B.

With the narrowing of the basin, and possibly accentuated by uplifts along the southern basin edge, fluvial plain conditions became dominant in the Westphalian C in a still humid climate. The microflora shows a decrease of *Densosporites sphaerotriangularis,* an important representative of the coastal and back swamp environments. The strong decrease of coal points to probable more local and short-lived swamps along rivers and lakes. Apart from arborescent plants, there occur the first indications of a tendency towards the open moor vegetation. Two species of *Cirratriradites* (Lycopods), several *Vestispora* and *Triquitrites* species (respectively Sphenopsids and ferns) characterize a non-marine environment transitional from the *Lycospora* towards a monolete environment, or rather, from forest to open moor conditions. The Westphalian D is characterized by an open moor vegetation in a climate which becomes increasingly arid. Since widespread paralic conditions had disappeared by this time, *Densosporites* assemblages are rarely recognized in this area, in contradistinction to the paralic Westphalian D in some parts of the United States.

Finally we would like to draw attention to the occurrence of the megaspore *Lagenicula crassiaculeata* in the Westphalian A of Zeddam-1 (ZED1) (Dijkstra, Appendix). Apart from this occurrence *L. crassiaculeata* has not been recorded either in The Netherlands or elsewhere from sediments younger than Namurian B. Since a reworked occurrence here seems highly unlikely we are inclined to believe that the extended range of *L. crassiaculeata* is environmentally controlled.

It is concluded that apart from time and a changing climate in the Upper Westphalian, miospore distribution has been influenced by the sedimentary environment. Due to the low relief within the basin, however, the major environmental belts extended over vast areas, and shifted only very gradually in time. The miospore assemblages of The Netherlands, as defined in this paper, together with those of the surrounding areas to which they are closely related, are regarded therefore as being primarily controlled by time, at least within the North Sea basin.

7. SYSTEMATICS

It is beyond the scope of this paper to give exhaustive descriptions of all species. We have selected only those, which are either of interest because of their more or less restricted stratigraphical range or which have attracted our attention during this study. Some of the more common miospore genera such as *Calamospora, Leiotriletes, Lycospora* and *Florinites,* which usually make up the bulk of our samples, have not been treated at all.

For each species the occurrence in other areas in Northwestern Europe is given. Information has been taken for the Ruhr area from Grebe (1972), for the Campine from Somers (1971), for the North of France from Loboziak (1969) and for Great Britain from Smith & Butterworth (1967). The occurrence of miospores in Limburg (i.c. South Limburg or mining area) and in other Dutch onshore and offshore exploration boreholes has been established by the present authors.

Genus *Apiculatisporis* POTONIE & KREMP 1956
Pl. 1, fig. 1, 2.

Remarks: Amb more or less rounded; surface with coni, granae or spinulae; laesurae simple. For the purpose of this paper no distinction has been made between the different species.

Occurrence:
Limburg – frequent in the Westphalian A; infrequent to rare in Westphalian B-C.
Dutch boreholes – frequent in Westphalian A-B; infrequent in Westphalian C; rare in Westphalian D.
Ruhr area – rare in Upper Westphalian A to extremely rare in Upper Westphalian C.
Campine – Westphalian A-C.
North of France – Westphalian A-D.
Britain – infrequent to occasionally frequent in Westphalian A-D.

Genus *Lophotriletes* (NAUMOVA) POTONIE & KREMP 1954
Lophotriletes cf. *microsaetosus* (LOOSE) POTONIE & KREMP 1955
Pl. 1, fig. 3.

Remarks: Amb triangular with concave sides and rounded angles; ornament consists of coni of about 2-3 μ. Specimens similar to those described by Smith & Butterworth (1967, p. 158, pl. 6, fig. 10, 11).

Occurrence:
Limburg – rare in Upper Westphalian A to Westphalian C.
Ruhr area – rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent to occasionally frequent in Lower Westphalian B; infrequent in Upper Westphalian B to Westphalian D.
Not recorded from Dutch boreholes.

Genus *Cadiospora* (KOSANKE) VENKATACHALA & BHARDWAJ 1964
Cadiospora magna KOSANKE 1950
Pl. 1, fig. 4.

Remarks: Amb rounded; laesurae distinctly ridged and connected near margin by small arcuate ridges; surface minutely granulate with occasional verrucae.

Occurrence:
Dutch boreholes – infrequent in Westphalian D.
Britain – infrequent in Westphalian D.
Not recorded from Limburg, Ruhr area, Campine and North of France.

Genus *Raistrickia* (SCHOPF, WILSON & BENTALL) POTONIE & KEMP 1954

Remarks: Several species of *Raistrickia* occur throughout the Westphalian. They usually constitute only a very small percentage of the microflora, but in some samples, especially in the Westphalian C they may make up several percents. They do not seem to have much stratigraphic value.

Raistrickia saetosa (LOOSE) SCHOPF, WILSON & BENTALL 1944
Pl. 1, fig. 6-8.

Remarks: Amb rounded; laesurae rarely visible; ornament of bacula of varying shape and length (up to 15 μ long), bacula being truncated, apiculate, rounded or bifurcate at their top.

Occurrence:
Limburg – infrequent in Westphalian A-C, absent in uppermost samples of Jabeek Formation.
Dutch boreholes – infrequent to frequent in Westphalian A-C; rare in Westphalian D.
Ruhr area – Upper Westphalian A to Upper Westphalian C; rare to extremely rare.
Campine – Upper Westphalian A to Westphalian B.
North of France – Westphalian A-D.
Britain – infrequent or occasionally frequent in Westphalian A-D.

Genus *Microreticulatisporites* (KNOX) SMITH & BUTTERWORTH 1967
Microreticulatisporites nobilis (WICHER) KNOX 1950
Pl. 1, fig. 5.

Remarks: Amb triangular with rounded angles and straight to slightly convex sides; muri high, produced into small low rounded projections, giving the margin an undulating aspect; lumina small. Species close to *M. sulcatus,* from which it is distinguished by the lower ornament.

Occurrence:
Limburg – rare to infrequent in Westphalian B-C.
Dutch boreholes – rare in Westphalian C.
Ruhr area – sporadic in Middle Westphalian B to frequent in Upper Westphalian C.

Campine – Middle Westphalian B to Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent in Westphalian B-C.

Microreticulatisporites sulcatus (WILSON & KOSANKE) SMITH & BUTTERWORTH 1967
Pl. 1, fig. 9.

Remarks: Like *M. nobilis,* but with sides more strongly convex and larger lumina and a more coarse ornament.

Occurrence:
Limburg – rare in Upper Westphalian C.
Dutch boreholes – infrequent in Westphalian C; frequent in Westphalian D.
Britain – infrequent in Westphalian C-D.
This species has not been recorded from the Ruhr area, Campine or North of France.

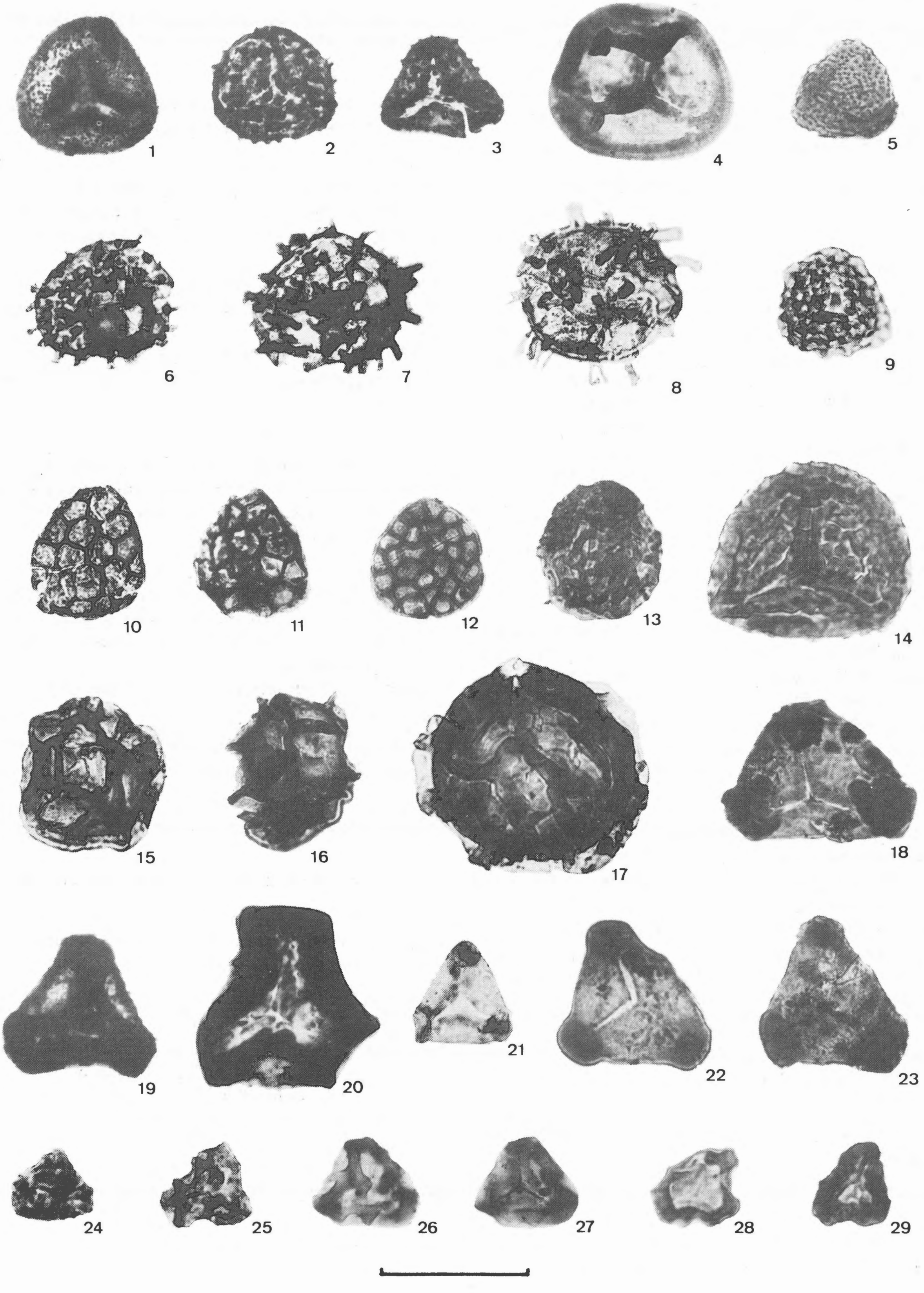
Genus *Dictyotriletes* (NAUMOVA) SMITH & BUTTERWORTH 1967
Dictyotriletes bireticulatus (IBRAHIM) SMITH & BUTTERWORTH 1967
Pl. 1, fig. 10-12.

Remarks: Amb rounded-triangular; laesurae indistinct; reticulate ornament confined to distal surface, consisting of large, regular lumina and distinct but low and thin muri.

Occurrence:
Limburg – rare to infrequent in the Westphalian A; in the Lower and basal part of Upper Westphalian B this species occurs in small numbers in practically all samples.
Dutch boreholes – rare in Westphalian A; frequent in Lower Westphalian B.
Ruhr area – rare in Upper Westphalian A; frequent in small

PLATE 1
(scale = 50 μ)

Fig. 1 *Apiculatisporis* cf. *aculeatus.* GB188; 40.9 x 109.2. Upper part of Upper Westphalian A, SM Emma.
Fig. 2 *Apiculatisporis* sp. GB189; 23.5 x 98.5. Base of Lower Westphalian B, SM Emma.
Fig. 3 *Lophotriletes* cf. *microsaetosus.* GB205; 50.7 x 112.8. Lower part of Lower Westphalian B, SM Emma.
Fig. 4 *Cadiospora magna.* NAM6719, Hellevoetsluis-1 Borehole, 2913 m. Westphalian D.
Fig. 5 *Microreticulatisporites nobilis.* GB148; 44.4 x 108.1. Upper Westphalian C, XLV Borehole.
Fig. 6 *Raistrickia saetosa.* GB196; 24.2 x 111.3. Lower part of Upper Westphalian B, SM Emma.
Fig. 7 *Raistrickia saetosa.* GB189; 35.0 x 106.6. Base of Lower Westphalian B, SM Emma.
Fig. 8 *Raistrickia saetosa.* NAM1039, Haaksbergen-1 Borehole 945 m. Upper Westphalian C.
Fig. 9 *Microreticulatisporites sulcatus.* NAM6675, Hellevoetsluis-1 Borehole, 2913 m. Westphalian D.
Fig. 10 *Dictyotriletes bireticulatus.* GB203; 26.0 x 90.6. Top of Lower Westphalian B, SM Emma.
Fig. 11 *Dictyotriletes bireticulatus.* NAM9265, Hardenberg-2 Borehole, 3310 m. Westphalian B.
Fig. 12 *Dictyotriletes bireticulatus.* GB205; 40.0 x 108.6. Lower part of Lower Westphalian B, SM Emma.
Fig. 13 *Dictyotriletes falsus.* GB150; 32.7 x 102.6. Upper Westphalian C, XLV Borehole.
Fig. 14 *Camptotriletes bucculentus.* GB150; 30.9 x 101.1. Upper Westphalian C, XLV Borehole.
Fig. 15 *Dictyotriletes reticulocingulum.* GB140; 37.0 x 111.8. Upper Westphalian C, XLV Borehole.
Fig. 16 *Dictyotriletes reticulocingulum.* GB151; 35.0 x 103.6. Upper Westphalian C, XLV Borehole.
Fig. 17 *Dictyotriletes* cf. *muricatus.* GB145, 52.0 x 100.7. Base of Upper Westphalian C, XLV Borehole.
Fig. 18 *Triquitrites tribullatus.* GB9; 35.7 x 100.0. Upper Westphalian C, XLV Borehole.
Fig. 19 *Ahrensisporites guerickei.* GB205; 39.7 x 103.9. Lower part of Lower Westphalian B, SM Emma.
Fig. 20 *Ahrensisporites guerickei.* NAM1399, Lochem-2 Borehole, 962 m. Westphalian B.
Fig. 21 *Triquitrites bransonii.* NAM6686, K7-1 Borehole, 3445 m. Westphalian D.
Fig. 22 *Triquitrites bransonii.* GB27; 52.5 x 106.4. Upper Westphalian C, XLV Borehole.
Fig. 23 *Triquitrites tribullatus.* GB145; 42.6 x 107.8. Base of Upper Westphalian C, XLV Borehole.
Fig. 24 *Triquitrites sculptilis.* GB147; 49.9 x 99.6. Lower Westphalian C, XLV Borehole.
Fig. 25 *Triquitrites sculptilis.* GB140; 29.1 x 99.7. Upper Westphalian C, XLV Borehole.
Fig. 26 *Triquitrites sculptilis.* Distal view. NAM1233, Haaksbergen-1 Borehole, 914 m. Upper Westphalian C.
Fig. 27 Same specimen as fig. 26. Proximal view.
Fig. 28 *Triquitrites velensis.* GB18; 36.2 x 90.8. Upper Westphalian C, XLV Borehole.
Fig. 29 *Triquitrites velensis.* GB141; 46.0 x 100.0. Upper Westphalian C, XLV Borehole.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numbers in Westphalian B; rare to extremely rare in Westphalian C.
Campine – Upper Westphalian A to Westphalian C.
North of France – middle part of Westphalian A to Lower Westphalian D.
Britain – Westphalian A to Lower Westphalian C; most abundant in uppermost Westphalian A and Westphalian B.

Dictyotriletes falsus POTONIE & KREMP 1955
Pl. 1, fig. 13.

Remarks: Amb about circular; reticulate ornament with thick muri and relatively small lumina.

Occurrence:
Limburg – rare in Westphalian C.
Dutch boreholes – rare in Westphalian A-C.
Ruhr area – rare to extremely rare in Westphalian B-C.
Campine – Upper Westphalian A – Westphalian B.
North of France – uppermost Westphalian B – Lower Westphalian D.
Britain – infrequent in Westphalian A to Lower Westphalian C.

Dictyotriletes reticulocingulum (LOOSE) SMITH & BUTTERWORTH 1967
Pl. 1, fig. 15, 16.

Remarks: Amb more or less rounded; reticulate ornament may be less well developed on proximal side; lumina relatively small, irregular; muri narrow and relatively high. Species rather similar to *D. mediareticulatus.* The latter species is here distinguished by its larger lumina and larger size.

Occurrence:
Limburg – rare to infrequent in Lower Westphalian C; frequent in Upper Westphalian C.
Dutch boreholes – extremely rare in Westphalian B.
Ruhr area – extremely rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Westphalian C – Lower Westphalian D.
Britain – Infrequent in Lower Westphalian A to Lower Westphalian C.

Dictyotriletes cf. *muricatus* (KOSANKE) SMITH & BUTTERWORTH 1967
Pl. 1, fig. 17.

Remarks: Amb rounded; muri relatively high; lumina irregular and large.

Occurrence:
Limburg – very rare in Lower Westphalian C – base of Upper Westphalian C.
Dutch boreholes – extremely rare in Westphalian B-C.

Genus *Camptotriletes* (NAUMOVA) POTONIE & KREMP 1954
Camptotriletes bucculentus (LOOSE) POTONIE & KREMP 1955
Pl. 1, fig. 14.

Remarks: Amb rounded-triangular; ornament consisting of low short muri and isolated short spines and verrucae.

Occurrence:
Limburg – infrequent in Lower Westphalian C.
Dutch boreholes – extremely rare in Westphalian A-D.
Ruhr area – very rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Lower Westphalian B.
North of France – Upper Westphalian A – Westphalian D.

Genus *Ahrensisporites* POTONIE & KREMP 1954
Ahrensisporites guerickei (HORST) POTONIE & KREMP 1954
Pl. 1, fig. 19, 20.

Remarks: Amb triangular with rounded angles and concave sides; surface smooth or with loosely distributed granae; large kyrtomes meeting at amb and sometimes modified into truncated auriculae.

Occurrence:
Limburg – rare in Lower Westphalian B.
Dutch boreholes – extremely rare in Westphalian A-B.
Ruhr area – very rare in Upper Westphalian A and Lower Westphalian B.
Campine – Upper Westphalian A to base of Upper Westphalian B.
North of France – Upper Westphalian A to Upper Westphalian C.
Britain – Westphalian A-B.

Genus *Triquitrites* (WILSON & COE) POTONIE & KREMP 1954
Triquitrites bransonii WILSON & HOFFMEISTER 1956
Pl. 1, fig. 21, 22.

Remarks: Amb triangular with truncate, thickened angles forming auriculae; surface laevigate.

Occurrence:
Limburg – Upper Westphalian C; rare.
Dutch boreholes – infrequent to occasionally frequent in Upper Westphalian C and Westphalian D.
Campine – Westphalian B-D.
Britain – infrequent in Upper Westphalian C and Westphalian D.
Not recorded from Ruhr area and North of France (may there have been included in *T. tribullatus?*)

Triquitrites sculptilis (BALME) SMITH & BUTTERWORTH 1967
Pl. 1, fig. 24-27.

Remarks: Amb triangular with rounded or lobed angles and more or less straight sides; distal surface with varying ornament of verrucate thickenings.

Occurrence:
Limburg – frequent in Westphalian C.
Dutch boreholes – rare in Westphalian B; frequent in Westphalian C-D.
Ruhr area – extremely rare in Upper Westphalian A and B; infrequent to frequent in Westphalian C.
Campine – Westphalian B-D.
North of France – Upper Westphalian B to Westphalian D.
Britain – infrequent to frequent in Upper Westphalian B to Lower Westphalian D.

Triquitrites tribullatus (IBRAHIM) POTONIE & KREMP 1956
Pl. 1, fig. 18, 23.

Remarks: Amb triangular with distinct thickening of truncate to lobed angles, which do not form true auriculae as in *T. bransonii.* The latter species is smaller.

Occurrence:
Limburg – infrequent to rare in Lower Westphalian C.
Dutch boreholes – rare in Westphalian A-B; infrequent in Westphalian C-D.
Ruhr area – rare from Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian B.
North of France – Upper Westphalian A to Westphalian D.
Britain – Westphalian A-C.

Triquitrites velensis (BHARDWAJ) comb. nov.
Pl. 1, fig. 28, 29.

Ahrensisporites velensis BHARDWAJ 1957, pl. 25, fig. 68.
Ahrensisporites velensis BHARDWAJ & GREBE 1972, pl. 10, fig. 4-8.

Remarks: Amb triangular with more or less rounded to truncate angles; laesurae often indistinct; distal ornament varying from a center with verrucate thickenings with an incomplete cingulate crassitude to a practically laevigate center with a complete cingulum. Cingulum may be slightly thicker at angles than at interradial sides. In *Ahrensisporites* no cingulum is present. Some specimens appear to be quite similar to *T. sculptilis* and are difficult to distinguish from that species. The more typical specimens seem to have a laevigate distal part.

Occurrence:
Limburg – rare in Lower Westphalian C, frequent in Upper Westphalian C.
Dutch boreholes – recorded from Westphalian C; in routine analyses this species may have been grouped with *T. sculptilis.*
Ruhr area – rare in Upper Westphalian C.
Not recorded from Campine, North of France and Britain. There probably included in *Westphalensisporites irregularis?*

Genus *Reticulatisporites* (IBRAHIM) NEVES 1964
Reticulatisporites polygonalis (IBRAHIM) SMITH & BUTTERWORTH 1967
Pl. 2, fig. 30, 31.

Remarks: Amb polygonal to irregularly rounded; cingulum broad and composed of three different zones; distally, three radial muri in interradial position meet cingulum and may be connected in such a way that they enclose a single irregularly shaped lumen.

Occurrence:
Limburg – rare in Westphalian C.
Dutch boreholes – extremely rare in Upper Westphalian A to Lower Westphalian C.
Ruhr area – extremely rare in Upper Westphalian B and Westphalian C; single occurrence in Upper Westphalian A.
Campine – Upper Westphalian A – Lower Westphalian C.
North of France – Upper Westphalian A to Lower Westphalian C.
Britain – infrequent in Westphalian A to lowermost Westphalian C.

Genus *Savitrisporites* BHARDWAJ 1955
Savitrisporites nux (BUTTERWORTH & WILLIAMS) SULLIVAN 1964
Pl. 2, fig. 32.

Remarks: Amb triangular with rounded angles; narrow but distinct cingulum; laesurae bordered by crenulate thickening; distal part with verrucae and coni. Species slightly larger and more ornamented than *S. concavus.*

Occurrence:
Limburg – rare in Westphalian A-C.
Dutch boreholes – frequent in Westphalian A to Lower Westphalian C.
Ruhr area – extremely rare in Upper Westphalian A.
Campine – Upper Westphalian A to Lower Westphalian B.
North of France – Westphalian A – Lower Westphalian C.
Britain – Westphalian A-B.

Savitrisporites concavus MARSHALL & SMITH 1965
Pl. 2, fig. 33, 34.

Remarks: Amb triangular with rounded angles and concave sides; margin slightly crenulate; laesurae simple with sometimes more or less well developed ridges along them; proximal part laevigate except for ridges; distal face with large verrucae, which are usually arranged in a radial pattern from the distal pole to angles; cingulum of more or less uniform width.

Occurrence:
Limburg – frequent in Upper Westphalian C.
Dutch boreholes – occasionally frequent in Westphalian C-D.
Campine – Upper Westphalian A to Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Not recorded from Ruhr and Britain. It is not impossible that *S. concavus* and *B. nitidus* have been included in the same species by most authors. SMITH & BUTTERWORTH (1967) and GREBE (1972) mentioned only *B. nitidus.* LOBOZIAK (1969) and SOMERS (1971) only recognized *S. concavus.* All these authors give as range for their species the total range of our *B. nitidus* (Westphalian A-B in Limburg) and *S. concavus* (Upper Westphalian C). POTONIE (1960) stated that *Bellispores* and *Savitrisporites* are rather similar. In our concept of the species *Bellispores nitidus* lacks the distal verrucae.

Genus *Bellispores* (ARTÜZ) SULLIVAN 1964
Bellispores nitidus (HORST) SULLIVAN 1964
Pl. 2, fig. 35, 36.

Remarks: Amb triangular with rounded angles and slightly concave sides; narrow cingulum; distal (?) ornament consisting of radial, foveolate thickenings parallel to laesurae.

Occurrence:
Limburg – rare in Westphalian A and Lower Westphalian B.
Dutch boreholes – extremely rare in Westphalian A.
Ruhr area – extremely rare in Upper Westphalian A.
Britain – infrequent in Lower Westphalian A.
Not recorded from Campine and North of France. There probably included in *Savitrisporites concavus* (Upper Westphalian A - Westphalian D)?

Genus *Simozonotriletes* (NAUMOVA) POTONIE & KREMP 1954
Simozonotriletes intortus (WALTZ) POTONIE & KREMP 1954
Pl. 2, fig. 37, 38.

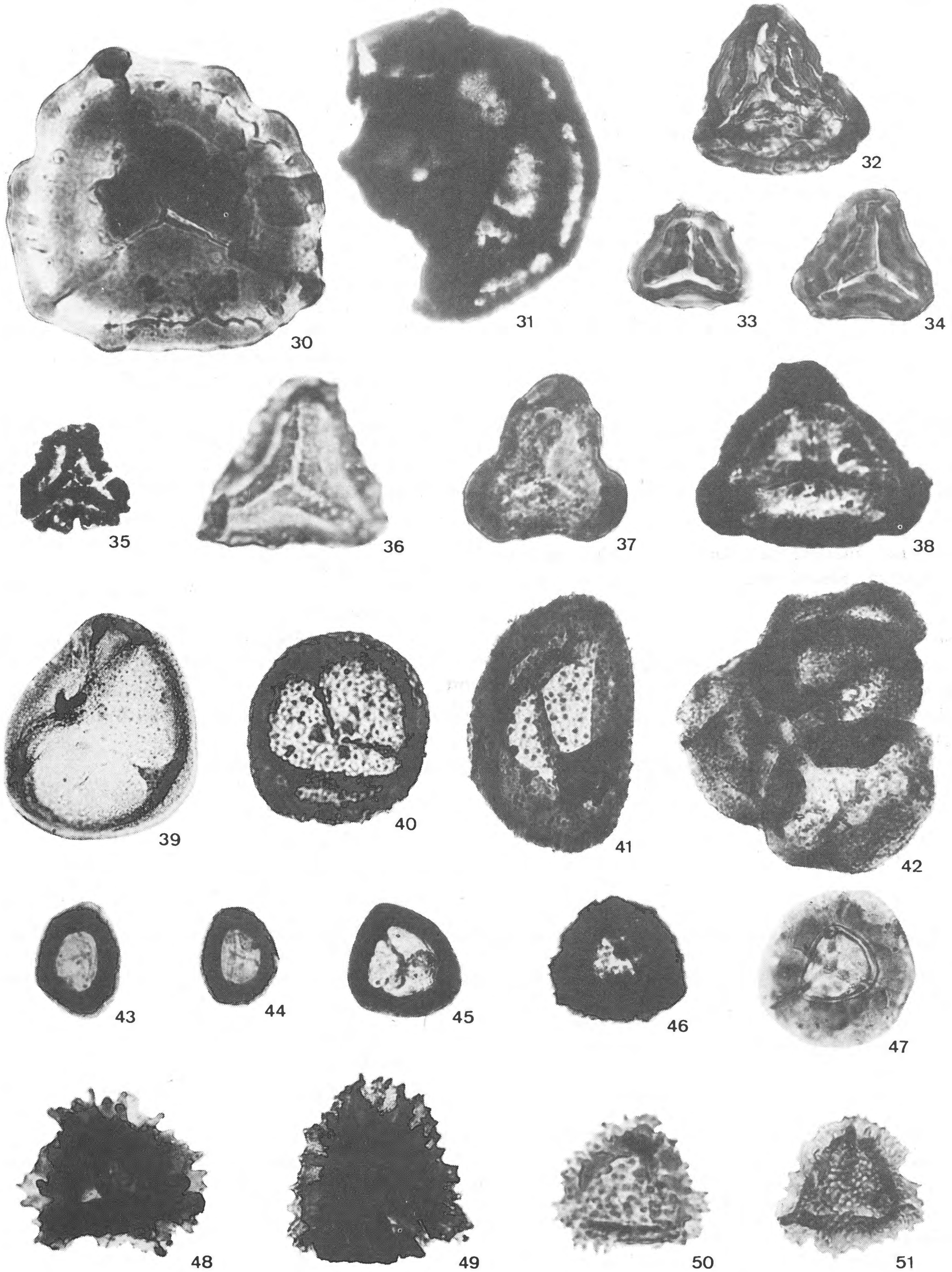
Remarks: Amb rounded-triangular to triangular with broadly rounded angles and concave sides; relatively broad cingulum with dark outer and light inner zone.

Occurrence:
Limburg – extremely rare in Westphalian A-C.
Dutch boreholes – extremely rare in Westphalian A to Lower Westphalian C.
Ruhr area – extremely rare in Upper Westphalian A to Lower Westphalian C.
Campine – Upper Westphalian A to basal Westphalian D.
North of France – Upper Westphalian A to Westphalian C.
Britain – infrequent in Westphalian A-B.

PLATE 2

(scale = 50 μ except for fig. 36, where scale = 25 μ)

Fig. 30 *Reticulatisporites polygonalis.*
GB145; 41.0 x 90.0. Base of Upper Westphalian C, XLV Borehole.
Fig. 31 *Reticulatisporites polygonalis.*
GB193; 42.8 x 100.5. Top of Westphalian A, SM Emma.
Fig. 32 *Savitrisporites nux.*
GB141; 22.4 x 98.2. Upper Westphalian C, XLV Borehole.
Fig. 33 *Savitrisporites concavus.*
GB141; 41.7 x 108.6. Upper Westphalian C, XLV Borehole.
Fig. 34 *Savitrisporites concavus.*
GB141; 45.5 x 91.4. Upper Westphalian C, XLV Borehole.
Fig. 35 *Bellispores nitidus.*
GB55. Lower Westphalian A (Finefrau Nebenbank Marine Band), SM Emma.
Fig. 36 *Bellispores nitidus.*
NAM1482, Sonnega-1 Borehole, 1966 m. Upper Westphalian A.
Fig. 37 *Simozonotriletes intortus.*
GB18; 28.1 x 111.5. Upper Westphalian C, XLV Borehole.
Fig. 38 *Simozonotriletes intortus.*
GB193; 33.6 x 105.8. Top of Westphalian A, SM Emma.
Fig. 39 *Crassispora kosankei.*
NAM1010, Slochteren-4 Borehole, 2887 m. Upper Westphalian A.
Fig. 40 *Crassispora kosankei.*
GB196; 50.6 x 108.5. Lower part of Upper Westphalian B, SM Emma.
Fig. 41 *Crassispora kosankei.*
GB196; 49.5 x 107.6. Lower part of Upper Westphalian B, SM Emma.
Fig. 42 *Crassispora kosankei.* Tetrad.
GB140; 53.5 x 104.5. Upper Westphalian C, XLV Borehole.
Fig. 43 *Densosporites anulatus.*
GB141; 48.3 x 96.7. Upper Westphalian C, XLV Borehole.
Fig. 44 *Densosporites anulatus.*
GB147; 47.0 x 107.9. Lower Westphalian C, XLV Borehole.
Fig. 45 *Densosporites anulatus.*
NAM1843, Zeddam-1 Borehole, 1508 m. Westphalian A.
Fig. 46 *Densosporites sphaerotriangularis.*
GB193; 33.8 x105.3. Top of Westphalian A, SM Emma.
Fig. 47. *Densosporites sphaerotriangularis.*
NAM1848, De Wijk-6 Borehole, 2558 m. Westphalian B.
Fig. 48 *Cristatisporites connexus.*
GB141; 58.9 x 95.0. Upper Westphalian C, XLV Borehole.
Fig. 49 *Cristatisporites indignabundus.*
GB197; 25.3 x 100.4. Lower part of Upper Westphalian B, SM Emma.
Fig. 50 *Cristatisporites solaris.*
GB27; 38.1 x 91.9. Upper Westphalian C, XLV Borehole.
Fig. 51 *Cristatisporites solaris.*
GB141; 28.8 x 110.8. Upper Westphalian C, XLV Borehole.



Genus *Crassispora* (BHARDWAJ) SULLIVAN 1964
Crassispora konsankei (POTONIE & KREMP)
BHARDWAJ 1957
Pl. 2, fig. 39-42.

Remarks: Amb subcircular; crassitudinous thickening at equator; laesurae rarely visible; distal ornament with small loosely distributed coni. This is one of the most common species in the Westphalian. Tetrads are regularly observed.

Occurrence:
Limburg – common in Westphalian A-C.
Dutch boreholes – frequent to occasionally abundant in Westphalian A-C; infrequent in Westphalian D.
Ruhr area – common in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Upper Westphalian D.
North of France – Westphalian A-D.
Britain – frequent to abundant in Westphalian A-D.

Genus *Densosporites* (BERRY) BUTTERWORTH, JANSONIUS, SMITH & STAPLIN 1964
Densosporites anulatus (LOOSE) SCHOPF, WILSON & BENTALL 1944
Pl. 2, fig. 43-45.

Remarks: Amb rounded-triangular to suboval; narrow smooth cingulum; central area laevigate; laesurae rarely visible.

Occurrence:
Limburg – infrequent to frequent in Westphalian A-C.
Dutch boreholes – frequent in Westphalian A-C; infrequent in Westphalian D.
Ruhr area – common in Upper Westphalian A and B; less common to rare in Westphalian C.
Campine – Upper Westphalian A to basal Westphalian D.
North of France – Westphalian A-D.
Britain – infrequent to abundant in Westphalian A to Lower Westphalian C.

Densosporites sphaerotriangularis KOSANKE 1950
Pl. 2, fig. 46, 47.

Remarks: Amb rounded-triangular; cingulum wide, sometimes with distinct coni or verrucae and with transparant outer zone, which is much smaller than dark inner zone; laesurae frequently well visible; central area granulate to coarsely granulate.

Occurrence:
Limburg – frequent in Westphalian A to Lower Westphalian C; infrequent in Upper Westphalian C.
Dutch boreholes – frequent in Westphalian A to Lower Westphalian C; infrequent in Upper Westphalian C; infrequent to frequent in Westphalian D.
Ruhr area – frequent in Upper Westphalian A to Lower Westphalian C; rare to very rare in Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Westphalian A-D.
Britain – infrequent to abundant in Westphalian A to Lower Westphalian C; infrequent in Upper Westphalian C; infrequent to abundant in Westphalian D.

Genus *Cristatisporites* (POTONIE & KREMP) BUTTERWORTH, JANSONIUS, SMITH & STAPLIN 1964
Cristatisporites connexus POTONIE & KREMP 1955
Pl. 2, fig. 48.

Remarks: Amb rounded-triangular; wide cingulum with closely packed verrucae, which are arranged in rows parallel to the margin; margin modified by projecting verrucae. This species is close to *C. indignabundus.* Both species have been taken together in the range charts. *C. indignabundus* has a more spinous instead of verrucate ornament, and the number of projecting elements at the margin is higher.

Occurrence:
Limburg – (here counted together with *C. indignabundus*) infrequent in uppermost Westphalian A to basal Upper Westphalian C.
Dutch boreholes – (here counted together with *C. indignabundus*) rare to infrequent in Westphalian A to Lower Westphalian C.
Ruhr area – rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to basal Upper Westphalian B.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent to common in Upper Westphalian A and Westphalian B.

Cristatisporites indignabundus (LOOSE) STAPLIN & JANSONIUS 1964
Pl. 2, fig. 49.

Remarks: Amb rounded-triangular; cingulum with several rows of serrate ridges and closely packed setose spines; margin strongly modified by projecting elements consisting of serrate ridges and some isolated spines. For comparison with *C. connexus* see above.

Occurrence:
Limburg – see under *C. connexus.*
Dutch boreholes – see under *C. connexus.*
Ruhr area – rare in Upper Westphalian A to Upper Westphalian C.
Campine – Westphalian B-D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent to common in Westphalian B.

Cristatisporites solaris (BALME) BUTTERWORTH & SMITH 1964
Pl. 2, fig. 50, 51.

Remarks: Amb rounded-triangular to subtriangular with strongly convex sides; narrow cingulum; cingulum and central area ornamented with tubercules, spines and verrucae. This species is distinguished from *C. connexus* and *C. indignabundus* by its narrower cingulum, smaller size and ornament consisting of both verrucae, spines and tubercules.

Occurrence:
Limburg – rare in upper part of Lower Westphalian C; frequent in Upper Westphalian C.
Dutch boreholes – rare to infrequent in Westphalian B-C.
Ruhr area – very rare in Westphalian B to Upper Westphalian C.
Campine – Westphalian B-D.
North of France – Upper Westphalian A – Lower Westphalian D.
Britain – Infrequent to abundant in Upper Westphalian B and Westphalian C.

Genus *Cirratriradites* WILSON & COE 1940
Cirratriradites cf. *megaspinosus* (IBRAHIM) SMITH & BUTTERWORTH 1967
Pl. 3, fig. 52, 53, 55.

Remarks: Amb rounded-triangular; well developed equatorial flange, which appears to be foveolate in some cases; laesurae ridged, extending into flange; distal surface with isolated long hooked spines or baculae; isolated much shorter spines and baculae may occur on the distal part of the flange; diameter including flange between 78 and 144 μ. Only one sample at the base of the Upper Westphalian C in Limburg has yielded several specimens. They are distinguished from the specimens described by SMITH & BUTTERWORTH (1967) by their larger size. *C. ornatus* has smaller and more delicate spines, but has a practically similar size (80-110 μ).

Occurrence:
Limburg – base of Upper Westphalian C.
Dutch boreholes – single occurrence in Lower Westphalian C.
Britain – infrequent in Upper Westphalian C and Westphalian D.

Cirratriradites saturni (IBRAHIM) SCHOPF, WILSON & BENTALL 1944
Pl. 3, fig. 54, 56.

Remarks: Amb subtriangular with strongly convex sides; equatorial flange relatively narrow, often serrate; laesurae ridged, extending to margin; body granulate to verrucate; one large distal fovea.

Occurrence:
Limburg – rare to infrequent in Westphalian A and Lower Westphalian B; frequent and sometimes abundant in Upper Westphalian B to Upper Westphalian C.
Dutch boreholes – rare to infrequent in Westphalian A; frequent in Westphalian B-C; extremely rare in Westphalian D.
Ruhr area – rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent to frequent in Westphalian A-C.

Genus *Cingulizonates* (DYBOVA & JACHOWICZ) BUTTERWORTH, JANSONIUS, SMITH & STAPLIN 1964
Cingulizonates loricatus (LOOSE) BUTTERWORTH & SMITH 1964
Pl. 3, fig. 57.

Remarks: Amb subrounded; cingulum with dark zone broader than outer light zone; laesurae simple; central area laevigate, sometimes small granae are visible.

Occurrence:
Limburg – infrequent to rare in Westphalian B and C.
Dutch boreholes – rare to infrequent in Westphalian A-C.
Ruhr area – frequent to rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Westphalian A-C.
Britain – infrequent to abundant in Upper Westphalian A to Lower Westphalian C; infrequent in Upper Westphalian C.

Genus *Radiizonates* STAPLIN & JANSONIUS 1964

Radiizonates aligerens (KNOX) STAPLIN & JANSONIUS 1964
Pl. 3, fig. 58-60.

Syn.: *Endosporites plicatilis* LAVEINE 1961, Ann. Soc. Geol. Nord, 81, 92, pl. 7, fig. 6.

Remarks: Amb subcircular; inner part of cingulum rather narrow; outer zone broad, transparent and with numerous radial ribs.

Occurrence:
Limburg – short range somewhat halfway the Upper Westphalian A; specimens in Limburg often strongly corroded; rare.
Dutch boreholes – frequent in Upper Westphalian A.
Ruhr area – rare in Upper Westphalian A.
Campine – Upper Westphalian A.
Britain – Upper Westphalian A.
This species has not been recorded from the North of France, where Loboziak (1969) noted a rather similar species: *R. rotatus.* This latter species occurs there from Upper Westphalian A to Lower Westphalian C.

Radiizonates difformis (KOSANKE) STAPLIN & JANSONIUS 1964
Pl. 3, fig. 63.

Remarks: Similar to *R. aligerens*, but inner dark part of cingulum is relatively broader; the number of radial ribs is also lower.

Occurrence:
Limburg – rare in Westphalian A.
Dutch boreholes – rare in Upper Westphalian A and Lower Westphalian B.
Ruhr area – rare in Upper Westphalian A and Lower Westphalian B.
North of France – Upper Westphalian A to Upper Westphalian C.
Britain – infrequent to frequent in Upper Westphalian A.
Not recorded from Campine.

Radiizonates striatus (KNOX) STAPLIN & JANSONIUS 1964
Pl. 3, fig. 61, 62.

Remarks: Inner dark zone of cingulum broader than outer transparent zone; reduced number of radial ribs. This species has not been distinguished from *R. tenuis* in Limburg. The latter species should have a much broader cingulum and more radial ribs.

Occurrence:
Limburg – (together with *R. tenuis*) rare in Westphalian A and basal Westphalian B.
Dutch boreholes – (together with *R. tenuis*) infrequent to frequent in Westphalian A to Lower Westphalian C; rare in Upper Westphalian C.
Ruhr area – regularly occurring in Upper Westphalian A; rare in Westphalian B; extremely rare in Lower Westphalian C.
Campine – Upper Westphalian A to basal Westphalian C.
North of France – Upper Westphalian B to Lower Westphalian C.
Britain – infrequent to common in Westphalian A-B.

Radiizonates tenuis (LOOSE) BUTTERWORTH & SMITH 1964

Remarks: See under *R. striatus.*

Occurrence:
Limburg – see under *R. striatus.*
Dutch boreholes – see under *R. striatus.*
Ruhr area – rare to very rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to basal Westphalian D.
North of France – Upper Westphalian B to Upper Westphalian C.
Britain – infrequent to common in Westphalian B to Lower Westphalian C.

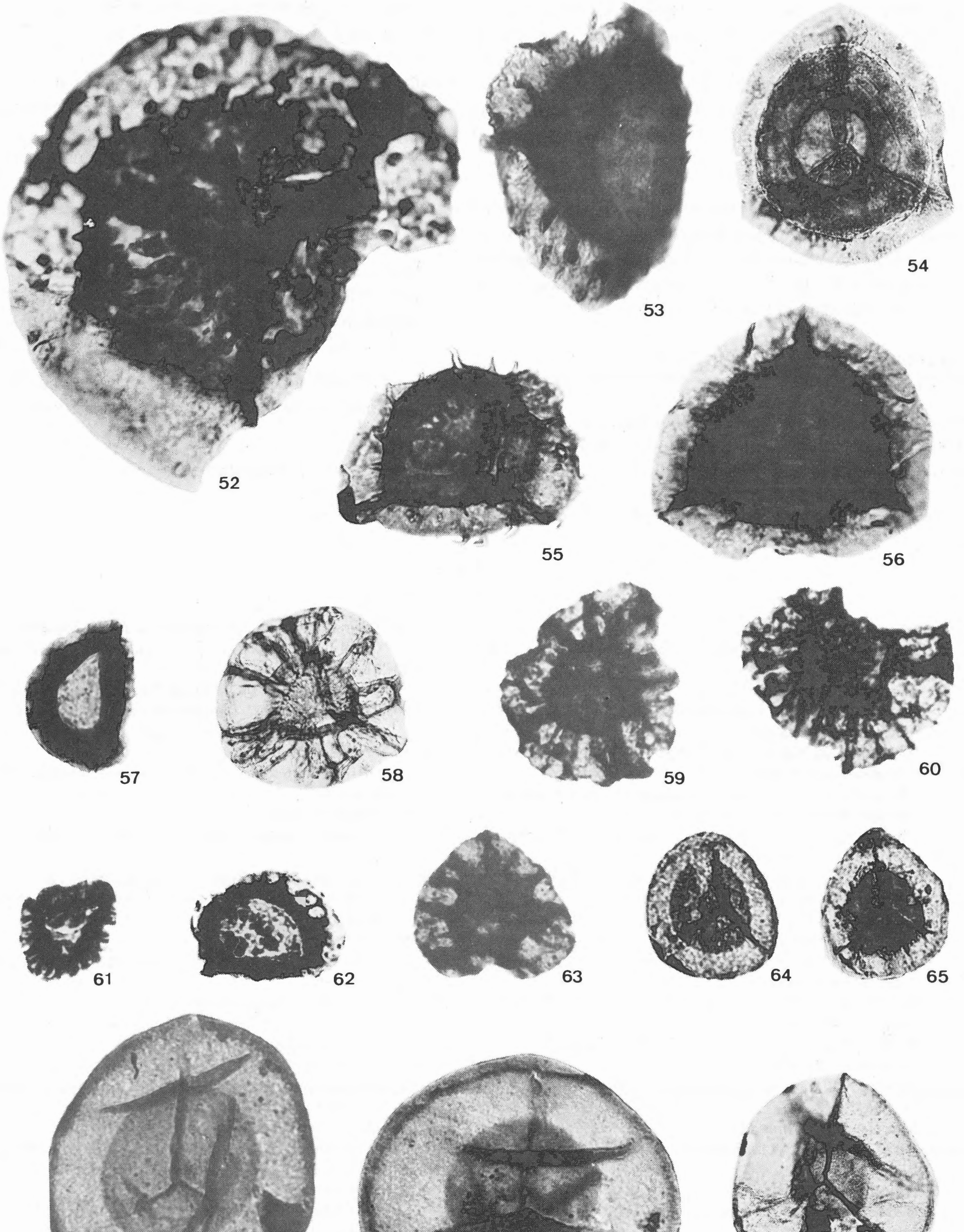
Genus *Endosporites* WILSON & COE 1940
Endosporites globiformis (IBRAHIM) SCHOPF, WILSON & BENTALL 1944
Pl. 3, fig. 66-68.

Remarks: Amb rounded; width pseudosaccus greater than body radius; narrow limbus present.

Occurrence:
Limburg – rare in uppermost Westphalian A and Lower

PLATE 3
(scale = 50 μ)

Fig. 52 *Cirratriradites megaspinosus.*
GB143; 58.5 x 100.6. Upper Westphalian C, XLV Borehole.
Fig. 53 *Cirratriradites megaspinosus.*
GB143; 41.9 x 109.0. Upper Westphalian C, XLV Borehole.
Fig. 54 *Cirratriradites saturni.*
NAM9264, Hellevoetsluis-1 Borehole, 3312 m. Lower Westphalian C.
Fig. 55 *Cirratriradites megaspinosus.*
GB143; 43.0 x 108.2. Upper Westphalian C, XLV Borehole.
Fig. 56 *Cirratriradites saturni.*
GB143; 46.0 x 107.2. Upper Westphalian C, XLV Borehole.
Fig. 57 *Cingulizonates loricatus.*
GB141; 40.0 x 105.5. Upper Westphalian C, XLV Borehole.
Fig. 58 *Radiizonates aligerens.*
NAM1216, Slochteren-4 Borehole, 2887 m. Upper Westphalian A.
Fig. 59 *Radiizonates aligerens.*
GB154; 51.6 x 107.1. Upper Westphalian A, SM Maurits.
Fig. 60 *Radiizonates aligerens.*
GB73; 38.9 x 91.8. Upper Westphalian A, SM Emma.
Fig. 61 *Radiizonates* cf. *striatus.*
GB184; 26.7 x 97.8. Base of Upper Westphalian A, SM Emma.
Fig. 62 *Radiizonates* cf. *striatus.*
GB189; 28.3 x 107.0. Base of Lower Westphalian B, SM Emma.
Fig. 63 *Radiizonates difformis.*
GB154; 32.6 x 110.1. Upper Westphalian A, SM Maurits.
Fig. 64 *Endosporites parvus.*
GB203; 51.9 x91.7. Top of Lower Westphalian B, SM Emma.
Fig. 65 *Endosporites parvus.*
GB203; 41.1 x 109.2. Top of Lower Westphalian B, SM Emma.
Fig. 66 *Endosporites globiformis.*
GB145; 99.8 x 104.7. Base of Upper Westphalian C, XLV Borehole.
Fig. 67 *Endosporites globiformis.*
GB145; 32.1 x 108.6. Base of Upper Westphalian C, XLV Borehole.
Fig. 68 *Endosporites globiformis.*
NAM1018, Dwingelo-2 Borehole, 2508 m. Westphalian B.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Westphalian B; frequent in Upper Westphalian B to Upper Westphalian C.
Dutch boreholes – rare in Westphalian A; infrequent in Lower Westphalian B; frequent to occasionally abundant in Upper Westphalian B and Westphalian C; infrequent in Westphalian D.
Ruhr area – rare in Upper Westphalian A and Lower Westphalian B; frequent in Upper Westphalian B to Upper Westphalian C.
Campine – Westphalian B-D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent Upper Westphalian A; infrequent to common in Westphalian B; frequent to very common in Lower Westphalian C; infrequent to abundant in Upper Westphalian C and Westphalian D.

Endosporites parvus STAPLIN 1960
Pl. 3, fig. 64, 65.

Remarks: Rather small species (diameter less than 50 μ); extremely narrow limbus present; width pseudosaccus equal to radius body.

Occurrence:
Limburg – very rare in Lower Westphalian B.
Campine – Upper Westphalian A to basal Westphalian C.
Not recorded from Ruhr area, North of France and Britain. It is not impossible, that Loboziak's (1969) *E. micromanifestus* and *E. egemeni* are conspecific with our specimens. *E. micromanifestus* occurs in Upper Westphalian B in the North of France (rare). *E. egemeni* is there rare in Upper Westphalian A to Lower Westphalian C. This species has not been recorded from Dutch boreholes.

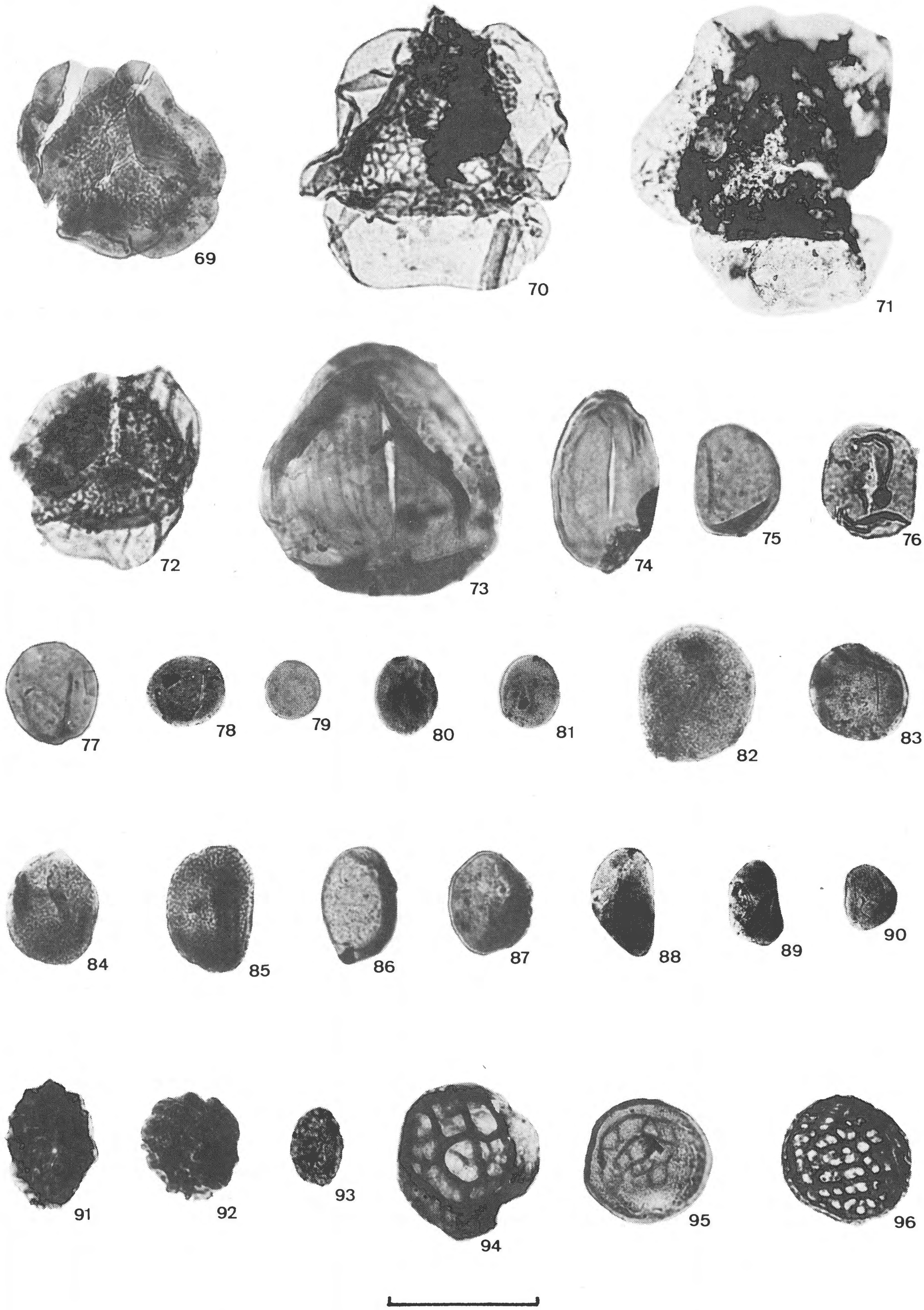
Genus *Alatisporites* (IBRAHIM) SMITH & BUTTERWORTH 1967
Alatisporites pustulatus (IBRAHIM 1932) IBRAHIM 1933
Pl. 4, fig. 69-72.

Remarks: Amb of body triangular with rounded angles; tripseudosaccate; body distally crenulate-verrucate.

Occurrence:
Limburg – rare in Westphalian C.

PLATE 4
(scale = 50 μ)

Fig. 69 *Alatisporites pustulatus.*
GB145; 38.0 x 102.4. Base of Upper Westphalian C, XLV Borehole.
Fig. 70 *Alatisporites pustulatus.*
GB27; 54.6 x 103.4. Upper Westphalian C, XLV Borehole.
Fig. 71 *Alatisporites pustulatus.*
NAM1080, De Wijk-6 Borehole, 2508 m. Westphalian B.
Fig. 72 *Alatisporites pustulatus.*
GB11; 27.6 x 107.1. Upper Westphalian C, XLV Borehole.
Fig. 73 *Laevigatosporites vulgaris.*
GB147; 55.9 x 99.7. Lower Westphalian C, XLV Borehole.
Fig. 74 *Laevigatosporites minor.*
GB141; 32.7 x 100.9. Upper Westphalian C, XLV Borehole.
Fig. 75 *Laevigatosporites minimus.*
GB12; 35.8 x 100.3. Upper Westphalian C, XLV Borehole.
Fig. 76 *Laevigatosporites minimus.*
GB140; 36.7 x 105.1. Upper Westphalian C, XLV Borehole.
Fig. 77 *Latosporites globosus.*
GB141; 28.3 x 94.0. Upper Westphalian C, XLV Borehole.
Fig. 78 *Latosporites globosus.*
NAM9259, K7-1 Borehole, 3449 m. Westphalian D.
Fig. 79 *Latosporites minutus.*
NAM9257, Reutum-1 Borehole, 2454 m. Upper Westphalian C.
Fig. 80 *Punctatosporites minutus.*
GB203; 41.2 x 109.3. Top of Lower Westphalian B, SM Emma.
Fig. 81 *Punctatosporites minutus.*
NAM9256, Reutum-1 Borehole, 2454 m. Upper Westphalian C.
Fig. 82 *Punctatosporites granifer.*
GB148; 34.0 x 94.1. Upper Westphalian C, XLV Borehole.
Fig. 83 *Punctatosporites granifer.*
NAM9255, Reutum-1 Borehole, 2454 m. Upper Westphalian C.
Fig. 84 *Torispora securis.* Transitional to *Punctatosporites granifer?*
GB141; 27.6 x 95.7. Upper Westphalian C, XLV Borehole.
Fig. 85 *Torispora securis.*
GB143; 48.0 x 108.7. Upper Westphalian C, XLV Borehole.
Fig. 86 *Torispora securis.* Transitional to *Punctatosporites granifer.*
GB9; 46.0 x 108.0. Upper Westphalian C, XLV Borehole.
Fig. 87 *Torispora securis.*
GB145; 35.6 x 109.2. Base of Upper Westphalian C, XLV Borehole.
Fig. 88 *Torispora securis.*
NAM9263, Hellevoetsluis-1 Borehole, 3056 m. Upper Westphalian C.
Fig. 89 *Torispora securis.* Note two crassitudes!
NAM9261, Hellevoetsluis-1 Borehole, 3056 m. Upper Westphalian C.
Fig. 90 *Torispora securis.*
NAM1298, Haaksbergen-1 Borehole, 914 m. Upper Westphalian C.
Fig. 91 *Thymospora pseudothiessenii.*
GB140; 53.1 x 92.5. Upper Westphalian C, XLV Borehole.
Fig. 92 *Thymospora pseudothiessenii.*
GB148; 36.5 x 95.6. Upper Westphalian C, XLV Borehole.
Fig. 93 *Thymospora pseudothiessenii.*
NAM6664, Hellevoetsluis-1 Borehole, 2914 m. Westphalian D.
Fig. 94 *Vestispora* sp. Operculum.
GB140; 35.2 x 101.4. Upper Westphalian C, XLV Borehole.
Fig. 95 *Vestispora* sp. Operculum.
NAM6709, Hellevoetsluis-1 Borehole, 2913 m. Westphalian D.
Fig. 96 *Vestispora* sp. Operculum.
GB199; 37.4 x 110.6. Base of Upper Westphalian B, SM Emma.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Dutch boreholes – rare in Upper Westphalian A to Westphalian C.
Ruhr area – extremely rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent in Upper Westphalian A to Lower Westphalian C.

Genus *Laevigatosporites* IBRAHIM 1933

Remarks: Distinction between different species has not been systematically applied in the analyses of borehole samples in The Netherlands.

Laevigatosporites vulgaris IBRAHIM 1933
Pl. 4, fig. 73.

Remarks: Bean-shaped monolete; laevigate; length more than 65 μ. We have not distinguished between *L. vulgaris* and *L. maximus.* A few isolated specimens of slightly more than 100 μ are here included in *L. vulgaris.* The photographed specimen shows some longitudinal striae, which have not been observed on other specimens.

Occurrence:
Limburg – rare in uppermost Westphalian B and Lower Westphalian C.
Ruhr area – rare to occasionally common in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Britain – Westphalian B (infrequent to common).

Laevigatosporites minor LOOSE 1934
Pl. 4, fig. 74.

Remarks: As *L. vulgaris,* but length between 35 and 65 μ.

Occurrence:
Limburg – common to abundant in Westphalian A-C.
Ruhr area – frequent in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Britain – frequent to abundant in Westphalian A-D.

Laevigatosporites minimus (WILSON & COE) SCHOPF, WILSON & BENTALL 1944
Pl. 4, fig. 75, 76.

Remarks: As *L. minor*, but length between 15 and 35 μ.

Occurrence:
Limburg – frequent in Upper Westphalian C.
Ruhr area – rare in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian C and Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent to frequent in Westphalian D.

Genus *Latosporites* POTONIE & KREMP 1954
Latosporites globosus (SCHLEMEL) POTONIE & KREMP 1956
Pl. 4, fig. 77, 78.

Remarks: Amb circular; sutura about one-half to two-thirds the spore diameter 20-40 μ.

Occurrence:
Limburg – extremely rare in Upper Westphalian C.
Dutch boreholes – rare to occasionally frequent in Upper Westphalian C and Westphalian D.
Campine – Upper Westphalian B to Westphalian D.
Britain – infrequent to frequent in Upper Westphalian C and Westphalian D.
Species not recorded from Ruhr area and North of France.

Latosporites minutus BHARDWAJ 1957
Pl. 4, fig. 79.

Remarks: Similar to *L. globosus,* but diameter between 10 and 20 μ; thin exine.

Occurrence:
Dutch boreholes – extremely rare in uppermost Westphalian C and Westphalian D.
Britain – infrequent to frequent in Upper Westphalian C and Westphalian D.
Species not recorded from Limburg, Ruhr area, Campine and North of France.

Genus *Punctatosporites* IBRAHIM 1933
Punctatosporites minutus IBRAHIM 1933
Pl. 4, fig. 80, 81.

Remarks: Amb oval-rounded; surface minutely granulate; diameter 20-30 μ.

Occurrence:
Limburg – rare in uppermost Westphalian A and Westphalian B; frequent in Westphalian C.
Dutch boreholes – rare in Upper Westphalian A and Westphalian B; frequent in Westphalian C-D.
Ruhr area – rare to occasionally common in Upper Westphalian A to Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Westphalian B-D.
Britain – infrequent to common in Westphalian A-D.

Punctatosporites granifer POTONIE & KREMP 1956
Pl. 4, fig. 82, 83.

Remarks: Amb oval to circular; surface minutely to distinctly granulate; exine usually somewhat thickened; length 20-38 μ. This species seems close to *P. minutus*. In uppermost Westphalian B and lowermost Westphalian C it is often difficult to distinguish between these species. For that reason, they have been taken together in the range-chart for Limburg. It should be noted, of course, that *P. granifer* is not considered to be a Westphalian A-B element. In uppermost

Westphalian C and in Westphalian D relatively large and frequently less regularly oval specimens of *P. granifer* occur. In these specimens the exine is distinctly more thickened than in specimens from lower parts of the Westphalian C.

Occurrence:

Limburg – infrequent to common in Lower Westphalian C; common in Upper Westphalian C, but always in small numbers.
Dutch boreholes – infrequent to occasionally frequent in Upper Westphalian C and Westphalian D.
Ruhr area – rare in Lower Westphalian C; common in Upper Westphalian C.
Campine – Westphalian C-D.
North of France – Westphalian B-D.
Britain – infrequent in Upper Westphalian C; infrequent to frequent in Westphalian D.

Genus *Torispora* (BALME) ALPERN, DOUBINGER & HORST 1965
Torispora securis BALME 1952
Pl. 4, fig. 84-90.

Remarks: Bean-shaped monolete, often distorted by irregular dark thickening of exine at one extremity; exine granulate; laesurae sometimes indistinct or apparently absent. There is a complete transition from true *T. securis* to true *P. granifer.*

Occurrence:

Limburg – rare in Upper Westphalian C.
Dutch boreholes – infrequent in Upper Westphalian C; infrequent to occasionally frequent in Westphalian D.
Ruhr area – common (in very small numbers) in Upper Westphalian C.
Campine – Westphalian C-D.
North of France – Upper Westphalian C and D.
Britain – infrequent to occasionally abundant in Upper Westphalian C and Westphalian D.

Genus *Thymospora* WILSON & VENKATACHALA 1963
Thymospora pseudothiessenii (KOSANKE) WILSON & VENKATACHALA 1963
Pl. 4, fig. 91-93.

Remarks: Elongate oval monolete with irregular margin because of ornament of large verrucae; exine rather thick resulting in often very dark spores.

Occurrence:

Limburg – a few isolated occurrences in the uppermost part of the Jabeek Formation, some 100-200 m above the base of the Upper Westphalian C.
Dutch boreholes – infrequent in Westphalian D.
Ruhr area – extremely rare in Upper Westphalian C.
Campine – Westphalian D.
North of France – uppermost Westphalian C and D.
Britain – infrequent to frequent in Westphalian D.

Genus *Vestispora* (WILSON & HOFFMEISTER) WILSON & VENKATACHALA 1963
Vestispora costata (BALME) SPODE 1967
Pl. 5, fig. 106-108.

Remarks: Species with ornament consisting of relatively rarely branching muri without incipient carination. This species is close to *V. tortuosa.* The latter can be distinguished by more frequently branching muri with incipient carination. Since many specimens are folded, it is often difficult to distinguish between them. In boreholes, both species have been taken together.

Occurrence:

Limburg – rare in uppermost Westphalian A to lowermost Westphalian C; common in higher parts of Westphalian C.
Dutch boreholes – (together with *V. tortuosa*) rare in uppermost Westphalian A; frequent in Westphalian B-C.
Ruhr area – very rare in Lower Westphalian B to Upper Westphalian C.
Campine – uppermost Westphalian A to Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent in Lower Westphalian B; infrequent to frequent in Upper Westphalian B to Upper Westphalian C.

Vestispora tortuosa (BALME) SPODE 1967
Pl. 5, fig. 105.

Remarks: See under *V. costata.*

Occurrence:

Limburg – infrequent from uppermost Westphalian A to Upper Westphalian C.
Britain – infrequent to frequent in Upper Westphalian A to Lower Westphalian C.
Species not recorded from Ruhr area, Campine and North of France, where it probably is included in *V. costata.*

Vestispora fenestrata (KOSANKE & BROKAW) SPODE 1967
Pl. 5, fig. 109-111.

Remarks: Characterized by foveolate ornament. It is not impossible, that we have included *V. velensis* in this species.

Occurrence;

Limburg – rare in Upper Westphalian C.
Dutch boreholes – infrequent to frequent in Upper Westphalian C and Westphalian D.
Ruhr area – very rare in Upper Westphalian C.
Campine – Upper Westphalian C and Westphalian D.
North of France – Upper Westphalian C and D.
Britain – infrequent to frequent in Upper Westphalian C and D.

Vestispora laevigata WILSON & VENKATACHALA 1963
Pl. 5, fig. 97, 98.

Remarks: Laevigate species; laesurae generally reaching borders of operculum. Some folding may simulate costate ornament.

Occurrence:
Limburg – one questionable isolated occurrence in Upper Westphalian C.
Dutch boreholes – infrequent in Upper Westphalian C and Westphalian D.
Campine – Westphalian D.
Britain – infrequent in uppermost Westphalian C and Westphalian D.
Not recorded from Ruhr area (probably because section does not reach there Westphalian D) and North of France. In the latter area, the species may have been included in *V. lucida.*

Vestispora magna (BUTTERWORTH & WILLIAMS) SPODE 1967
Pl. 5, fig. 99, 100, 104.

Remarks: Amb rounded; margin often deformed by strong reticulate ornament consisting of primary muri, which form a coarse reticulate network and enclose a smaller secondary reticulum with lumina of about 4-6 μ wide. Muri much coarser than in *V. pseudoreticulata*. Lumina of secondary reticulum more irregular and larger than in *V. pseudoreticulata.*

Occurrence:
Limburg – common and occasionally abundant in Westphalian C.
Dutch boreholes – rare in Upper Westphalian B; frequent in Westphalian C; extremely rare in lowermost Westphalian D.
Ruhr area – sporadic in Westphalian B and Westphalian C; common in Lower Westphalian C.
Campine – upper part of Lower Westphalian B to Westphalian D.
Britain – infrequent to common in Upper Westphalian B and Westphalian C.
Not recorded from North of France.

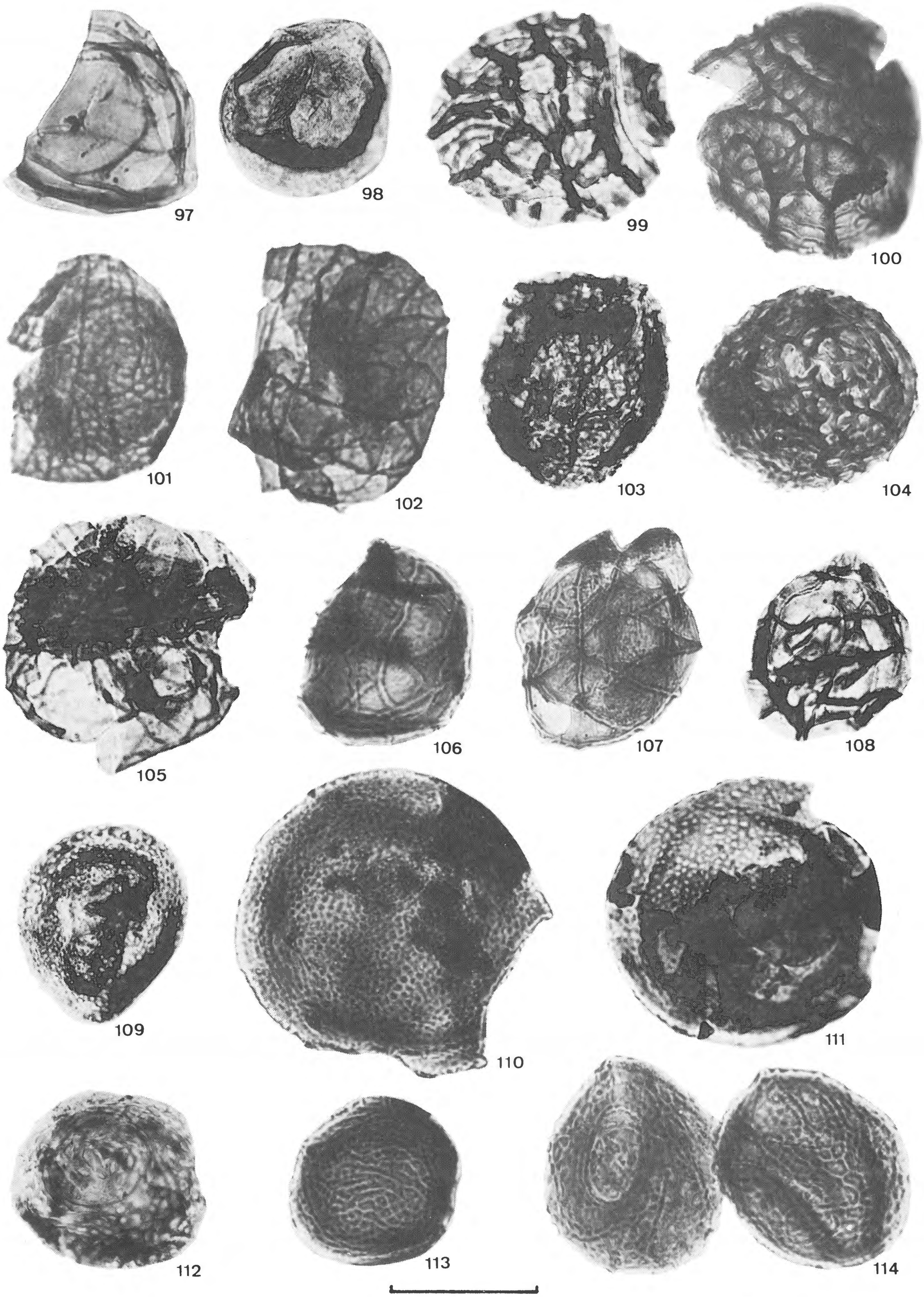
Vestispora pseudoreticulata SPODE 1967
Pl. 5, fig. 101-103.

Remarks: Ornament consisting of weak and irregular reticulum of primary muri, which enclose a well developed secondary reticulum. Primary muri less than one-half the width of those in *V. magna.*

Occurrence:
Limburg – infrequent in uppermost Westphalian A and basal Westphalian B; common in middle and upper parts of Lower Westphalian B; infrequent to rare in Upper Westphalian B and Lower Westphalian C; disappears at base of Upper Westphalian C.

PLATE 5
(scale = 50 μ)

Fig. 97 *Vestispora* cf. *laevigata.*
GB140; 47.2 x 104.3. Upper Westphalian C, XLV Borehole.
Fig. 98 *Vestispora laevigata.*
NAM6714, Hellevoetsluis-1 Borehole, 2913 m. Westphalian D.
Fig. 99 *Vestispora magna.*
NAM6699, Hellevoetsluis-1 Borehole, 3305 m. Lower Westphalian C.
Fig. 100 *Vestispora magna.*
GB151; 28.1 x 106.0. Upper Westphalian C, XLV Borehole.
Fig. 101 *Vestispora pseudoreticulata.*
GB145; 49.3 x 100.6. Base of Upper Westphalian C, XLV Borehole.
Fig. 102 *Vestispora pseudoreticulata.*
GB145; 29.6 x 106.0. Base of Upper Westphalian C, XLV Borehole.
Fig. 103 *Vestispora pseudoreticulata.*
NAM1749, De Wijk-6 Borehole, 2545 m. Westphalian B.
Fig. 104 *Vestispora magna.*
GB150; 34.6 x 101.6. Upper Westphalian C, XLV Borehole.
Fig. 105 *Vestispora tortuosa.*
GB145; 38.3 x 97,6. Base of Upper Westphalian C, XLV Borehole.
Fig. 106 *Vestispora costata.*
GB145; 32.6 x 99.6. Base of Upper Westphalian C, XLV Borehole.
Fig. 107 *Vestispora costata.*
GB148; 39.4 x 103.6. Upper Westphalian C, XLV Borehole.
Fig. 108 *Vestispora costata.*
NAM6706, Hellevoetsluis-1 Borehole, 3306 m. Lower Westphalian C.
Fig. 109 *Vestispora fenestrata.*
NAM6678, K7-1 Borehole, 3449 m. Westphalian D.
Fig. 110 *Vestispora fenestrata.*
GB145; 53.8 x 98.9. Base of Upper Westphalian C, XLV Borehole.
Fig. 111 *Vestispora fenestrata.*
GB145; 25.5 x 99.5. Base of Upper Westphalian C, XLV Borehole.
Fig. 112 *Vestispora* cf. *reticulata.*
NAM9266, Reutum-1 Borehole, 2454 m. Upper Westphalian C.
Fig. 113 *Vestispora* cf. *reticulata.*
GB145; 38.8 x 95.6. Base of Upper Westphalian C, XLV Borehole.
Fig. 114 *Vestispora* cf. *reticulata.*
GB148; 53.7 x 98.2. Upper Westphalian C, XLV Borehole.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Dutch boreholes – frequent in uppermost Westphalian A to Westphalian C.
Ruhr area – one single specimen near base of Upper Westphalian C.
Campine – Upper Westphalian A to Westphalian D.
North of France – Upper Westphalian A to Westphalian D.
Britain – infrequent to common in Westphalian B to Lower Westphalian C.

Vestispora cf. *reticulata* (LAVEINE) LOBOZIAK 1969
Pl. 5, fig. 112-114.

Remarks: Reticulum rather uniform with relatively small lumina; if we should have to distinguish between primary and secondary muri, these would be described as practically of same width and height.

Occurrence:
Limburg – rare in Upper Westphalian C.
Dutch boreholes – rare to occasionally frequent in Upper Westphalian C and Westphalian D.
North of France – Upper Westphalian C.
Not recorded from Ruhr area, Campine and Britain.

TABLE III
List of boreholes in which age of Paleozoic rocks has been revised since Thiadens (1963).

Borehole	Depth in m	Age
Annerveen-Anlo-1	2994.5 - 3014.5	Westphalian A-B
Beilen-1	2896 - 2943	Westphalian B
Haaksbergen-1	882 - 1008	Upper Westphalian C
Haastrecht-1	2504 - 2507	Westphalian D
Ried-1	3001 - 3039	Westphalian A
Zeddam-1	1216 - 1964	Westphalian A
Wanneperveen-1	2019.5 -? 2070	Westphalian A

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APPENDIX

NOTE ON SOME WESTPHALIAN MEGASPORES FROM THE NETHERLANDS

S.J. DIJKSTRA

The rapid increase of data on detailed stratigraphic sections through the Westphalian in wells in The Netherlands and the Dutch part of the continental platform during the past ten years has shown that the stratigraphic range of some megaspore species in this area is slightly longer than I suggested in former publications.

Cystosporites verrucosus, Superbisporites superbus, Valvisisporites auritus and *Setosisporites praetextus* occur already in the middle part of the Upper Westphalian A (miospore zone *Radiizonates aligerens,* lamellibranch zone *Carbonicola communis*). Up to now, assemblages with these spores had been considered to characterize the Westphalian B and C.

On the other hand, the first occurrence of *Triletisporites tuberculatus* and *Valvisisporites stephanensis* PIERART 1965 (formerly described as *Triletes auritus* var. *grandis*) in the top of the Upper Westphalian C has been confirmed.

A most contradictory isolated occurrence of *Lagenicula crassiaculeata,* up to now only known from the Dinantian and Namurian A-B of Scotland, Poland and Turkey (Dijkstra 1952), in undoubted Upper Westphalian A of the Zeddam-1 borehole at 1243.50 meter should further be noted. According to Jongmans (pers. comm.), this species may be the megaspore of *Lepidodendron acuminatum,* a plant which disappeared at the end of the Namurian B. In the Upper Westphalian A sample of Zeddam-1, numerous specimens and a complete sporangium with these spores have been recognized from a coal seam. It seems hardly possible that these specimens with well preserved spines represent a reworked element in a further normal Upper Westphalian A microflora.

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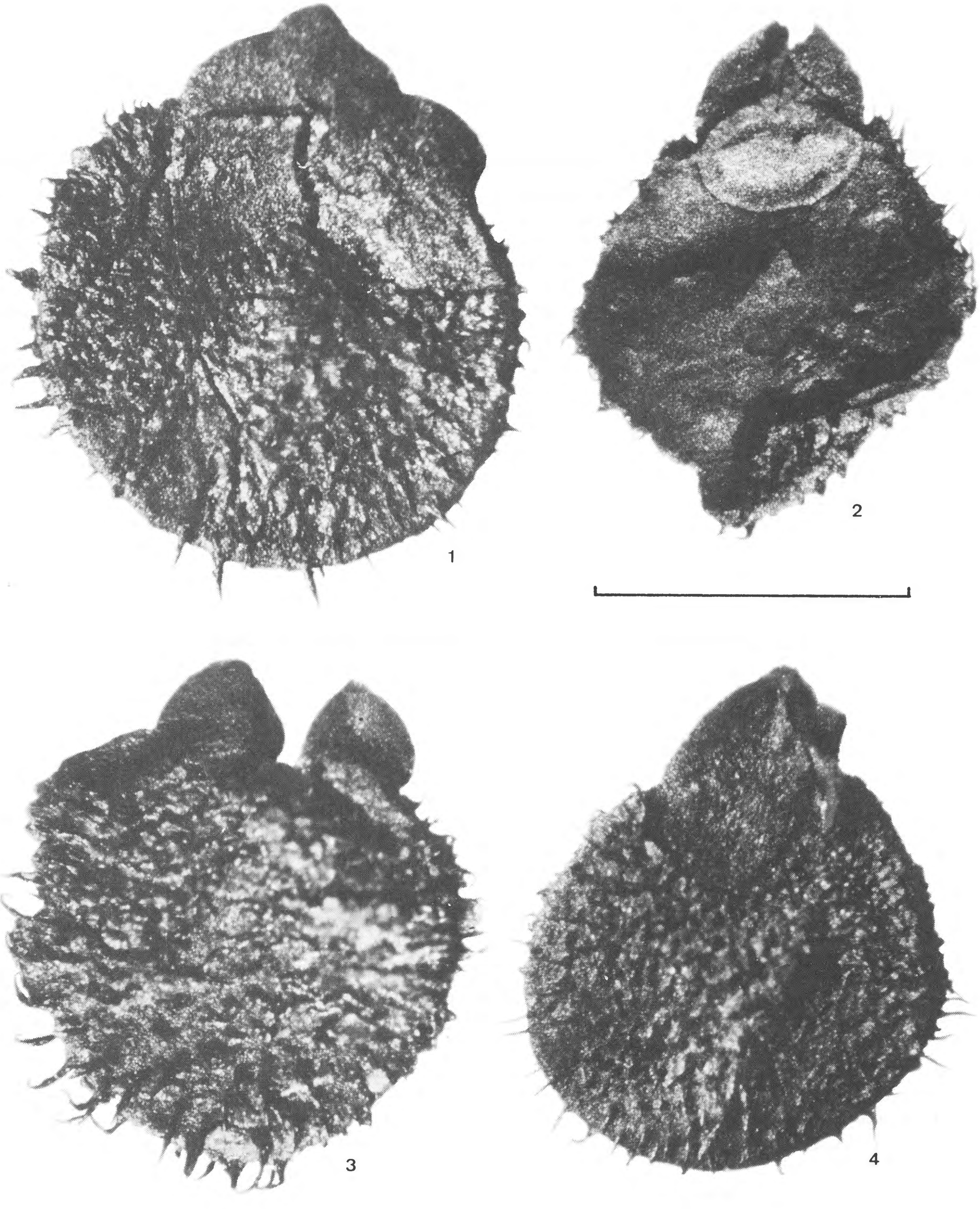

PLATE 1
(scale = 1 mm)

Fig. 1-4 *Lagenicula crassiaculeata.*
Zeddam-1 Borehole, 1243,50 m. Upper Westphalian A, zone with *Radiizonates aligerens* and *Carbonicola communis.* Species also recognized in same borehole at 1396.98 m, 1541.10 m and 1810.0 m.