A PALYNOSTRATIGRAPHIC CLASSIFICATION OF THE WESTPHALIAN OF THE SOUTHERN NORTH SEA CARBONIFEROUS BASIN.

By

DUNCAN McLEAN

A thesis submitted in partial fulfilment of the requirements of the the degree of Doctor of Philosophy.

Centre for Palynological Studies,
Department of Earth Sciences,
University of Sheffield,
October, 1993

A PALYNOSTRATIGRAPHIC CLASSIFICATION OF THE WESTPHALIAN OF THE SOUTHERN NORTH SEA CARBONIFEROUS BASIN.

DUNCAN McLEAN

SUMMARY.

Based upon the examination of the palynostratigraphy of 28 well sections and 6 multi-well studies, the Westphalian sequences in the Southern North Sea Carboniferous Basin are divided into 7 biozones and 12 sub-biozones. These are related, via the known regional northwest European palynostratigraphy, to the chronostratigraphic units of the Westphalian.

Analysis of 164 palynological samples from Westphalian sections in the Murdoch Gas Field wells 44/22-1, 44/22-3 and 44/22-4, coupled with the recognition of diagnostic macrofossil faunas indicative of the Vanderbeckei Marine Band, allows the direct calibration of part of the palynostratigraphic classification with the chronostratigraphy.

Palynological assemblages from these wells contain significant numbers of acritarch and miospore taxa interpreted as being reworked from Lower Palaeozoic, Devonian and early Namurian sediments, possibly during multiple phases of reworking. Assemblages also contain unusually old examples of striate disaccate and monocolpate pollen.

One new genus (*Marasmosporites*) and eighteen new species (*Auroraspora? pickerillensis, Dibolisporites ranunculioides, Elaterites anfractus, Endosporites pygmaeus, Hymenospora murdochensis, Knoxisporites biceps, Kraeuselisporites crassus, K. pseudoornatus, Marasmosporites semiesus, Neoraistrickia exigua, N. virgultorum, Pityosporites inaequus, Protohaploxypinus masonii, Raistrickia parvula, Savitrisporites semotus, Spelaeotriletes oppletus, S. bulboides* and *Vestispora dubia*) are described.

For

Jean and **Andy**

and the memory of

Keith.

ACKNOWLEDGEMENTS.

I should like to give especial thanks to Dr. R. Neves for the initiation of this study, for guidance and encouragement throughout its course, and for the use of the facilities of the Industrial Palynology Unit, the University of Sheffield.

I am indebted to Prof. A. Spears for the use of the facilities of the Department of Earth Sciences, the University of Sheffield.

I am indebted to Conoco (UK) Ltd. for the provision of, and permission to work with, materials from the southern North Sea and I should like to thank the many people in that company who have facilitated and encouraged this project, in particular John Wood, Mike Mason, Kim Watson, Jon Newbery, David Oliver and Mike Gage.

I should like to acknowledge Nick Turner, Michael O'Liathain, John Keating, Nick Hogg, Mike Snape, Ted Spinner, Dave Jolley, Tony Loy and Nicky Hine: colleagues who have helped in many ways with the development of my ideas and with the production of this thesis.

Drs. W.H.C. Ramsbottom, R. Neves and M. Mason are thanked for their work in collecting and identifying macrofossils.

I should like to thank the technical staff of the Department of Earth Sciences and in particular Mike Cooper (for valued advice in the use of drafting software) and Barry Piggott (for reproduction of the photographic plates).

Many friends deserve thanks for support and forbearance. They know who they are. Especial recognition goes to those with whom I have lived during the course of this study: Carmel and Emma, and Kat and Billie-Mo.

Finally I should like to thank Drs. A. McLean and R. Broughton for imparting the secret knowledge of how to complete a doctoral thesis in less than eight years.

CONTENTS.

1. INTRODUCTION.

Recent, important hydrocarbon discoveries in the Silesian of the southern North Sea have focussed attention on the palaeontological division and recognition of these sequences. Traditional macropalaeontology is of limited use in this area due to the destruction of macrofossils during drilling. Micropalaeontological and, in particular (due to the lithological and palaeoenvironmental nature of the sequences), palynological techniques have a great advantage.

In order to integrate the palaeontological data from several wells which penetrate Westphalian (late Silesian) sections in the Southern North Sea Carboniferous Basin it has proved desirable to erect a standard palynostratigraphic classification for these sequences. This has been achieved by reference to palynological data acquired over the last twenty or so years by routine and review analyses of over fifty Westphalian well sections from the Southern North Sea Carboniferous Basin by the Industrial Palynology Unit of the University of Sheffield. Further data has been acquired from numerous unpublished Ph.D. theses from the University of Sheffield and from an extensive literature describing onshore European Carboniferous palynostratigraphy.

In order to attempt to calibrate the palynostratigraphic classification with the standard chronostratigraphy, three well sections from the southern North Sea from which independent macropalaeontological control is available have been analysed in detail.

1.1. THE SOUTHERN NORTH SEA CARBONIFEROUS BASIN.

Drilling and seismic data reveal the presence of a pre-Permian sedimentary basin beneath the southern North Sea (Glennie *et al.*, 1987; Evans *et al.*, 1992). Carboniferous rocks within this basin are broadly disposed in a large, gentle ESE-plunging anticline (Eames, 1975; Smith, 1985) and are unconformably overlain by the Rotliegendes (Parsley, 1986). The name Southern North Sea Carboniferous Basin (S.N.S.C.B.) has been applied to this regional structure by Leeder & Hardman (1990).

1.1.1. Historical introduction.

It has long been recognised that Carboniferous sediments provide the source for gas discovered in Rotliegendes and Bunter reservoirs in the Southern North Sea (e.g. Eames, 1975; Cornford, 1984; Hedemann, 1985). Although oil has been produced from Carboniferous reservoirs of onshore UK since the 1930's (Lees & Cox, 1937; Kent, 1985; Bowen, 1991) rocks of similar age in the S.N.S.C.B. have poor reservoir qualities compared with the overlying Rotliegendes sandstones (Glennie, 1986). Furthermore, the lack of interest in Carboniferous hydrocarbon plays was compounded by the problem of poor seismic resolution and the difficulties of subsurface mapping of these sequences (Besley, 1990). Consequently, until recently the Carboniferous has been considered to be economic basement in the southern North Sea, and most exploration wells do not penetrate more than 10 or 20m. into 'ratholes' in the oxidised Carboniferous sediments lying beneath the Permian unconformity. These oxidised sediments rarely contain palynomorphs and so stratigraphic control on these short penetrations into the Carboniferous is lacking.

Recognition of the development of widespread secondary porosity in Westphalian sandstones and advances in the understanding of basin evolution, together with economic factors such as the improvements in the prospective prices for gas in the early 1980s and encouragement by the UK Department of Energy, have led to reappraisal of the reservoir potential of the Silesian of the S.N.S.C.B. (Cowan, 1989; Besley, 1990). A major development in hydrocarbon exploration in the North Sea Gas Basin has been the drilling of deep wells beneath the Permian into the Carboniferous. Several of these wells have proved thick Silesian sequences (Leeder & Hardman, 1990; Leeder *et al.*, 1990) some of which have yielded commercial quantities of natural gas (Besley, 1990). Subsequently, hydrocarbon exploration has identified several economic Silesian reservoirs (e.g. Bailey, *et al.*, 1993; Besley, *et al.*, 1992; Hollywood & Whorlow, 1993), such as the Murdoch/Caister Sandstone (Gunn *et al.*, 1993; Ritchie & Pratsides, 1993)

In view of this increased interest, many of the Carboniferous sections in the S.N.S.C.B. have been re-evaluated by exploration companies. Even so, there are many large gaps in the understanding of the geology of the basin. The principal methodology for interpretation remains the extrapolation into the off-shore from onshore sequences in the surrounding area (Besley, 1990). Given the similarities between Silesian sequences across Northwest Europe, there does seem to be an *a priori* case for the comparison of S.N.S.C.B. sedimentary sequences and facies with those from onshore UK (Besley, 1988). This appears to be borne out by sedimentological studies which find that off-shore well sections compare closely with onshore sections from the Northumberland Trough and the Pennine Basin (Collinson *et al.*, 1993).

1.2. SILESIAN STRATIGRAPHY.

The Silesian Subsystem of the Carboniferous System corresponds to the Upper Carboniferous of Western Europe (van Leckwijk, 1960). The major divisions of the Silesian (Namurian, Westphalian and Stephanian) are regarded as Series (George & Wagner, 1972; Ramsbottom *et al.*, 1978). The Chronostratigraphy of the Carboniferous of Northwest Europe is outlined in Figure 1.

The lower limit of the Silesian Subsystem corresponds with the lower limit of the Pendleian Stage of the Namurian Series. This boundary is defined as the base of the strata containing the goniatite species *Cravenoceras leion* Bisat 1930. This definition is biostratigraphical in concept. There has yet to be a stratotype assigned to define the base of the Silesian, although Ramsbottom (1981) has proposed such a section.

The upper limit of the Silesian is defined by the base of the overlying Permian. This too has yet to be formally agreed but this does not represent a problem in Britain and the southern North Sea where the upper part of the Silesian is absent. Here the preserved Silesian succession contains scarcely any sediments attributable to the Upper Carboniferous in the Russian sense (Figure 2). The highest Silesian sediments are only slightly younger than the top of the Russian Middle Carboniferous and the American Middle Pennsylvanian (Wagner, 1974; Ramsbottom *et al.*, 1978).

1.2.1. A comment on the future of Carboniferous stratigraphic nomenclature.

International agreement on the division of the Carboniferous System is due to undergo a major change. Following ten years of discussion on Carboniferous nomenclature (Lane & Manger, 1985) the Subcommission on Carboniferous Stratigraphy in 1984 approved a proposal to establish a formal boundary between the upper and lower parts of the System. The designation of this boundary, which will be located at the horizon of the Subglobusum

SYSTEM	SUBSYSTEM	SERIES	STAGE
CARBONIFEROUS	SILESIAN	Stephanian	Stephanian C
			Stephanian B
			Baruellian
			Cantabrian
		Westphalian	Westphalian D
			Bolsovian
			Duckmantian
			Langsettian
		Namurian	Yeadonian
			Marsdenian
			Kinderscoutian
			Alportian
			Chokierian
			Arnsbergian
			Pendleian
	DINANTIAN	Viséan	Brigantian
			Asbian
			Holkerian
			Arundian
			Chadian
		Tournaisian	Courceyan

Figure 1. Chronostratigraphic Units of the Carboniferous of Europe. After Wagner (1974) and George *et al.* (1976).

Marine Band (Riley *et al.*, 1987), will bring into existence two, as yet unnamed, subsystems, neither of which are equivalent to the Dinantian/Silesian nor the Mississippian/Pennsylvanian of current usage (Figure 2). The formal establishment of the new boundary and subsystems is expected in 1993 or 1994 (John Varker, pers. comm. January, 1993). It is probable, then, that the stratigraphic nomenclature of subsystems used in this thesis is soon to be out of date.

1.2.2. Subdivision of the Westphalian.

The 2nd International Congress on Carboniferous Stratigraphy in Heerlen, 1935, defined contiguous Stages within the Westphalian as Westphalian A, B, C, and D in ascending sequence (Jongmans & Gothan, 1937). Owens *et al.* (1985) proposed replacement of the Heerlen terminology with stage names based on stratotypes within the British Isles. In their classification the Westphalian A is replaced by the Langsettian Stage, the Westphalian B by the Duckmantian Stage, and the Westphalian C by the Bolsovian Stage. The stratigraphic classification of the Westphalian is shown in Figure 3.

The base of the Langsettian Stage is defined by the base of the Subcrenatum Marine Band (= Pot Clay M.B. = Sarnsbank M.B.). The Stage is equivalent to the Westphalian A of the Heerlen classification with its upper limit being placed within the Modiolaris Zone at the Vanderbeckei Marine Band. The top of the Langsettian Stage corresponds to the base of the Duckmantian.

The base of the Duckmantian is defined by the base of the Vanderbeckei Marine Band (= Clay Cross M.B. = Amman M.B. = Katharina M.B.). The stage is equivalent to the Westphalian B of the Heerlen 1935 classification and embraces the upper part of the Modiolaris and the whole of the Lower Similis-Pulchra Zones (Owens *et al.*, 1985). The top of the Duckmantian corresponds to the base of the Bolsovian Stage which is taken at the base of the Aegiranum Marine Band (= Mansfield M.B. = Aegir M.B.).

In this account the stratigraphic nomenclature of Owens *et al.* (1985) is used for the Westphalian in preference to the "international" nomenclature proposed by Harland *et al.* (1982), based on Russian sections. The latter has yet to gain wide acceptance in Britain.

Europe Series	C.I.S. Series	U.S.A. Subsystems	China Series	Proposed Worldwide Series
Stephanian	Upper Carboniferous	Pennsylvanian	Upper Carboniferous	Unnamed (Upper Carboniferous)
Westphalian	Middle Carbonifeous			
Namurian		▥	?	
	Lower Carboniferous	Mississippian	Lower Carboniferous	Unnamed (Lower Carboniferous)
Viséan				
Tournaisian				

Figure 2. International Correlation of the Carboniferous. After Wagner (1974), George *et al.* (1976), Ramsbottom *et al.* (1978) and Riley *et al.* (1987).

Sub-system	Series	Stages Jongmans & Gothan (1937)	Stages Owens et al. (1985)	Marker goniatite bands
SILESIAN	Westphalian	Westphalian D	Westphalian D	
		Westphalian C	Bolsovian	
				A. aegiranum
		Westphalian B	Duckmantian	
				A. vanderbeckei
		Westphalian A	Langsettian	
				G. subcrenatum
	Namurian (pars.)	Namurian C	Yeadonian	

Figure 3. Chronostratigraphic Units of the Westphalian.

1.3. THE SILESIAN OF NORTHWESTERN EUROPE.

The Silesian palaeogeography and palaeotectonic setting of Northwest Europe is illustrated in Figures 4 and 5. Details of the European Silesian geology can be found in Ziegler (1990) and references therein.

1.3.1. Tectonic setting of Northwest Europe.

Plate tectonic reconstructions suggest that the British Isles and the southern North Sea lay in an equatorial to subequatorial position North of the active Devonian/Carboniferous Variscan orogenic belt. This orogenic belt resulted from the collision of African Gondwanaland with European Laurussia (Ziegler, 1981; Leeder, 1988b). The initial deformation of the belt started in the Late Devonian across central Europe, associated with a northward dipping subduction zone. Related to this was a back-arc seaway extending from south west England into central Germany. As the orogen evolved the deformation front migrated northwards. The closure and deformation of the back-arc seaway led to the formation of a flexural foreland basin on which were developed the Central Pennine and Southern North Sea Carboniferous Basins (see below). Contrasting models have been developed to explain subsidence patterns which controlled deposition on this foreland. These include crustal extension (Leeder, 1988b), transtension and dextral shear (Dewey, 1982) and loading of the foreland by advancing nappe sheets (Dewey, 1982). The foreland migrated northwards during the Namurian and Westphalian, reaching its maximum northward extent in central England during the Westphalian and Stephanian. Regional Variscan deformation reached these areas in the Autunian producing widespread folding and block faulting. This was associated with, and followed by, major erosion which formed the Saalian ("basal Permian") Unconformity.

1.3.2. Background Geology of the Southern North Sea Carboniferous Basin.

The S.N.S.C.B. is part of a large, retro-arc structure located on the Carboniferous foreland immediately to the north of the Anglo-Brabant High and immediately south of the Mid North Sea High (Figure 8). It is best viewed as an eastern continuation of the Pennine Carboniferous Basin. The two sub-basins are separated in the south by the East Midlands Shelf, an area of relatively low subsidence during the Silesian, intruded by ?Caledonian granitoids (Leeder & Hardman, 1990; Donato, 1993).

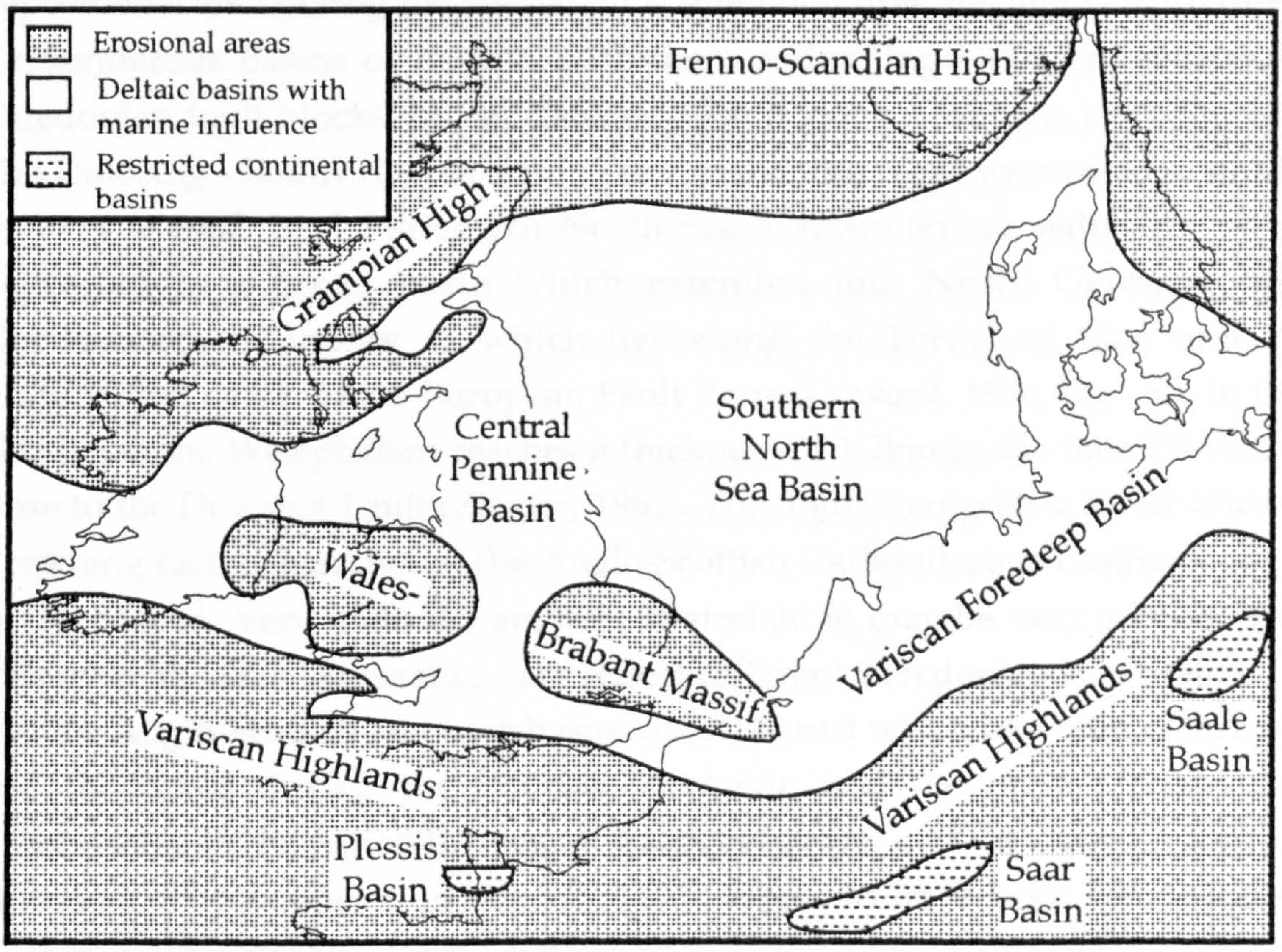


Figure 4. Westphalian palaeogeographic reconstruction of Northwest Europe (after Ziegler, 1990 and Cope *et al.*, 1992).

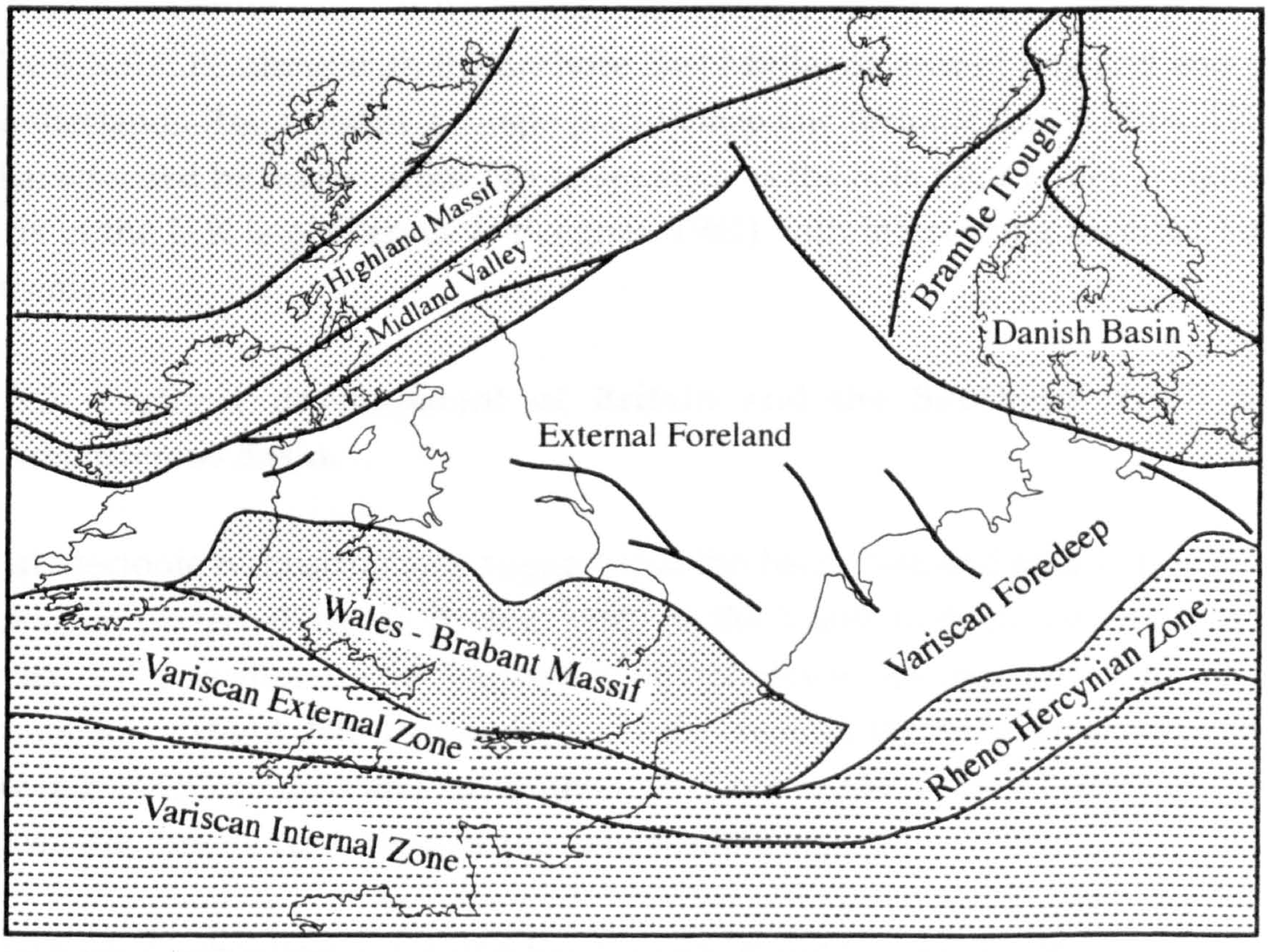


Figure 5. Westphalian tectonic reconstruction of Northwest Europe (after Ziegler, 1990).

The S.N.S.C.B. formed a morphologically smooth and almost horizontal depositional area during the Silesian. It is separated from the more complicated Carboniferous basins of Britain, with their underlying basement of broken Caledonian fault blocks, by the Dowsing Fault Zone (Coward, 1990, fig. 16). The Dowsing - South Hewett Fault Zone marks the Northeastern edge of the Brabant Massif. In the southern North Sea, Carboniferous sediments were deposited in a broad basin which extended into North Germany, the Northeastern boundary of which lies along the Tornquist Line and its continuation as the Trans-European Fault Zone (Coward, 1990, Fig. 16). In the North Sea the Westphalian reaches a thickness of 1.2km in the Sole Pit Basin, close to the Dowsing Fault (Ziegler, 1981). This figure suggests a lower crustal stretching factor than that of the Anglo-Scottish Carboniferous Basins, though as the basin is very wide the amount of stretching may be very similar. The difference in basin kinematics may reflect different Caledonian inheritance, in that the Anglo-Scottish and Irish basins overlay crust which had been deformed and thickened during the Silurian-Devonian and the main stretch was concentrated in the region between the Iapetus suture and the older Cadomian basement. The extension in the S.N.S.C.B. seems to have been concentrated further south, possibly along a continuation of the North German Caledonides (Coward, 1990).

The S.N.S.C.B., along with the onshore East Midlands area of England and the Netherlands Basin, forms a single post-Palaeozoic tectonic unit (Gibbs, 1986) characterised by major strike-slip zones such as the Sole Pit, Market-Weighton axis in the U.K (e.g. Glennie & Boegner, 1981) with intervening inverted sub-basins.

1.3.3. Tectonic development of Britain and the Southern North Sea Carboniferous Basin.

Plate tectonic reconstructions suggest that the North Sea and adjacent onshore areas lay 'external' (*sensu* Besley, 1988) to the Variscan front, i.e. occupied a more distal position on the Variscan foreland. Basin fills were only affected by moderate or slight deformation in the latest stages of the Variscan orogeny and are unmetamorphosed and autochthonous. Even so the tectonic history of these areas was largely controlled by the nature of the orogen.

The Early Carboniferous Central Pennine Basin and S.N.S.C.B. were established on the fragmentary remains of the "Old Red Sandstone Continent" broken up by widespread crustal extension in the area of the Anglo-Brabant Massif. Tectonic control and subsidence of these basins was determined by the location of Precambrian and Caledonian granites (Bott, 1967; Donato, 1993) and earlier relict structural grain (Fraser *et al.*, 1990; Leeder & Hardman, 1990). The mechanism behind this Early Carboniferous extension is the subject of debate (see Haszeldine, 1984; Read, 1988). Nevertheless, the whole of the S.N.S.C.B. suffered lithospheric extension in the Late Devonian to mid Carboniferous with the development and filling of active fault-bounded half grabens.

During the late Carboniferous differential subsidence associated with crustal extension gave way to more uniform thermal subsidence interpreted by Leeder & Hardman (1990) as a post-rift phase of thermal sag subsidence. Haszeldine (1984) interprets the Langsettian/Duckmantian basins of the British Isles as being of tensional rift origin with sediment source reactivation due to uplift related to crustal fracturing which extended to the west and northeast of the British Isles. A much more uniform distribution of sediment thickness is seen in the Namurian and early to middle Westphalian of the Central Pennine Basin and S.N.S.C.B., although syndepositional faulting continued to affect the southern margins of the basins (Fulton & Williams, 1988; Besley, 1990). Furthermore, seismic data from the S.N.S.C.B. shows the regional development of a post-rift megasequence over the S.N.S.C.B. (Fraser & Gawthorpe, 1990). Isopachs for the post-rift section exhibit a classic "bullseye" pattern (Figure 6) which is best interpreted as resulting from a phase of passive thermal subsidence (Leeder & Hardman, 1990).

From the middle Duckmantian onwards, patterns of sedimentation were increasingly affected by the approach of the Variscan deformation front. Fault activity in the basin increased and local unconformities developed in the late Bolsovian and Westphalian D. In the S.N.S.C.B. crustal shortening caused growth folding and the development of syn-tectonic unconformities along the margins of the growth folds and their surrounding aprons of fluviatile red beds (Leeder & Hardman, 1990).

North-South compression associated with the Variscan orogeny is invoked to account for late Carboniferous inversion in the Northwest-Southeast zone of crustal weakness in the Sole Pit area (Glennie & Boegner, 1981). In the late Carboniferous inversion phase, right-lateral movement resulted from North-South compression, and in the Permian subsidence phase, East-West tension is presumed to have resulted in further right-lateral movement along

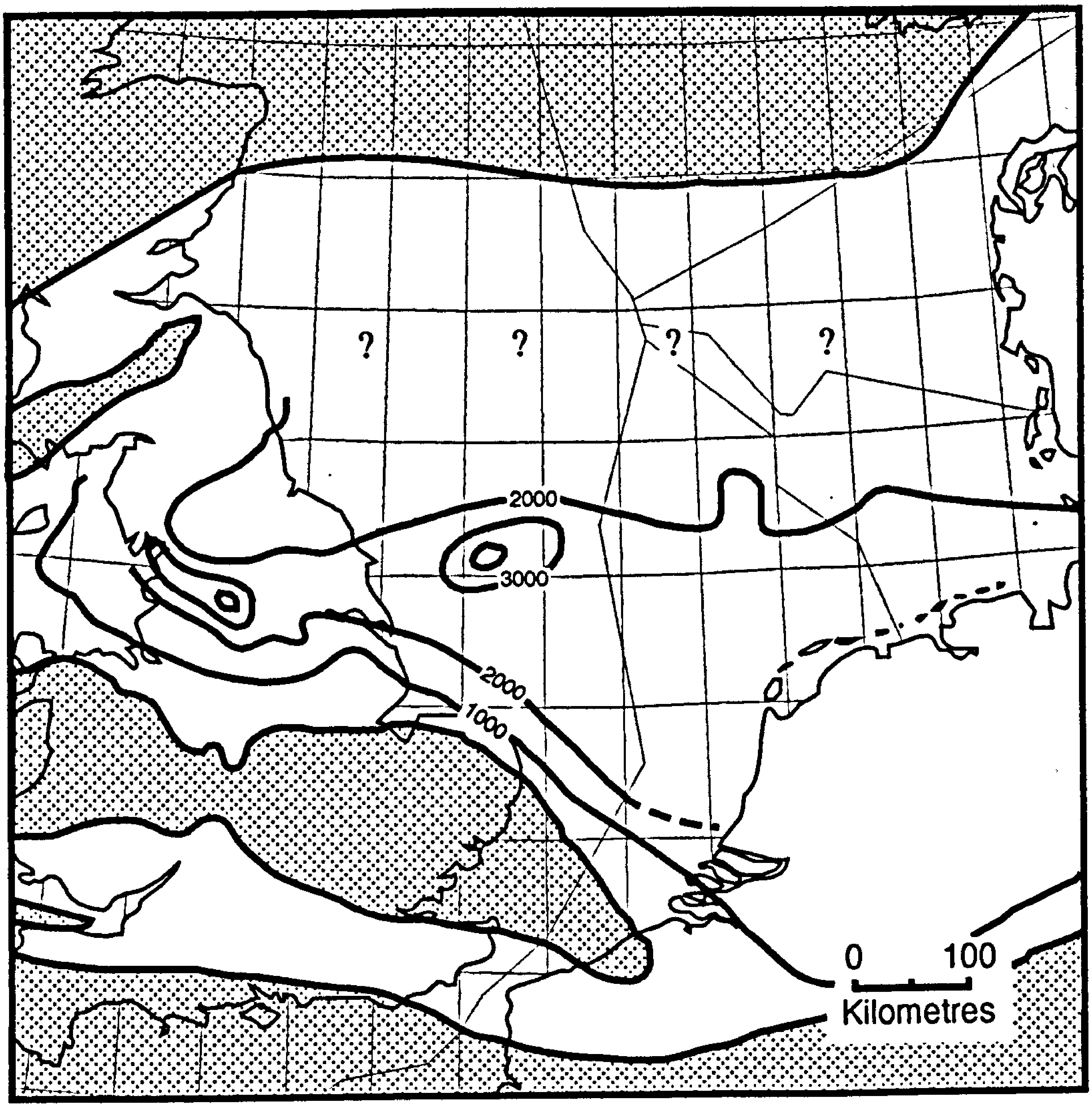


Figure 6. Generalised Langsettian/Duckmantian isopach map of the Central Pennine and Southern North Sea Basins (after Guion & Fielding (1988), Leeder & Hardman (1990) and Ziegler (1990)). Isopachs in metres.

approximately the same faults (Glennie, 1986). In the late Westphalian the Silesian basins were inverted by the onset of a regional East-West compressive stress in the Variscan foreland. In some areas (structural domain 1 of Leeder & Hardman (1990)) anticlines developed by the simple compressive reactivation of earlier listric normal growth faults. In others groups of *en-echelon* anticlines indicate a more complex relationship with pre-existing basin structures. Sediment was redistributed from structural highs within the basin during the late Westphalian and a profound erosion of the main inverted areas continued throughout the Stephanian and early Permian. This latest Westphalian and Stephanian inversion was a response to compressional stresses that affected the Variscan foreland during the terminal phases of the Variscan orogeny (Anderton *et al.,* 1979).

Following the North-South compression associated with the Variscan orogeny, relative movement between Laurasia and Gondwana became orientated East-West (Ziegler, 1982b). The resulting system of Northwest-Southeast trending right-lateral and conjugate left-lateral Northeast-Southwest trending wrench faults brought about the collapse of the Variscan fold belt in the Stephanian and Autunian. In the S.N.S.C.B. many of these wrench faults are aligned parallel to the Precambrian Charnoid structures of the East Midlands of England.

The post-Carboniferous tectonic evolution of the S.N.S.C.B. is described by Glennie (1990). The topic is too extensive to be covered in this work. Suffice it to say that within the S.N.S.C.B. are several distinct sub-basins which have had different subsidence and inversion histories during the latest Palaeozoic, Mesozoic and Cenozoic. These include the Sole Pit, Silver Pit, Cleaver Bank, Amethyst Platform and Cleveland Basins (Glennie & Boegner, 1981). Details of the structural and tectonic evolution of these, and their relations to hydrocarbon evolution can be found in works in Glennie (1990), Abbotts (1991) and Quirk (1993).

1.3.4. Pre-Carboniferous Basement.

Little is known about the pre-Upper Palaeozoic basement to the S.N.S.C.B.. It is probably underlain by Caledonian low-grade metamorphic rocks and granitoid intrusions (Frost *et al.,* 1981). The basement probably represents a branch of the mid-European Caledonides that links the English Lake District and northern Pennines to the Ardennes (Pharaoh *et al.;* 1987; Soper *et al.,* 1987).

There is evidence from wells in Quadrants 30, 36, 37 and 38 that the Dinantian sequences that dip off the southern flank of the Mid North Sea High are underlain by substantial thicknesses of Late Devonian fluviatile clastic sediments. In central Quadrant 37 there is evidence that Permian strata rest directly upon the Lower Palaeozoic basement (Leeder & Hardman, 1990). However, as these pre-Carboniferous sediments are too deeply buried to play any role in the hydrocarbon prospectivity of the southern North Sea they have been rarely studied (Richards, 1990).

1.3.5. Dinantian stratigraphy.

Dinantian sequences penetrated on the southern flank of the Mid North Sea High vary from fluviatile red bed facies of Old Red Sandstone type to alternating limestone/clastic facies of Yoredale type. Coeval onshore analogues of these facies are present in the syn-rift basins of Stainmore, Askrigg, Alston and Northumberland. Facies of Scremerston Coal Group type have also been penetrated off-shore (Leeder & Hardman, 1990).

Dinantian strata have not been penetrated in the central part of the S.N.S.C.B.. Seismic evidence seems to suggest that the Dinantian to the south of the Mid North Sea High may be represented by a basinal mudstone facies (Leeder & Hardman, 1990) with shallow water marine and fluvio-deltaic deposition over relative highs (Bailey *et al.*, 1993).

1.3.6. Namurian stratigraphy.

Namurian strata have been penetrated beneath the Permian subcrop and also in deep wells which penetrate beneath the Westphalian. Depocentres, probably related to former syn-rift lows accumulated over 2000m of sediment. Namurian facies development is exemplified by well 48/3-3 (described by Leeder *et al.* (1990) and reinterpreted by Collinson *et al.* (1993)) which shows a large-scale coarsening upwards sequence representing the progressive infilling of a deep water, formerly active syn-rift basin. In this well Marsdenian? (Leeder *et al.*, 1990) or Pendleian-Arnsbergian (Collinson *et al.*, 1993) deep water black shales pass up into delta-front turbidites and delta slope deposits, in turn overlain by coarse grained fluvio-deltaic distributary channel sandbodies. This facies evolution represents the repeated Southwesterly progradation of successive major fluvio-deltaic systems which were frequently interrupted by rapid marine transgressions. On a basinal scale, there is a gradual southwards migration of the axes of fluvial deposition with time (see Leeder & Hardman, 1990, fig. 4).

1.3.7. Langsettian/Duckmantian stratigraphy.

A Langsettian/Duckmantian depocentre is located in southern Quadrant 43 where over 1000m of sediment accumulated (Glennie, 1986; Collinson et al., 1993). This section thins southwards onto the flanks of the Anglo-Brabant High. Along much of the northern margin of this high the Langsettian/Duckmantian sediments overstep the Namurian to lie upon older strata in a 'steer's head' onlap geometry (Leeder & Hardman, 1990).

Early Langsettian sequences comprise dominantly fluvio-deltaic sediments deposited in a lower delta plain setting (Guion & Fielding, 1988), with thin marine mudstones common in the lower part and especially in the western part of the basin (Leeder & Hardman, 1990). Upper delta plain environments dominated the later Langsettian and Duckmantian sedimentation. Marine influence was minimal with the exception of the widespread, probably eustatic, transgressions of the Vanderbeckei and Aegiranum Marine Bands, and more localised marine and brackish flooding events restricted to the central part of the basins.

Major Langsettian/Duckmantian facies are represented in Guion & Fielding (1988, table 13.1) and generalised facies associations by Cowan (1989, fig. 3) (see Figure 7). In general, the sediments are similar in nature to those described in the Durham Coalfield by Fielding (1984a,b), on the Northumberland coast by Haszeldine & Anderton (1980), and in the Pennine Basin by Guion & Fielding (1988)(Glennie, 1986; Cowan, 1989). There is a general consensus that the sedimentological model developed by Fielding (1984a,b, 1986) for the Langsettian/Duckmantian of the Durham Coalfield can be applied to the bulk of the coeval sediments encountered in the central part of the S.N.S.C.B. with the addition of pebbly braided distributary channel facies. Major distributary channels were the main pathways of sediment dispersal across the delta plain. Channel systems were of several types with a range of sinuosities including braidplain sheets and laterally restricted, variably sinuous channel belts. Channels fed a hierarchy of minor distributary deltas, crevasse systems and overbank deposits, depositing sediments in shallow interdistributary lakes and bays formed primarily by compactional-induced subsidence. Deposition was predominantly by overbank flooding and crevassing into interdistributary bays

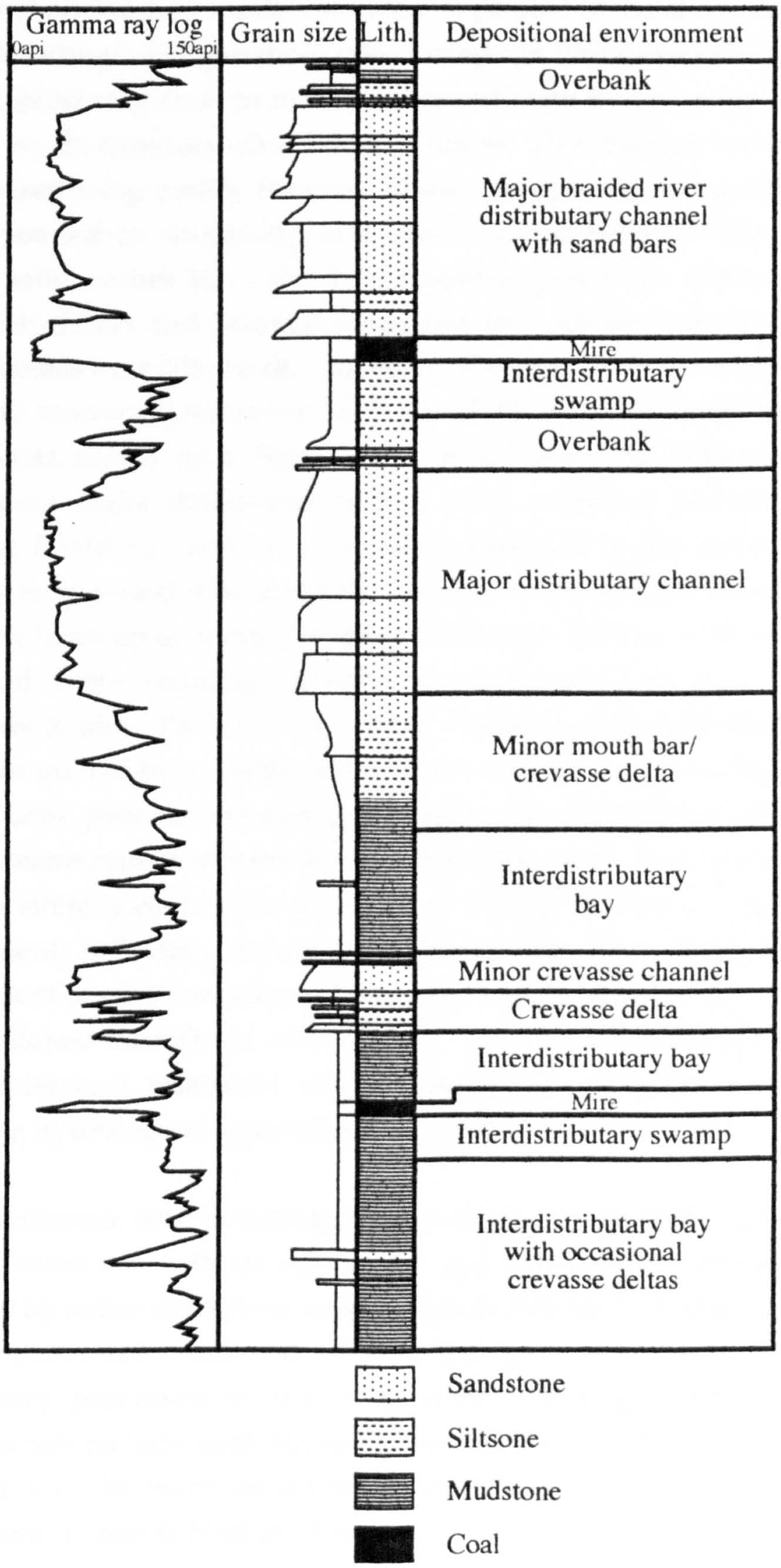


Figure 7. Simplified typical Westphalian facies associations encountered in the S.N.S.C.B., based upon Langsettian to Bolsovian cored sections (after Cowan,1989).

and lakes producing argillaceous sequences which often coarsen upwards. Thin sands interbedded with mudstones were deposited in distal crevasse splay and overbank settings, and proximal crevasse splays (minor mouth bars) produce upward-coarsening fine- to medium-grained sand bodies, often cut into and overlain by distributary channel sandstones. The channel sandstones have distinct electric-log motifs, forming 'blocky' or upward-fining sequences, and were deposited in shoestring and sheet-like geometries. The distributary channel sand bodies have the best reservoir potential. These sands show variable thickness and internal structures but can form stacked multistory channel bodies over 30m thick. Grain size is highly variable, ranging from fine-grained to microconglomeratic (Cowan, 1989). The channels formed sandy channel belts, mostly up to 5km wide, as they crossed the delta plain (Fielding, 1986). These major distributaries may have exhibited patterns of regular switching (Fielding, 1986) or may have occupied a particular belt over a relatively long period (Guion, 1978). Between these channel belts lay enclosed freshwater lakes up to about 10m deep with wave fetches of the order of 20km (estimated from palaeogeographical reconstructions and wave-ripple parameters (Guion, 1978; Fielding, 1982, 1984b)) and peat forming mires. The lakes were infilled by a combination of crevasse-splay/minor delta deposition and overbank processes enabling repeated episodes of peat mire formation. The coal seams represent such mire deposits. Coals are more abundant, thicker and more laterally continuous in the upper delta plain than in lower delta plain environment, reflecting the more frequent, long-term and more extensive development of mire conditions. They accumulated relatively slowly on infilled and abandoned lakes/bays and channels. Conversely, some of the interseam facies underwent relatively rapid deposition. Channels were subject to fluctuating hydrological regimes, possibly seasonally controlled.

Tectonic influence on sedimentation is considered to have been generally subtle although some major faults appear to have been active. Sedimentation was controlled by major delta progradation and switching on a larger scale, tectonic and compactionally induced subsidence on a medium scale, and local sedimentary processes on the small scale (Fielding, 1984b). Controls on sedimentation include both allocyclic mechanisms (eustasy and tectonics), as well as autocyclic mechanisms (delta switching at a variety of scales, and compaction) (Guion & Fielding, 1988).

Wherever the Westphalian 'grey measures' lie close to the sub Permian unconformity they are stained, predominantly red or purple, and to a lesser extent brown and yellow (Besley *et al.*, 1993). This staining which affects measures at any horizon decreases in intensity downwards, generally disappearing entirely in non-arenaceus measures within 20 metres of the unconformity. It results from deep oxidative weathering in the final stages of subaerial exposure before Permian sediments were deposited (Anderson & Dunham, 1953). Such weathering has been described from onshore UK by Mykura (1960) where it may affect up to 500m of the sub-Permian succession. Deep penetrative weathering is influenced by the nature of the Permian groundwater table and may develop to considerable depths along permeable fault planes and sandstones which acted as Permian aquifers (Mykura, 1960; Besley et al., 1993).

1.3.8. Bolsovian/Westphalian D stratigraphy.

Several hundred metres of primary red beds are well developed in the Westphalian of the Silver Pit Basin and adjacent areas of the Dutch Sector and South Hewett Shelf (Tubb *et al.*, 1986; Besley *et al.*, 1993). By analogy with the informal nomenclature used onshore these off-shore primary red beds are informally termed the Barren Red Measures or Barren Red Group. Their age is problematical due to a lack of biostratigraphic data (Besley, 1990; Besley *et al.*, 1993) although palynological data from several wells in the Silver Pit area (e.g. McLean, 1991a, 1993; Turner, 1990b; Besley *et al.*, 1993) indicates a latest Duckmantian to Westphalian D age for at least some of these sediments. In the South Hewett Shelf area they overlie Bolsovian coal-bearing sequences and are correlated with the onshore Westphalian D Keele Formation (Tubb *et al.*, 1986). Undoubtedly the boundary between red bed and coal measures facies is diachronous as seen in the English Midlands onshore (Besley, 1988). The relationship between the two facies is further complicated by the development of contemporaneous growth folds such that the red beds onlap onto the partly eroded flanks of major anticlinal structures, while conformable sequences occur in the adjacent synclines (Leeder & Hardman, 1990).

Reddening of the Barren Red Measures may be either syndepositional or of later, deeply penetrative origin beneath the pre-Permian unconformity. Differentiation of the different origins of reddening is possible (Besley *et al.*, 1993; Collinson *et al.*, 1993). The Barren Red Measures facies are characterised by red floodplain siltsones and mudstones with mature, fining-upwards channel sandstones and overbank sheet sandstones. The most distinctive feature of the facies is the development of abundant ferralitic and calcrete palaeosols which are comparable to those from onshore UK (Besley, 1987, 1988). Unlike the underlying Langsettian-Bolsovian Coal Measures facies coals and high gamma mudstones of marine origin are mostly absent. The Barren Red Measures facies represents the diachronous spread of well drained alluvium sourced from a drainage system that developed upon syn-depositional growth folds such as the Murdoch Anticline (Leeder & Hardman, 1990). Besley *et al.* (1993) recognise two lithostratigraphic divisions of the Barren Red Measures: a syn-depositionally reddened Bolsovian sequence with lithologies much like the underlying Coal Measures facies, and which passes laterally south- and eastwards into grey Coal Measures facies; and a syn-depositionally reddened Westphalian D sequence, entirely fluvial in origin and characterised by the presence of caliche palaeosols.

1.3.9. Structure.

The main tectonic structural elements within the UK sector of the Southern North Sea are shown in Figure 8. These elements are inferred from gravity data and, to a lesser extent, seismic data (Collinson *et al.*, 1993). The main structural elements south of the Mid North Sea High are eastward extensions of onshore basins (Cleveland Basin and Humber Basin), the Silver Pit and Sole Pit Basins and several granitoid-cored blocks (Silver Well Block, Amethyst Block, eastward extension of the Market-Weighton Block) (Donato & Megson, 1990; Collinson *et al.*, 1993).

Leeder & Hardman (1990) recognise three structural domains in the S.N.S.C.B. based upon seismic mapping (Figure 9). Domain 1 comprises a belt of Northwest-Southeast trending *en echelon* non-cylindrical, symmetrical buckle folds (such as the Murdoch anticline). Some of the folds are associated with thrust faults. Three generations of folds are recognised: growth folds of Bolsovian/Westphalian D age; pre-Permian folds reactivated during Mesozoic inversion; and post-Carboniferous, largely Cretaceous, folds with no pre-Permian truncation. Swarms of Northwest-Southeast trending faults cut the Carboniferous surface. They possibly reflect the upward splaying of deep-seated crustal fractures (Glennie, 1986, 1990). Many of the faults have been reactivated during later periods of Mesozoic and Cenozoic crustal stress.

Domain 2 is a ramp-like feature with steady southward thinning and progressive onlap of the Dinantian, Namurian and Westphalian sequences onto the Anglo-Brabant Massif. Intra-Carboniferous structures and pre-Permian

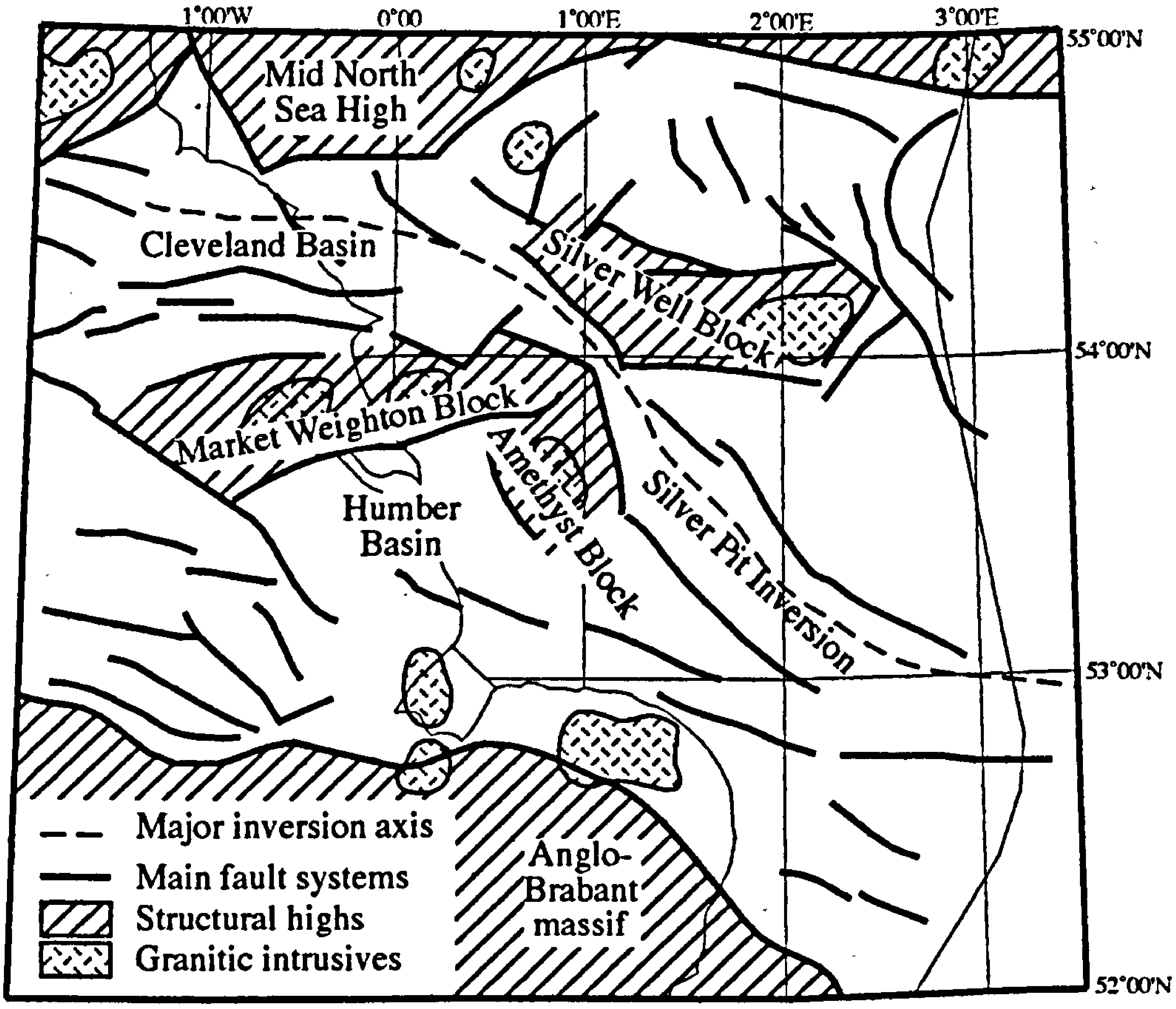


Figure 8. Tectonic framework of the southern North Sea (after Collinson *et al.*, 1993).

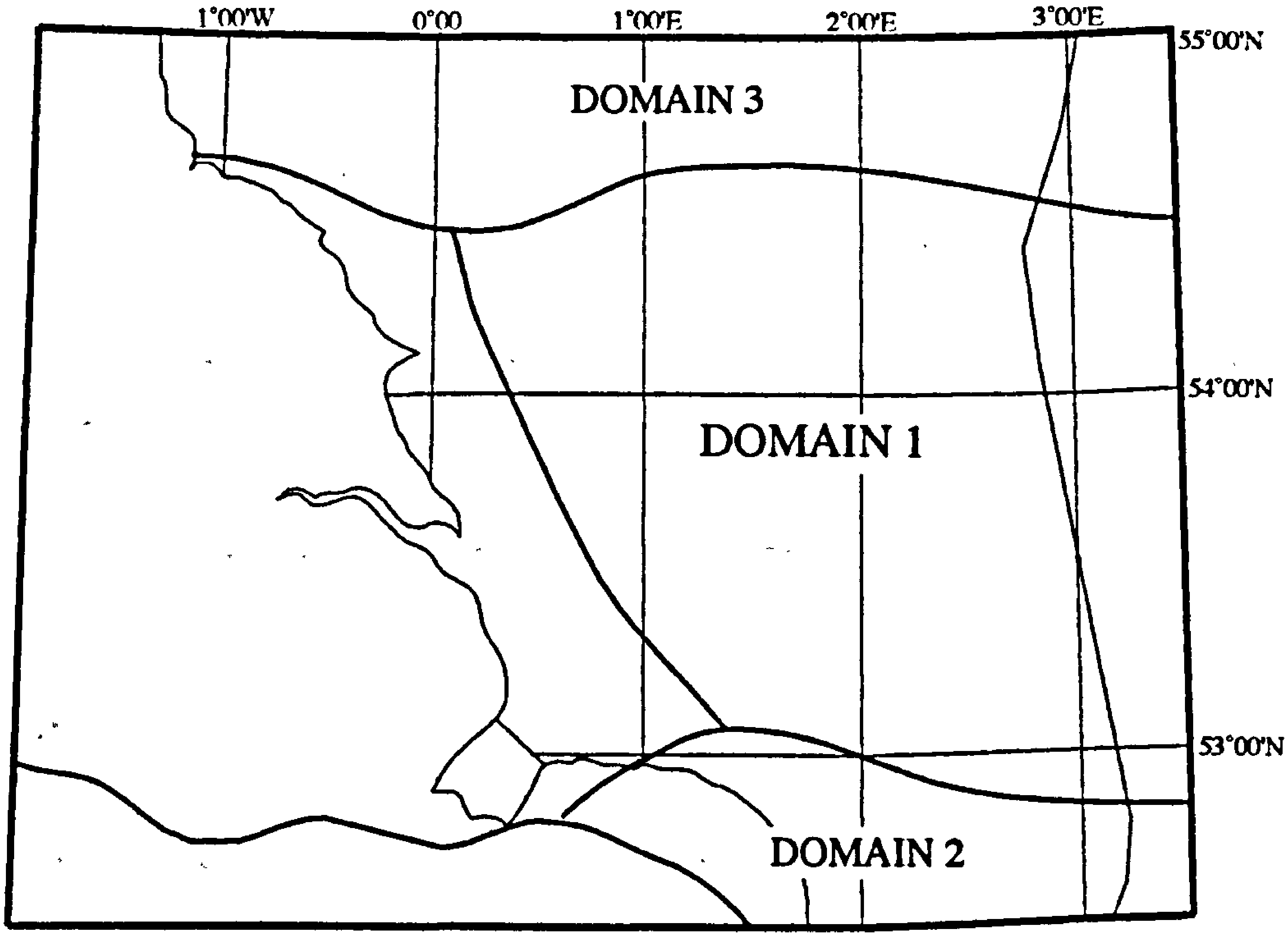


Figure 9. Structural domains in the Southern North Sea Carboniferous Basin (from Leeder & Hardman, 1990).

folds are impossible to recognise within this domain because of a dense network of Mesozoic normal faults (Leeder & Hardman, 1990).

Domain 3 is characterised by largely homoclinal strata separated by large normal faults of broadly East-West orientation which probably define intra-Dinantian tilt blocks. The domain represents the eastward extension of the northern England tilt block province. The domain occupies the southern flanks of the Mid North Sea High which represented an extension of the Southern Uplands Block during the Carboniferous. Dinantian sequences thin gradually onto the core of the High and it is assumed that during the Silesian the whole High was covered with a relatively thin onlapping Silesian sequence which was subsequently removed by erosion during the pre-Permian inversion event (Leeder & Hardman, 1990).

1.4. CORRELATION OF WESTPHALIAN SEQUENCES.

Several methods of correlating Westphalian sequences have been employed in the study of the on- and off-shore basins. Many of these, however, have severe limitations when dealing with off-shore basins from which the only available data is provided by boreholes and/or geophysical techniques. The principal difficulty lies in the fact that rock samples are usually recovered from wells in the form of fragmentary ditch cuttings in which the preservation potential for most macrofossil groups is negligible or nil. Even core and sidewall core recovery from boreholes present a low probability of macrofossil recovery. The onus on borehole biostratigraphy therefore lies with the microfossil groups, but in the S.N.S.C.B. the utility of many of these is limited by facies and paleaoenvironments of deposition, such that palynology is usually the only biostratigraphic tool available.

A comparison of the classification schemes derived from each of these methods for the Carboniferous of the S.N.S.C.B. and adjacent areas is shown in Figure 10

1.4.1. Marine Faunas.

Precise local, regional and intercontinental correlation of the laterally impersistent lithofacies characteristic of the northwest European Silesian is made possible by the presence of repeated occurrences of marine mudrocks with rapidly evolving and diagnostic goniatite faunas. Individual marine

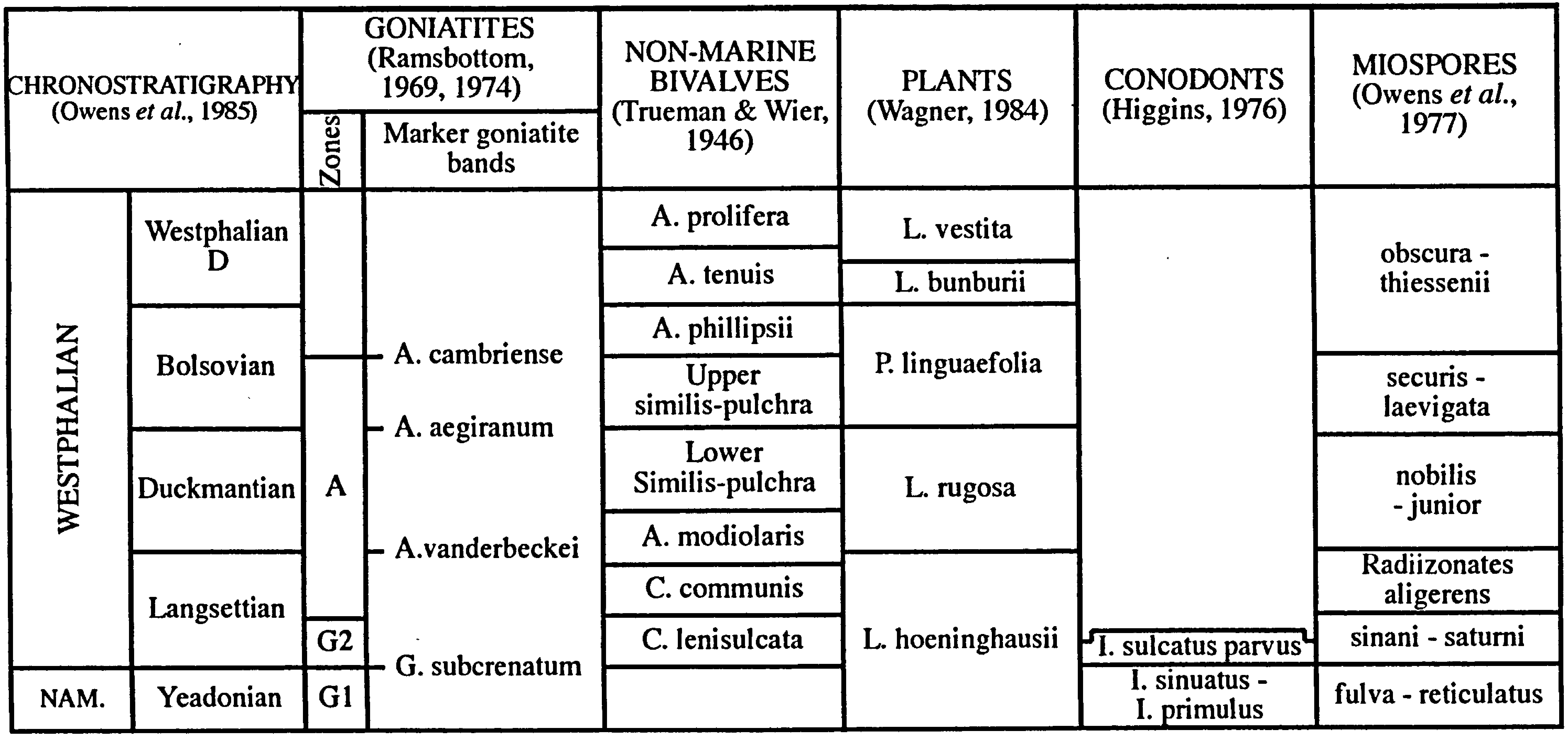


Figure 10. Correlation of Westphalian zonation schemes for various fossil groups.

horizons are of wide geographical extent and short duration, representing virtual time planes (Ramsbottom, 1969b; Ramsbottom, *et al*., 1978). Some 60 or so of these horizons occur in the Silesian, giving an accuracy of correlation comparable to that achieved using Mesozoic ammonoids (Ramsbottom, 1969b).

Silesian stage boundaries are taken at exceptionally widespread marine bands (see above). Calver (1968, 1969) reviewed the use of marine bands in correlation and their lateral facies changes and geographical distribution. In some cases the horizon of a marine band may be determined by its fauna, but in others the significance of the band lies more in its existence as a marker band than in the actual fauna it contains. The principal marine horizons are characterised by diagnostic species of goniatites or by especially rich and characteristic faunas.

Goniatites possess many of the characteristics considered desirable in fossils used for biostratigraphic zonation. During the Carboniferous they evolved rapidly and underwent successive morphological radiations. Their nektonic mode of life and potential for post-mortem distribution resulted in individual species and, more particularly, in genera being geographically widespread. The main disadvantage of the goniatites is that they may be strongly facies-bound, occurring abundantly in basinal mudstones and reefs, but rarely elsewhere. (Ramsbottom & Saunders, 1985).

The value and reliability of goniatites in Carboniferous stratigraphy is such that they have been used to set up a virtual 'orthochronology' against which zonations based on other groups of fossils have been compared. (Ramsbottom & Saunders, 1985) (Figure 10). Linking the goniatite-based biostratigraphic units of the upper Carboniferous with cyclothems, probably of glacio-eustatic origin, provides a chronostratigraphic framework for most of the major units in all but the uppermost Carboniferous. It is probable that the rapid evolution of the ammonoids was connected with the rapid eustatic changes in sea level, for new faunas appeared with the transgressions and extinctions frequently coincided with regressions (Ramsbottom, 1977, 1979). Northwest European cyclothems usually have their own diagnostic goniatite species, a fortuitous circumstance that allows the sophisticated integration of stratigraphy and palaeontology described above (Ramsbottom & Saunders, 1985).

Though useful as facies indicators, marine faunas other than goniatites (brachiopods, bivalves, gastropods, crinoids, fish (Ramsbottom, 1974)) do not usually possess a notable stratigraphic value (Paproth *et al.*, 1983). However, in

PAGE
MISSING
IN
ORIGINAL

1.4.4. Plant macrofossils.

Silesian Plant macrofossils have frequently been used for stratigraphical purposes and long distance correlations (Dix, 1934; Crookall, 1955). However, while plants give a good indication of broad stratigraphic divisions, the ranges of individual species are usually too long to provide the finer resolution provided by non-marine bivalves (Ramsbottom *et al.*, 1978). The most significant recent development in Silesian plant biostratigraphy has been the publication of the European classification of Wagner (1984) (see Figure 10). General accounts of the most important publications on this subject, and reviews of problems and biases associated with macrofloral biozonation in the Silesian are presented by Stockmans (1962) and Cleal (1991)..

1.4.5. Conodonts.

Silesian conodonts are poorly known from Europe. Their stratigraphic distribution is probably best known from Britain, particularly from the Namurian Series (Higgins, 1985). A conodont biozonation for the Namurian and earliest Westphalian, based on assemblages principally from the Craven Basin, is applicable to much of western Europe (Higgins, 1975, 1985). Little is known of later Westphalian and Stephanian conodont faunas from Europe, and no biozonation exists for these series.

1.4.6. Foraminifera.

The foraminiferal assemblages of the Western European Silesian are incompletely known (Paproth *et al.*, 1983). However, the Marine Bands of the Westphalian have yielded large numbers of benthonic agglutinated foraminifera (Pastiels, 1956). Usually, the faunas are monotonous and characterised by only a few taxa and are of little biostratigraphic utility.

1.4.7. Palynology.

Northwest European Westphalian palynostratigraphy is concerned primarily with the study and application of terrestrial palynomorphs (miospores and prepollen). Among the most significant characteristics of such fossils are their abundance, their relative resistance to destruction, and the extraordinary scope for their dispersal, especially by water. Assemblages of dispersed miospores may be preserved in both terrestrial and marine sediments. Except in autochthonous coals, each assemblage as a whole tends to reflect the combined vegetation of various parts of the drainage basin, whereas individual components of the assemblage may vary both quantitatively and qualitatively according to sedimentary factors and local concentrations of the parent vegetation onshore. Assemblages are commonly composed of thirty or more stratigraphically useful species, and many thousands of specimens may be present in a few grams of rock (Richardson & McGregor, 1986). For these reasons palynology has been able to provide a sophisticated tool in the biostratigraphic analysis of well sections in the S.N.S.C.B.

The economic applicability of palynostratigraphy to the coal and hydrocarbon reserves of the Westphalian has resulted in the development of numerous schemes for its zonal subdivision. Of the published palynological divisions which have been introduced for the Westphalian, that of Smith & Butterworth (1967), which superseded several earlier zonations of Butterworth & Millott (1954, 1960), has been most extensively applied. They synthesized data on miospores exclusively from coal seams from the British coal fields and produced a scheme of 11 concurrent range zones. Loboziak *et al.* (1976) and Coquel *et al.* (1976) synthesized data from coal basins of western Europe to and proposed more widely applicable zonations for the Westphalian and Stephanian. Data from basins throughout the whole of the Carboniferous of northwestern Europe was synthesized by Clayton *et al.* (1977) to produce a palynostratigraphic classification applicable in a regional context. Owens *et al.* (1978) attempted to establish correlations beyond the bounds of the work of Clayton *et al.* (1977) by correlating the zonal schemes of Loboziak *et al.* (1976), Smith & Butterworth (1976), and those developed for Carboniferous sequences in the Donetz Basin by Teteriuk (1976).

Given the amount of hydrocarbon exploration and development activity in the S.N.S.C.B. over the last ten years it is not surprising that many 'in-house' Carboniferous palynostratigraphic classification schemes have been developed by both hydrocarbon exploration companies (e.g. BP, Shell) and biostratigraphic service companies (e.g Simon Petroleum International). Such schemes usually involve the integration of data from off-shore well sections within a regional framework developed from published data and onshore sections (Kim Watson, pers comm. July 1990). For reasons of confidentiality and competitive advantage such schemes remain outside of the public domain and have not been available for study in this work.

1.4.8. Lithological correlation.

For short distance correlation lithological comparisons remain important. This is so for coal seams, seat earths and sandstones and also for other distinctive lithologies such as tuffs and fragmental clay rocks (Richardson & Francis, 1970) and kaolinitic claystones and/or tonsteins (e.g. Williamson, 1961; Eden *et al.*, 1963; Spears & Kanaris-Sitiriou, 1979). Coal seams are usually used as a basis for correlation within onshore coalfields, as they often contain distinctive durain bands, possess a characteristic chemical signature (e.g. high sulphur contents), or are associated with easily recognisable marker bands such as '*Estheria*' horizons (Elliott, 1968; Jones, 1980). It is significant, however, that not all coal seams correlated over large distances represent synchronous peat-forming events (Fulton & Williams, 1988). With the correlation of non-coal lithologies, however, lateral facies variations and the repetitive stacking of these facies in the delta plain and alluvial plain settings of the Westphalian of the S.N.S.C.B. make lithostratigraphic correlation very difficult (Hollywood & Whorlow, 1993).

1.4.9. Geophysical log correlation.

Lithological or macropalaeontological analyses of subsurface sections is limited when only rock cuttings are recovered from the borehole. Cored sections are expensive and usually represent only a small part of the stratigraphic section. Wireline geophysical logging is used to measure various radioactive, electrical and physical properties of subsurface sections. The electrical traces produced by wireline logging can be used in stratigraphic correlation (Whittaker *et al.*, 1985; Hurst *et al.*, 1990).

Of particular importance in the log correlation of Silesian sequences is the spectral gamma logging tool. This measures the natural gamma radiation of borehole sequences and allows marine horizons, enriched in authigenic Uranium (Leeder *et al.*, 1990), and so producing a distinctive 'spike' on gamma-ray logs, to be recognised. Such recognition is fraught with difficulties (see Archard & Trice, 1990; Leeder, *et al.*, 1990; Maynard *et al.*, 1991). Furthermore, recognised marine horizons can only be identified with recourse to a biostratigraphic framework. Whittaker *et al.* (1985) emphasise that great caution should be exercised in making gamma ray log correlations without palaeontological control.

1.4.10. Geochemical correlation.

Geochemical logging and correlation of sedimentary sequences is currently in vogue with, for example, individual chemical element concentrations, clay matrix geochemistry (Herron & Herron, 1990) and sterane isomerisation data (Pantano & Lerche, 1989) being applied to the recognition of vertical sedimentological sequences and well-to-well correlations. Leeder *et al.* (1990) have shown that marine bands can be detected geochemically by organic Carbon/Sulphur analysis of well material. However, as with geophysical detection of marine bands, individual horizons can only be identified with recourse to a biostratigraphic framework. Furthermore, as with lithological correlation, the lateral facies variations and the repetitive stacking of these facies in the delta plain and alluvial plain settings of the Westphalian of the S.N.S.C.B. make geochemical correlation very difficult (Hollywood & Whorlow, 1993).

1.4.11. Seismic stratigraphy and seismic sequence stratigraphy

'In house' seismostratigraphic classifications for the S.N.S.C.B. have been developed by many hydrocarbon exploration companies and ancillary service companies but these exist outside of the public domain (David Oliver, pers. comm., November 1992). Ebdon *et al.* (1990), Fraser *et al.* (1990) and Fraser & Gawthorpe (1990) have published seismostratigraphic classifications for the Carboniferous of northern England which are probably, on a coarse scale, applicable to the S.N.S.C.B.

The author feels that any application of sequence stratigraphic concepts to the interpretation of the Westphalian of the S.N.S.C.B. should be treated with extreme caution for the following reasons:

1. Sequence stratigraphic models have been developed for a particular (i.e. passive continental margin) tectonic setting. Whether the principles can be applied to basins in other tectonic settings, such as the intra-cratonic Central Pennine Basin and S.N.S.C.B., remains to be demonstrated (Collinson *et al.*, 1992).

2. There is undoubtedly a component of eustatic control on the stratigraphy of the Carboniferous of onshore and off-shore UK (e.g. Ramsbottom, 1977, 1979; Leeder & Hardman, 1990). However, there is also a significant influence

exerted by tectonic controls which are responsible for producing depositional hiatuses (Hudson & Turner, 1930; Rayner, 1953; Besley, 1988). In the S.N.S.C.B. this is especially true after the mid Duckmantian initiation of the phase of basin inversion (Leeder & Hardman, 1990). Basin development in the S.N.S.C.B. is related to the tectonic evolution of the Variscan orogen (see above). As such, interpretation of Carboniferous sequences in the S.N.S.C.B. ought to consider the variety of syndepositional tectonic controls which operated and must be able to distinguish between eustatically and tectonically driven sedimentary sequences.

3. Sequence boundaries identified by one worker do not always coincide with those identified by another worker, implying a degree of subjectivity in the recognition of seismic sequences. This is exemplified by the fact that sequence boundaries identified in the works of Ebdon *et al.* (1990) and Fraser & Gawthorpe (1990) for the same sections in northern England do not always coincide. Furthermore, the identification of sequence boundaries is often contrary to the field evidence. For example, the sequence boundaries of Ebdon *et al.* (1990) do not always coincide with the field evidence provided by Ramsbottom (1973, 1977). Similarly, the resolution of seismic stratigraphy is a lot coarser than that provided by biostratigraphy, and true sequence boundaries may be overlooked in the interpretation of seismic data. As noted by Riley (1993), the horizon of the Isohomoceras subglobosum Marine Band is a well constrained unconformable boundary recognised in North Africa, Eurasia and the U.S.A. yet it has not been recognised in the seismic sequence stratigraphies of Ebdon *et al.* (1990) or Fraser & Gawthorpe (1990).

2. PALYNOSTRATIGRAPHIC CLASSIFICATION.

A biostratigraphic classification should ideally be referable to a standard section which has established lithostratigraphic and chronostratigraphic units. Satisfactory correlations may be effected without reference to such a section but this precludes any precise chronostratigraphic correlation. As far as the S.N.S.C.B. is concerned the most effective location for a standard section is clearly onshore, where detailed palaeontological and chronostratigraphic data exist. As mentioned above, there is a well-founded assumption that the geology of the S.N.S.C.B. is closely comparable to that of the neighbouring onshore basins. This assumption has been carried into the application of onshore biostratigraphic schemes to the sediments of the S.N.S.C.B. (see below). The Westphalian rocks of the British Isles have a refined biostratigraphy established from the study of ammonoid faunas and provide the most suitable reference section for micropalaeontological research. Furthermore, the palynology of the onshore Westphalian sections is well documented and published palynostratigraphic classifications, related to the ammonoid-based Chronozones, exist (Figures 10, 12-14). Therefore, existing onshore palynostratigraphic data from the Carboniferous of Britain and Northwest Europe (i.e. Smith & Butterworth, 1967; Clayton *et al.*, 1977) have been used to provide a framework for this classification of the southern North Sea Westphalian. In this way the classification should be relatable, via the onshore palynostratigraphy, to the onshore stratotypes and the established chronostratigraphy.

2.1. DATABASE.

Large amounts of palynological work have been carried out in the S.N.S.C.B. Much of this work from the off-shore has been carried out by hydrocarbon exploration and service companies and remains outside of the public domain and so unavailable for inclusion in this study. Nevertheless, significant sections in the Westphalian of the S.N.S.C.B. have been drilled by Conoco (UK) Ltd and analysed by the University of Sheffield Industrial Palynology Unit. Interpretive results, range charts, working data sheets and original slide material from all of these sections have been made available for use in this study where required. Of these well sections, those that have considerable core and sidewall core coverage and which provided well-preserved palynological assemblages have been selected to constitute a database. A list of these wells and reference to the original biostratigraphic reports is given in Table 1. Six multi-well studies have also been included in the database. In each case an informal, local-scale (i.e. Block-scale) palynostratigraphic classification has been developed for the particular stratigraphic interval involved. The composite ranges of taxa identified in these studies has provided an important source of biostratigraphic data. The geographic distribution of the wells is shown in Figure 11 which indicates that the majority of the wells are located close to the S.N.S.C.B. depocentre (Figure 6). The stratigraphic interval encountered in each well is shown in Figure 12.

2.2. METHODS.

The original biostratigraphic analyses of the well sections (see Table 1 for references) interpret the palynology of the sections in terms of the classification schemes of Clayton *et al.* (1977) and Smith & Butterworth (1967) and relate these to the chronostratigraphy. Therefore, these schemes have been used as a framework against which the qualitative and quantitative stratigraphic distributions of individual miospore taxa have been plotted. It is recognised that this will produce a situation in which the stratigraphic distribution of several taxa (i.e. those which are used to define the onshore biozonal boundaries) appear identical to those onshore, but this is considered inevitable. As Ager (1993) states: "In stratigraphy we measure one ruler with another."

Of the several hundred miospore taxa recorded from the S.N.S.C.B. Westphalian, it has been necessary to select a relatively small number which may be used to define the biozones within the palynostratigraphic classification. Each taxon selected has the following attributes.

1. Easily recognisable and distinguishable morphography,

2. Common occurrence within its stratigraphic range,

3. Coeval range top or range base in more than one well section and/or a well documented biostratigraphic range which is proven to be consistent in adjacent onshore areas.

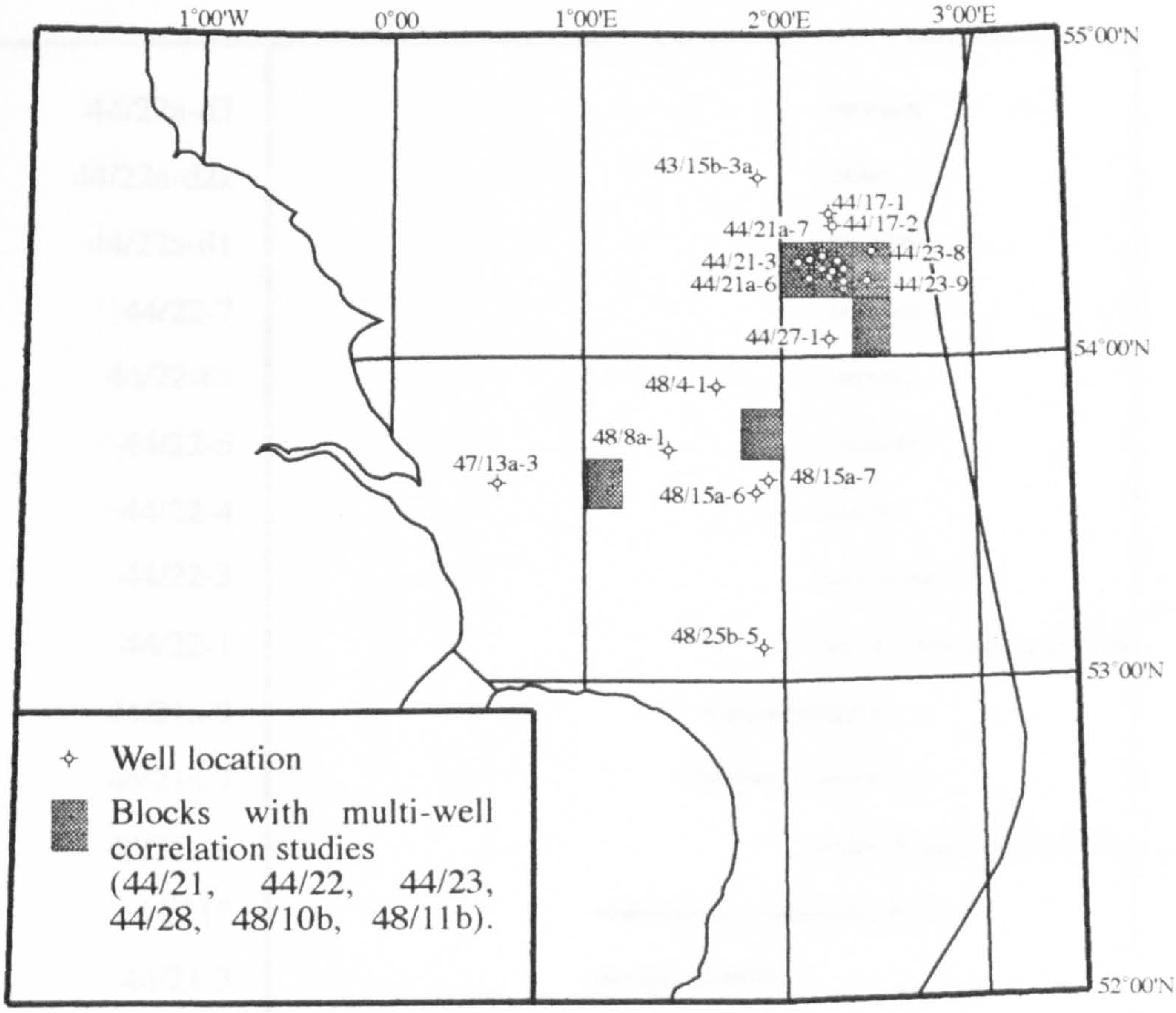


Figure 11. Location of database well sections. 11 wells in Block 44/22 not numbered.

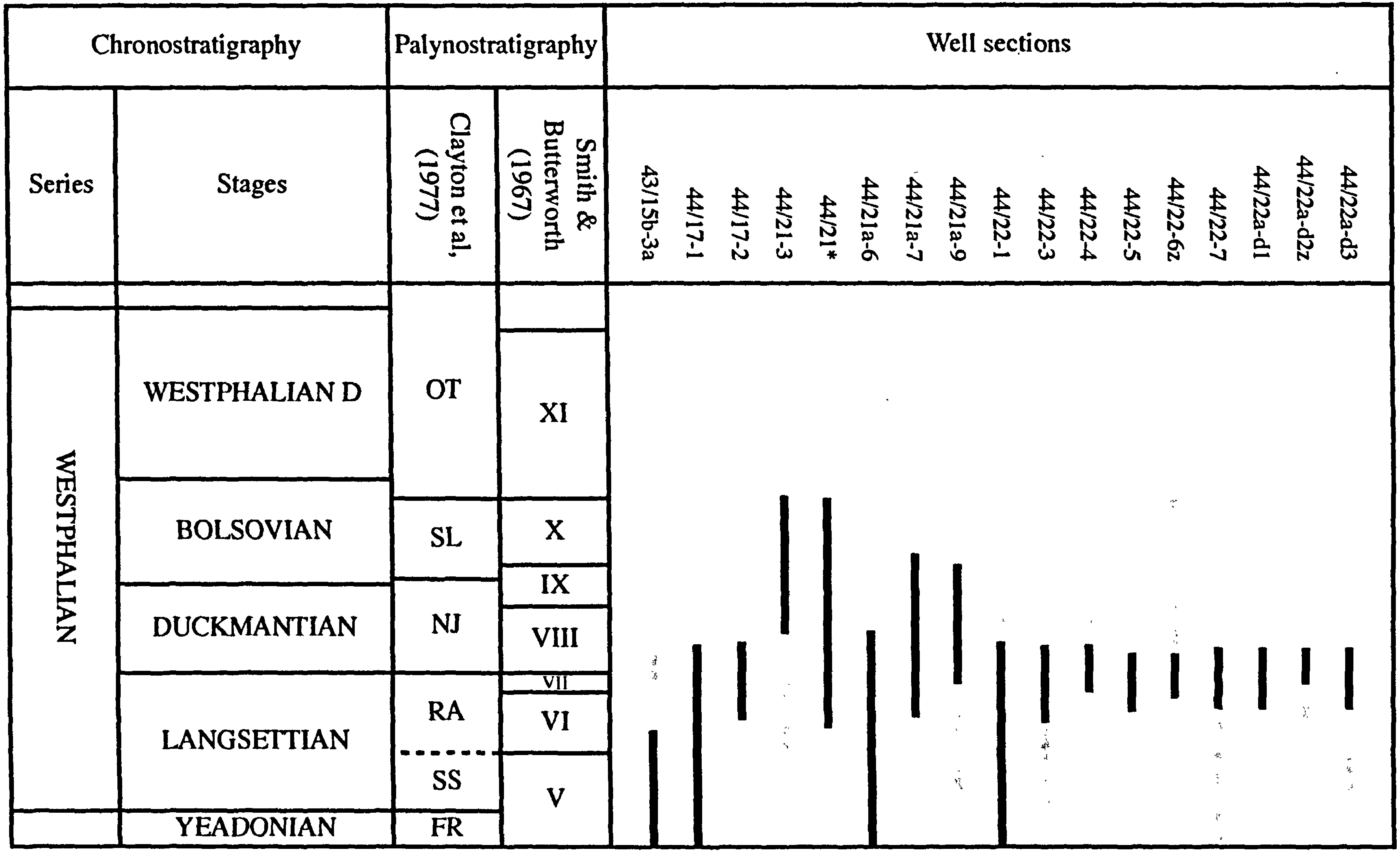


Figure 12a. Stratigraphic ranges of SouthernNorth Sea Carboniferous Basin well sections.

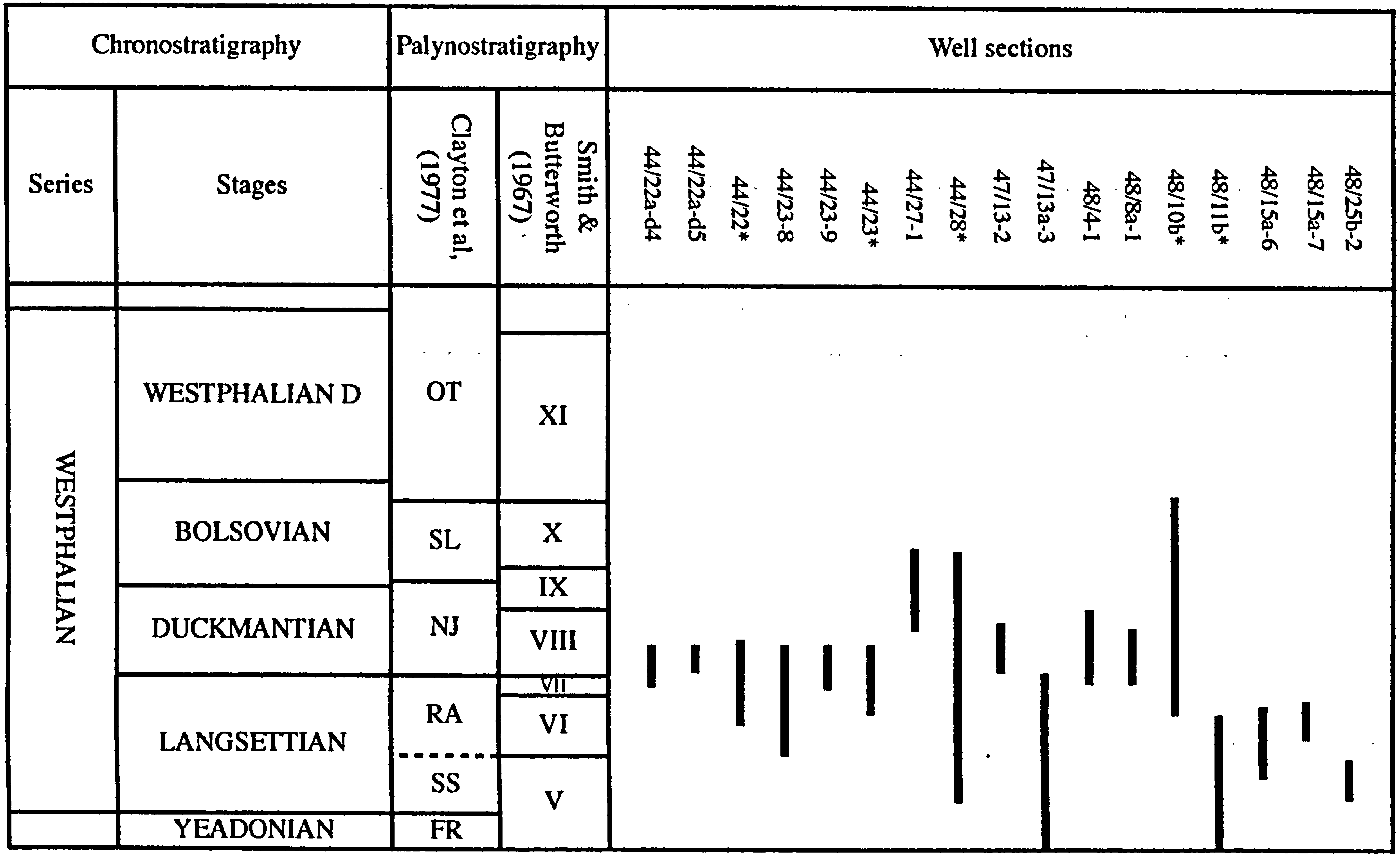


Figure 12b. Stratigraphic ranges of Southern North Sea carboniferous basin well sections.

WELL NUMBER	ORIGINAL BIOSTRATIGRAPHIC REPORT
43/15b-3a	McLean, (1992)b.
44/17-1	Neves, (1990).
44/17-2	Neves & Downie (1992).
44/21-3	Turner (1990)a.
44/21*	Turner (1990)b.
44/21a-6	Turner (1990)d.
44/21a-7	Turner (1991)a.
44/21a-9	McLean & Neves (1993)b.
44/22-1	Neves (1985)b.
44/22-3	Neves (1985)a.
44/22-4	Neves (1987)a.
44/22-5	Neves (1988)a.
44/22-6z	Neves (1988)b.
44/22-7	Neves (1988)c.
44/21a-d1	McLean (1992)a.
44/22a-d2z	McLean (1992)c.
44/22a-d3	McLean (1992)d.
44/22a-d4	McLean (1992)f.
44/22a-d5	McLean (1993).
44/22*	McLean & Turner (1990)a.
44/23-8	Neves & Turner (1989)a.
44/23-9	Neves & Turner (1989)b.
44/23*	McLean & Turner (1990)b.
44/27-1	Turner (1990)c.
44/28*	McLean & Neves (1992)a.
47/13-2	Neves (1973).
47/13a-3	Neves & Quincey (1986).
48/4-1	McLean & Neves (1992)b.
48/8a-1	Neves & McLean (1989).
48/10b*	McLean (1991)a.
48/11b*	McLean & Neves (1993)a.
48/15a-6	Neves *et al.* (1989).
48/15a-7	McLean (1992)e.
48/25b-5	Turner (1989).

Table 1. List of database wells and references to original biostratigraphic reports. Asterisked numbrers refer to multi-well correlation studies.

The first of these points is critical, and determines whether or not a taxon may be *consistently* recognised. Many Carboniferous miospore species exhibit extensive inter-generic and inter-specific variation (e.g. Sullivan, 1958; Somers, 1972, pl. 7; Clayton *et al*, 1977, p. 12), and so present problems in consistency of identification. This is particularly true for taxa of the infraturma APICULATI (Bennie & Kidston) Potonié 1956 (e.g. species of *Apiculatasporites* Ibrahim emend. Ravn 1986). A further consideration concerning consistency of identification of Carboniferous palynomorph taxa is that many species are distinguished on the basis of overall size difference alone. Mishell (1966) and Smith & Butterworth (1967), amongst others, demonstrated or recognised that preparation techniques may differentially and selectively alter the sizes of various palynomorph types. In view of this, species which are differentiated on the basis of size alone have not been chosen as key taxa.

The consistent recognition of taxa in the original biostratigraphic reports of the well sections has be taken at face value as the experience and academic credentials of the workers involved indicates that their results can be treated with a high degree of confidence. Generally it has not been practical to re-examine much of the original slide material. A principal exception to this has been in the examination of taxa identified by the informal notation "cf.", in which case marked specimens have been examined in order to clarify the nature of the comparative taxa and to standardise their recognition.

75 key taxa are recognised. Their stratigraphic distributions in the database well sections is illustrated in Figure 13. The composite range of each taxon is shown in Figure 14 and plotted against the biozones recognised in the classification for the S.N.S.C.B. Westphalian.

2.3. BIOZONE TYPES.

The 75 key taxa appear to be stratigraphically restricted over the S.N.S.C.B. Significant changes are apparent in the composition of palynological assemblages at certain horizons. These changes may be related to the inception and extinction of taxa, and also to the relative abundances of particular taxa. Stratigraphic range bases (evolutionary inceptions), stratigraphic range tops (evolutionary extinctions), and the bases and tops of species epiboles are used to define the boundaries of the biozones and sub-biozones. The biozones and sub-biozones are made up of total range biozones, partial range biozones,

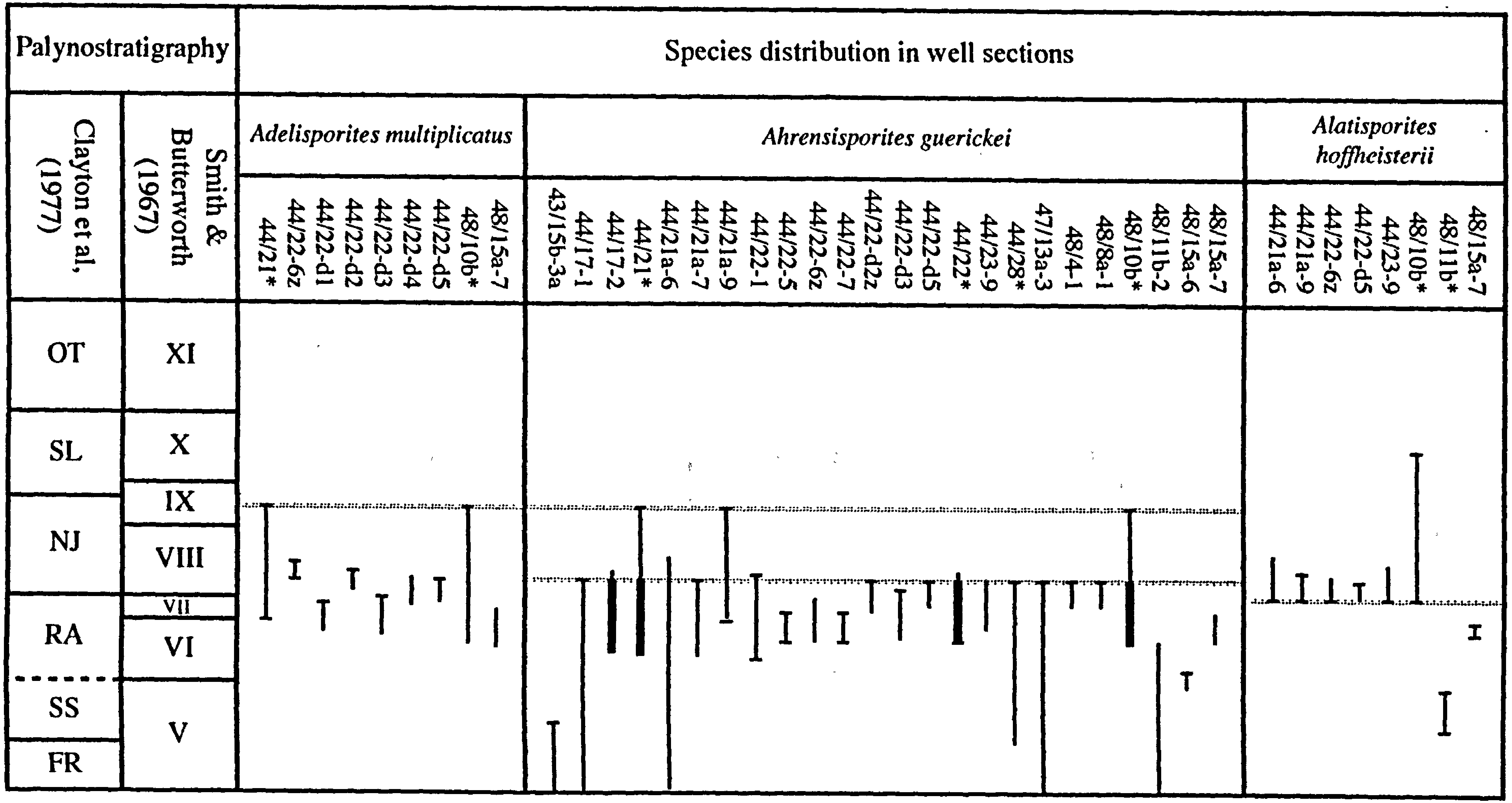


Figure 13a. Distribution of species in well sections.

I Range top and range base within well section. | Range top and range base restricted by well section.
Thickened lines represent species epiboles.

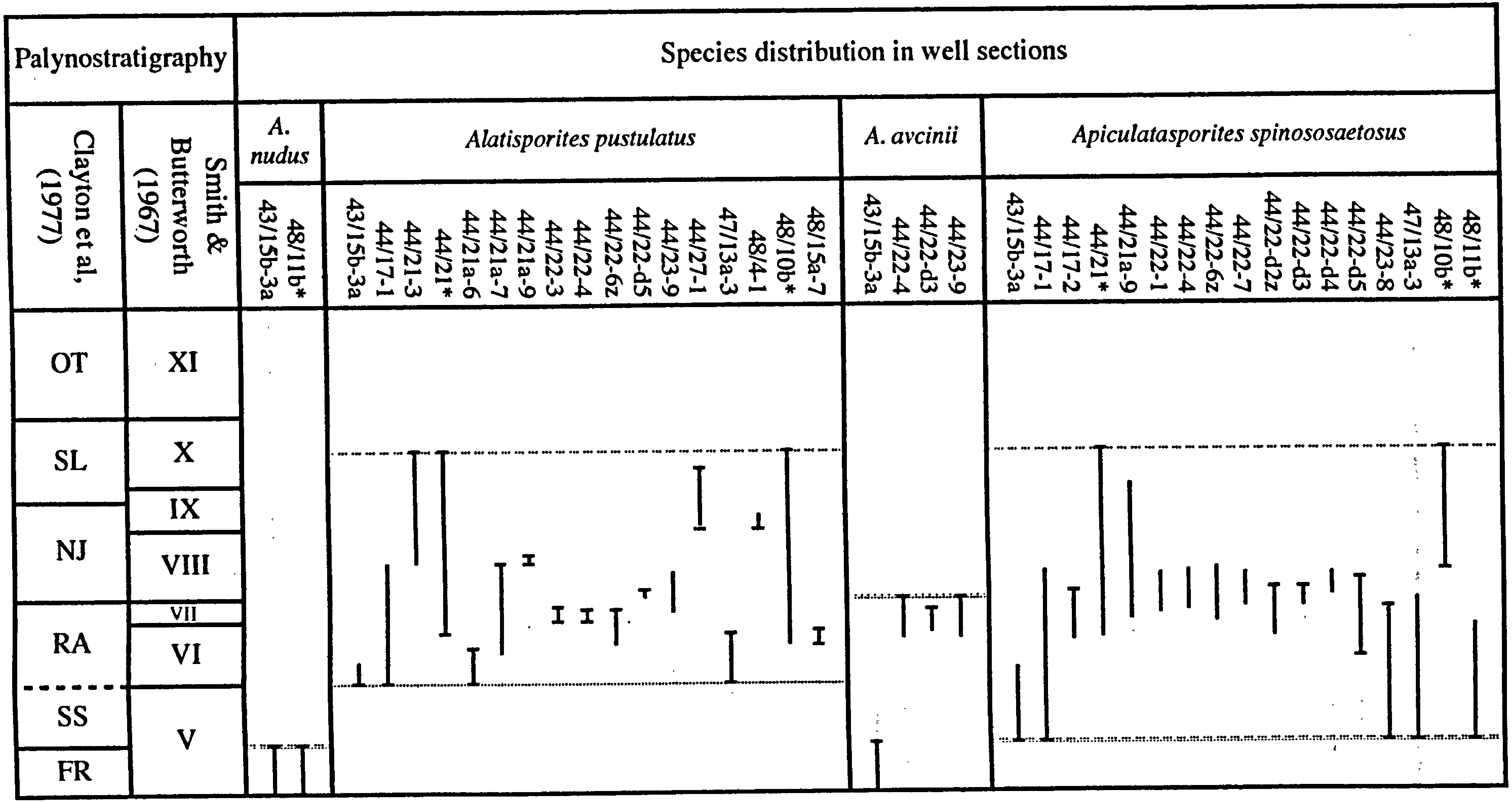


Figure 13b. Distribution of species in well sections.

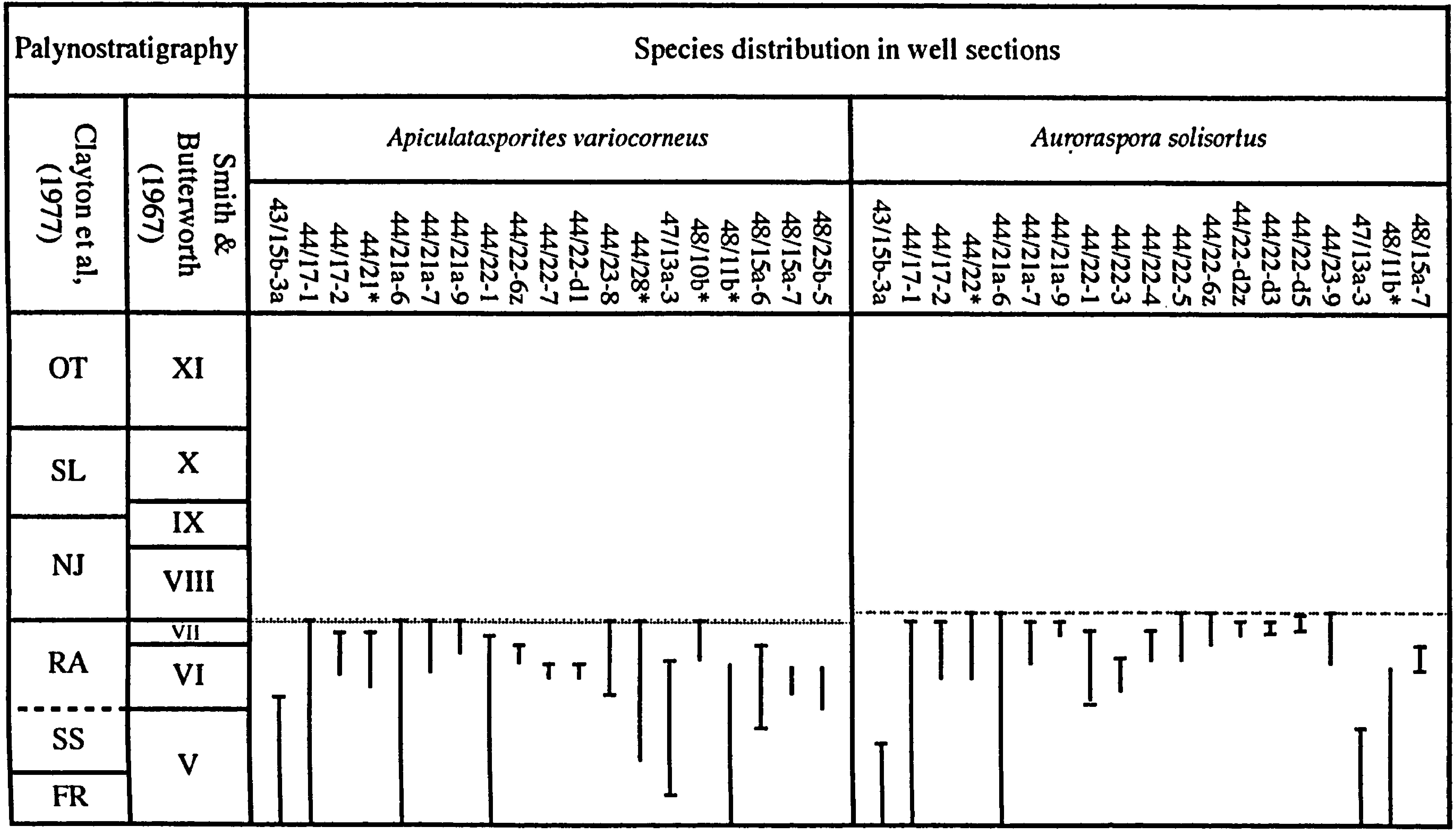


Figure 13c. Distribution of species in well sections.

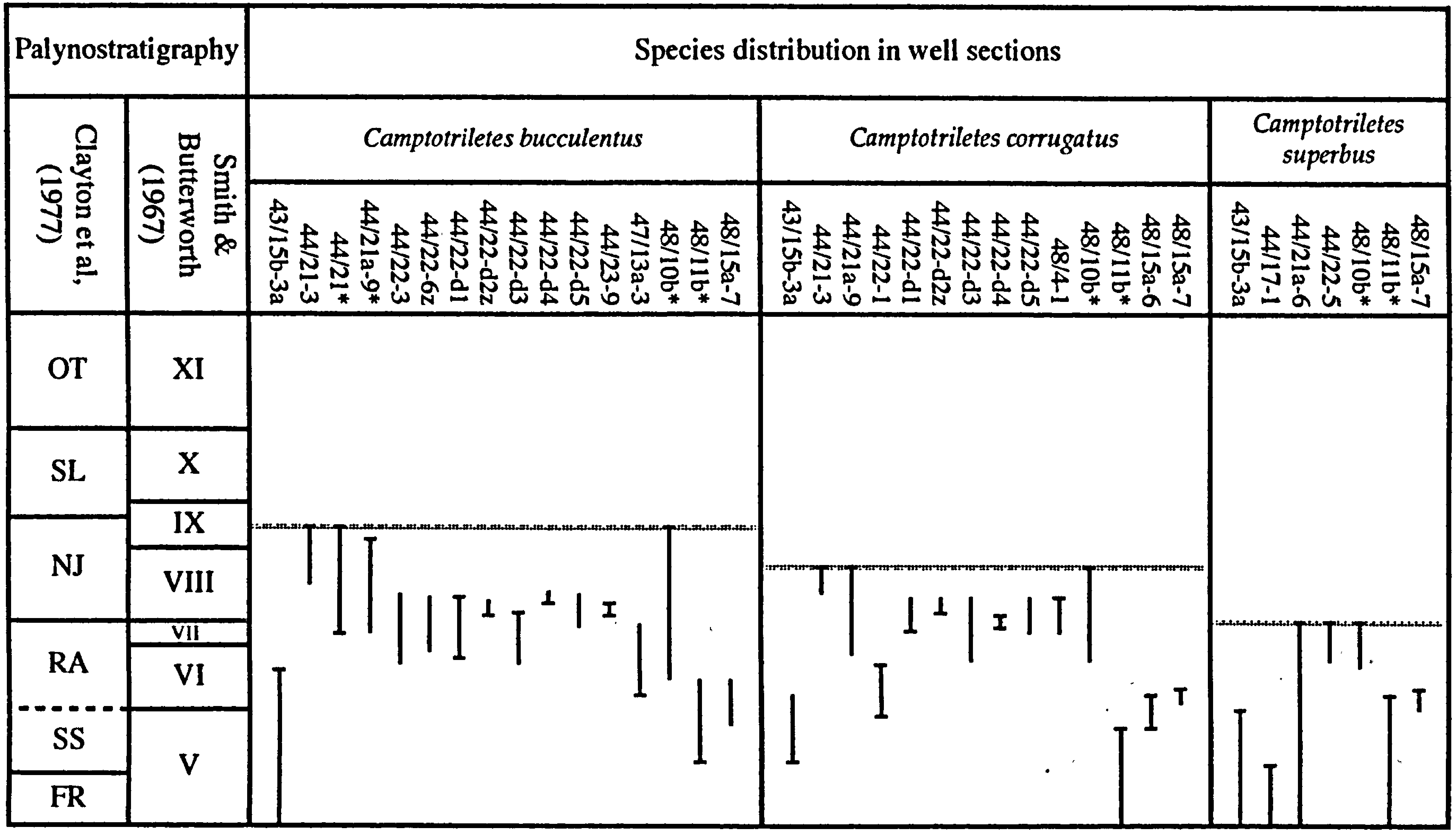


Figure 13d. Distribution of species in well sections.

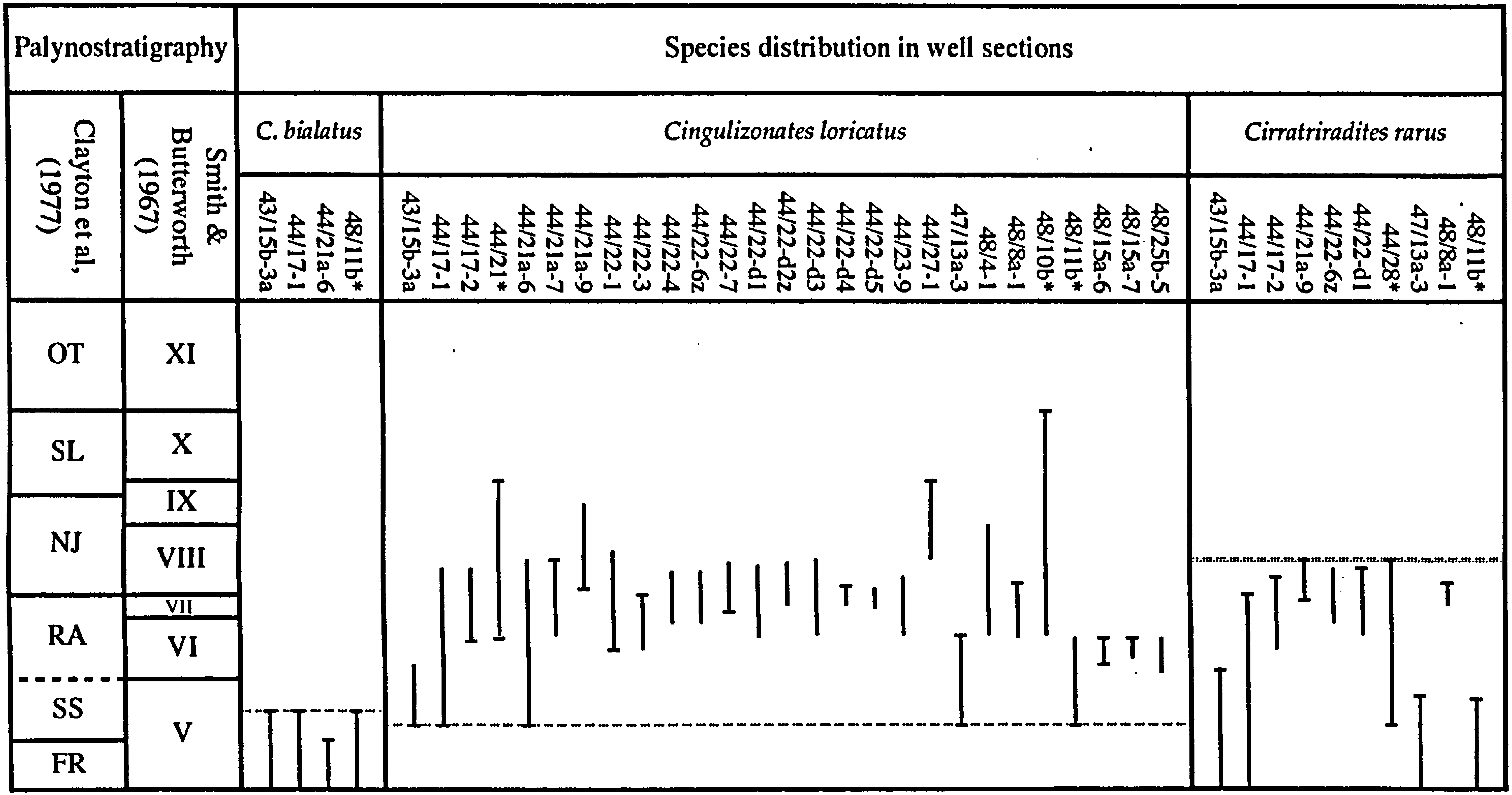


Figure 13e. Distribution of species in well sections.

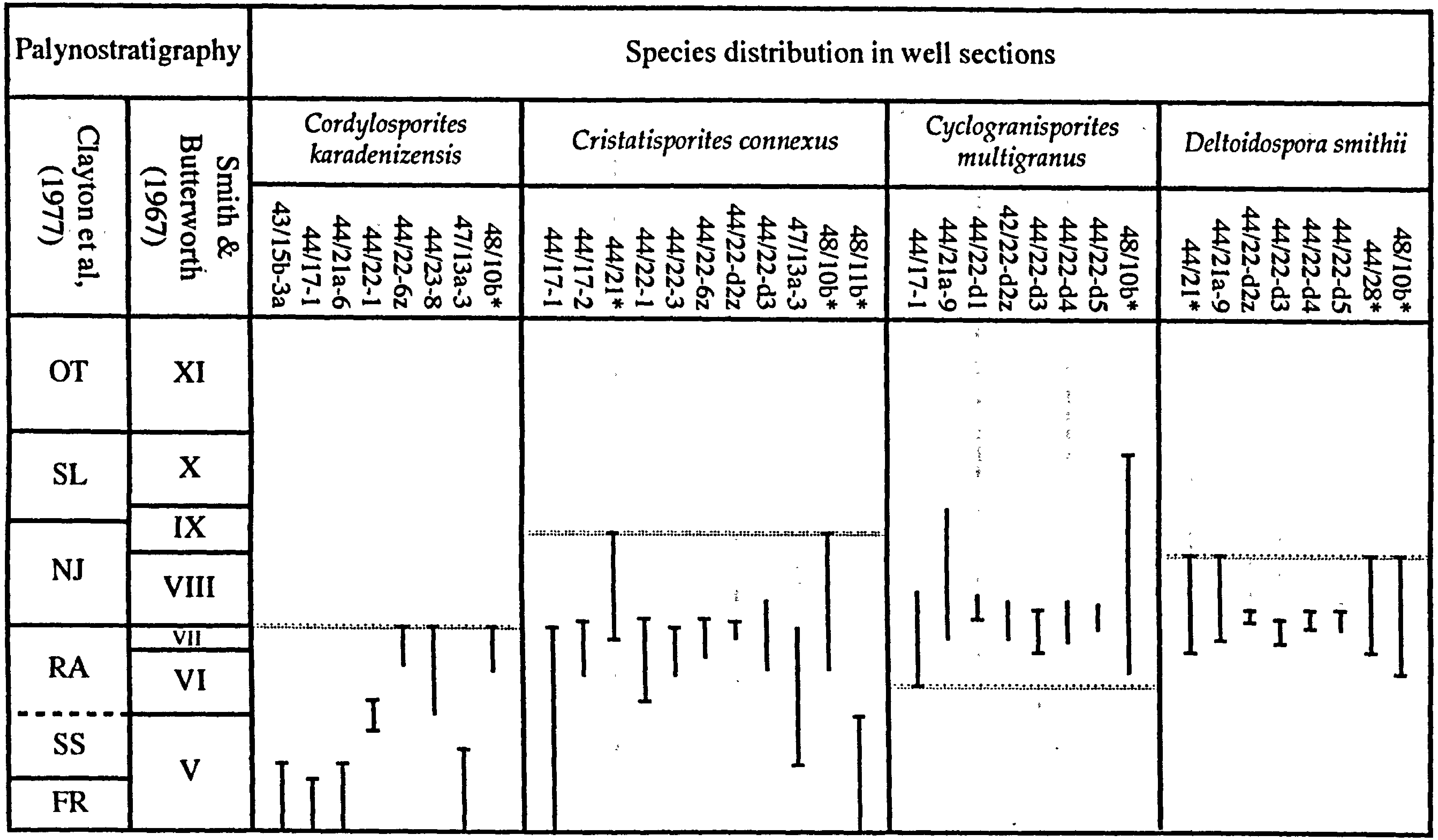


Figure 13f. Distribution of species in well sections.

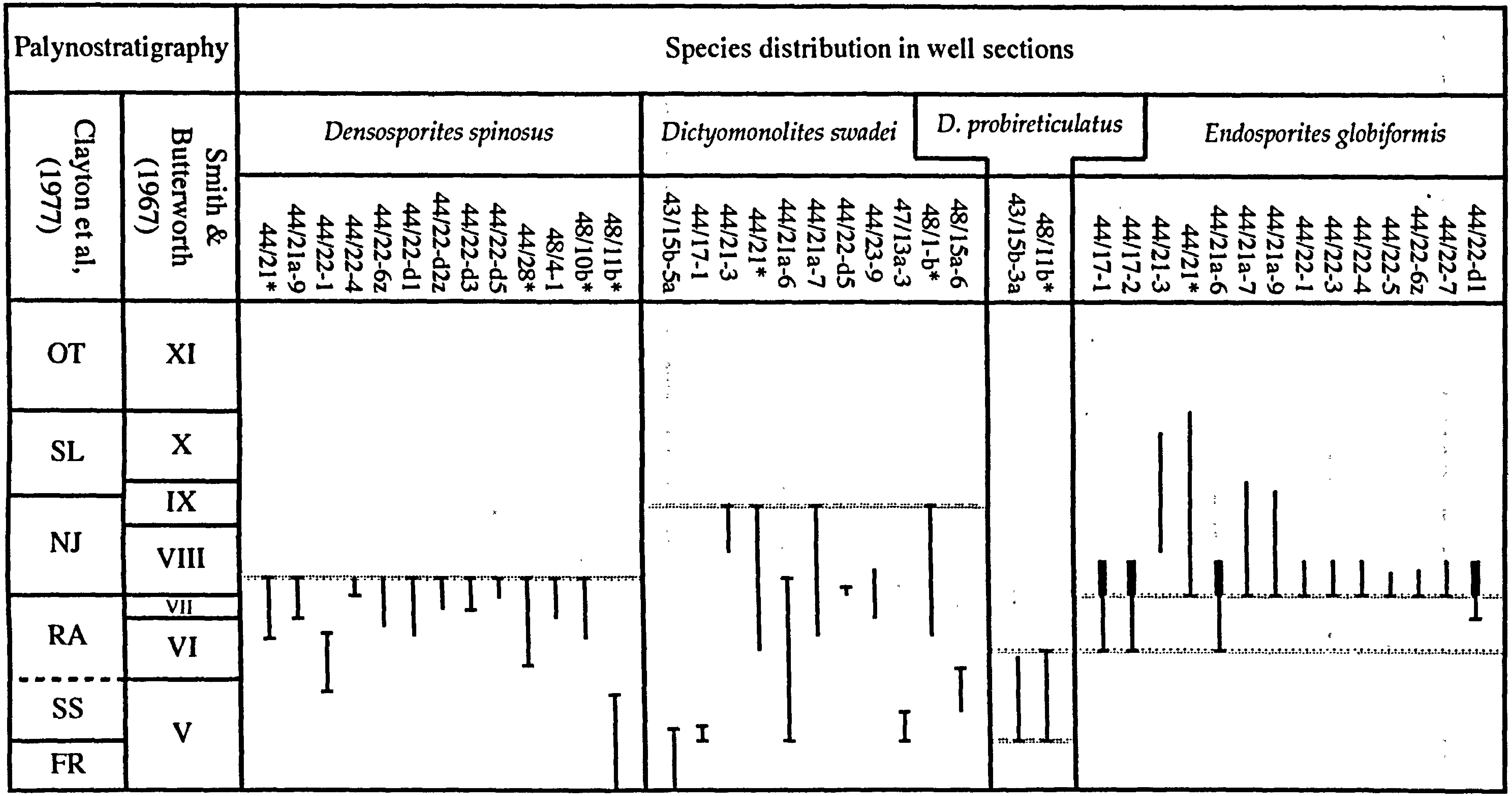


Figure 13g. Distribution of species in well sections.

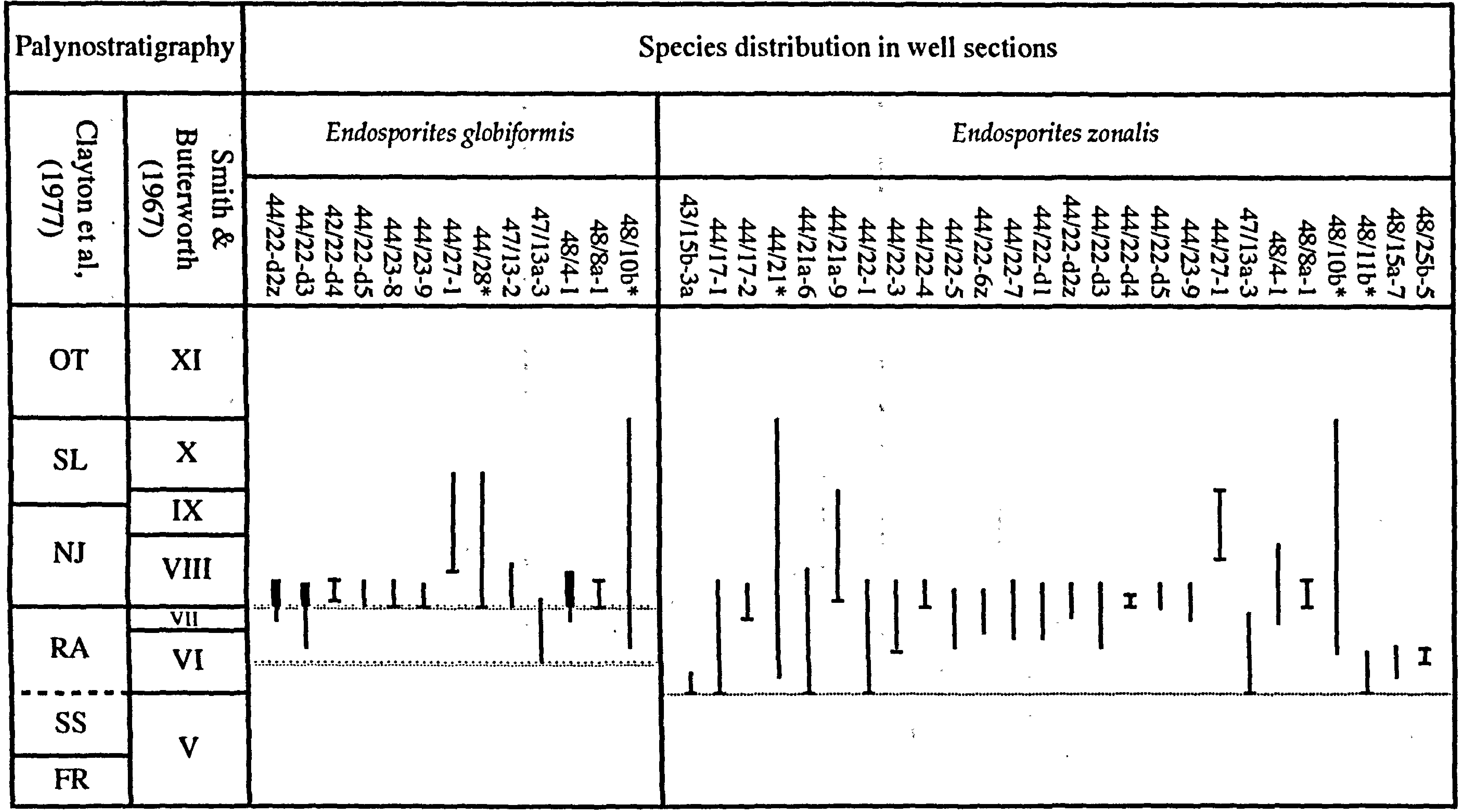


Figure 13h. Distribution of species in well sections.

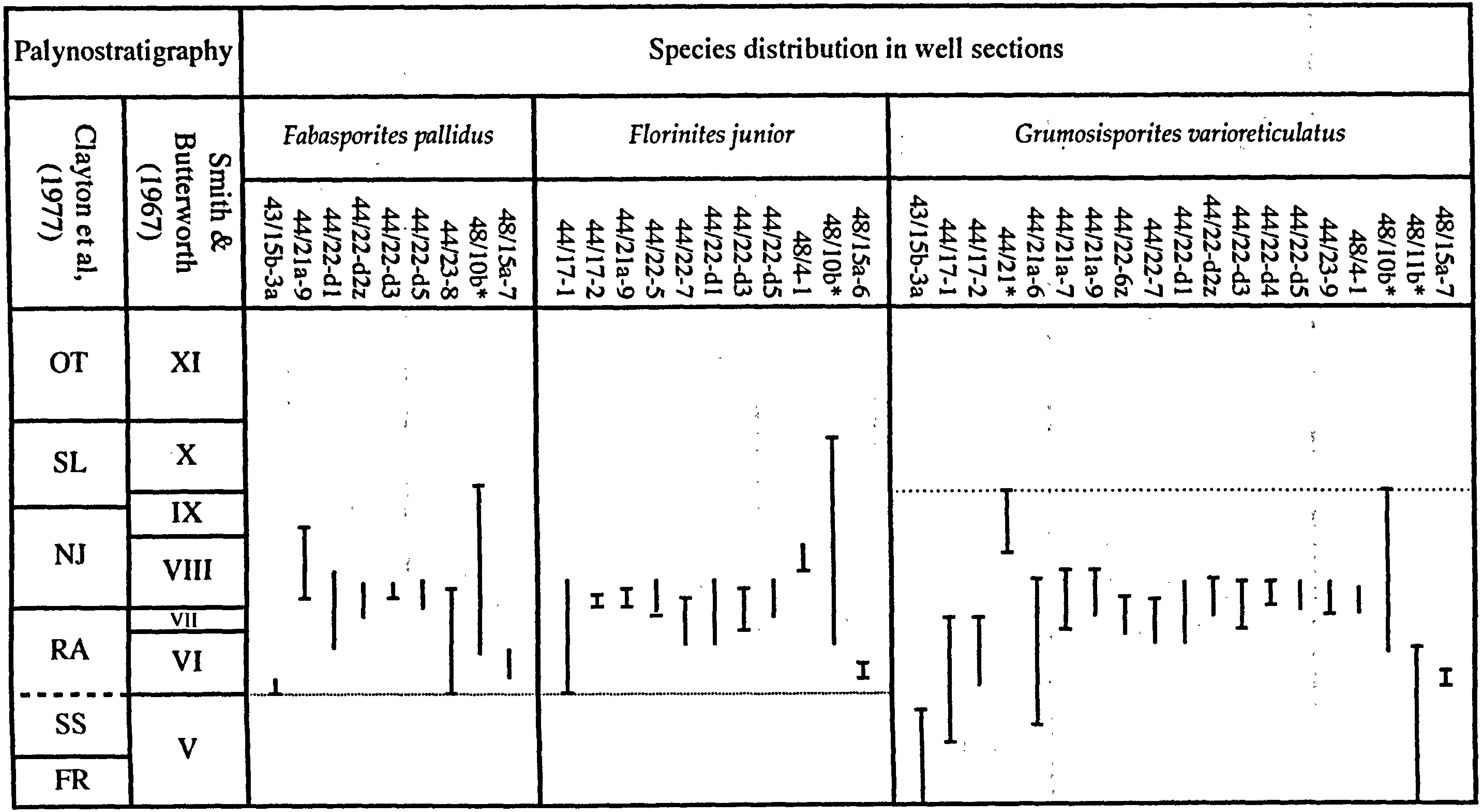


Figure 13i. Distribution of species in well sections.

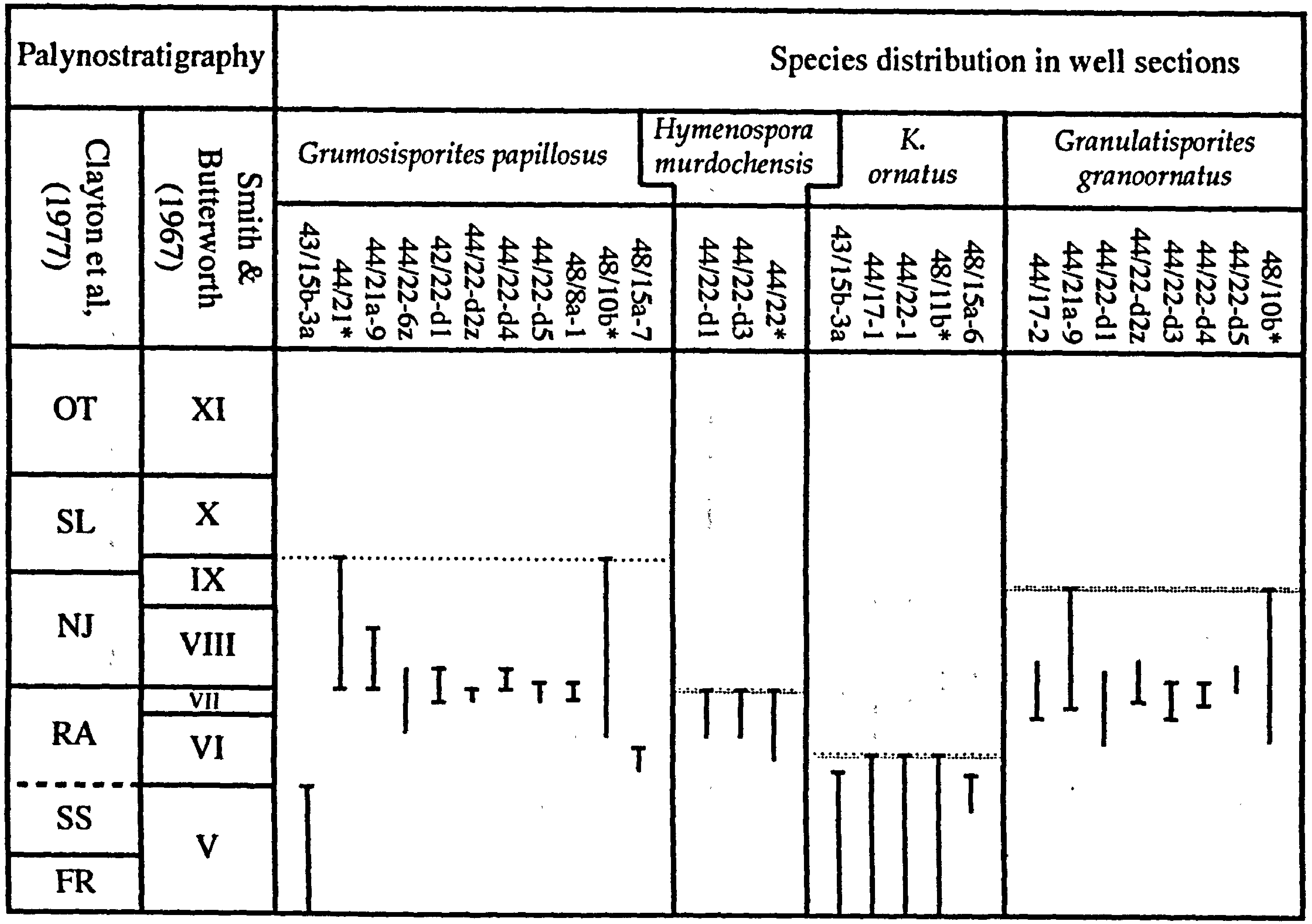


Figure 13j. Distribution of species in well sections.

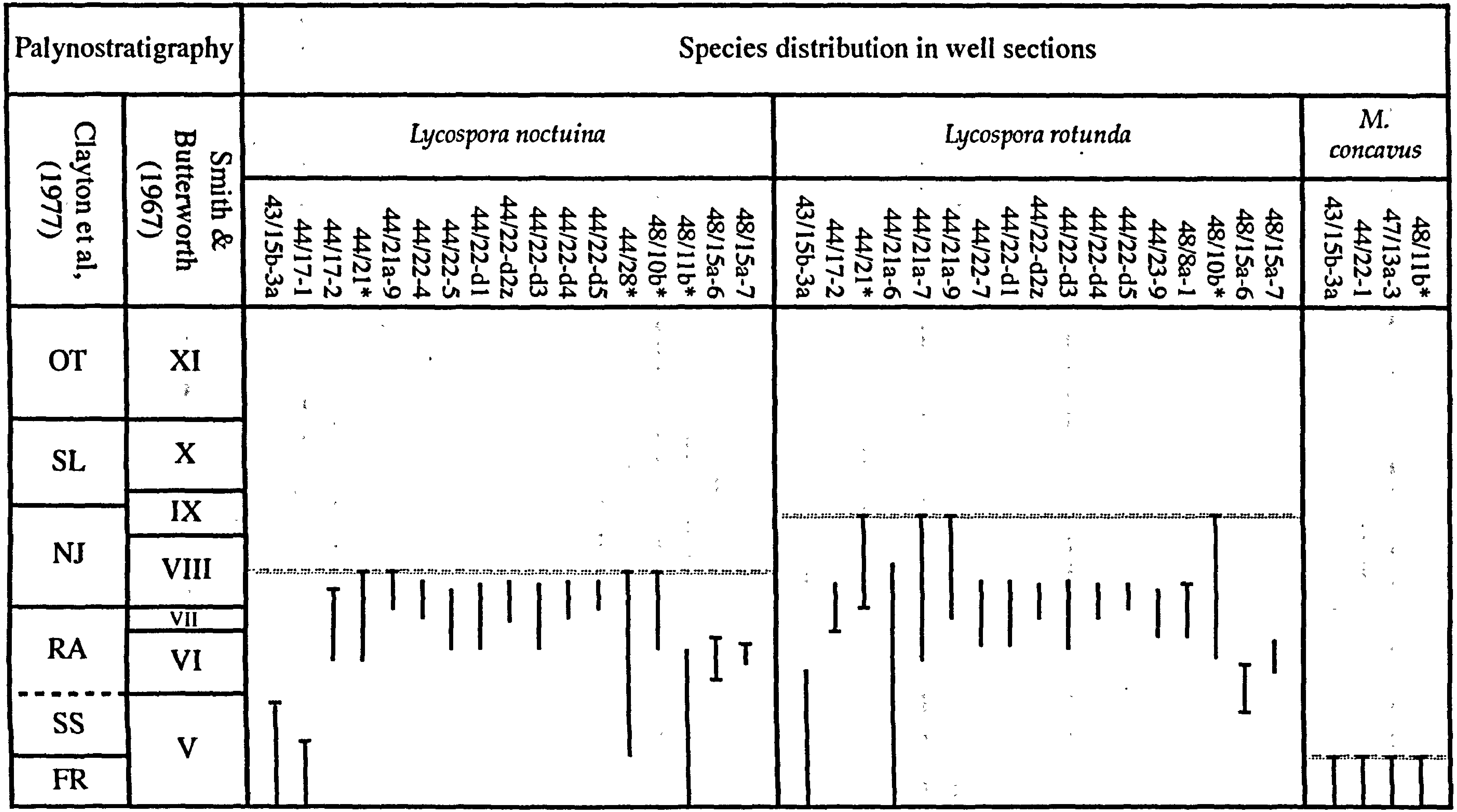


Figure 13k. Distribution of species in well sections.

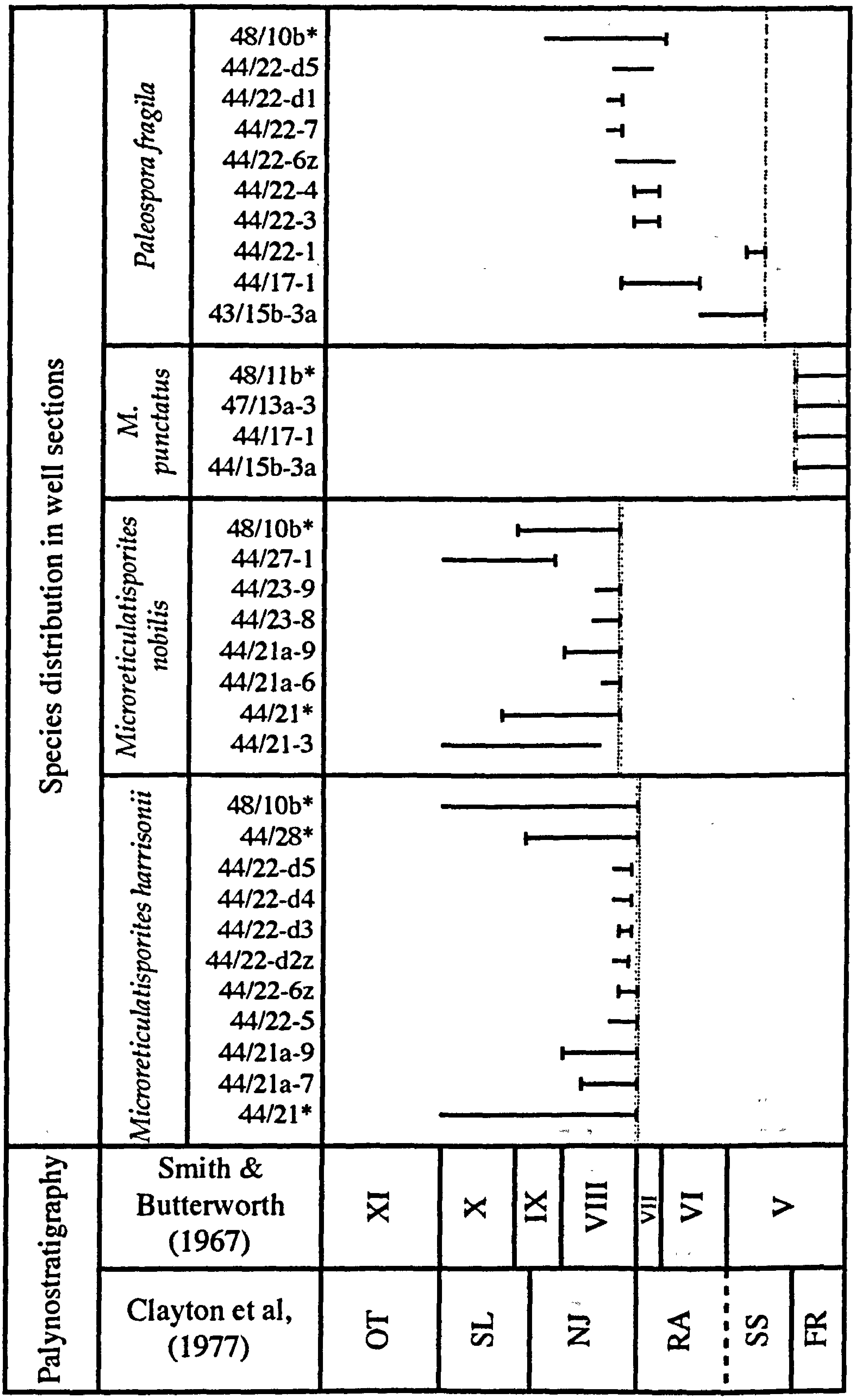


Figure 131. Distribution of species in well sections.

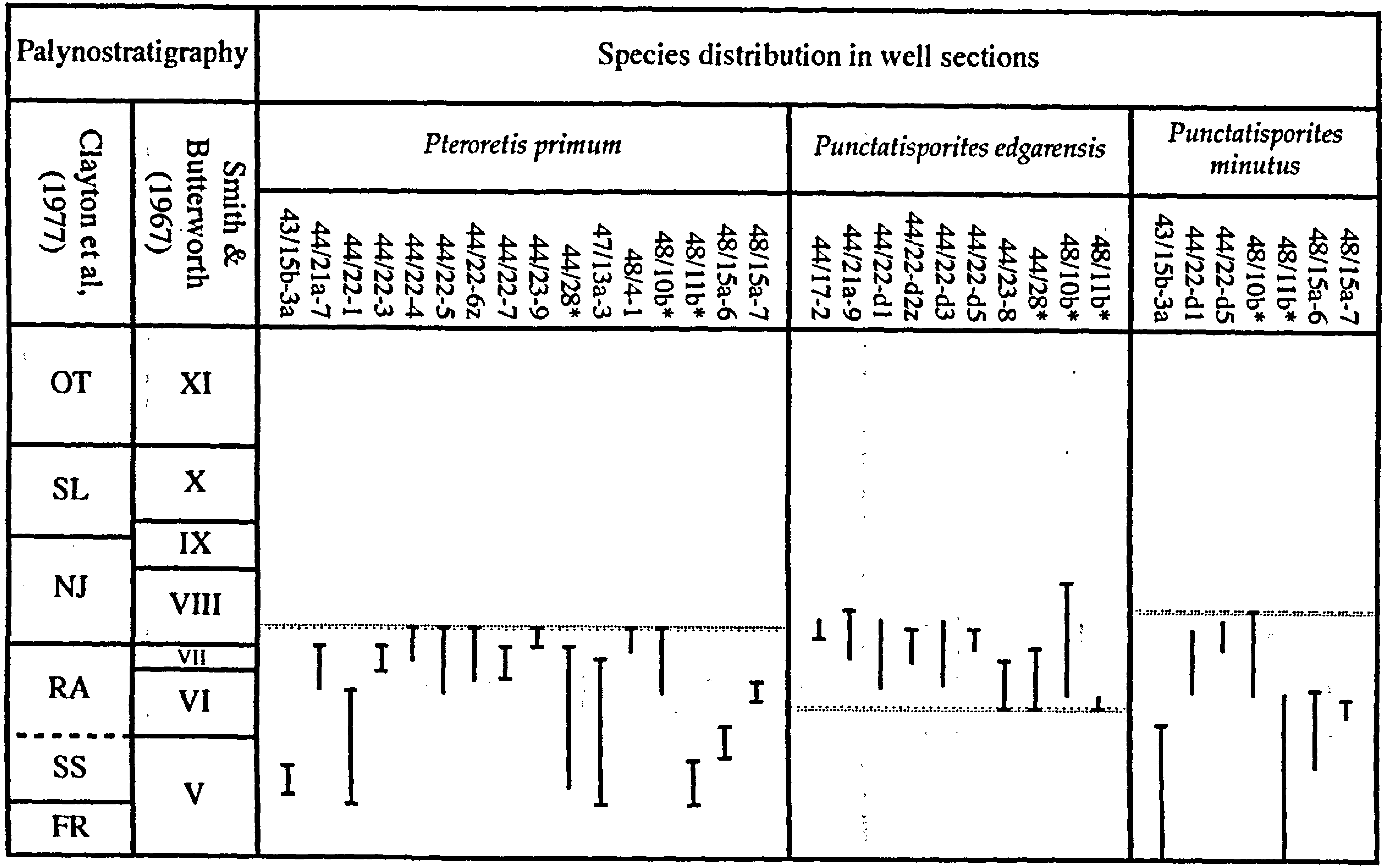


Figure 13m. Distribution of species in well sections.

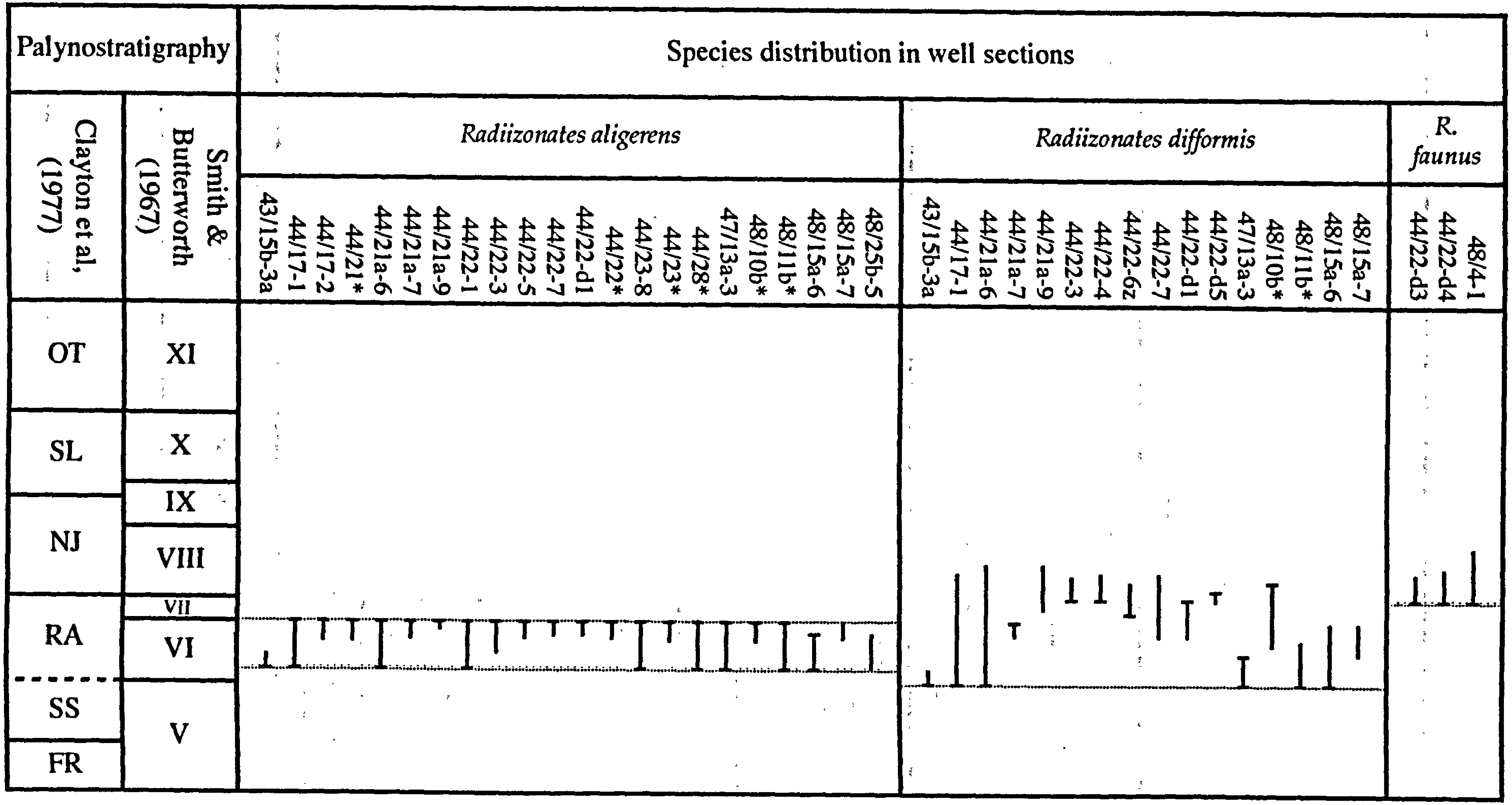


Figure 13n. Distribution of species in well sections.

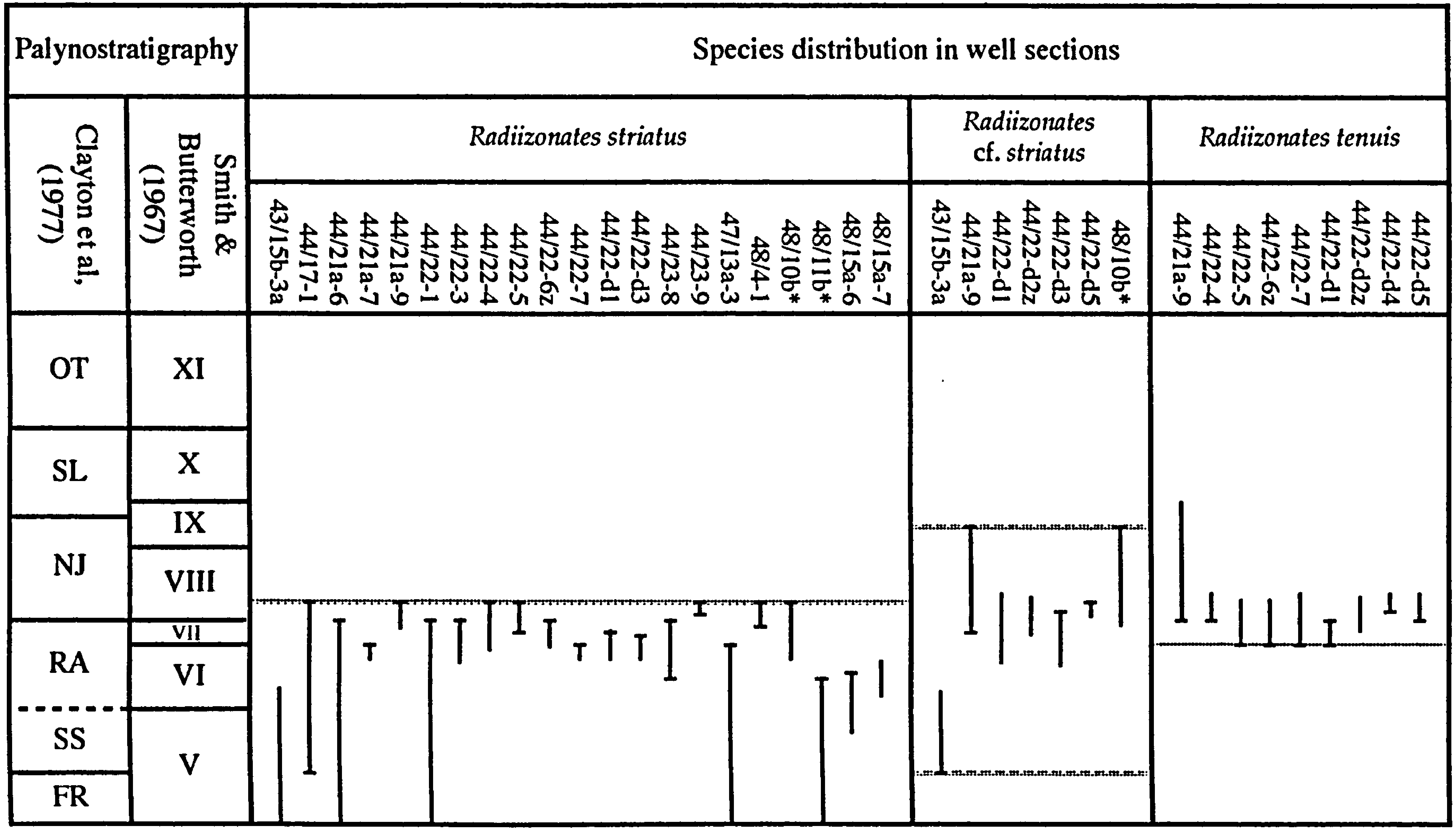


Figure 13o. Distribution of species in well sections.

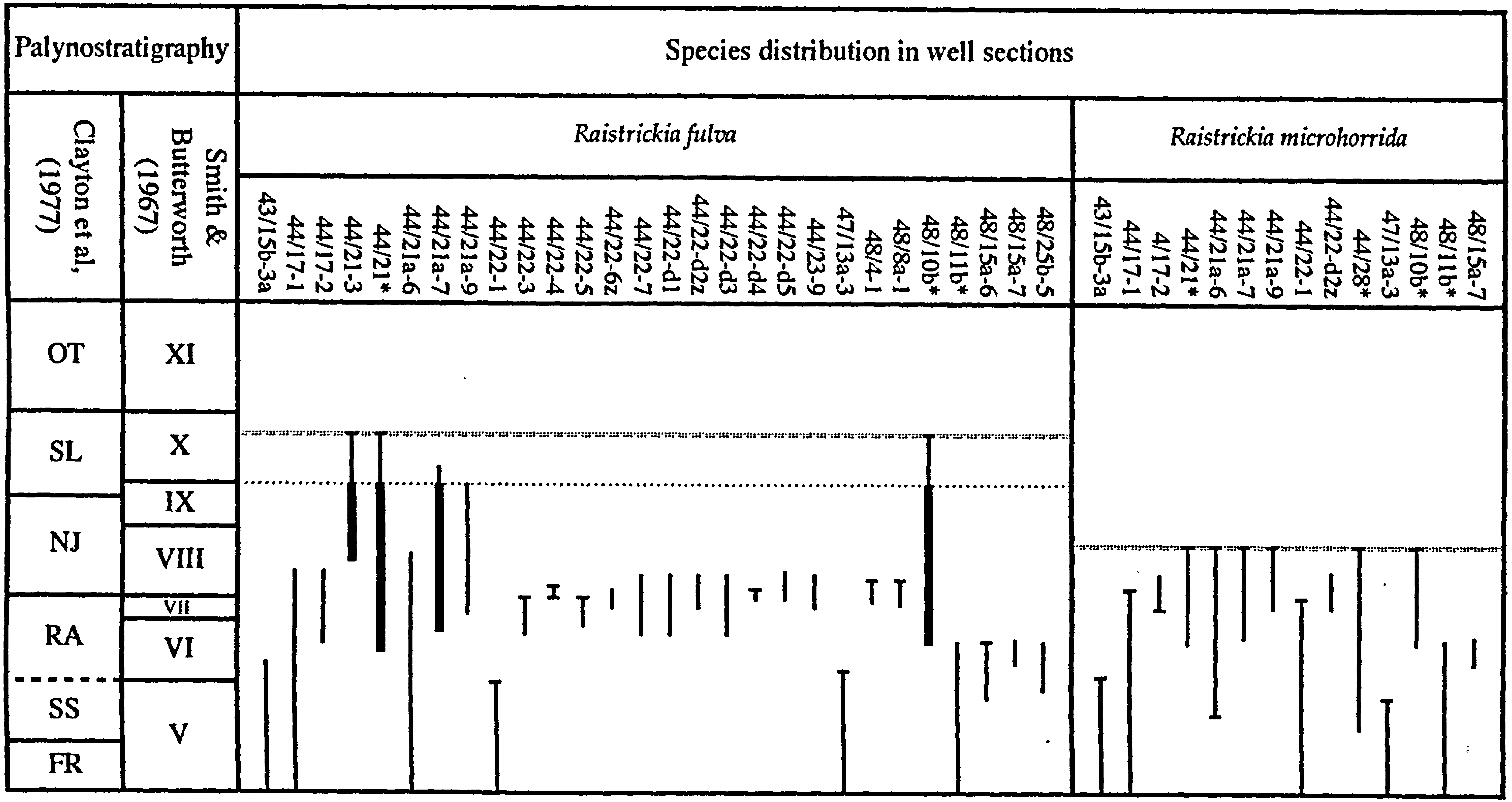


Figure 13p. Distribution of species in well sections.

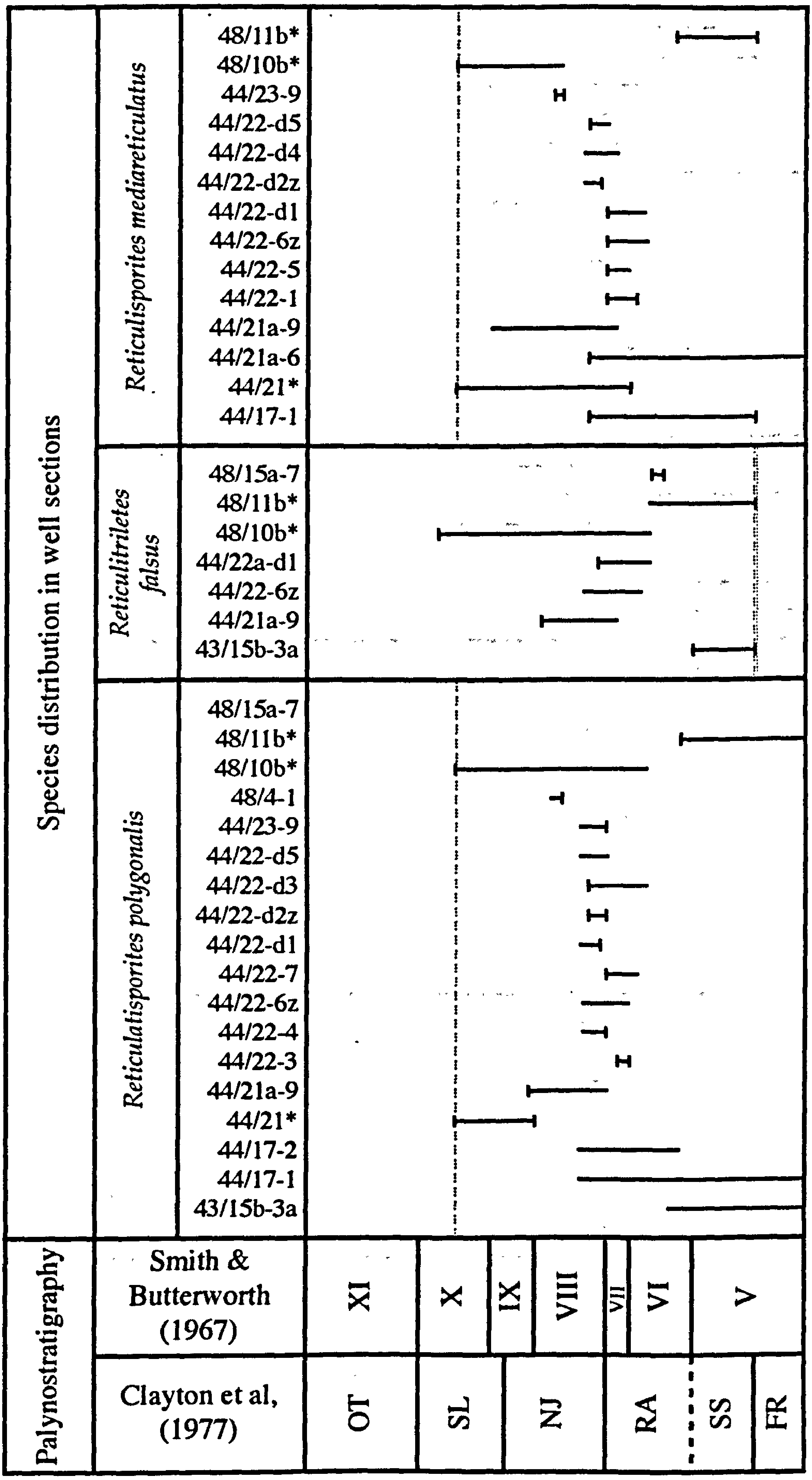


Figure 13q. Distribution of species in well sections.

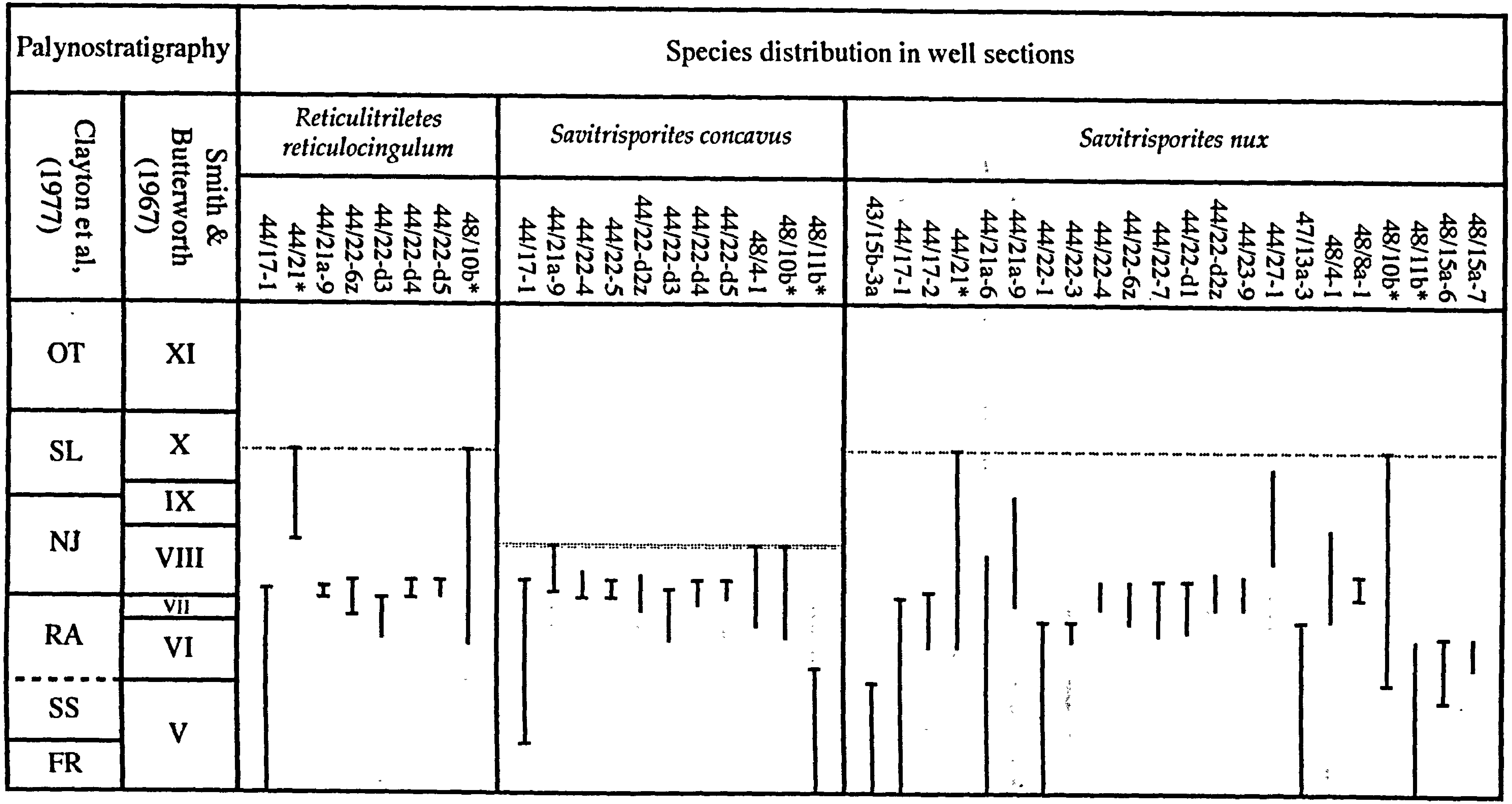


Figure 13r. Distribution of species in well sections.

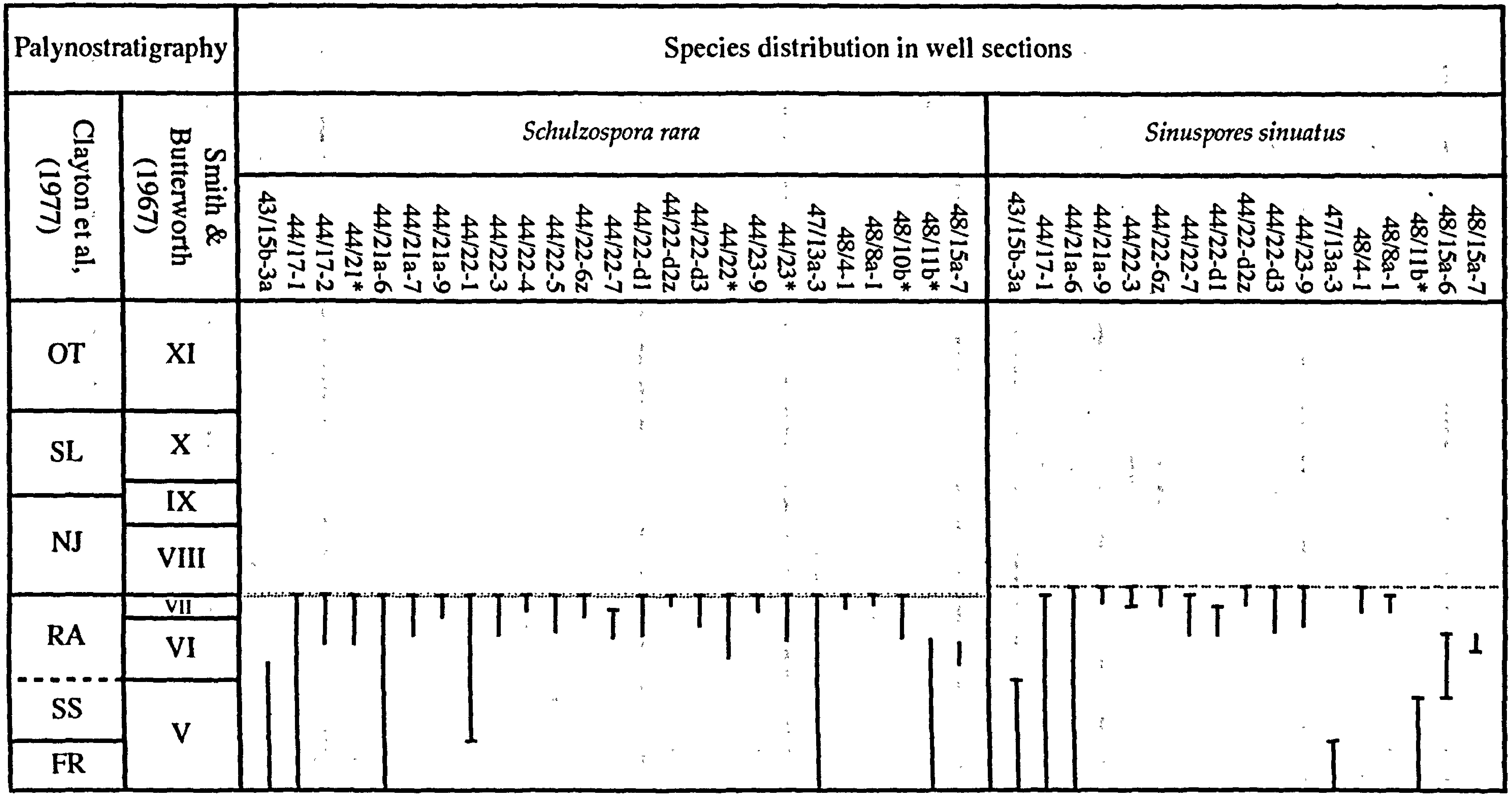


Figure 13s. Distribution of species in well sections.

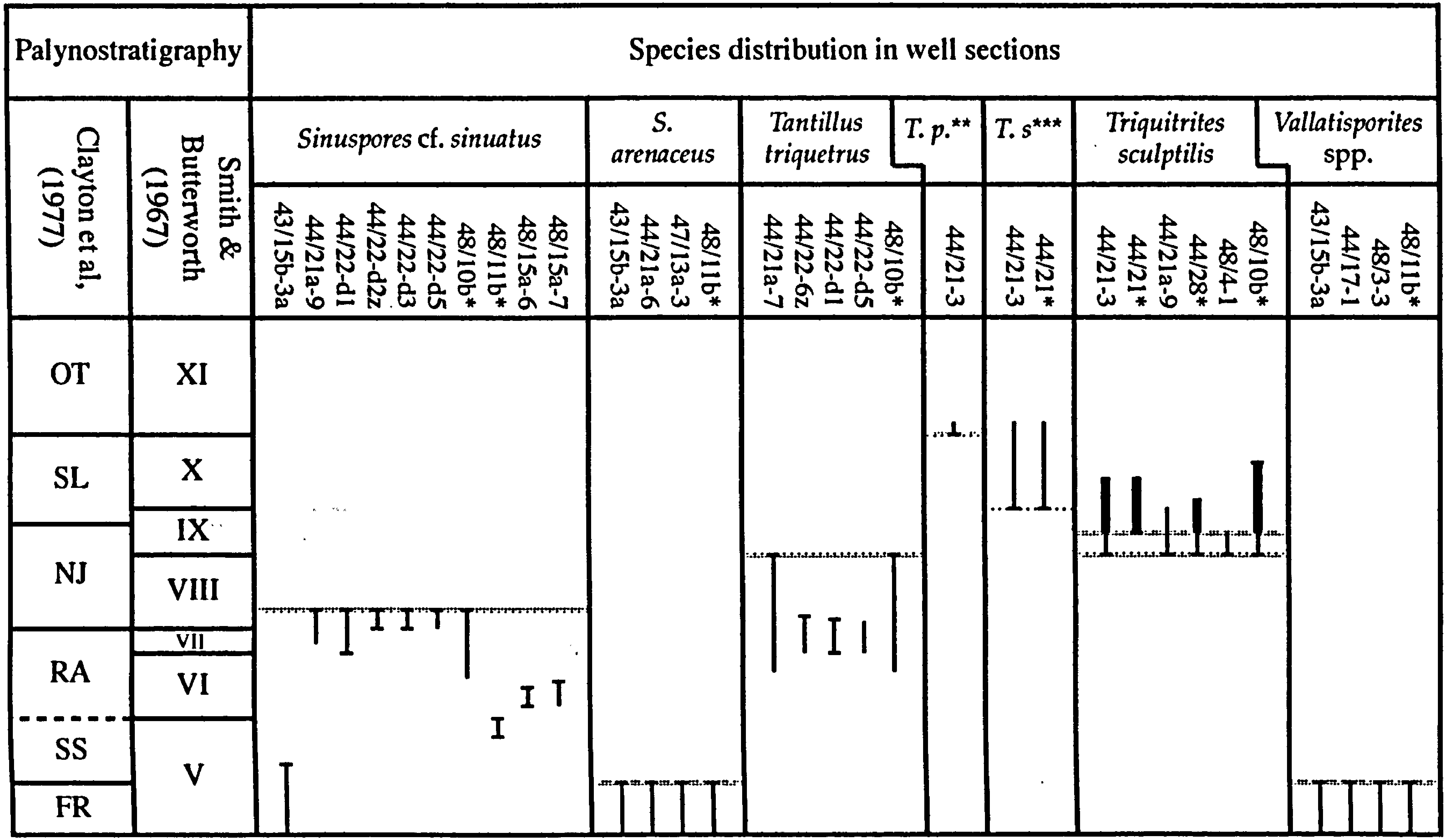


Figure 13t. Distribution of species in well sections.
(*T. p.*** = *Thymospora* spp. *T. s.**** = *Torispora securis*)

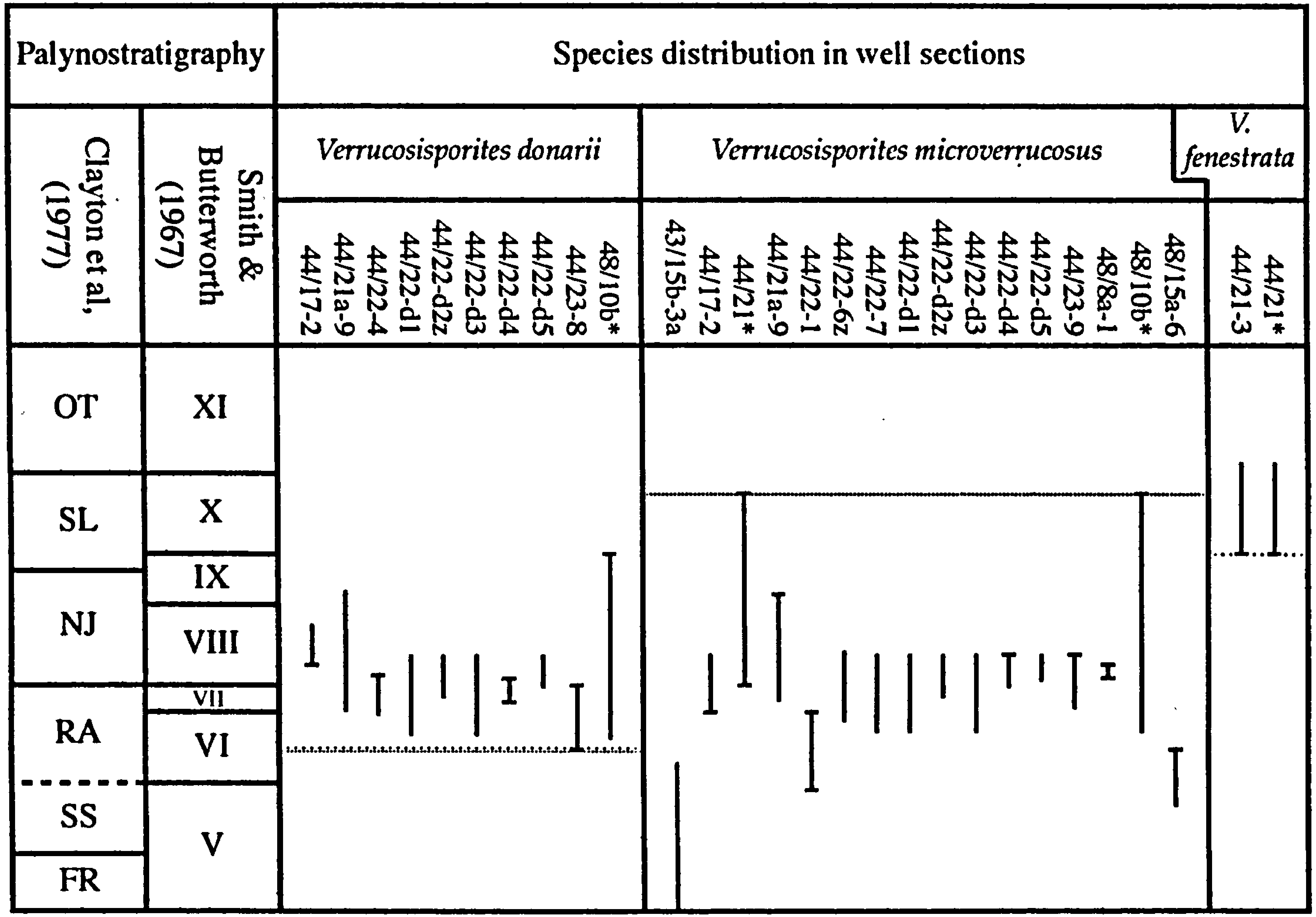


Figure 13u. Distribution of species in well sections.

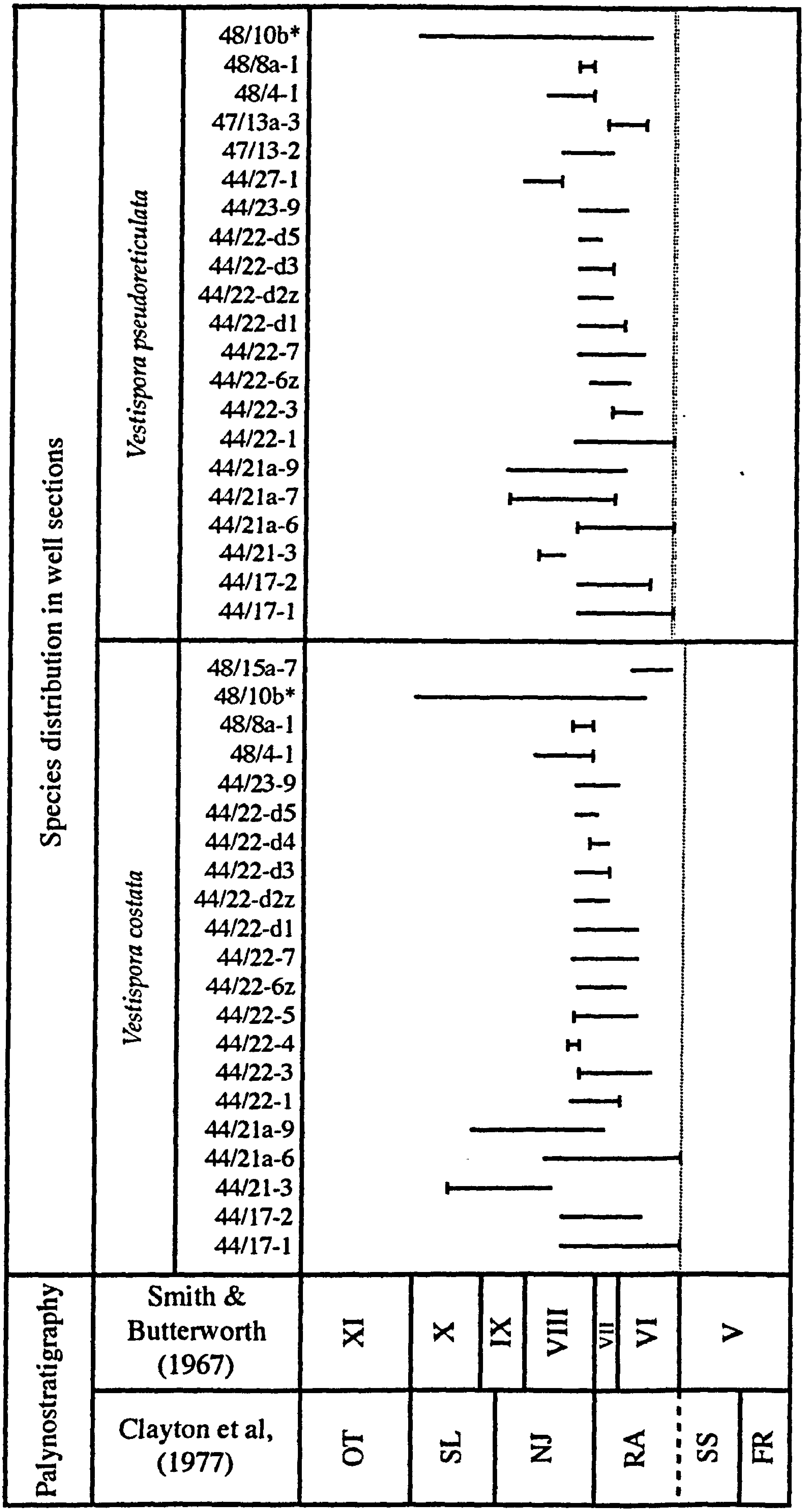


Figure 13v. Distribution of species in well sections.

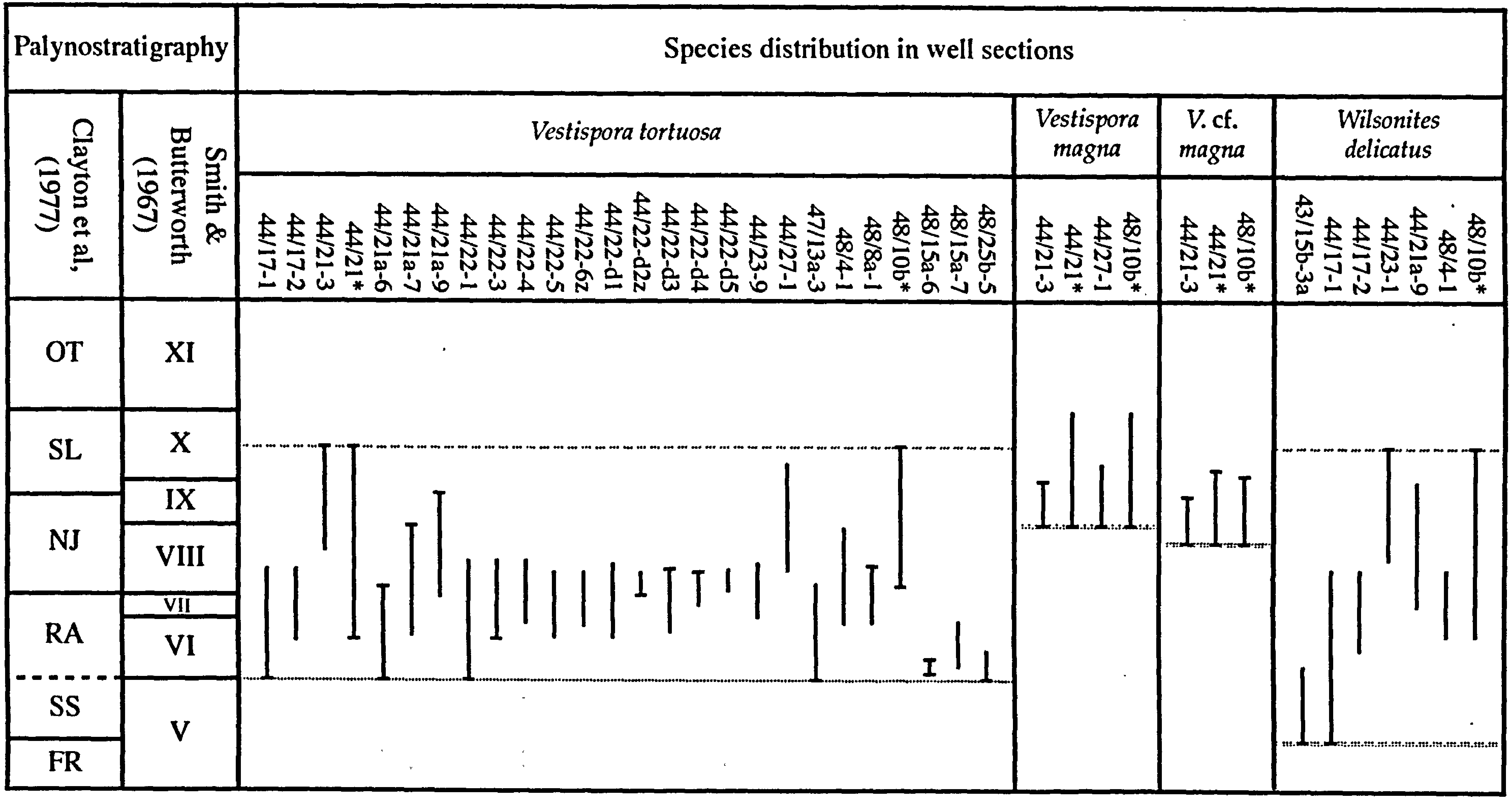


Figure 13w. Distribution of species in well sections.

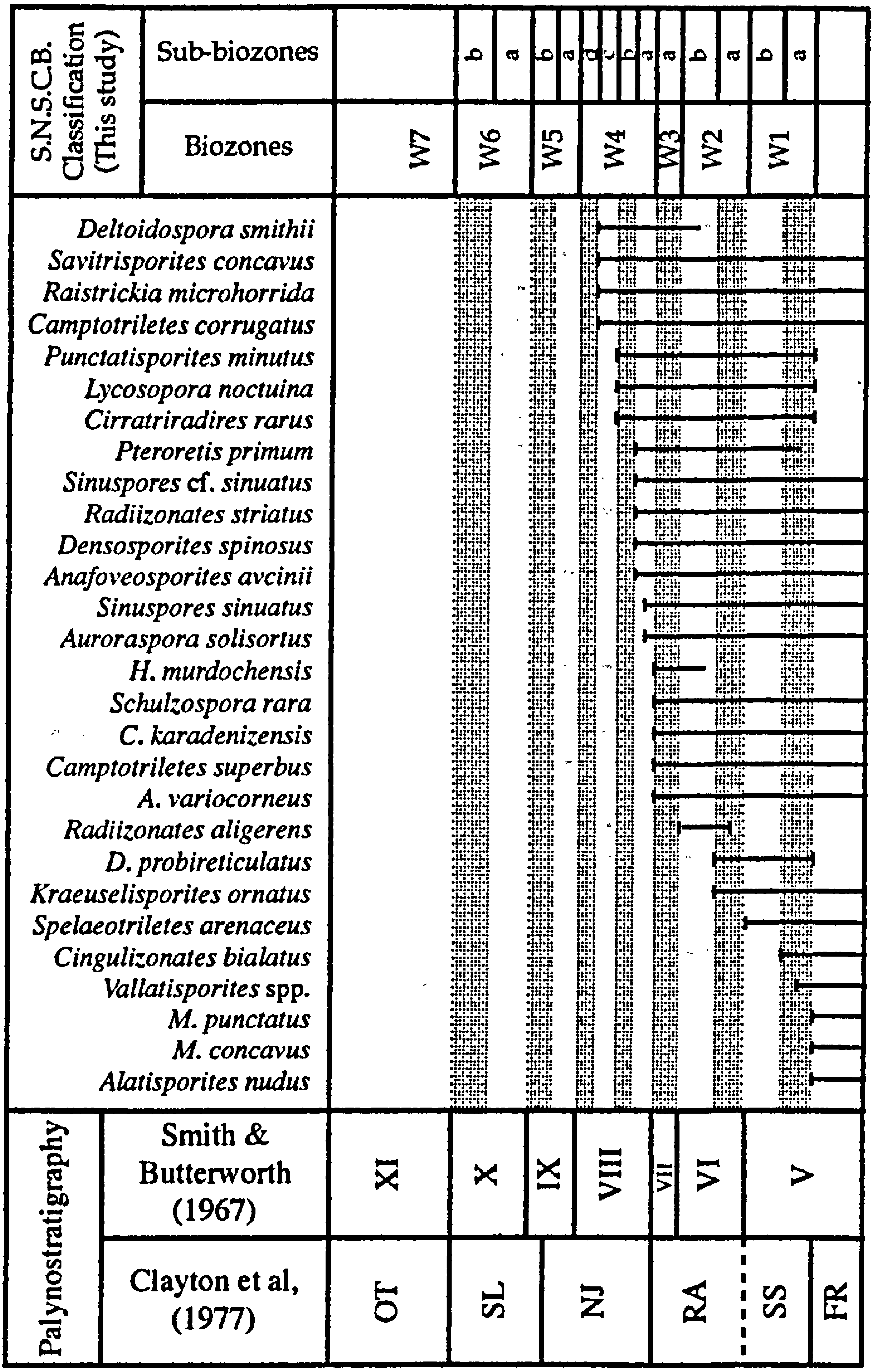


Figure 14a. Composite ranges of selected taxa in S.N.S.C.B well sections.

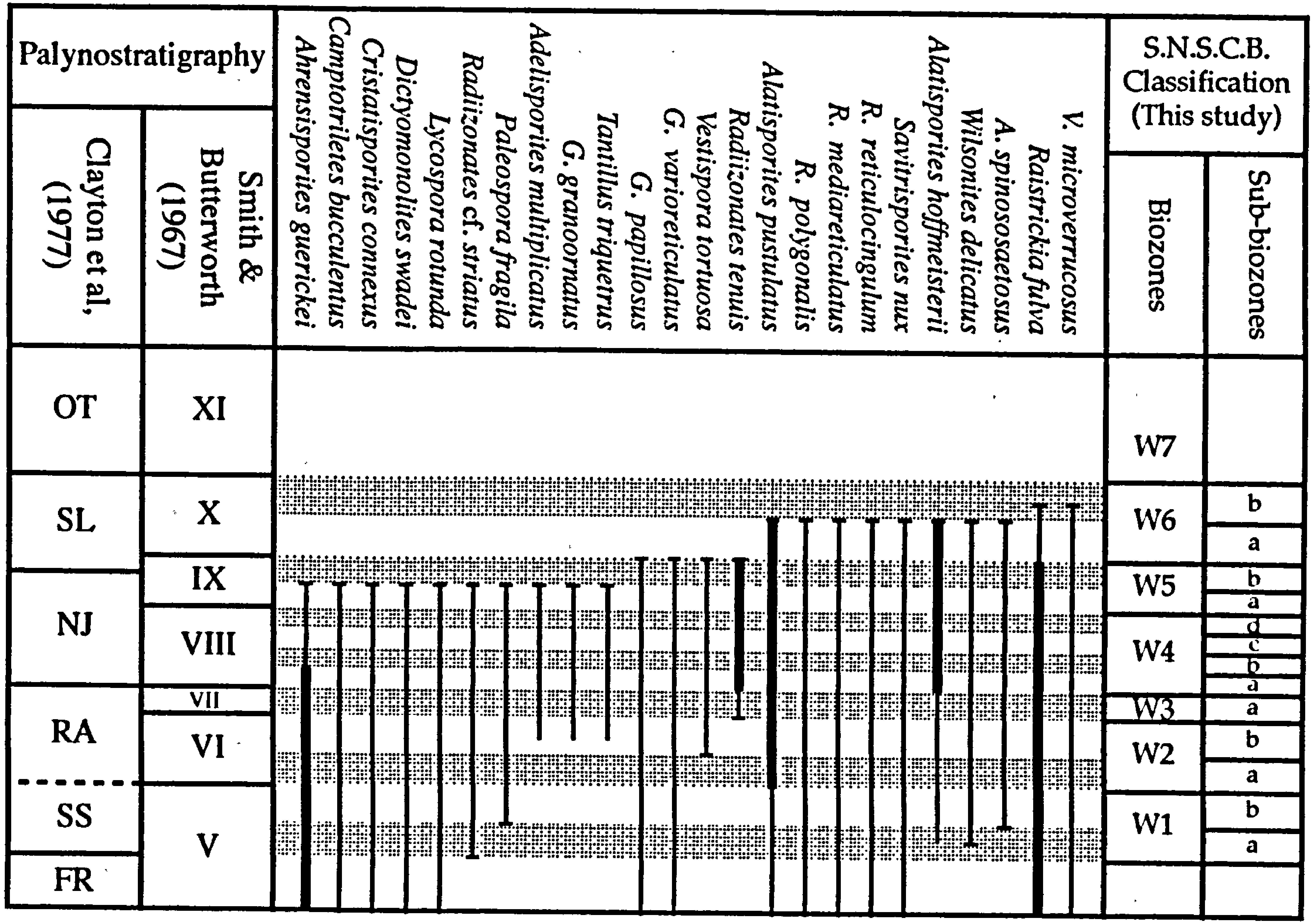


Figure 14b. Composite ranges of selected taxa in S.N.S.C.B well sections.

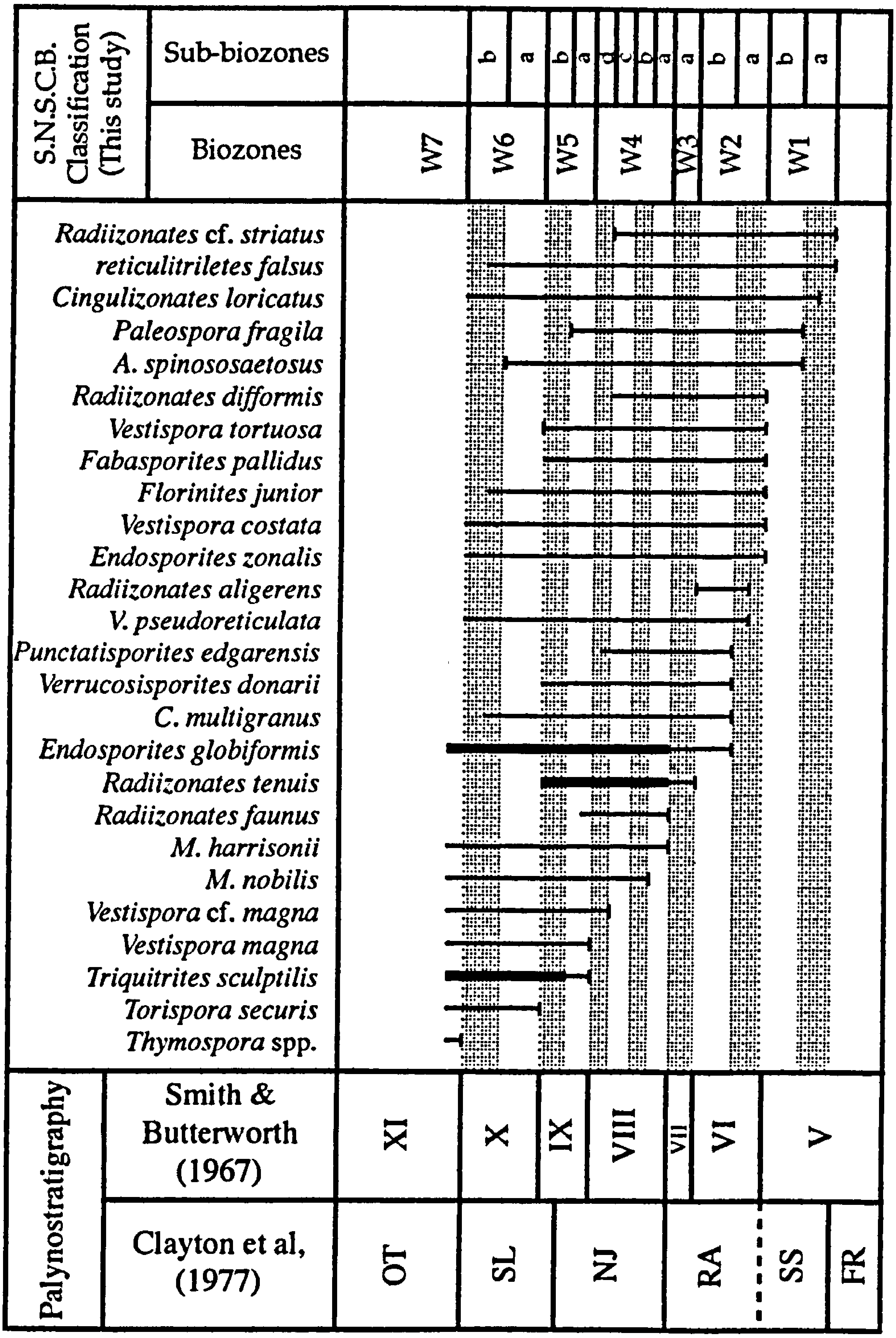


Figure 14c. Composite ranges of selected taxa in S.N.S.C.B well sections.

partial acme biozones and concurrent range biozones. Being based on such a *mélange* of biostratigraphic data, the precise nature of these zones is difficult to define. The nature of the qualitative and quantitative stratigraphic distribution of palynomorphs is more often than not such as to defy the application of simplistic biostratigraphic concepts of classification. Indeed, a striking feature of several of the published palynostratigraphic classifications of Carboniferous sequences (as well as those for other parts of the geological column), is the failure of workers (e.g. Clayton *et al.*, 1977) to define the types of zones that they employ. On the other hand, many workers apply assemblage biozones with their inherent difficulties of definition (e.g. see Whittaker *et al.*, 1991). With the exception of coal seam palynology (see Smith & Butterworth, 1967; Peppers, 1979) in which miospore assemblages by-and-large represent the parent vegetation from the coal-forming mire ecosystem, most Carboniferous palynological assemblages (i.e. from clastic sequences) do not represent a single ecosystem. As mentioned above, clastic palynological assemblages provide a representation of the plant ecosystems on a drainage basin-wide scale and so do not present fossil data amenable to use in assemblage biozones as defined by the International Stratigraphic Guide (Hedberg, 1976). Perhaps the biozonal concept most obviously applicable to Carboniferous palynostratigraphy is the concurrent range biozone (e.g. see Neves *et al.*, 1973). However, given the obvious changes in abundance and diversity of Carboniferous palynofloras at particular stratigraphic levels, it has proved a great temptation to many authors to embellish such units with species abundance data, thus transcending the limits of their rigid definition. Thus, for example the concurrent range biozones of Neves *et al.* (1973) became "concurrent miospore assemblage zones", and later "concurrent miospore assemblage range zones" in the eyes of Clayton *et al.* (1977). Clearly something else is meant here, but its definition has proved elusive.

In the palynostratigraphic classification outlined below the biozones and sub-biozones are best described as concurrent range biozones *sensu lato*, in that they allow for species abundance data as well as total and partial stratigraphic ranges of palynomorphs. As such, they correspond to the common European usage of that vague concept, the Oppelzone (Hancock, 1977).

2.4. BIOZONE NOMENCLATURE.

The Biozones and sub-Biozones are named with a lettering and numbering system rather than with the names of fossils. Although this is contrary to standard stratigraphic procedure (Hedberg, 1976) it is applied in order to simplify the classification and to facilitate its interpretation by the non-palaeontologist.

The Biozones are contiguous and are described in ascending sequence. Biozones defined for the Westphalian are named W1 to W7. Sub-biozones are identified by a suffix (a, b, c, etc.), also in ascending sequence. An *ascending* sequential numbering of the biozones is sensible in that the biozones may be expected to reflect the evolutionary development of the palynoflora.

2.5. DESCRIPTION OF THE BIOZONES.

As the biozones are contiguous, and in keeping with stratigraphic procedure, they are defined by their bases: bases of overlying units defining the tops of underlying units.

Ideally, the definition of a biozone should be accompanied by the selection and description of a representative type section, as has been demonstrated by Richardson & McGregor (1986) for a palynostratigraphic classification of the Silurian and Devonian. In this study, however, the confidential nature of unreleased lithostratigraphic well data precludes this practice.

Criteria used to define the biozones is summarised in Figure 15.

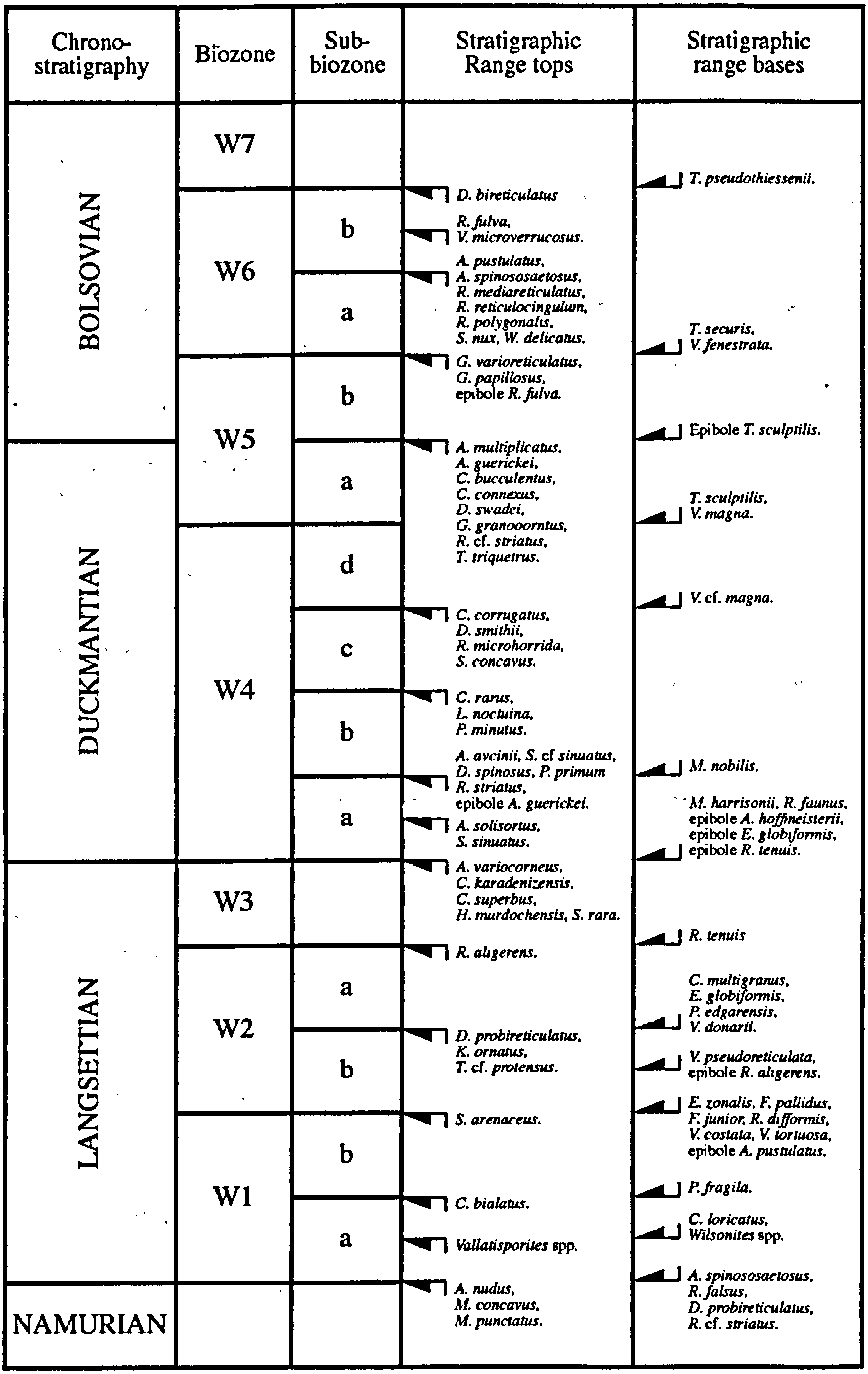


Figure 15. Summary of criteria used to define biozone boundaries.

2.5.1. Biozone W1.

Age:
Early Langsettian.

Definition of Biozone Base:
Range tops of *Alatisporites nudus, Microreticulatisporites concavus, M. punctatus* and *Vallatisporites* spp.

Range bases of *Dictyotriletes probireticulatus, Radiizonates* cf. *striatus, Reticulitriletes falsus* and *Apiculatasporites spinososaetosus.*

2.5.2. Sub-Biozone W1a.

Age:
Early Langsettian.

Definition of Sub-Biozone Base:
Range tops of *Alatisporites nudus, Microreticulatisporites concavus, M. punctatus* and *Vallatisporites* spp.

Range bases of *Dictyotriletes probireticulatus, Radiizonates* cf. *striatus, Reticulitriletes falsus* and *Apiculatasporites spinososaetosus.*

Remarks:
The range bases of *Cingulizonates loricatus* and *Wilsonites delicatus* occur within this sub-biozone.

2.5.3. Sub-Biozone W1b.

Age:
Early Langsettian.

Definition of Sub-Biozone Base:
Range top of *Cingulizonates bialatus.*

Range base of *Paleospora fragila.*

2.5.4. Biozone W2.

Age:
Late to middle Langsettian.

Definition of Biozone Base:
Range top of *Spelaeotriletes arenaceus.*

Range bases of *Endosporites zonalis, Fabasporites pallidus, Florinites junior, Radiizonates difformis, Vestispora costata* and *V. tortuosa.*

Base of common *Alatisporites pustulatus.*

2.5.5. Sub-Biozone W2a.

Age:
Middle Langsettian.

Definition of Sub-Biozone Base:
Range top of *Spelaeotriletes arenaceus.*

Range bases of *Endosporites zonalis, Fabasporites pallidus, Florinites junior, Radiizonates difformis, Vestispora costata* and *V. tortuosa.*

Base of common *Alatisporites pustulatus.*

Remarks:
The range base of *Vestispora pseudoreticulata* and the base of the epibole of *Radiizonates aligerens* occur within this sub-biozone.

2.5.6. Sub-Biozone W2b.

Age:
Late Langsettian.

Definition of Sub-Biozone Base:
Range tops of *Dictyotriletes probireticulatus, Kraeuselisporites ornatus,* and *Triquitrites* cf. *protensus.*

Range bases of *Cyclogranisporites multigranus, Endosporites globiformis, Punctatisporites edgarensis* and *Verrucosisporites donarii.*

2.5.7. Biozone W3.

Age:
Late Langsettian.

Definition of Biozone Base:
Range top of *Radiizonates aligerens.*

Range base of *Radiizonates tenuis.*

2.5.8. Biozone W4.

Age:
Late to early Duckmantian.

Definition of Biozone Base:
Range tops of *Apiculatasporites variocorneus, Camptotriletes superbus, Cordylosporites karadenizensis, Echinatisporis echinatoides, Hymenospora murdochensis* and *Schulzospora rara.*

Range bases of *Microreticulatisporites harrisonii* and *Radiizonates faunus.*

Base of epiboles of *Alatisporites hoffmeisterii, Endosporites globiformis* and *Radiizonates tenuis.*

2.5.9. Sub-Biozone W4a.

Age:
Early Duckmantian.

Definition of Sub-Biozone Base:
Range tops of *Apiculatasporites variocorneus, Camptotriletes superbus, Cordylosporites karadenizensis, Echinatisporis echinatoides, Hymenospora murdochensis* and *Schulzospora rara.*

Range bases of *Microreticulatisporites harrisonii* and *Radiizonates faunus.*

Base of epiboles of *Alatisporites hoffmeisterii, Endosporites globiformis* and *Radiizonates tenuis.*

Remarks:
The range tops of *Auroraspora solisortus* and *Sinuspores sinuatus* occur in the middle part of this sub-biozone.

2.5.10. Sub-Biozone W4b.

Age:
Middle Duckmantian.

Definition of Sub-Biozone Base:
Range tops of *Anafoveosporites avcinii, Densosporites spinosus* and *Sinuspores* cf. *sinuatus.*

Top of epibole of *Ahrensisporites guerickei.*

Range base of *Microreticulatisporites nobilis.*

2.5.11. Sub-Biozone W4c.

Age:
Middle Duckmantian.

Definition of Sub-Biozone Base:
Range tops of *Cirratriradites rarus, Lycospora noctuina* and *Punctatisporites minutus.*

2.5.12. Sub-Biozone W4d.

Age:
Late Duckmantian.

Definition of Sub-Biozone Base:
Range tops of *Camptotriletes corrugatus, Deltoidospora smithii, Raistrickia microhorrida* and *Savitrisporites concavus.*

Range base of *Vestispora* cf. *magna.*

2.5.13. Biozone W5.

Age:
Early Bolsovian to late Duckmantian.

Definition of Biozone Base:
Range bases of *Vestispora magna* and *Triquitrites sculptilis.*

2.5.14. Sub-Biozone W5a.

Age:
Latest Duckmantian.

Definition of Sub-Biozone Base:
Range bases of *Vestispora magna* and *Triquitrites sculptilis.*

2.5.15. Sub-Biozone W5b.

Age:
Early Bolsovian.

Definition of Sub-Biozone Base:
Range tops of *Adelisporites multiplicatus, Ahrensisporites guerickei, Camptotriletes bucculentus, Cristatisporites connexus, Dictyomonolites swadei, Granulatisporites granoornatus, Lycospora rotunda, Radiizonates* cf. *striatus* and *Tantillus triquetrus.*

Base of epibole of *Triquitrites sculptilis.*

2.5.16. Biozone W6.

Age:
Late to early Bolsovian.

Definition of Biozone Base:
Range tops of *Grumosisporites papillosus* and *G. varioreticulatus.*

Top of epibole of *Raistrickia fulva.*

Range bases of *Torispora securis* and *Vestispora fenestrata.*

2.5.17. Sub-Biozone W6a.

Age:
Middle and early Bolsovian.

Definition of Sub-Biozone Base:
Range tops of *Grumosisporites papillosus* and *G. varioreticulatus.*

Top of epibole of *Raistrickia fulva.*

Range bases of *Torispora securis* and *Vestispora fenestrata.*

Remarks:
The base of the epibole of *Punctatosporites* spp. occurs slightly above the base of this sub-biozone.

2.5.18. Sub-Biozone W6b.

Age:
Late Bolsovian.

Definition of Sub-Biozone Base:
Range top of *Alatisporites pustulatus, Apiculatasporites spinososaetosus, Reticulatisporites polygonalis, Reticulitriletes mediareticulatus, R. reticulocingulum, Savitrisporites nux, Vestispora tortuosa* and *Wilsonites delicatus.*

Remarks:
The range tops of *Raistrickia fulva* and *Verrucosisporites microverrucosus* occur in the middle part of this sub-biozone.

2.5.19. Biozone W7.

Age:
Westphalian D and latest Bolsovian.

Definition of Biozone Base:
Range top of *Dictyotriletes bireticulatus.*

Range base of *Thymospora* spp.

2.6. DISCUSSION.

To a certain extent the development of a palynostratigraphic classification from subsurface sections without independent control becomes an exercise in homotaxial stratigraphy (*sensu* Scott, 1965). This does not necessarily detract from the value of the classification in itself, but in order to appreciate the implications of the application of it in a larger (extra-basinal) context requires integration with a larger-scale stratigraphy (i.e. the chronostratigraphy).

Fortunately, the Silesian ammonoid ortho-chronostratigraphy is able to provide this, but only in exceptional circumstances where ammonoids and palynology can be directly related (i.e. are recovered from the same rock sample). As mentioned earlier, macrofossils are rarely recovered from boreholes. Where they are they must be used as an acid test of the homotaxial palynostratigraphic model. Only in this way can the palynostratigraphy be calibrated with and integrated with the chronostratigraphy.

PAGE

NUMBERING

AS ORIGINAL

3. CALIBRATION OF THE CLASSIFICATION.

As the described palynostratigraphic classification is related, via the known onshore distribution of palynomorphs, to the Silesian chronostratigraphy, it should provide a model which may be used to predict the distribution of chronostratigraphic units (i.e. stages) in the S.N.S.C.B. This implies that it should be able to predict or define the positions of goniatite-bearing marine bands or their lateral equivalents in the S.N.S.C.B. Attempting to use the classification as such a predictive model would achieve two things. Firstly it would test its accuracy and applicability to new sections within the S.N.S.C.B. Secondly, if the model can accurately predict and/or define the position of marine band sediments, it would enable direct calibration with the Silesian chronostratigraphy. In other words, identification of biozonal boundaries in association with independently identified stage boundary marine bands in an off-shore section would provide a direct calibration of the biostratigraphy with the chronostratigraphy. This would obviate the need to use the regional onshore palynostratigraphy to mediate between the two.

The prime difficulty in testing and calibrating the classification in this way is that marine bands in S.N.S.C.B wells are usually identified by their geophysical log signatures and/or their palynology (Leeder *et al.*, 1990). In order to avoid circular reasoning it would be necessary to have an independent means of identifying marine bands. Ideally, this would be achieved by the recognition of a marine macrofauna. However, goniatites or other marine macrofauna are rarely, if ever, identified in S.N.S.C.B. boreholes as, for practical reasons, there is generally a lack of core material from which they may be extracted. Furthermore, most cores are taken through reservoir sandstones rather than through mudstone sequences.

The palynological identification of the Langsettian-Duckmantian boundary in the area of the Murdoch Gas Field, Block 44/22, lends itself to the testing and calibration of the classification. Wells in this field have provided large amounts of core material. Furthermore, the identification of the Vanderbeckei Marine Band, based on previous geophysical log and palynological analyses is subject to debate.

3.1. THE MURDOCH GAS FIELD.

The Murdoch Gas Field is located in Block 22 of Quadrant 44 in the Silver Pit area of the southern North Sea. It lies some 160km from the Yorkshire coast and some 25km from the UK-Netherlands median line (Figure 16). The Field consists of a Carboniferous gas accumulation which was discovered in 1984 (Gunn *et al.*, 1993). The accumulation is trapped within a faulted northwest to southeast trending anticline which is bounded to the northeast by a major reverse fault. The stratigraphy of the Field is typical of the S.N.S.C.B. except that the Rotliegende Leman Sandstones are absent as they pass laterally into mudstones of the Silver Pit Formation in the area. The reservoir is formed by Westphalian fluvio-deltaic sandstones which are sealed by mudstones of Duckmantian age and by mudstones of the Rotliegend Group Silver Pit Formation (Figure 17), (Green & Slatt, 1992; Bailey *et al.*, 1993; Ritchie & Pratsides, 1993). Carboniferous, Westphalian, Coal Measures provide the source of the gas (Cornford, 1984; Bailey *et al.*, 1993).

3.1.1. History of research.

The Murdoch Carboniferous gas accumulation was first discovered in 1984. Palynostratigraphic monitoring of the first 7 wells to penetrate the Carboniferous sequences in the Field was carried out at Sheffield University Industrial Palynology Unit (Neves, 1985a,b, 1987, 1988a,b,c; Turner, 1990). These provided a palynostratigraphic breakdown suitable for the requirements of the exploration phase of the Field. The palynostratigraphy was interpreted in terms of the onshore palynostratigraphic classifications of Smith & Butterworth (1967) and Clayton *et al.* (1977). Subsequently the palynostratigraphy of the sequences immediately sub- and supradjacent to the reservoir sandstone was refined by McLean & Turner (1990a) for application to the development phase of hydrocarbon exploitation. From the point of view of this study the most important aspect of this palynological research is that the Vanderbeckei Marine Band was identified as lying immediately beneath the Murdoch reservoir sandstone. However, palynostratigraphic and palynofacies analyses carried out by other consultants, and based on an unpublished, 'in house' zonation, identified the Vanderbeckei Marine Band either above the Murdoch reservoir sandstone (Whitaker & Easterfield, 1987a,b,c) or below it (Buck & Cubitt, 1986; Whitaker, *et al.*, 1987).

There is thus a question regarding the exact stratigraphic position of the Vanderbeckei Marine Band in the Murdoch Gas Field. The problem lends itself

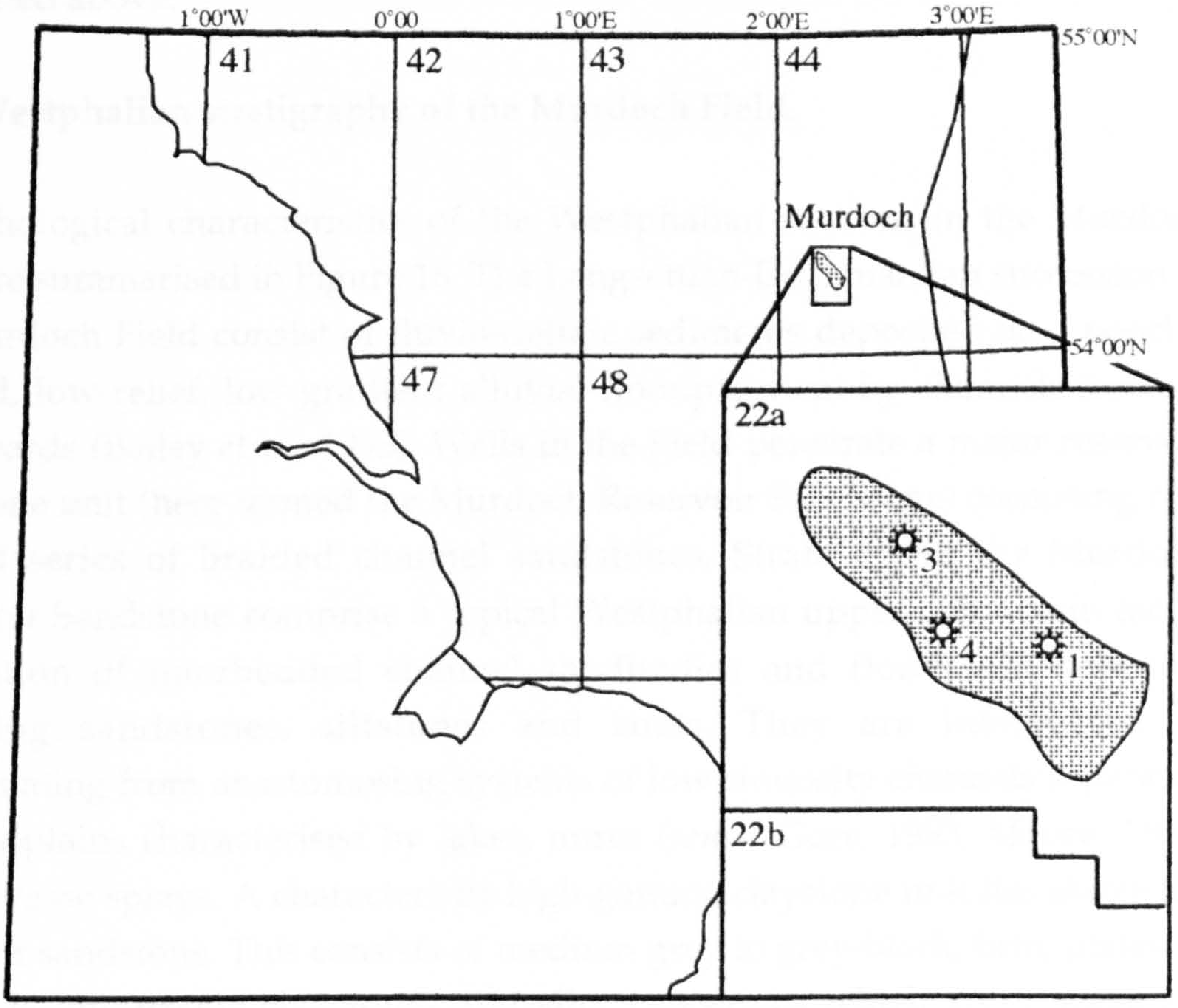


Figure 16. Location of Murdoch Gas Field in Quadrant 44, Block 22, and position of wells 44/22-1, 44/22-3 and 44/22-4.

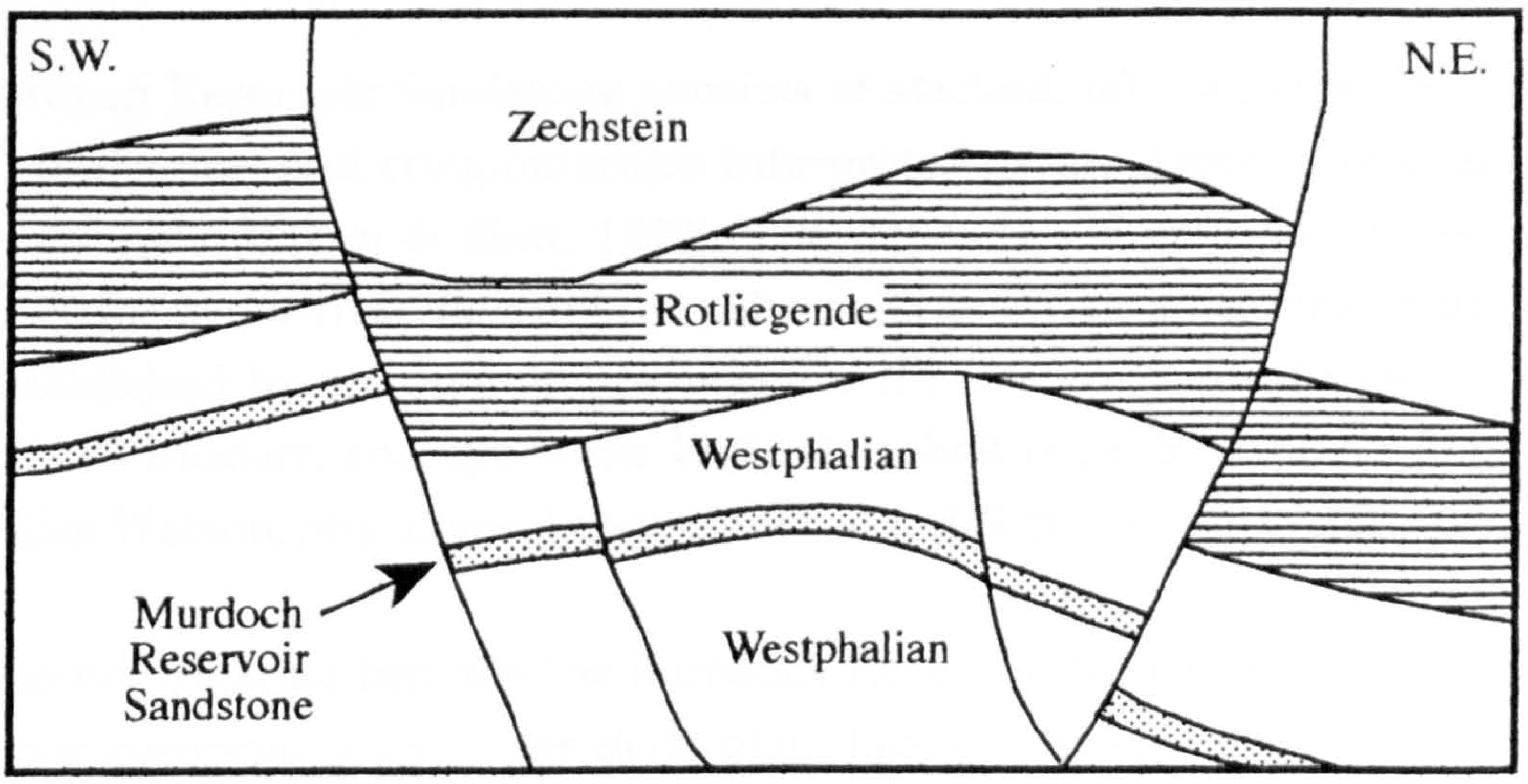


Figure 17. Simplified structural cross-section through the Murdoch Gas Field.

to a critical test of the established palynostratigraphic classification, as mentioned above.

3.1.2. Westphalian stratigraphy of the Murdoch Field.

The lithological characteristics of the Westphalian sections in the Murdoch Field are summarised in Figure 18. The Langsettian-Duckmantian succession in the Murdoch Field consist of fluvio-deltaic sediments deposited on a poorly-drained, low-relief, low-gradient alluvial floodplain cut by channels flowing southwards (Bailey *et al.*, 1993). Wells in the Field penetrate a major reservoir sandstone unit (here termed the Murdoch Reservoir Sandstone) consisting of a stacked series of braided channel sandstones. Strata above the Murdoch Reservoir Sandstone comprise a typical Westphalian upper delta plain facies association of interbedded channel sandbodies and floodplain deposits, including sandstones, siltstones and coals. They are interpreted as accumulating from anastomosing systems of low sinuosity channels separated by floodplains characterised by lakes, mires (*sensu* Gore, 1983; Moore, 1987) and crevasse splays. A characteristic high-gamma claystone unit lies above the reservoir sandstone. This consists of medium grey to grey-black, firm, platey to subfissile, micaceous claystones and silty claystones which are moderately carbonaceous and contain occasional interbeds of dolomite-indurated fine sands. According to Whitaker & Easterfield (1987a,b,c) these high-gamma claystones represent the Vanderbeckei Marine Band.

The Murdoch Reservoir Sandstone consists of stacked, tabular, cross-bedded, pebbly sandstones and conglomerates interpreted as the deposits of braided fluvial channels (Green & Slatt, 1992). The depositional channels represent either a major trunk-river flowing over the delta plain, or an extensive braidplain established by tectonic rejuvenation of the basin. By comparison with onshore and modern analogues the braidplain belt is probably over 5km in width (Kim Watson, *pers. comm.*) and may be over 10km (Collinson *et al.*, 1993).

The sequence of strata beneath the Murdoch Reservoir Sandstone is similar to that above, comprising an upper delta plain facies association of interbedded channel sandbodies and floodplain deposits, including sandstones, siltstones and coals. Immediately beneath the reservoir sandstone lies a high-gamma claystone unit. This consists of medium grey to grey-black, firm, blocky, platey or subfissile, micaceous, non-calcareous, carbonaceous claystones and silty claystones. A thin, indurated, sandy unit occurs within this unit. The high-gamma claystone is interpreted by Neves (1985a,b), Buck & Cubitt (1986), and

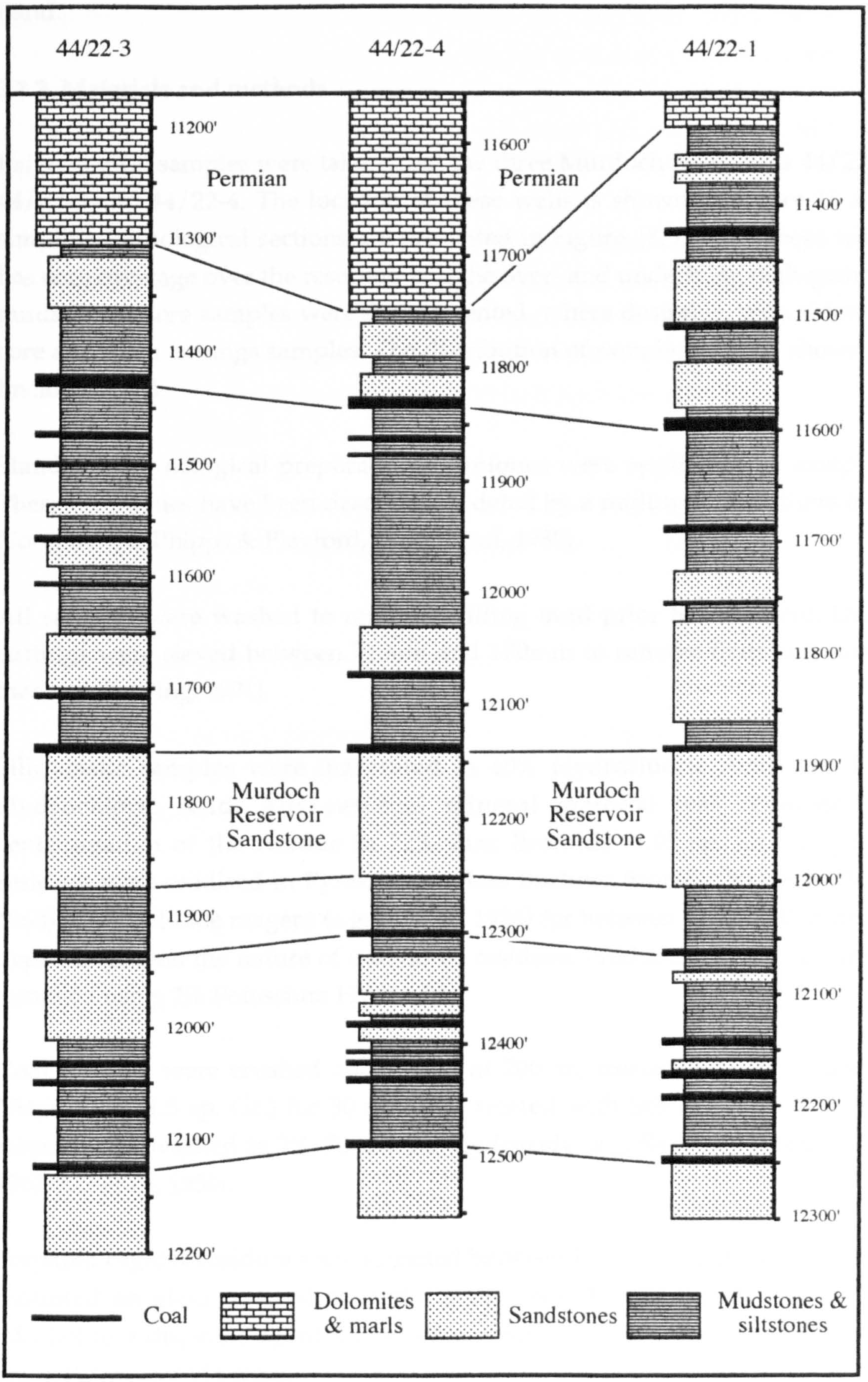


Figure 18. Simplified Langsettian-Duckmantian well sections in Murdoch Field study wells (coal seam correlations after McLean & Turner, 1990).

Whitaker *et al.* (1987) as the equivalent horizon of the Vanderbeckei Marine Band.

3.1.3. Materials and methods.

Palynological samples were taken from the three Murdoch Field wells 44/22-1, 44/22-3 and 44/22-4. The location of these wells is shown in Figure 16 and simplified lithological sections are presented in Figure 18. Each of these wells has core coverage over the reservoir and the over- and underlying high-gamma mudstones. Core samples were supplemented, where desirable, with sidewall core and ditch cuttings samples. The distribution of sample points is shown in Enclosures 1-3.

Standard palynological preparation techniques were applied to all samples. These techniques have been described in detail by a multitude of authors (e.g. Norem, 1956; Phipps & Playford, 1984; Rasul, 1985).

All samples were washed to remove drilling mud prior to treatment. Ditch cuttings were sieved between 710μm and 170mm to remove fines and caved material (Keating, 1991).

Siliciclastic samples were macerated in 40% Hydrofluoric Acid and 35% Hydrochloric Acid. Any residual mineral material was removed by centrifugation of the residue in 72% Zinc Bromide (1.95 sp. Gr.). Organic residues were oxidised in Pyrex sinter-glass Buchner funnels (Neves & Dale, 1963) using Schulze reagent (e.g. Norem, 1956) for between 20 and 60 minutes depending upon the nature of individual residues. Products of oxidation were removed using 2% Potassium Hydroxide.

Coal samples were crushed and sieved at 200μm, treated with 95% fuming Nitric Acid (1.5 sp. Gr.) for 30 minutes, treated with Schulze reagent for 30 minutes and washed in 2% Potassium Hydroxide (e.g. Smith & Butterworth, 1967; Kosanke, 1950).

Prepared organic residues were screened between 10μm and 180μm sieves and mounted on glass cover slips (Jeffords & Jones, 1959) using 1% Polyvinyl Alcohol as a dispersal agent. Cover slips were mounted on microscope slides using Petropoxy 154 resin.

At least two slides of the palynological assemblage from each sample were examined under transmitted light using an Olympus BH-2 binocular microscope. An initial count of 200 specimens was made following Barkley (1934). The count traverses were made across the central part of each slide to minimise bias (Brooks & Thomas, 1967). All other taxa were recorded while scanning the remaining area of the slides.

Partly broken or badly folded palynomorphs were included in the counts if identification was possible. It is recognised, however, that this may introduce bias as some taxa (e.g. *Lycospora* spp.) are more readily identified, even in a severely damaged state, than other taxa. Forms which could not be identified at generic level (e.g. many monosaccate specimens) were recorded under separate categories in the counts.

Several claystone samples were processed for conodonts. Samples weighing up to 50g. were crushed, disaggregated using Bromine and the residues picked over for organic remains.

3.1.4 Palynostratigraphy of the well sections.

The distribution of palynomorphs from the three wells 44/22-1, 44/22-2 and 44/22-4 is shown in Enclosures 1-3. The distributions of species which are considered significant in the palynostratigraphic classification are shown in Figure 19.

In all three wells the W2-W3 biozonal boundary can be clearly identified by the first occurrence downhole (extinction datum) of *Radiizonates aligerens*. Similarly the W3-W4 biozonal boundary can be clearly identified in all three wells by the first occurrence downhole of *Schulzospora rara* and *Hymenospora murdochensis*. This indication is supported by the stratigraphic position of the base of the common occurrence of *Endosporites globiformis* and, in wells 44/22-3 and -4, the last occurrence downhole of *Microreticulatisporites harrisonii*. Furthermore, the two biozonal boundaries W2-W3 and W3-W4 occur at consistent horizons within the three wells; the W3-W4 boundary being consistently associated with the high-gamma mudstone unit beneath the Murdoch Reservoir sandstone, and the W2-W3 boundary being associated with a prominent coal seam horizon 200' beneath the base of this mudstone unit.

Identification of the boundary between Sub-biozones W4a and W4b is achieved in wells 44/22-3 and 44/22-4 by the recognition of the first occurrence

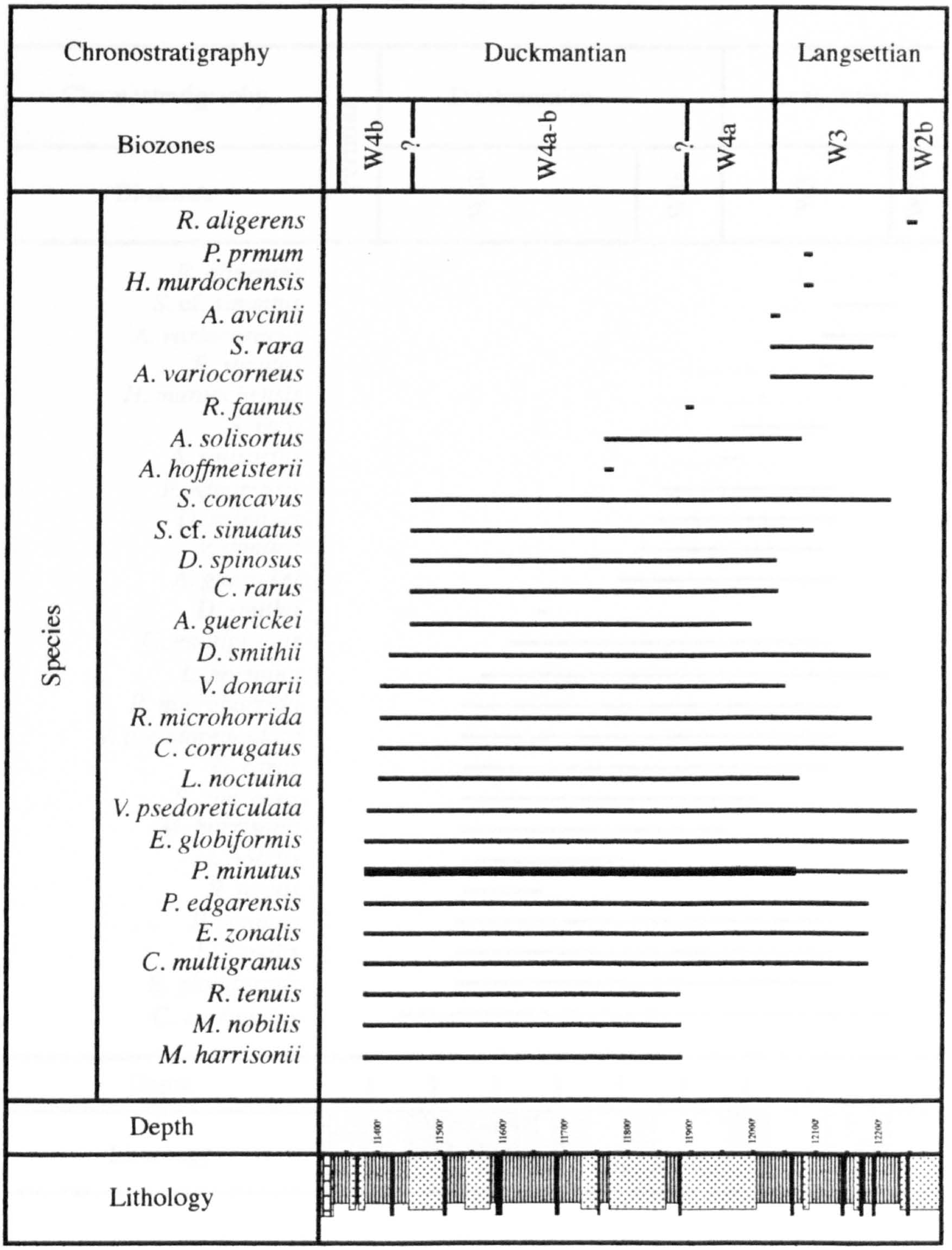


Figure 19a. Distribution of critical miospore taxa in well 44/22-1.

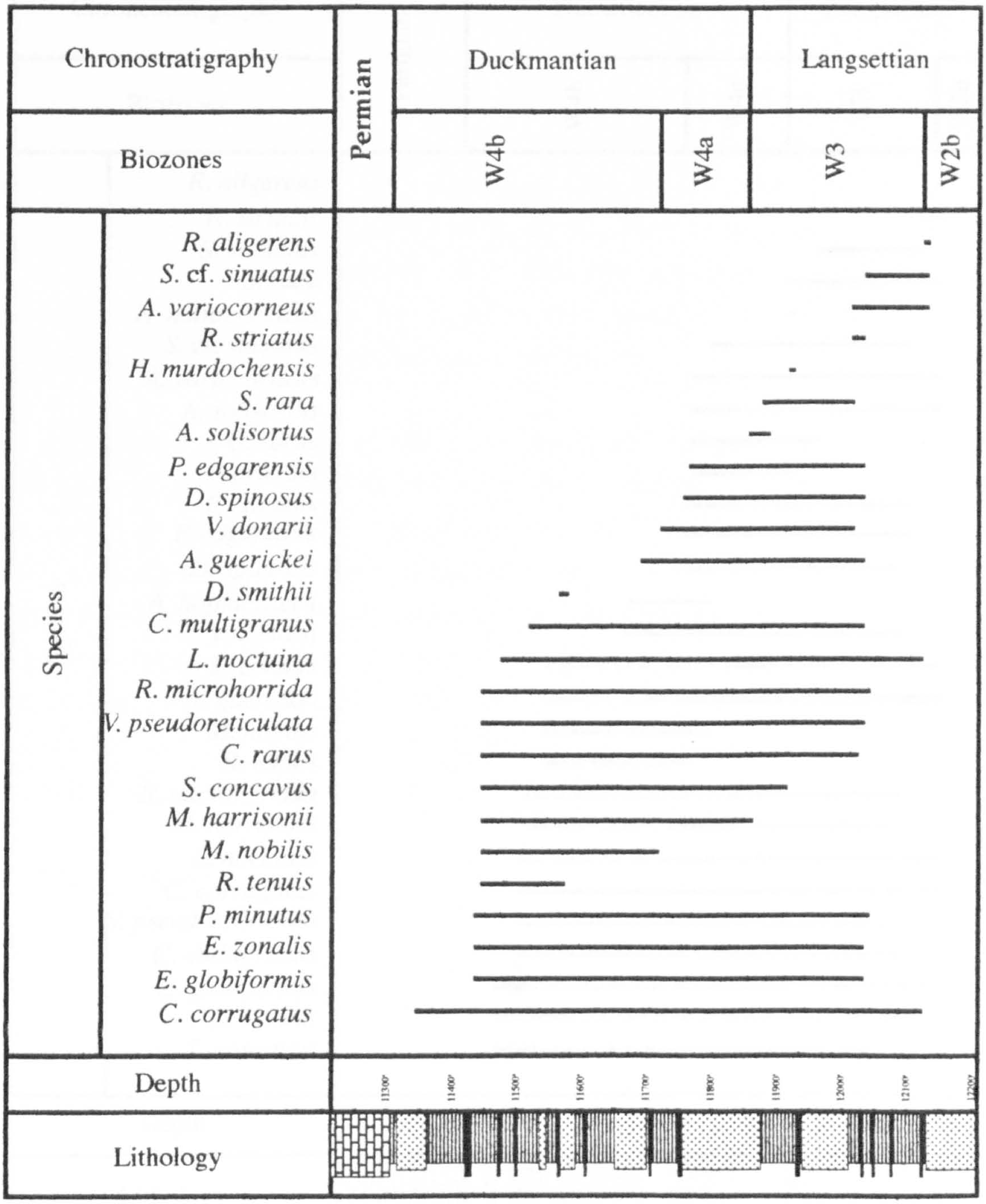


Figure 19b. Distribution of critical miospore taxa in well 44/22-3.

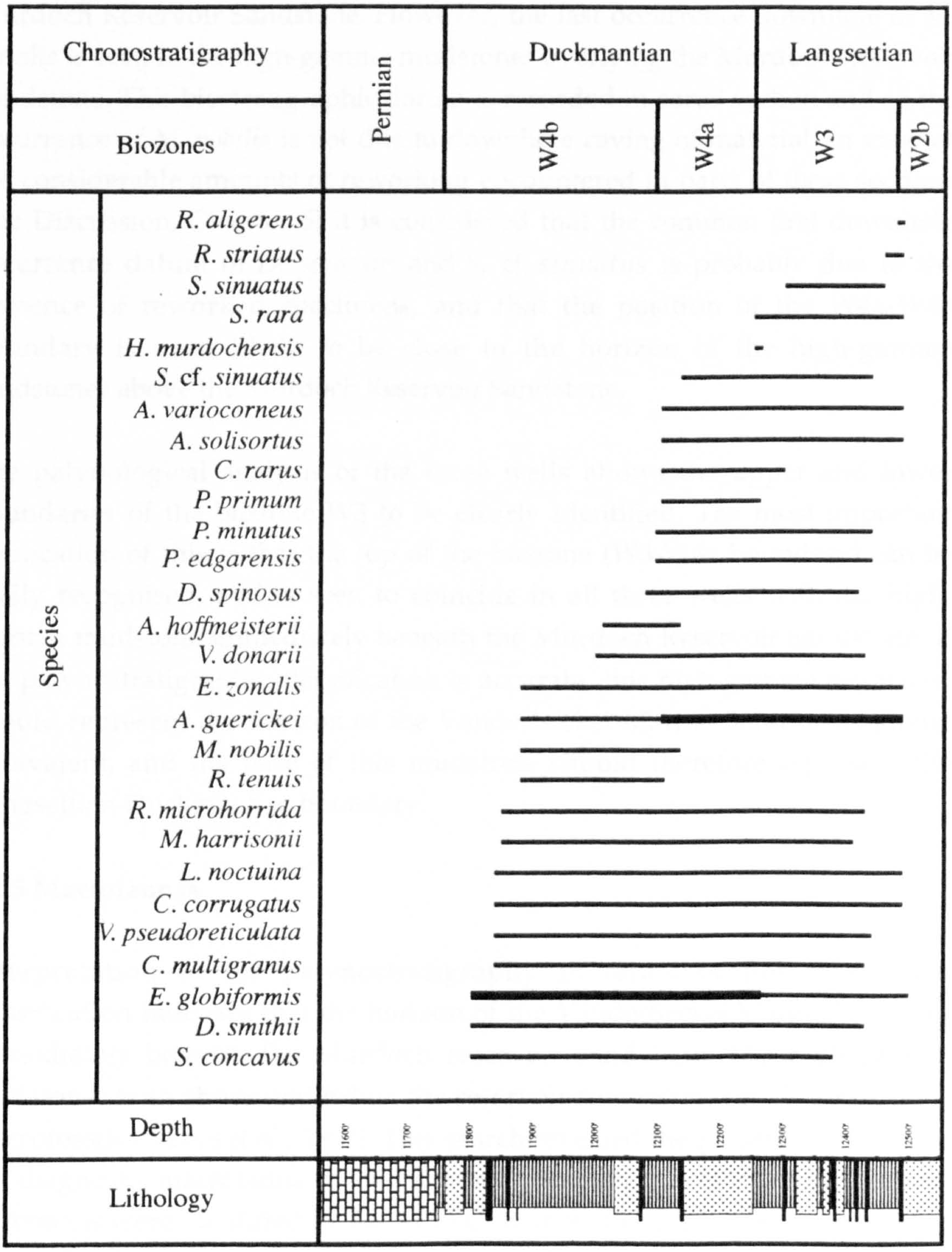


Figure 19c. Distribution of critical miospore taxa in well 44/22-4.

downhole of *Densosporites spinosus, Sinuspores* cf. *sinuatus* and *Pteroretis primum,* and by the last occurrence downhole of *Microreticulatisporites nobilis.* In both wells this boundary is associated with the upper part of the mudstone-siltstone unit which overlies the Murdoch Reservoir Sandstone. The identification of this sub-biozonal boundary in well 44/22-1 is problematical. The first occurrence downhole of *D. spinosus* and *S.* cf. *sinuatus* is some 450' above the top of the Murdoch Reservoir Sandstone. However, the last occurrence downhole of M. nobilis is seen in the high-gamma mudstones overlying the Murdoch Reservoir Sandstone. This biostratigraphic datum is recorded in cored section and so the occurrence of *M. nobilis* is not due to downhole caving of material. In view of the considerable amounts of reworking encountered in parts of these sections (see Discussion, Chapter 5) it is considered that the common first downhole occurrence datum of *D. spinosus* and *S.* cf. *sinuatus* is probably due to the presence of reworked specimens, and that the position of the W4a-W4b boundary is most likely to be close to the horizon of the high-gamma mudstones above the Murdoch Reservoir Sandstone.

The palynological analysis of the three wells allows the upper and lower boundaries of the biozone W3 to be clearly identified. The most important implication of this is that the top of the biozone (W3-W4a boundary) can be easily recognised, and is seen to coincide in all three wells with the high-gamma mudstone immediately beneath the Murdoch Reservoir Sandstone. If the palynostratigraphic classification is accurate, this high-gamma mudstone should represent the horizon of the Vanderbeckei Marine Band or its lateral equivalent, and the base of this mudstone should therefore represent the Langsettian-Duckmantian boundary.

3.1.5 Macrofaunas.

Interpretation of the palynostratigraphy in terms of the established classification indicates that the horizon of the Vanderbeckei Marine Band lies immediately beneath the Murdoch reservoir sandstone. The high-gamma mudstones both above and below the reservoir sandstone were examined for macrofossils (Neves *et al*., 1989). This search revealed the presence of a sparse but diagnostic macrofauna in the claystones beneath the reservoir sandstones. Specimens were identified by Dr. W.H.C. Ramsbottom. Taxa recorded belong to the Brachiopoda: *Spirifer pennystonensis* (Plate 20, figure 4), *Spirifer* sp., *Productus* sp., *Lingula mytilloides* (Plate 20, figure 5), *Lingula* sp. and *Levipustula* sp. (=?*L. piscariae*). Fragments of crinoid ossicles (Plate 20, figure 6) were also recovered but no goniatites were found. The fossils are well preserved and nonabraided. This is taken to indicate that they are recovered from *in situ,* and have not been transported. The stratigraphic distribution of these taxa is shown in Table 2.

This fauna is considered to be representative of the Productoid faunal facies (*sensu* Calver, 1968) of a Marine Band. The presence of *Lingula* at the base of the high-gamma mudstone unit is interpreted as representing the incursion phase of a marine transgressive event. The brachiopod and crinoid fauna represents the acme of a the transgression with the development of a Productoid facies, and the overlying repeated *Lingula* phase represents the regression of the flooding event (Figure 20). This distribution of incursion-acme-regressive phase fossils is similar to that described by Calver (1968) from the Marine Bands in the Westphalian of the Central Pennine Basin.

The fauna is taken to indicate the presence of the Vanderbeckei Marine Band, although diagnostic goniatites were not recovered. *Levipustula piscariae* and *Spirifer pennystonensis* are recorded from the Vanderbeckei Marine Band onshore (e.g., George, 1928; Francis, 1956; Manson, 1957; Calver, 1968) and *S. pennystonensis* is considered to be stratigraphically restricted to the Vanderbeckei Marine Band (Calver, 1968).

The high gamma claystones above the Murdoch reservoir sandstones were also found to contain macrofossils. These have been identified by Dr. R. Neves as an assemblage of the bivalve *Anthracosia ovum* (Plate 20, figure 7). The *A. ovum* acme biozone occupies the earliest Duckmantian (Calver 1956). The occurrence of *A. ovum* is described by Calver (1956) and Eager (1956) as characteristic of the upper part of the Modiolaris non-marine bivalve biozone. The genus *Anthracosia* is restricted to non-marine sediments and is indicative of fresh or brackish water palaeoenvironments (Eager, 1960; Calver (1968).

Conodonts have been recorded from the Vanderbeckei Marine Band onshore (e.g. Calver, 1968). However, no conodonts were recovered from any of the samples processed in this study. This is undoubtedly partly due to the general scarcity of conodonts in Langsettian/Duckmantian sediments in northwest Europe (Higgins, 1985), and to the small sample size prepared. Analyses of Westphalian Marine band sediments for conodonts usually require a large sample size (e.g. 3kg. samples processed by Eager *et al.,* (1991); 55g. samples prepared by Maynard *et al.,* (1991)). Such volumes of rock were not available from the cores in the Murdoch Field wells studied.

Macrofaunal species	Wells and sample depths		
	44/22-1	44/22-3	44/22-4
Anthracosia ovum	11878'	11730'	
Spirifer pennystonensis	12031' 12032'	11872'	12252'
Spirifer sp.			12257'
?Levipustula piscarae	12031'		
Productus sp.	12031'		
Lingula mytiloides	12019' 12045'	11872'	
Crinoid ossicles	12031'	11872'	

Table 2. Distribution of macrofossil species in Murdoch Field wells.

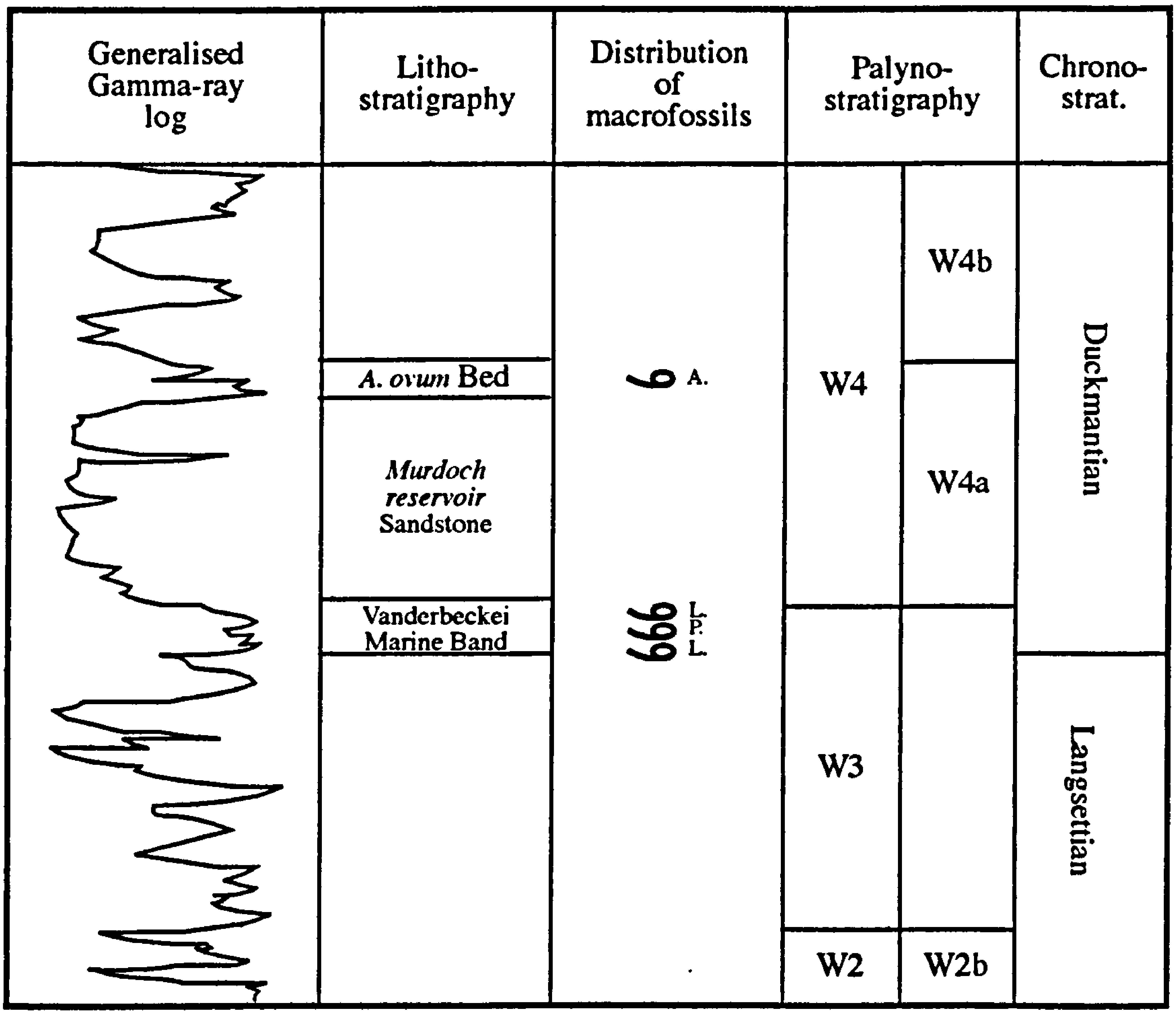


Figure 20. Summary of biostratigraphic interpretations. A. *Anthracosia ovum* fauna, L. *Lingula* fauna, P. Productoid fauna

3.1.6. Conclusions of test.

The presence of a productoid fauna indicative of the Vanderbeckei Marine Band at the boundary of the W4a-W3a biozones shows that the palynostratigraphic classification can be directly calibrated with the onshore chronostratigraphy. These results indicate that the classification can be used as a predictive model for palynostratigraphic to chronostratigraphic correlation in off-shore well-sections. However, it must be stressed that the coincident availability of macrofaunas and palynological data represents a special case. In order for the whole of the classification to be calibrated with the chronostratigraphy it would be necessary to examine any such co-occurrences in considerable detail. Such an exercise, no matter how desirable, is clearly beyond the scope of this thesis.

4. SYSTEMATIC ACCOUNT.

4.1. INTRODUCTION.

4.1.1. Nomenclature

The use of nomenclature in this account follows the rules and recommendations of the International Code of Botanical Nomenclature (I.C.B.N.) (Greuter & McNeill, 1988) and its interpretation by various authors (e.g. Fensome *et al.*, 1992; Jansonius, 1992).

Notation for open nomenclature follows the recommendations of Bengtson (1988), i.e.:

aff. reflates a new, undescribed taxon to a named taxon.

cf. indicates that the identification is provisional.

? indicates that the taxonomic assignation is uncertain.

Although Bengtson referred specifically to nomenclature covered by the International Code of Zoological Nomenclature, his recommendations in no way contradict the rules and recommendations of the I.C.B.N., and an approach at stabilising the use of open nomenclature is to be welcomed.

4.1.2. Supra-generic Classification.

The supra generic classification used in this account follows Dettmann (1963) as modified by Neves & Owens (1966), and incorporates several more recent modifications or suggestions for modifications by Hart (1961 MS), Smith & Butterworth (1967), Williams (1971 MS), Spode (1974 MS), Razzo (1985 MS). The suprageneric hierarchy used is summarised in Figures 21, 22 and 23. Taxa are arranged alphabetically within suprageneric categories.

4.1.3. Terminology.

Descriptive terminology follows the usages of Kremp (1965) and Grebe (1971). Terms relating to exine layering follow Neves & Owens (1966).

TURMA	SUPRASUB TURMA	SUBTURMA	INFRATURMA	GENUS
TRILETES	ACAMERATITRILETES	AZONOTRILETES	LAEVIGATI	*Adelisporites* *Calamospora* *Deltoidospora* *Punctatisporites* *Retusotriletes* *Scutulum* *Sinuspores* *Waltzispora*
			APICULATI	*Anapiculatisporites* *Apiculatasporites* *Apiculiretusispora* *Converrucosisporite* *Cyclogranisporites* *Dibolisporites* *Echinatisporis* *Granasporites* *Granulatisporites* *Lophotriletes* *Neoraistrickia* *Pileatisporites* *Pilosisporites* *Planisporites* *Pustulatisporites* *Raistrickia* *Spackmanites* *Spinositriletes* *Tantillus* *Tricidarisporites* *Verrucosisporites*
			MURONATI	*Anafoveosporites* *Camptotriletes* *Convolutispora* *Corrugitriletes* *Dictyotriletes* *Foveosporites* *Marasmospora* *Microreticulatisporites* *Reticulitriletes*
		ZONOTRILETES	AURICULATI	*Ahrensisporites* *Tripartites* *Triquitrites*
			TRICRASSITI	*Diatomozonotriletes* *Reinschospora* *Trinidulus*
			CINGULATI	*Bellispores* *Knoxisporites* *Reticulatisporites* *Rotaspora* *Savitrisporites* *Stenozonotriletes*
			PSEUDOCINGULATI	*Secarisporites*
			PATINATI	*Archaeozonotriletes*
			ZONATI	*Fragilipollenites* *Kraeuselisporites*

Figure 21. Suprageneric classification of the anteturma SPORITES, turma TRILETES (pars.). See text for authors.

TURMA	SUPRASUBTURMA	SUBTURMA	INFRATURMA	GENUS
TRILETES	CAMERATITRILETES	SOLUTITRILETES	PLANATI	*Auroraspora* *Cystoptychus* *Endosporites* *Spencerisporites*
			DECORATI	*Grandispora* *Grumosisporites* *Rugospora* *Spelaeotriletes*
		MEMBRANATITRILETES	CONTINUATI	*Discernisporites* *Spinozonotriletes* *Ibrahimispores*
			CINGULICAMERATI	*Cingulizonates* *Cirratriradites* *Crassispora* *Cristatisporites* *Densosporites* *Hymenozonotriletes* *Lycospora* *Radiizonates* *Simozonotriletes* *Vallatisporites*
			MEMBRANATI	*Diaphanospora* *Hymenospora*
			POLYCAMERATI	*Alatisporites*
		Indeterminate	Indeterminate	*Colatisporites* *Schulzospora*
	Indet.	Indeterminate	Indeterminate	*Elaterites* *Pteroretis*
M *	Am *	AZONOMONOLETES	LAEVIGATOMONOLETI	*Laevigatosporites* *Latosporites*
			SCULPTATOMONLETI	*Columinisporites* *Dictyomonolites* *Punctatosporites*
A *	Aa *	AZONALETES	PSILONAPITI	*Fabasporites*
H *	Ah *	SOLUTIHILATES	EPITYGMATI	*Vestispora*

Figure 22. Suprageneric classification of the anteturma SPORITES, turmae TRILETES (pars.), MONOLETES, ALETES and HILATES. See text for authors.

M* MONOLETES	Am* ACAMERATOMONOLETES
A* ALETES	Aa* ACAMERATALETES
H* HILATES	Ah* ACAMERATIHILATES

TURMA	SUBTURMA	INFRATURMA	GENUS
SACCITES	MONOSACCITES	TRILETESACCITI	*Costatascyclus* *Guthoerlisporites* *Tinnulisporites* *Wilsonites*
		MONOLETESACCITI	*Peppersites* *Potonieisporites* *Quasillinites*
		ALETESACCITI	*Florinites*
		Indeterminate	striate monosaccate
	DISACCITES	DISACCITRILETI	*Parasporites*
		DISACCIATRILETI	*Limitisporites* *Pityosporites*
		PODOCARPOIDITI	*Platysaccus*
		STRIATITI	*Illinites* *Protohaploxypinus*
PLICATES	PRAECOLPATES	Indeterminate	*Zonalosporites*
	MONOCOLPATES	Indeterminate	*Cycadopites*

Figure 23. Suprageneric classification of the anteturma POLLENITES. See text for authors.

4.1.4. Synonymy.

For the sake of brevity, only the basionym (and first validly or effectively published name, if relevant) and currently applied name are stated unless a species has undergone major nomenclatural changes and/or has other synonymies which are in common usage in northwest european Carboniferous palynology.

4.1.5. Curation of specimens.

All described and figured specimens are housed in the collection of the Industrial Palynology Unit, University of Sheffield.

4.2. SYSTEMATIC ACCOUNT.

4.2.1. Anteturma SPORITES H. Potonié 1893.

Turma TRILETES Reinsch emend. Dettmann 1963.
Suprasubturma ACAMERATITRILETES Neves & Owens 1966.
Subturma AZONOTRILETES Luber emend. Dettmann 1963.
Infraturma LAEVIGATI Bennie & Kidston emend. Potonié 1956.

Adelisporites **Ravn 1979.**

Type species. *A. multiplicatus* Ravn 1979.
Diagnosis. See Ravn (1979, p. 25).
Remarks. As suggested by Ravn (1986) these may be aborted or immature spores related to some other genera. However, they do show a remarkably consistent morphology and appear to be, as Ravn (1986) suggests, useful stratigraphically.

Adelisporites multiplicatus Ravn 1979.
Plate 1, figures 1, 2.
1979 *Adelisporites multiplicatus* Ravn, p. 25, pl. 4, figs 2-6.
Holotype. Ravn (1979, pl. 4, fig. 2).
Diagnosis. See Ravn (1979, p. 25).
Remarks. Both laevigate and granulate-micrognulate forms have been included in this species.

Calamospora Schopf *et al.* 1944.

Type species. *C. hartungiana* Schopf *in* Schopf *et al.* 1944.
Diagnosis. See Schopf *et al.* (1944, p. 49).

Calamospora breviradiata Kosanke 1950.

Plate 1, figure 6.

1950 *Calamospora breviradiata* Kosanke, p. 41, pl. 9, fig. 4.

Holotype. Kosanke (1950, pl. 9, fig. 4).
Diagnosis. Kosanke (1950, p. 41).
Remarks. For an extended synonymy see Ravn (1986, p. 58).

Calamospora hartungiana Schopf *in* Schopf *et al.* 1944.

Plate 1, figure 7.

1944 *Calamospora hartungiana* Schopf *in* Schopf *et al.*, p. 51-52, text-fig. 1.

Holotype. Kosanke (1982, pl. 2, fig. 2).
Diagnosis. See Schopf *et al.* (1944, p. 51).

Calmospora labiata Butterworth & Mahdi 1982.

Plate 2, figure 4.

1982 *Calamospora labiata* Butterworth & Mahdi, p. 487, pl. 1, figs. 4,5.
non 1984 *Calamospora labiata* Gao *in* Gao & Wang, p. 395, pl. 149, figs. 18,19.

Holotype. Butterworth & Mahdi (1982, pl. 1, fig. 4).
Diagnosis. See Butterworth & Mahdi (1982, p.487).

Calamospora laevigata (Ibrahim) Schopf *in* Schopf *et al.* 1944.

1933 *Laevigati-sporites laevigatus* Ibrahim, p. 17, pl. 6, fig. 46.
1944 *Calamospora laevigata* (Ibrahim) Schopf in Schopf *et al.*, p. 52.

Holotype. Ibrahim (1933, pl. 6, fig. 46).
Diagnosis. See Potonié & Kremp (1955, p. 48).

Calamospora cf. *laevigata* (ibrahim) Schopf *in* Schopf *et al.* 1944.

Plate 1, figure 11.

Remarks. This name is applied *sensu* Smith & Butterworth (1967) to forms which are smaller than those described by Schopf *in* Schopf *et al.* (1944) and which have a darkened contact area.

Calamospopra liquida Kosanke 1950.

Plate 2, figure 6.

1950 *Calamospora liquida* Kosanke, p. 41-42, pl. 9, fig. 1.

Holotype. Kosanke (1950, pl. 9, fig. 1).
Diagnosis. See Kosanke (1950, p. 41).

Calamospora magnifica Azcuy 1975.

Plate 1, figure 10.

1975 *Calamospora magnifica* Azcuy, p. 28, pl. 5, fig. 30, pl. 6, fig. 33.

Holotype. Azcuy (1975, pl. 5, fig. 30).

Diagnosis. see Azcuy (1975, p. 28).

Calamospora majus Saksena 1970.

Plate 1, figure 9.

1970 *Calamospora majus* Saksena, p. 243, pl. 1, figs. 11, 12.

Holotype. Saksena (1970, pl. 1, fig. 11).

Diagnosis. See Saksena (1970, p. 243).

Calamospora microrugosa (Ibrahim) Schopf *in* Schopf *et al.* 1944.

Plate 2, figure 5.

1932 *Sporonites microrugosus* Ibrahim *in* Potonié *et al.*, p. 447, pl. 14, fig. 9.
1944 *Calamospora microrugosa* (Ibrahim) Schopf *in* Schopf *et al.*, p. 52.

Holotype. Ibrahim (1932, pl. 14, fig. 9).

Diagnosis. See Potonié & Kremp (1955, p. 49).

Remarks. For an extended synonymy list see Smith & Butterworth (1967, p. 133).

Calamospora multiplicata Habib 1966.

Plate 1, figure 5.

1966 *Calamospora multiplicata* Habib, p. 632, pl. 104, figs. 6,7.
non 1969 *Calamospora multiplicata* Menéndez & Azcuy, p. 84, pl. 1, figs. K,L.

Holotype. Habib (1966, pl. 104, fig. 6).

Diagnosis. See Habib (1966, p. 632).

Calamospora mutabilis (Loose) Schopf *et al.* 1944.

Plate 2, figure 7.

1932 *Calamati?-Sporonites mutabilis* Loose *in* Potonié *et al.*, p. 451, pl. 19, figs. 50a-c.
1944 *Calamospora mutabilis* (Loose) Schopf *et al.*, p. 52.

Holotype. Potonié *et al.* (1932, pl. 19, fig. 50b).

Diagnosis. See Potonié & Kremp (1955, p. 49).

Calamospora obtecta Winslow 1962.

Plate 2, figure 8.

1962 *Calamospora obtecta* Winslow, p. 56, pl. 17, figs. 4,5,7,8.

Holotype. Winslow (1962, pl. 17, fig. 5).

Diagnosis. See Winslow (1962, p. 56).

Calamospora pallida (Loose) Schopf *et al.* 1944.

Plate 2, figure 3.

1932 *Sporonites pallidus* Loose *in* Potonié *et al.*, p. 449, pl. 18, fig. 31.
1944 *Calamospora pallida* (Loose) Schopf *et al.*, p. 52.

Holotype. Loose (1932, pl. 18, fig. 31).

Diagnosis. See Potonié & Kremp (1955, p. 50).

Calamospora cf. *pallida.*

Plate 2, figure 2.

Remarks. Specimens assigned to this taxon are smaller than the type material (27(34)37μ; 30 specimens).

Calamospora parva Guennel 1958.

Plate 1, figure 3.

1958 *Calamospora parva* Guennel, p. 70-71, pl. 4, fig. 12, text-fig. 16.

Holotype. Guennel (1958, text-fig. 16).

Diagnosis. See Guennel (1958, p. 70).

Calamospora pedata Kosanke 1950.

Plate 1, figure 8.

1950 *Calamospora pedata* Kosanke, p. 42, pl. 9, fig. 3.

Holotype. Kosanke (1950, pl. 9, fig. 3).

Diagnosis. See Kosanke (1950, p. 42).

Calamospora perrugosa (Loose) Schopf *et al.* 1944.

Plate 2, figure 1.

1934 *Laevigati-sporites perrugosus* Loose, p. 145, pl. 7, fig. 13.
1944 *Calamospora perrugosa* (Loose) Schopf *et al.*, p. 52.

Holotype. Loose (1934, pl. 7, fig. 13).

Diagnosis. See Smith & Butterworth (1967, p. 137).

Calamospora straminea Wilson & Kosanke 1944.

Plate 1, figure 4.

1944 *Calamospora straminea* Wilson & Kosanke, p. 329, pl. 1, fig. 1.

Holotype. Wilson & Kosanke (1944, pl. 1, fig. 1).

Diagnosis. See Wilson & Kosanke (1944, p. 329).

Deltoidospora Miner 1935.

1935 *Deltoidospora* Miner, p. 618.
1938 *Leiotriletes* Naumova, p. 355 (in part).
1952 *Leiotriletes* Naumova *ex* Ischenko, p. 9.
1954 *Leiotriletes* Naumova emend. Potonie & Kremp, p. 28.

Type species. *D. hallii* Miner 1935.

Diagnosis. See Miner (1935, p. 618).

Remarks. Application of the name *Deltoidospora* to triangular, laevigate, trilete spores is a departure from the usual practice followed in most of the literature on Carboniferous palynology in which such spores are assigned to the genus *Leiotriletes* Naumova emend. Potonié & Kremp 1954. However, Staplin (1960), McGregor (1973) and Srivastava (1977) have conclusively demonstrated the priority of *Deltoidospora* over *Leiotriletes*. Braman and Hills (1977) and Ravn (1986, 1991) also consider *Leiotriletes* to be a junior synonym of *Deltoidospora*. A more completes synonomy than that given above can be found in McGregor (1973, p. 15).

Deltoidospora adnata Kosanke comb. nov.

Plate 2, figure 10.

1950 *Granulati-sporites adnatus* Kosanke, p. 20, pl. 3, fig. 9.
1955 *Leiotriletes adnatus* (Kosanke) Potonié & Kremp, p. 39, pl. 11, fig. 111.

Holotype. Kosanke (1950, pl. 3, fig. 9).

Diagnosis. See Kosanke (1950, p. 20).

Deltoidospora convexa (Kosanke) Ravn 1986.

Plate 2, figure 15.

1950 *Granulati-sporites convexus* Kosanke, p. 20, pl. 3, fig. 6.
1955 *Leiotriletes convexus* (Kosanke) Potonié & Kremp, p. 39, pl. 11, fig. 110.
1986 *Deltoidospora convexa* (Kosanke) Ravn, p. 24.

Holotype. Kosanke (1950, pl. 3, fig. 6).

Diagnosis. See Kosanke (1950, p. 20).

Deltoidospora inerma (Waltz) Braman & Hills 1977.

Plate 2, figure 11.

1936 *Azonotriletes inermis* Waltz *in* Luber & Waltz, p. 11, pl. 1, fig. 3, pl. 5, fig. 58, pl. A, fig. 2.
1952 *Leiotriletes inermis* (Waltz) Ischenko, p. 9, pl. 1, figs. 2,3.
1955 *Leiotriletes inermis* (Waltz) Potonié & Kremp, p. 37.
1977 *Deltoidospora inerma* (Waltz) Braman & Hills, p. 598.

Holotype. None designated.

Diagnosis. See Smith & Butterworth (1967, p. 122).

Remarks. Despite common usage in European Silesian palynology the absence of a designated holotype for this species means that it remains a *nomen nudum*.

Deltoidospora levis (Kosanke) Ravn 1986.

Plate 2, figure 14.

1950 *Granulati-sporites levis* Kosanke, p. 21, pl. 3, fig. 5.
1955 *Leiotriletes levis* (Kosanke) Potonié & Kremp, p. 38.
1986 *Deltoidospora levis* (Kosanke) Ravn, p. 22, pl. 1, fig. 5.

Holotype. Kosanke (1950, pl. 3, fig. 5).

Diagnosis. See Kosanke (1950, p. 21).

Deltoidospora minuta (Knox) comb. nov.

Plate 3, figure 1.

1950 *Calamospora minutus* Knox, p. 332.
1955 *Leiotriletes minutus* (Knox) Potonié & Kremp, p. 41, pl. 11, fig. 119.

Lectotype. Potonié & Kremp (1955, pl. 11, fig. 119).

Diagnosis. See Knox (1950, p. 332).

Deltoidospora ornata (Ischenko) Braman & Hills 1977.

Plate 2, figure 16.

1956 *Leiotriletes ornatus* Ischenko, p. 22, pl. 2, figs. 18-21.
1977 *Deltoidospora ornata* (Ischenko) Braman & Hills, p. 598, pl. 1, fig. 12.

Holotype. Ischenko (1956, pl 2, fig. 18).

Diagnosis. Ischenko (1956, p. 22).

Deltoidospora priddyi (Berry) McGregor 1973.

Plate 3, figure 2.

1937 *Zonales-sporites priddyi* Berry, p. 156, text-fig. 2.
1955 *Leiotriletes priddyi* (Berry) Potonié & Kremp, p. 38.
1973 *Deltoidospora priddyi* (Berry) McGregor, p. 16, pl. 1, figs. 6,7.

Holotype. Berry (1937, p. 159, text-fig. 2).

Diagnosis. See Berry (1937, p. 156).

Deltoidospora smithii Ravn 1986.

Plate 2, figure 17.

non 1954*Leiotriletes turgidus* Kara-Murza, p. 34, pl. 1, fig. 8.
1965 *Leiotriletes turgidus* Marshall & Smith, p. 658, pl. 99, figs. 1-3.
1986 *Deltoidospora smithii* Ravn, p. 23, pl. 1, figs. 10-13.

Holotype. Marshall & Smith (1965, pl. 99, fig. 1).

Diagnosis. See Marshall & Smith (1965, p. 658).

Remarks. Ravn (1986) recognised *L. turgidus* Marshall & Smith 1965 as a junior homonym and proposed the new name *D. smithii.*

Deltoidospora sphaerotriangula (Loose) Ravn 1986.

Plate 3, figure 3.

1932 *Sporonites sphaerotriangulus* Loose in Potonié *et al.*, p. 451, pl. 18, fig. 45.
1954 *Leiotriletes sphaerotriangulus* (Loose) Potonié & Kremp, p. 120.
1986 *Deltoidospora sphaerotriangula* (Loose) Ravn, p. 23, pl. 1, fig. 4.

Holotype. Potonié & Kremp (1955, pl. 11, fig. 107).

Diagnosis. See Potonié & Kremp (1955, p. 41).

Remarks. For a more complete synonymy see Ravn (1986, p. 23).

Deltoidospora subadnatoides (Bhardwaj) Ravn 1986.

Plate 2, figure 9.

1957 *Leiotriletes subadnatoides* Bhardwaj, p. 80, pl. 22, figs. 5-7,fig. 14.
1986 *Deltoidospora subadnatoides* (Bhardwaj) Ravn, p. 23, pl. 1, fig. 2.

Holotype. Bhardwaj (1957a, pl. 22, fig. 6).

Diagnosis. See Bhardwaj (1957a, p. 80).

Deltoidospora subintorta (Waltz) Braman & Hills 1977.

Plate 2, figure 13.

1941 *Azonotriletes subintortus* Waltz in Luber & Waltz, p. 13-14, pl. 2, fig. 15b
1977 *Deltoidospora subintorta* (Waltz) Braman & Hills, p. 598, pl. 1, fig. 13.

Holotype Luber & Waltz (1941, pl. 2, fig. 15b).

Diagnosis. See Luber & Waltz (1941, p. 13).

Deltoidospora tumida (Butterworth & Williams) Ravn 1986.

1958 *Leiotriletes tumidus* Butterworth & Williams, p. 128, pl. 32, figs. 10-12.
1986 *Deltoidospora tumida* (Butterworth & Williams) Ravn, p. 24.

Holotype. Smith & Butterworth (1967, pl. 1, fig. 11).

Diagnosis. See Butterworth & Williams (1958, p. 359).

Deltoidospora aff. *tumida*.

Plate 3, figures 6, 7, 11.

Remarks. Present specimens have consistently straight interradial areas, unlike the convex interradial areas demonstrated by the holotype and paratype or the isotype illustrated by Smith & Butterworth (1967, pl. 1, fig. 12). The present specimens also have slight thickenings poorly defining the contact areas.

Punctatisporites Ibrahim emend. Potonié & Kremp 1954.

Type species. *P. punctatus* (Ibrahim) Ibrahim 1933.

Diagnosis. See Potonié & Kremp (1954, p. 120).

Punctatisporites aerarius Butterworth & Williams 1958.

Plate 3, figure 16.

1958 *Punctatisporites aerarius* Butterworth & Williams, p. 360. pl. 1, figs. 10, 11.

Holotype. Butterworth & Williams (1958, pl. 1, fig. 11).

Diagnosis. See Butterworth & Williams (1958, p. 360).

Punctatisporites edgarensis Peppers 1970.

Plate 3, figure 12.

1970 *Punctatisporites edgarensis* Peppers, p. p. 82, pl. 1, figs. 16, 17.
1979 *Punctatisporites* cf. *edgarensis* Peppers; Ravn, p. 22, pl. 2, fig. 7.

Holotype. Peppers (1970, pl. 1, fig. 16).

Diagnosis. See Peppers (1970, p. 82).

Punctatisporites flavus (Kosanke) Potonié & Kremp 1955.

Plate 3, figures 17, 20.

1950 *Calamospora flava* Kosanke, p. 41, pl. 9, fig. 2.
1955 *Punctatisporites flavus* (Kosanke) Potonié & Kremp, p. 42.

Holotype. Kosanke (1950, pl. 9, fig. 2).

Diagnosis. See Kosanke (1950, p. 41).

Punctatisporites glaber (Naumova *in* Luber & Waltz) Playford 1962.

Plate 3, figures 10, 14.

1938 *Azonotriletes glaber* Naumova *in* Luber & Waltz, p. 8, pl. 1, fig. 2.
1962 *Punctatisporites glaber* (Naumova) Playford, p. 576-577, pl. 78, figs. 15, 16.

Holotype. Luber & Waltz (1938, pl. 1, fig. 2).

Remarks. A more complete synonymy for this taxon is given in Ravn (1986, p. 25).

Punctatisporites minutus Kosanke 1950.

Plate 2, figures 8, 9.

1950 *Punctati-sporites minutus* Kosanke, p. 15, pl. 16, fig. 3.

Holotype. Kosanke (1950, pl. 16, fig. 3).

Diagnosis. See Kosanke (1950, p. 15).

Punctatisporites nitidus Hoffmeister *et al.* 1955.

Plate 3, figure 13.

1955 *Punctatisporites nitidus* Hoffmeister *et al.*, p. 393, pl. 36, fig. 4.

Holotype. Hoffmeister *et al.* (1955, pl. 36, fig. 4).

Diagnosis. See Hoffmeister *et al.* (1955, p. 393).

Punctatisporites obesus (Loose) Potonié & Kremp 1955.

Plate 3, figure 18.

1932 *Sporonites obesus* Loose *in* Potonié *et al.*, p. 451, pl. 19, fig. 49.
1955 *Punctatisporites obesus* (Loose) Potonié & Kremp, p. 43, pl. 11, fig. 124.

Holotype. Loose (1932, pl. 19, fig. 49).

Diagnosis. See Loose (1934, p. 145).

Remarks. A more complete synonymy is provided by Ravn (1986, p. 27).

Punctatisporites pseudopunctatus Neves 1961.

Plate 3, figure 19.

1961 *Punctatisporites pseudopunctatus* Neves, p. 251-252, pl. 30, fig. 3.

Holotype. Neves (1961, pl. 30, fig. 3).

Diagnosis. See Neves (1961, p. 252).

Punctatisporites punctatus (Ibrahim) Ibrahim 1933.

Plate 3, figure 15.

1932 *Sporonites punctatus* Ibrahim *in* Potonié *et al.*, p. 448, pl. 15, fig. 18.
1933 *Punctati-sporites punctatus* Ibrahim, p. 21, pl. 2, fig. 18.

Holotype. Potonié *et al.* (1932, pl. 15, fig. 18).

Diagnosis. See Ibrahim (1933, p. 21).

Retusotriletes Naumova emend. Streel 1964.

Type species. *R. simplex* Naumova 1953.

Diagnosis. See Streel (1964, p. B7).

Retusotriletes minutus Butterworth & Mahdi 1982.

Plate 3, figures 4, 5.

1982 *Retusotriletes minutus* Butterworth & Mahdi, p. 487-488, pl. 1, figs. 6-8.

Holotype. Butterworth & Mahdi (1982, pl. 1, fig. 6).

Diagnosis. See Butterworth & Mahdi (1982, p. 487).

Scutulum Felix & Burbridge 1967.

Type species. *S pusillum* Felix & Burbridge 1967.
Diagnosis. See Felix & Burbridge (1967, p. 382).

Scutulum pusillum Felix & Burbridge 1967.
Plate 4, figure 2.
1967 *Scutulum pusillum* Felix & Burbridge, p. 382-383, pl. 58, fig. 7.
Holotype. Felix & Burbridge (1967, pl. 58, fig. 7).
Diagnosis. See Felix & Burbridge (1967, p. 382).

Sinuspores Artüz emend. Ravn 1986.

Type species. *S. sinuatus* Artüz emend. Ravn 1986.
Diagnosis. See Ravn (1986, p. 80).

Sinuspores sinuatus Artüz emend. Ravn 1986.
Plate 4, figure 1.
1957 *Sinuspores sinuatus* Artüz, p. 254, pl. 7, fig. 48.
1961 *Punctatisporites sinuatus* (Artüz) Neves, p. 252.
1986 *Sinuspores sinuatus* Artüz emend Ravn, p. 80, pl. 23, figs. 9-12.
Holotype. Artüz (1957, pl. 7, fig. 48).
Diagnosis. See Ravn (1986, p. 80).
Remarks. For a more complete synonymy see Ravn (1986, p. 80).

Sinuspores cf. *sinuatus* .
Plate 3, figure 21.

Remarks. Specimens assigned to this taxon are smaller than the type material (40(55)70μ; 20 specimens). They may resemble the species *Punctatisporites edgarensis* Peppers 1970, but have a well developed curvatural crassitude characteristic of the genus *Sinuspores.*

Waltzispora Staplin 1960.

Type species. *W. lobophora* (Waltz) Staplin 1960.

Diagnosis. See Staplin (1960, p.18).

Waltzispora polita (Hoffmeister *et al.*) Smith & Butterworth 1967.

Plate 2, figure 12.

1955 *Granulati-sporites politus* Hoffmeister *et al.*, p. 389, pl. 36, fig. 13.
1967 *Waltzispora polita* (Hoffmeister *et al.*) Smith & Butterworth, p. 159, pl. 6, fig. 14.

Holotype. Hoffmeister *et al.* (1955, pl. 36, fig. 13).

Diagnosis. See Hoffmeister *et al.* (1955, p. 389).

Infraturma APICULATI Bennie & Kidston emend. Potonié 1956.

Anapiculatisporites Potonié & Kremp 1954.

Type species. *A. isselburgensis* Potonié & Kremp 1954.

Diagnosis. See Potonié & Kremp (1954, p. 133).

Remarks. Use of this genus follows the practice of Playford (1971) and Ravn (1986) and rejects the emendation of Smith & Butterworth (1967).

Anapiculatisporites baccatus (Hoffmeister *et al.*) Ravn 1986.

Plate 4, figure 17.

1955 *Punctatisporites? baccatus* Hoffmeister *et al.*, p. 392, pl. 36, fig. 2.
1967 *Anaplanisporites baccatus* (Hoffmeister *et al.*) emend. Smith & Butterworth, p. 166, pl. 7, figs. 1-5.
1967 *Anapiculatispoites baccatus* (Hoffmeister *et al.*) Ravn, p. 85, pl. 23, figs. 2,3.

Holotype. Hoffmeister *et al.* (1955, pl. 36, fig. 2).

Diagnosis. See Smith & Butterworth (1967, p. 166).

Anapiculatisporites northumbriensis Butterworth *et al.* comb. nov.

Plate 4, figure 3.

1988 *Anaplanisporites northumbriensis* Butterworth *et al.*, p. 70, pl. 3, figs. 1-5.

Holotype. Butterworth *et al.* (1988, pl. 3, fig. 3).

Diagnosis. See Butterworth *et al.* (1988, p. 70).

Remarks. *Anaplanisporites* Jansonius 1962 is improperly typified and is here considered to be a junior synonym of *Anapiculatisporites* (Playford, 1971b; Morbey, 1975; Ravn, 1986), thus necessitating the recombination of this species.

Anapiculatisporites protuberatus (Hagemann) Ravn 1986.

Plate 4, figure 4.

1966 *Pustulatisporites protuberata* Hagemann, p. 824, pl. 9, figs. 4, 5.
1986 *Anapiculatisporites protuberatus* (Hagemann) Ravn, p. 85-86, pl. 23, fig. 4.

Holotype. Hagemann (1966, pl. 9, fig. 4).

Diagnosis. See Ravn (1986, p. 86).

Apiculatasporites Ibrahim emend. Ravn 1986.

1933 *Apiculati-sporites* Ibrahim, p. 23 (in part).
1933 *Apiculata-sporites* Ibrahim, p.37.
1954 *Apiculatisporites* Ibrahim emend. Potonié and Kremp, p.130.
1956 *Apiculatisporis* Potonié and Kremp, p.94.
1967 *Apiculatasporites* Ibrahim emend. Smith and Butterworth, p. 176.
1986 *Apiculatasporites* Ibrahim emend Ravn, p. 38.

Type species. *A. spinulistratus* (Loose) Ibrahim 1933.

Diagnosis. See Ravn (1986, p. 38).

Remarks. Ravn (1986) argues convincingly for the synonymy of the genera *Apiculatasporites and Apiculatisporis.* The former has clear priority and so is used here.

Apiculatasporites aculeatus (Ibrahim emend. Smith & Butterworth) Ravn 1986.

Plate 4, figure 18.

1933 *Apiculati-sporites aculeatus* Ibrahim, p. 23, pl. 6, fig. 57.
1955 *Apiculatisporites aculeatus* (Ibrahim) Potonié & Kremp, p. 94, pl. 14, figs. 235, 236, 241.
1967 *Apiculatisporis aculeatus* (Ibrahim) emend. Smith & Butterworth, p. 170, pl. 7, figs. 12, 13.
1986 *Apiculatasporites aculeatus* (Ibrahim emend. Smith & Butterworth) Ravn, p. 39, pl. 5, figs. 6, 7.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 235).

Diagnosis. See Smith & Butterworth (1967, p. 170).

Apiculatasporites latigranifer (Loose) Ravn 1986.

Plate 4, figures 20, 21.

1932 *Sporonites latigranifer* Loose *in* Potonié *et al.*, p. 452, pl. 19, fig. 54.
1955 *Apiculatisporites latigranifer* (Loose) Potonié & Kremp, p. 79, pl. 14, figs. 244, 245.
1967 *Apiculatisporis latigranifer* (Loose) Smith & Butterworth, p. 172.
1986 *Apiculatasporites latigranifer* (Loose) Ravn, p. 39, pl. 6, fig. 7.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 244).

Diagnosis. See Potonié & Kremp (1955, p. 79).

Remarks. For further synonymy see Smith & Butterworth (1967, p. 172) and Ravn (1986, p. 39).

Apiculatasporites setulosus (Kosanke) Ravn 1986.

Plate 4, figure 23.

1950 *Punctati-sporites setulosus* Kosanke, p. 15, pl. 2, fig. 1.
1955 *Apiculatisporites setulosus* (Kosanke) Potonié & Kremp, p. 77.
1962 *Apiculatisporis setulosus* (Kosanke) Piérart, table 2.
1967 *Apiculatasporites setulosus* (Kosanke) Ravn, p. 40, pl. 6, fig. 6.

Holotype. Kosanke (1950, pl. 2, fig. 1).

Diagnosis. See Kosanke (1950, p. 15).

Apiculatasporites spinososaetosus (Loose) Ravn 1986.

Plate 4, figure 22.

1932 *Sporonites spinososaetosus* Loose *in* Potonié *et al.*, p. 452, pl. 19, fig. 55.
1933 *Apiculati-sporites spinososaetosus* (Loose) Ibrahim, p. 24.
1944 *Raistrickia spinososaetosus* (Loose) Schopf *et al.*, p. 56.
1955 *Apiculatisporites spinosaetosus* (sic) (Loose) Potonié & Kremp, 80, pl. 14, figs. 249.
1962 *Apiculatisporis spinosaetosus* (sic) (Loose) Piérart, tab. 2.
1967 *Apiculatisporis spinososaetosus* (Loose) Smith & Butterworth, p. 173, pl. 7, figs. 22,23.
1986 *Apiculatasporites spinososaetosus* (Loose) Ravn, p. 40, pl. 5, fig. 18.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 249).

Diagnosis. See Potonié *et al.* (1932, p. 452).

Apiculatasporites spinulistratus (Loose) Ibrahim 1933.

Plate 4, figure 19.

1932 *Sporonites spinulistratus* Loose in Potonié *et al.*, p. 450, pl. 18, fig. 47.
1933 *Apiculata-sporites spinulistratus* (Loose) Ibrahim, p. 37.
1955 *Planisporites spinulistratus* (Loose) Potonié & Kremp, p. 71, pl. 14, figs. 214-219.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 214)

Diagnosis. See Potonié & Kremp (1955, p. 71).

Remarks. For a more complete synonymy see Ravn (1986, p. 40).

Apiculatasporites variocorneus (Sullivan) Ravn 1986.

Plate 4, figure 24.

1964 *Apiculatisporis variocorneus* Sullivan, p. 363, pl. 58, figs. 4-8.
1986 *Apiculatasporites variocorneus* (Sullivan) Ravn, p. 41, pl. 6, fig. 8, 9.

Holotype. Sullivan (1964b, pl. 58, fig. 4).

Diagnosis. See Sulivan (1964b, p. 363).

Apiculiretusispora Streel emend. Streel 1967.

Type species. *A. brandtii* Streel 1964.

Diagnosis. See Streel (1967, p. 32).

Apiculiretusispora granulata Butterworth *et al.* 1988.

Plate 4, figure 8.

1988 *Apiculiretusispora granulata* Butterworth *et al.*, p. 64-67, pl. 3, figs. 8-10.

Holotype. Butterworth *et al.* (1988, pl. 3, fig. 8).

Diagnosis. Butterworth *et al.* (1988, p. 67).

Apiculiretusispora minuta Butterworth *et al.* (1988).

Plate 4, figure 9.

1988 *Apiculiretusispora minuta* Butterworth *et al.*, p. 67, pl. 1, figs. 11.

Holotype. Butterworth *et al.* (1988, pl. 1, fig. 8).

Diagnosis. See Butterworth *et al.* (1988, p. 67).

Converrucosisporites Potonié & Kremp 1954.

Type species. *C. triquetrus* (Ibrahim) Potonié & Kremp 1954.

Diagnosis. See Potonié & Kremp (1954, p. 137).

Converrucosisporites armatus (Dybová & Jachowicz) Smith & Butterworth 1967.

Plate 5, figure 17.

1957a *Converrucitriletes armatus* Dybová & Jachowicz, p. 128, pl. 32, fig. 1.

1967 *Converrucosisporites armatus* (Dybová & Jachowicz) Smith & Butterworth, p. 146-147, pl. 4, figs. 19-21.

Holotype. Dybová & Jachowicz (1957a, pl. 32, fig. 1).

Diagnosis. See Dybová & Jachowicz (1957b, p. 182).

Converrucosisporites vermiformis Ravn 1986.

1986 *Converrucosisporites vermiformis* Ravn, p. 82, pl. 21, figs. 17-20.

Holotype. Ravn (1986, pl. 21, fig. 17).

Diagnosis. See Ravn (1986, p. 82).

Converrucosisporites aff. *vermiformis.*

Plate 5, figures 11, 16.

Remarks. The current specimens are smaller (27(29)32μ; 6 specimens) than the material described by Ravn (1986)) and have straight or concave sides but with less well-rounded apices than Ravn's material. Verrucae are never pointed but they do however form the characteristic negative reticulum. The current specimens appear distinct from the type, but too few specimens of this taxon were found in a single population to allow for the erection of a new species.

Cyclogranisporites Potonié & Kremp 1954.

Type species. *C. leopoldii* (Kremp) Potonié & Kremp 1954.
Diagnosis. See Potonié & Kremp (1954, p. 126).

Cyclogranisporites aureus (Loose) Potonié & Kremp 1955.

Plate 5, figure 2.

1934 *Reticulati-sporites aureus* Loose, p. 155, pl. 7, fig. 24.
1955 *Cyclogranisporites aureus* (Loose) Potonié & Kremp, p. 61, pl. 13, figs. 184-186.

Holotype. Potonié & Kremp (1955, pl. 13, fig. 184).
Diagnosis. See Potonié & Kremp (1955, p. 61).
Remarks. For a full synonymy see Ravn (1986, p. 30).

Cyclogranisporites leopoldii (Kremp) Potonié & Kremp 1954.

Plate 5, figure 5.

1952 *Granulatisporites leopoldi* Kremp, p. 348, pl. 15b, figs. 15, 16.
1954 *Cyclogranisporites leopoldi* (Kremp) Potonié & Kremp, p. 126, pl. 20, fig. 103
1986 *Cyclogranisporites leopoldii* (Kremp) Potonié & Kremp; Ravn, p. 31, pl. 3, figs. 9,10.

Holotype. Potonié & Kremp (1955, pl. 13, fig. 174).
Diagnosis. See Potonié & Kremp (1955. p. 62).
Remarks. Ravn (1986, p. 31) corrected the orthography of this taxon.

Cyclogranisporites minutus Bhardwaj emend. Ravn 1986.

Plate 5, figure 4.

1957 *Cyclogranisporites minutus* Bhardwaj, p. 83, pl. 22, figs. 22-23.
1967 *Cyclogranisporites* cf. *minutus* Bhardwaj; Smith & Butterworth, p. 143, pl. 4, figs. 4-7.
1986 *Cycloganisporites minutus* Bhardwaj emend. Ravn, p. 31, pl. 3, figs. 3,4.

Holotype. Bhardwaj (1957a, pl. 22, fig. 22).
Diagnosis. See Ravn (1987, p. 31).

Cyclogranisporites multigranus Smith & Butterworth 1967.

Plate 5, figure 3.

1967 *Cyclogranisporites multigranus* Smith & Butterworth, p. 144, pl. 4, figs. 10-13.

Holotype. Smith & Butterworth (1967, pl. 4, fig. 12).
Diagnosis. See Smith & Butterworth (1967, p. 144).

Dibolisporites Richardson 1965.

Type species. *D. echinaceus* (Eisenack) Richardson 1965.
Diagnosis. See Richardson (1965, p. 568).

Dibolisporites ranunculioides sp. nov.

Plate 4, figures 25, 29, 30.

Diagnosis. Trilete, acamerate miospores. Laesurae straight, simple, two-thirds radius, usually difficult to discern. Equatorial outline circular. Proximal and distal ornament of spinae with bulbous bases (galae). Spinae slender, tapering, 2.5μ to 20μ in length (exclusive of bulbous base), bases hemispherical, 2μ to 4μ in diameter. Ornament coarsest distally, reduced on the proximal face and smallest near the proximal pole. Size of miospores 30(35.5)39μ; 30 specimens.
Derivation of name. L. *ranunculus* - tadpole, L. *-oides* - like; in reference to the similarity of specimens to a mass of tadpoles.
Type locality. Well 44/22-1, southern North Sea.
Type horizon. Mudstones in core at 11878'; Duckmantian.
Holotype. Plate 4, figure 29.
Comparison. *Anapiculatisporites northumbriensis* Butterworth *et al.* comb. nov. is smaller. It has a less coarse ornament of similar form but with much shorter spinae and which is restricted to the distal surface.
Remarks. This species is assigned to *Dibolisporites* as it possesses a 'biform' sculpture of rounded verrucae surmounted by spinae.
Specimens rarely show a triletes mark and may appear like an acritarch. However, attached tetrad specimens are common (Plate 4, figure 25) and occasional specimens with a distinct trilete mark occur (Plate 4, figure 30), indicating that the form is a miospore.

Echinatisporis Krutzsch 1959.

Type species.*E. longechinus* Krutsch 1959.
Diagnosis. See Krutzsch (1959, p. 132).
Remarks. Because of the ambiguities of typification and generic circumscription of the genus *Acanthotriletes* Naumova *ex* Naumova emend. Potonie & Kremp 1954 described by Ravn (1986), species which would previously have been assigned to *Acanthotriletes* and which have a circular amb are here assigned to *Echinatisporis.*

Echinatisporis knoxiae Ravn1986.

Plate 6, figure 24.

1950 *Spinoso-sporites echinatus* Knox, p. 313, pl. 17, fig. 208.
1955 *Acanthotriletes echinatus* (Knox) Potonié & Kremp, p. 84.
non 1955 *Acanthotriletes echinatus* Hoffmeister *et al.*, p. 379, pl. 38, figs. 1, 2.
1967 *Acanthotriletes echinatus* (Knox) Potonié & Kremp ex Smith & Butterworth, p. 178, pl. 8, fig. 9.
1986 *Echinatisporis knoxiae* Ravn, p. 87-88, pl. 7, fig. 4.

Neotype. Smith & Butteworth (1967, pl. 8, fig. 9).

Diagnosis. See Knox (1950, p. 313).

Remarks. Ravn (1986) erected the new name *E. knoxiae* to avoid producing a junior homonym when he coincidentally recombined *A. echinatus* Hoffmeister *et al.* 1955. *A. echinatus* (Knox) Potonié & Kremp 1955 was not validated until Smith & Butterworth (1967) selected a neotype and so is junior.

Granasporites Alpern emend. Ravn *et al.* 1986.

1959 *Granasporites* Alpern, p. 139.
1966 *Cappasporites* Urban, p. 122.
1983 *Cappasporites* Urban emend. Chadwick, p. 205.
1986 *Granasporites* Alpern emend. Ravn *et al.*, p. 428.

Type species. *G. medius* (Dybová & Jachowicz) Ravn *et al.* 1986.

Diagnosis. See Ravn *et al.* (1986, p. 428.

Remarks. Ravn *et al.* (1986) provide a full taxonomic analysis of this genus.

Granasporites medius (Dybová & Jachowicz) Ravn *et al.* 1986.

Plate 5, figure 1.

1957 *Granisporites medius* Dybová & Jachowicz, p. 77, pl. 10, figs. 1,2.
1959 *Granasporites irregularis* Alpern, p. 139, pl. 1, figs. 7-9.
1966 *Cappasporites distortus* Urban, p. 114, pl. 1, figs. 1-14.
1967 *Apiculatisporis irregularis* (Alpern) Smith & Butterworth, p. 171, pl. 7, figs. 18,19.
1986 *Granasporites medius* (Dybová & Jachowicz) Ravn *et al.* p. 429, pl. 1, figs. 1-8, pl. 2, figs. 1-5.

Holotype. Dybová & Jachowicz (1957, pl. 10, fig. 1).

Diagnosis. Dybová & Jachowicz (1957, p. 77).

Remarks. Ravn *et al.* (1986) provide a full taxonomic analysis of this species.

Granulatisporites Ibrahim emend. Potonié & Kremp 1954.

Type species. *G. granulatus* Ibrahim 1933.

Diagnosis. See Potonié & Kremp (1954, p. 126).

Granulatisporites adnatoides (Potonié & Kremp) Smith & Butterworth 1967.

Plate 5, figure 7.

1955 *Leiotriletes adnatoides* Potonié & Kremp, p. 38, pl. 11, figs. 112-115.

1967 *Granulatisporites adnatoides* (Potonié & Kremp) Smith & Butterworth, p. 139, pl. 3, figs. 12-14.

Holotype. Potonié & Kremp (1955, pl. 11, fig. 112).

Diagnosis. See Smith & Butterworth (1967, p. 139).

Granulatisporites granooronatus (Artüz) comb. nov.

Plate 5, figure 6.

1957 *Lophotriletes granoornatus* Artüz, p. 244, pl. 2, fig. 13.

Holotype. Artüz (1957, pl. 2, fig. 13).

Diagnosis. See Artüz (1957, p. 244).

Remarks. Artüz (1957) described the ornament of *L. granoornatus* as granulate. The species should therefore reside in the genus *Granulatisporites.* Peppers (1970) and Ravn (1979) considered the ornament of American specimens of this species to be granulate and discussed the possibility that the species might best be included in *Granulatisporites.* Smith & Butterworth (1967) described an ornament of pointed, rounded or slightly flattened coni and maintained the species in *Lophotriletes* Naumova *ex* Ischenko emend. Potonié & Kremp 1954. Specimens observed from the Southern North Sea Carboniferous Basin conform to the diagnosis of Artüz (1957), i.e. bear grana, and the species is here transferred to the genus *Granulatisporites.*

Granulatisporites granulatus Ibrahim 1933.

Plate 5, figure 10.

1933 *Granulatisporites granulatus* Ibrahim, p. 22, pl. 6, fig. 51.

Holotype. Ibrahim (1933, pl. 6, fig. 51).

Diagnosis. See Potonié & Kremp (1955, p. 58).

Remarks. Ravn (1986, p. 28) gives a more complete synonymy.

Granulatisporites microgranifer Ibrahim 1933.

Plate 5, figure 9.

1933 *Granulatisporites microgranifer* Ibrahim, p. 22, pl. 5, fig. 32.

Holotype. Ibrahim (1933, pl. 5, fig. 32).

Diagnosis. See Potonié & Kremp (1955, p. 58).

Remarks. See Ravn (1986, p. 28) for a more complete synonymy.

Granulatisporites piroformis Loose 1934.

1934 *Granulatisporites piroformis* Loose, p. 147, pl. 7, fig. 19.

Holotype. Loose (1934, pl. 7, fig. 19).

Diagnosis. See Potonié & Kremp (1955, p. 60).

Granulatisporites cf. *piroformis*.

Plate 5, figure 8.

1967 *Granulatisporites* cf. *piroformis* Loose 1934; Smith & Butterworth, p. 141-142, pl. 4, figs. 1-3.
1982 *Granulatisporites* cf. *piroformis* Loose 1934; Ravn & Fitzgerald, p. 117, pl. 2, figs. 10, 11.
1986 *Granulatisporites* cf. *piroformis* Loose 1934; Ravn, p. 29, pl. 2, figs. 7, 8, 13).

Remarks. Observed specimens are smaller (20-30μ diameter) than the type material.

Lophotriletes Naumova emend. Potonié & Kremp 1954.

Type species. *L. gibbosus* (Ibrahim) Potonié & Kremp 1955.

Diagnosis. See Potonié & Kremp (1954, p. 129).

Lophotriletes commissuralis (Kosanke) Potonié & Kremp 1955.

Plate 4, figure 11.

1950 *Granulati-sporites commissuralis* Kosanke, p. 20, pl. 3, fig. 1.
1955 *Lophotriletes commissuralis* (Kosanke) Potonié & Kremp, p. 73, pl. 14, figs. 222, 223.

Holotype. Kosanke (1950, pl. 3, fig. 1).

Diagnosis. See Kosanke (1950, p. 20).

Lophotriletes gibbosus (Ibrahim) Potonié & Kremp 1955.

Plate 4, figure 12.

1933 *Verrucosi-sporites gibbosus* Ibrahim, p. 25, pl. 6, fig. 49.
1955 *Lophotriletes gibbosus* (Ibrahim) Potonié & Kremp, p. 74, pl. 14, figs. 220, 221.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 220).

Diagnosis. See Potonié & Kremp (1955, p. 74).

Remarks. For a more complete synonymy see Ravn (1986, p. 36).

Lophotriletes ibrahimii (Peppers) Pi-Radondy & Doubinger 1968.

Plate 4, figure 13.

1964 *Granulatisporites ibrahimi* Peppers, p. 20, pl. 2, figs. 9, 10.
1968 *Lophotriletes ibrahimii* (Peppers) Pi-Radondy & Doubinger, p. 412, pl. 1, fig. 2.

Holotype. Peppers (1964, pl. 2, fig. 9).

Diagnosis. See Peppers (1964, p. 20).

Lophotriletes microsaetosus (Loose) Potonié & Kremp 1955.

Plate 4, figure 15.

1932 *Sporonites microsaetosus* Loose *in* Potonié *et al.*, p. 450, pl. 18, fig. 46.
1955 *Lophotriletes microsaetosus* (Loose) Potonié & Kremp, p. 74, pl. 14, figs. 229, 230.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 229).

Diagnosis. See Potonié & Kremp (1955, p. 74).

Lophotriletes cf. *microsaetosus.*

Plate 4, figure 16.

Remarks. This taxon is used *sensu* Smith & Butterworth (1967, p. 158, pl. 6, figs. 10, 11).

Lophotriletes mosaicus Potonié & Kremp 1955.

Plate 4, figure 14.

1955 *Lophotriletes mosaicus* Potonié & Kremp, p. 75, pl. 14, figs. 227, 228.

Holotype. Potonié & Kremp 1955, pl. 14, fig. 227).

Diagnosis. See Potonié & Kremp (1955, p. 75).

Lophotriletes pseudaculeatus Potonié & Kremp 1955.

Plate 4, figure 10.

1955 *Lophotriletes pseudaculeatus* Potonié & Kremp, p. 75, pl. 14, figs. 232-234.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 232).

Diagnosis. See Potonié & Kremp (1955, p. 75).

***Neoraistrickia* Potonié 1956.**

Type species. *N. truncata* (Cookson) Potonié 1956.

Diagnosis. See Potonié (1956, p. 34).

Neoraistrickia exigua sp. nov.

Plate 6, figure 18, 19, 20.

Diagnosis. Trilete, acamerate miospores. Laesurae straight, simple, two-thirds radius. Equatorial outline triangular, interradial margins straight or slightly concave, radial margin rounded. Proximal and distal ornament of narrow, straight-sided, flat-topped baculae, 2μ to 3.5μ high, less than 1μ wide. Baculae c.2μ apart, less dense in the interradial areas. Miospore size 23(27.5)32μ; 25 specimens.

Derivation of name. L. *exiguus* - insignificant; in reference to the relatively small baculate ornament.

Type locality. 44/22-1, southern North Sea.

Type locality. Coal in core at 11506'; Duckmantian.

Holotype. Plate 6, figures 18, 19.

Comparison. Other Carboniferous species of *Neoraistrickia* (e.g. *N. baculata* (Neves) Ravn 1986, *N. coronata* Ravn 1991, *N. drybrookensis* Sullivan 1964, *N. muscatinensis* Ravn & Fitzgerald 1982, *N. williamsii* Ravn 1991) all have more conspicuous baculae. *Lophotriletes microsaetosus* may appear superficially similar, but has an ornament of tapering coni.

Neoraistrickia virgultorum sp. nov.
Plate 6, figures 21, 22.

Diagnosis. Radial, trilete, acamerate miospores. Amb rounded triangular, sides more or less straight, occasionally slightly concave or convex. Trilete straight, simple, laesurae extending one to two thirds of the dianmeter of the spore. Exine ornamented proximally and distally with pointed or round-topped baculae, 0.5μ to 2.5μ in diameter, 1.5μ to 3.5μ in height. Baculae are irregularly distributed over the exine, being concentrated into clumps, often at the radial positions, with laevigate exine and isolated baculae in between. Size of miospores 29(31.5)36μ; 9 specimens.

Derivation of name. L. *virgulta* - copse, with reference to the clumped distribution of the ornamental elements.

Holotype. Plate 6, figure 21.

Type locality. Well 44/22-4; southern North Sea.

Type horizon. Coal in core at 12138'; early Duckmantian.

Comparison. *N. virgultorum* is differentiated from other Carboniferous species of *Neoraistrickia* by the irregular distribution of the baculae.

Pileatisporites Peppers 1970.

Type species. *P. aequus* Peppers 1970.
Diagnosis. Peppers (1970, p. 101).

Pileatisporites bakerii Ravn & Fitzgerald1982.
Plate 6, figure 14, 15.
1982 *Pileatisporites bakerii* Ravn & Fitzgerald, p. 124, pl. 4, figs. 3-6.

Holotype. Ravn & Fitzgerald (1982, pl. 4, fig. 3).
Diagnosis. See Ravn & Fitzgerald (1982, p. 124).

Pilosisporites Delcourt & Sprumont emend. Döring 1965.

Type species. *P. trichopapillosus* (Thiergart) Delcourt and Sprumont 1955.
Diagnosis. See Döring (1965, p. 36).

Remarks. Because of the ambiguities of typification and generic circumscription of the genus *Acanthotriletes* Naumova emend. Potonié and Kremp 1954 described by Ravn (1986), species which would previously have been assigned to *Acanthotriletes* and which have a triangular amb are here assigned to *Pilosisporites.*

Pilosisporites aculeolatus (Kosanke) Ravn 1986.
Plate 4, figure 27.
1950 *Granulati-sporites aculeolatus* Kosanke, p. 22, pl. 3, fig. 8.
1955 *Acanthotriletes aculeolatus* (Kosanke) Potonié & Kremp, p. 84.
1986 *Pilosisporites aculeolatus* (Kosanke) Ravn, p. 43, pl. 7, fig. 5.

Holotype. Kosanke (1950, pl. 3, fig. 8).
Diagnosis. See Kosanke (1950, p. 22).

Pilosisporites microspinosus (Ibrahim) Ravn 1986.
Plate 4, figure 26.
1933 *Apiculati-sporites microspinosus* Ibrahim, p. 24, pl. 6, fig. 25.
1955 *Acanthotriletes microspinosus* (Ibrahim) Potonié & Kremp, p. 84-85, pl. 14, fig. 258.
1986 *Pilosisporites microspinosus* (Ibrahim) Ravn, p. 45.

Holotype. See Potonié & Kremp (1955, pl. 14, fig. 258).
Diagnosis. See Potonié & Kremp (1955, p. 85).

Pilosisporites williamsii Ravn 1986.

Plate 4, figure 28.

1986 *Pilosisporites williamsii* Ravn, p. 44,, pl. 7, figs. 1-3.

Holotype. Ravn (1986, pl 7, fig. 1).

Diagnosis. See Ravn (1986, p. 44).

Planisporites **Knox emend. Potonié 1960.**

Type species. *P. granifer* (Ibrahim) Knox 1950.

Diagnosis. See Potonié (1960, p. 39).

Planisporites granifer (Ibrahim) Knox 1950.

Plate 5, figure 21.

1933 *Granulati-sporites granifer* Ibrahim, p. 22, pl. 8, fig. 72.
1950 *Planisporites granifer* (Ibrahim) Knox, p. 315.

Holotype. Potonié & Kremp (1955, pl. 13, fig. 207).

Diagnosis. See Potonié & Kremp (1955, p. 71).

Pustulatisporites **Potonié & Kremp 1954.**

Type species. *P. pustulatus* Potonié & Kremp 1954.

Diagnosis. See Potonié & Kremp (1954, p. 134).

Pustulatisporites crenatus Guennel 1958.

Plate 5, figures 13, 14.

1958 *Pustulatisporites crenatus* Guennel, p. 63, pl. 3, fig. 11, text-fig. 15.

Holotype. Guennel (1958, pl. 3, fig. 11).

Diagnosis. See Guennel (1958, p. 63).

Pustulatisporites pustulatus Potonié & Kremp 1954.

Plate 5, figure 5.

1954 *Pustulatisporites pustulatus* Potonié & Kremp, p. 134, pl. 20, fig. 256.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 256).

Diagnosis. See Potonié & Kremp (1954, p. 134).

Raistrickia Schopf *et al.* emend. Potonié & Kremp 1954.

Type species. *R. grovensis* Schopf *in* Schopf *et al.* 1944

Diagnosis. See Potonié & Kremp (1954, p. 85).

Raistrickia? abdita (Loose) Schopf *et al.* 1944.

Plate 6, figure 8.

1932 *Sporonites abditus* Loose *in* Potonié *et al.*, p. 451, pl. 19, fig. 53.
1944 *?Raistrickia abditus* (Loose) Schopf *et al.*, p. 55.
1955 *Apiculatisporis abditus* (Loose) Potonié & Kremp, p. 78, pl. 14, figs. 237-239.

Holotype. Potonié & Kremp (1955, pl. 14, fig. 237).

Diagnosis. See Potonié & Kremp (1955, p. 78).

Remarks. Given the revision of *Apiculatasporites* (= *Apiculatisporis*) accepted here, this species is considered best accomodated within the genus *Raistrickia* in view of its ornament of blunt, often truncated, coni. For a full discussion of this generic placement see Ravn (1986, p. 46).

Raistrickia breveminens Peppers 1970.

Plate 6, figure 16.

1970 *Raisrtickia breveminens* Peppers, p. 102, pl. 7, figs. 3, 4, text-fig. 23a.

Holotype. Peppers (1970, pl. 7, fig. 3).

Diagnosis. See Peppers (1970, p. 102).

Raistrickia crinata Kosanke 1950.

Plate 6, figure 9.

1950 *Raistrickia crinata* Kosanke, p. 46, pl. 11, fig. 7.

Holotype. Kosanke (1950, pl. 11, fig. 7).

Diagnosis. See Kosanke (1950, p. 46).

Raistrickia digitosa Artüz 1957.

Plate 6, figure 13.

1957 *Raistrickia digitosa* Artüz, p. 246, pl. 33, fig. 20a,b.

Holotype. Artüz (1957, pl. 33, fig. 20a,b).

Diagnosis. See Artüz (1957, p. 246).

Raistrickia fulva Artüz 1957.

Plate 6, figure 12.

1957 *Raistrickia fulva* Artüz, p. 246, pl. 3, fig. 19.

Holotype. Artüz (1957, pl. 3, fig. 19).

Diagnosis. See Artüz (1957, p. 246).

Raistrickia lowellensis Peppers 1970.

Plate 6, figure 6.

1970 *Raistrickia lowellensis* Peppers, p. 105, pl. 8, figs. 3, 4, text-fig. 23e.

Holotype. Peppers (1970, pl. 105, fig. 3).

Diagnosis. See Peppers (1970, p. 105).

Raistrickia microhorrida (Horst) Potonié & Kremp 1955.

Plate 6, figures 7, 11.

1943 *Triletes ?(Apiculati) microhorridus* Horst, p. 161, pl. 21, fig. 35a, b.
1955 *Raistrickia microhorrida* (Horst) Potonié & Kremp, p. 36.

Holotype. Horst (1943, pl. 21, fig. 35a, b).

Diagnosis. See Horst (1955, p. 161).

Raistrickia parvula sp. nov.

Plate 6, figure 4.

Diagnosis. Radial, trilete, acamerate miospores. Amb circular. Laesurae straight, simple, three quarters of radius, often difficult to discern. Proximal and distal ornament of densely set, minute baculae 0.5μ to 2μ high and 0.25μ to 1μ in diameter. Baculae are mainly flat-topped but rare pilate baculae with slightly inflated, rounded tips may be present. Baculae are set 1μ to 2μ apart.

Derivation of name. L. *parvulus* - diminutive, with reference to the tiny baculae.

Type locality. Well 44/22-4, southern North Sea.

Type horizon. Mudstones in core at 12104'; early Duckmantian.

Holotype. Plate 6, figure 4.

Comparison. All other Carboniferous species of *Raistrickia* have much larger, more prominent baculae.

Raistrickia saetosa (Loose) Schopf *et al.* 1944.

Plate 6, figure 10.

1932 *Sporonites saetosus* Loose *in* Potonié *et al.*, p. 452, pl. 19, fig. 56.
1944 *Raistrickia saetosus* (Loose) Schopf *et al.*, p. 56.

Holotype. Potonié & Kremp (1955, pl. 15, fig. 264).

Diagnosis. See Potonié & Kremp (1955, p. 87).

Raistrickia subcrinata Peppers 1970.

Plate 6, figure 5.

1970 *Raistrickia subcrinata* Peppers, p. 108, pl. 8, figs. 5, 6, text-fig. 23f.

Holotype. Peppers (1970, pl. 8, fig. 5).

Diagnosis. Peppers (1970, p. 108).

Raistrickia superba (Ibrahim) Schopf *et al.* 1944.

Plate 6, figure 17.

1933 *Setosi-sporites superbus* Ibrahim, p. 27, pl. 5, fig. 42.
1944 *Raistrickia superbus* (Ibrahim) Schopf *et al.*, p. 56.

Holotype. Potonié & Kremp (1955, pl. 15, fig. 262).

Diagnosis. See Potonié & Kremp (1955, p. 88).

Spackmanites Habib emend. Ravn 1986.

Type species. *S. ellipticus* Habib emend. Ravn 1986.

Diagnosis. See Ravn (1986, p. 116).

Spackmanites habibii Ravn 1986.

Plate 5, figure 12.

1966 *Spackmanites facierugosus* Habib *auct. non* Loose, p. 638, pl. 105, fig. 19.
1986 *Spackmanites habibii* Ravn, p. 117, 118, pl. 35, figs. 9-11.

Holotype. Ravn (1986, pl. 35, figs. 10, 11).

Diagnosis. see Ravn (1986, p. 117).

Spinositriletes Dybová & Jachowicz emend. Ravn 1991.

Type species. *S. spinosus* (Kosanke) Dybová & Jachowicz 1957.

Diagnosis. See Ravn (1991, p. 89).

Spinositriletes minor (Butterworth & Williams) Ravn 1991.

Plate 4, figure 6.

1958 *Anapiculatisporites minor* Butterworth & Williams, p. 365, pl. 1, figs. 32-34.
1967 *Anapiculatisporites minor* Butterworth & Williams emend. Smith & Butterworth, p. 161, pl. 6, figs. 21-24.
1991 *Spinositriletes minor* (Butterworth & Williams) Ravn, p. 90.

Holotype. Butterworth & Williams (1958, pl. 1, fig. 34).

Diagnosis. See Butterworth & Williams (1958, p. 365).

Spinositriletes paucispinosus (Ravn) Ravn 1991.

Plate 4, figure 5.

1986 *Anacanthotriletes paucispinosus* Ravn, p. 65-66, pl. 1, figs. 32-34.
1991 *Spinositriletes paucispinosus* (Ravn) Ravn, p. 90.

Holotype. Ravn (1986, pl. 16, fig. 9).

Diagnosis. See Ravn (1986, p. 65-66).

Tantillus Felix & Burbridge 1967.

Type species. *T. triquetrus* Felix and Burbridge 1967.
Diagnosis. See Felix & Burbridge (1967, p.383).

Tantillus triquetrus Felix & Burbridge 1967.
Plate 4, figure 17.

1967 *Tantillus triquetrus* Felix & Burbridge, p. 383, pl. 64, figs. 4, 5.

Holotype. Felix & Burbridge (1967, pl. 64, fig. 4).
Diagnosis. See Felix & Burbridge (1967, p. 383).

Tricidarisporites Sullivan & Marshall emend. Gueinn, Neville & Williams *in* Neves *et al.* 1973.

Type species. *T. balteolus* Sullivan & Marshall 1966.
Diagnosis. See Neves *et al.* (1973, p. 31).

Tricidarisporites arcuatus Neville *in* Neves *et al.* 1973.
Plate 6, figure 23.

1974 *Tricidarisporites arcuatus* Neville *in* Neves *et al.*, p. 32, pl. 1, figs. 7, 8.

Holotype. Neves *et al.* (1973, pl. 1, fig. 7).
Diagnosis. See Neves *et al.* (1973, p. 32).

Verrucosisporites Ibrahim emend. Smith *et al.* 1964.

Type species. *V. verrucosus* (Ibrahim) Ibrahim 1933.
Diagnosis. See Smith *et al.* (1964, p. 1071).

Verrucosisporites cerosus (Hoffmeister *et al.*) Butterworth & Williams 1958.

1955 *Punctati-sporites? cerosus* Hoffmeister *et al.*, p. 392, pl. 36, fig. 6.
1958 *Verrucosisporites cerosus* (Hoffmeister *et al.*) Butterworth & Williams, p. 361, pl. 1, figs. 42, 43.

Holotype. Hoffmeister *et al.* (1955, pl. 36, fig. 6).
Diagnosis. See Hoffmeister *et al.* (1955, p. 392).

Verrucosisporites cf. *cerosus.*

Plate 5, figure 22.

Remarks. Specimens from this study are very similar to the material described and figured by Hoffmeister *et al.* (1955) and Smith & Butterworth (1967) but bear an ornament of poorly defined verrucae which are slightly coarser and more irregular in plan view.

Verrucosisporites cumbriensis Butterworth *et al.* 1988.

Plate 2, figure 25.

1988 *Verrucosisporites cumbriensis* Butterworth *et al.*, p. 68, pl. 4, figs. 2-6, pl. 5, fig. 8.

Holotype. Butterworth *et al.* (1988, pl. 4, fig. 3).

Diagnosis. See Butterworth *et al.* (1988, p. 68).

Verrucosisporites donarii Potonié & Kremp 1955.

Plate 5, figure 18.

1955 *Verrucosisporites donarii* Potonié & Kremp, p. 67, pl. 13, fig. 193.

Holotype. Potonié & Kremp (1955, pl. 13, fig. 193).

Diagnosis. See Potonié & Kremp (1955, p. 67).

Verrucosisporites eximius Playford 1962.

1962 *Verrucopsisporites eximius* Playford, p. 587, pl. 80, figs. 5-8, text-fig. 5d.

Holotype. Playford (1962, pl. 80, figs. 5, 6).

Diagnosis. See Playford (1962, p. 587).

Verrucosisporites cf. *eximius.*

Plate 6, figure 1.

Remarks. The present specimens do not possess the distinctive broad labra found in the type material.

Verrucosisporites gobbettii Playford 1962.

1962 *Verrucosisporites gobbettii* Playford, p. 586-587, pl. 80, figs. 1-4, text-fig. 5g.

Holotype. Playford (1962, pl. 80, fig. 1).

Diagnosis. Playford (1962, p. 586).

Verrucosisporites aff. *gobbettii.*

Plate 5, figures 19, 23.

Remarks. Many specimens of *Verrucosisporites* examined in this study have a conspicuous ornament of large verrucae. Such verrucate ornament is unusual in the Westphalian of northwest Europe although it has been reported (as *V. nitidus* and *V.* cf. *morulatus*) from the Kilbourn and Caseyville Formations (= early Duckmantian and late Langsettian respectively) of Iowa (Ravn, 1986).

This large verrucate ornament is more common amongst early Namurian and younger species of *Verrucosisporites*. The present specimens exhibit a wide range of morphographies of verrucae, forming a plexus of types centred around specimens very similar to *V. gobbettii*. It is likely that the specimens could be divided into more than one morphographic taxon.

Verrucosisporites microtuberosus (Loose) Smith & Butterworth 1967.

Plate 5, figure 26.

1932 *Sporonites microtuberosus* Loose *in* Potonié *et al.*, p. 450, pl. 18, fig. 33.
1967 *Verrucosisporites microtuberosus* (Loose) Smith & Butterworth, p. 149-150, pl. 5, figs. 9-11.

Holotype. Potonié & Kremp (1955, pl. 15, fig. 273).

Diagnosis. See Smith & Butterworth (1967, p. 150).

Verrucosisporites microverrucosus Ibrahim 1933.

Plate 6, figure 2.

1933 *Verrucosisporites microverrucosus* Ibrahim, p. 25, pl. 7, fig. 60.
1944 *Punctati-sporites microverrucosus* (Ibrahim) Schopf *et al.*, p. 31.
1950 *Verrucoso-sporites microverrucosus* (Ibrahim) Knox, p. 318, pl. 17, fig. 228.

Holotype. Potonié & Kremp (1955, pl. 13, fig. 300).

Diagnosis. See Ibrahim (1933, p. 25).

Verrucosisporites perverrucosus (Loose) Potoié & Kremp emend. Smith 1971.

Plate 5, figure 20, 24.

1932 *Sporonites perverrucosus* Loose *in* Potonié *et al.*, p. 45, pl. 18, fig. 48.
1955 *Verrucosisporites perverrucosus* (Loose) Potonié & Kremp, p. 68, pl. 13, fig. 194.
1971 *Verrucosisporites preverrucosus* (Loose) Potonié & Kremp emend. Smith, p. 72-73, pl. 18, figs. 1-15.

Holotype. See Smith (1971, pl. 18, figs. 1-3).

Diagnosis. See Smith (1971, p. 72).

Verrucosisporites sifati (Ibrahim) Smith & Butterworth 1967.

Plate 6, figure 3.

1933 *Reticulati-sporites sifati* Ibrahim, p. 35, pl. 8, fig. 67.
1967 *Verrucosisporites sifati* (Ibrahim) Smith & Butterworth, p. 152-153, pl. 6, fig. 1.

Holotype. Potonié & Kremp (1955, pl. 15, fig. 67).

Diagnosis. See Smith & Butterworth (1967, p. 152).

Verrucosisporites verrucosus (Ibrahim) Ibrahim 1933.

Plate 5, figure 27.

1932 *Sporonites verrucosus* Ibrahim *in* Potonié *et al.*, p. 448, pl. 15, fig. 17.
1933 *Verrucosi-sporites verrucosus* (Ibrahim) Ibrahim, p. 25, pl. 2, fig. 17.

Holotype. Potonié & Kremp (1955, pl. 13, fig. 196).

Diagnosis. See Potonié & Kremp (1955, p. 69).

Infraturma MURONATI Bennie & Kidston emend. Potonié 1956.

Anafoveosporites Ravn 1986.

Type species. *A. avcinnii* (Ravn and Fitzgerald) Ravn 1986.
Diagnosis. See Ravn & Fitzgerald (1982, p. 130).

Anafoveosporites avcinii (Ravn & Fitzgerald) Ravn 1986.

Plate 7, figure 24.

1982 *Foveosporites avcinii* Ravn & Fitzgerald, p. 130, pl. 6, figs. 1-6
1986 *Anafoveosporites avcinii* (Ravn & Fitzgerald) Ravn, p. 92, pl. 26, figs. 4-8.

Holotype. Ravn & Fitzgerald (1982, pl. 6, fig. 1).
Diagnosis. Ravn & Fitzgerald (1982, p. 130).
Remarks. Specimens observed from the S.N.S.C.B. consistently have an equatorial thickening (Curvatural ridge or limbus?) 2-4μm wide. Although this feature is not mentioned in the specific (or generic) diagnosis it can be seen in the photographs of the holotype and paratypes.

Camptotriletes Naumova 1939 *ex* Potonié & Kremp 1954.

Type species. *C. corrugatus* (Ibrahim) Potonié & Kremp 1954.
Diagnosis. See Potonié & Kremp (1954, p. 142).

Camptotriletes bucculentus (Loose) Potonié & Kremp 1954.

Plate 7, figure 3.

1934 *Verrucosi-sporites bucculentus* Loose, p. 154, pl. 7, fig. 15.
1955 *Camptotriletes bucculentus* (Loose) Potonié & Kremp, p. 104, pl. 16, figs. 287-288.

Holotype. Potonié & Kremp (1955, pl. 16, fig. 306).
Diagnosis. See Potonié & Kremp (1955, p. 104).
Remarks. For a more complete synonymy see Smith & Butterworth (1967, p. 199).

Camptotriletes corrugatus (Ibrahim) Potonié & Kremp 1954.

Plate 7, figure 8.

1933 *Reticulati-sporites corrugatus* Ibrahim, p. 35, pl. 5, fig. 41.
1955 *Camptotriletes corrugatus* (Ibrahim) Potonié & Kremp, p. 104, pl. 16, figs. 289, 290.

Holotype. Ibrahim (1933, pl. 5, fig. 41).
Diagnosis. See Potonié & Kremp (1955, p. 104).

Camptotriletes superbus Neves 1961.

Plate 7, figure 2.

1961 *Camptotriletes superbus* Neves, p. 257, pl. 31, fig. 8.

Holotype. Neves (1961, pl. 31, fig. 8).

Diagnosis. See Neves (1961, p. 257).

Camptotriletes triangularis Peppers 1970.

Plate 7, figure 7.

1970 *Camptotriletes triangularis* Peppers, p. 114, pl. 10, figs. 1,2, text-fig. 25.

Holotype. Peppers (1970, pl. 10, fig. 1).

Diagnosis. See Peppers (1970, p. 114).

Convolutispora **Hoffmeister** ***et al.*** **1955.**

Type species. *C. florida* Hoffmeister *et al.* 1955.

Diagnosis. See Hoffmeister *et al.* (1955, p. 384).

Convolutispora cerina Ravn 1979.

Plate 6, figure 28, 29.

1979 *Convolutispora cerina* Ravn, p. 32-33, pl. 8, figs. 12-15.

Holotype. Ravn (1979, pl. 8, fig. 12).

Diagnosis. See Ravn (1989, p. 32).

Convolutispora florida Hoffmeister *et al.* 1955.

Plate 6, figure 30.

1955 *Convolutispora florida* Hoffmeister *et al.*, p. 384, pl. 38, figs. 5,6.

Holotype. Hoffmeister *et al.* (1955, pl. 38, fig. 6).

Diagnosis. See Hoffmeister *et al.* (1955, p. 384).

Convolutispora mellita Hoffmeister *et al.* 1955.

Plate 7, figure 4.

1955 *Convolutispora mellita* Hoffmeister *et al.*, p. 384-385, pl. 38, fig. 10.

Holotype. Hoffmeister *et al.* (1955, pl. 38, fig. 10).

Diagnosis. See Hoffmeister *et al.* (1955, p. 384).

Convolutispora tessellata Hoffmeister *et al.* 1955.

Plate 7, figure 1.

1955 *Convolutispora tessellata* Hoffmeister *et al.*, p. 385, pl. 38, fig. 9.

Holotype. Hoffmeister *et al.* (1955, pl. 38, fig. 9).

Diagnosis. See Hoffmeister *et al.* (1955, p. 385).

Corrugitriletes Mishell *ex* Turner & Spinner 1992.

Type species. *C. radiatus* Turner & Spinner 1992.

Diagnosis. See Turner & Spinner (1992, p. 18).

Corrugitriletes radiatus Turner & Spinner 1992.

Plate 6, figures 26, 27.

1992 *Corrugitriletes radiatus* Turner & Spinner, p. 18. pl. 5, figs. 1-4.

Holotype. Turner & Spinner (1992, pl. 5, fig. 1).

Diagnosis. See Turner & Spinner (1992, p. 18).

Cordylosporites Playford and Satterthwaite 1985.

Type species. *C. sepositus* Playford and Satterthwaite 1985.

Diagnosis. See Playford & Satterthwaite (1985, p. 144).

Remarks. Several species of trilete, acamerate, azonate, reticulate Carboniferous miospores have been recognised which bear a secondary ornament associated with the junctions of the muri. The erection of *Cordylosporites* by Playford and Satterthwaite (1985) to accomodate reticulate miospores with a secondary non-spinose, "crestal" ornament will necessitate the transferrence of several of these taxa.

Cordylosporites karadenizensis (Artüz) comb. nov. emend.

Plate 7, figure 23.

1957 *Reticulatisporites karadenizensis* Artüz, p. 247, pl. 4, fig, 24.

1963 *Dictyotriletes karadenizensis* Owens, p. 136, pl. 12, fig. 2.

Holotype. Artüz (1957, pl. 4, fig. 24).

Emended Diagnosis. Trilete, radial, acamerate, azonate miospores with circular to sucircular equatorial outline. Trilete mark straight, simple, two thirds radius, often obscured by ornament. Reticulate ornament on proximal and distal surfaces. Muri densely set, 4-7μ wide, 2.5-5μ high with a "barrel-like" shape; peltate (mushroom-shaped) processes developed upon the junctions of the reticulum, processes up to 3μ high and 5-9μ in diameter, more or less circular in diameter. Lumina irregular in size, laevigate, less than 10μ in diameter.

Remarks. Artüz (1957) did not indicate the presence of peltate processes in his diagnosis. The processes are, however, visible on the photograph of the holotype, particularly on the right hand side of the specimen and, in plan view, over the body of the specimen.

Dictyotriletes **Naumova *ex* Potonié & Kremp emend. Ravn 1986.**

Type species. *D. bireticulatus* (Ibrahim) Potonié & Kremp emend. Smith & Butterworth 1967.

Diagnosis. See Ravn (1986, p. 90).

Remarks. The structural relationship between this genus and *Reticulatisporites* Ibrahim emend. Neves 1964a is discussed under the section relating to that genus.

Potonié & Kremp (1954, 1955) regarded the proximal and distal distribution of sculpture as a character of generic significance for most trilete miospore genera. However, in considering *Dictyotriletes* they failed to apply this distinction. In selecting *D. bireticulatus* as the type species they chose a form in which the reticulum is clearly restricted to the distal surface. Smith & Butterworth (1967) suggested that *Dictyotriletes* be emended to exclude forms with proximal and distal reticulation and Ravn (1986) achieved this. The acceptance of this emendation necessitates the transferrance of many species to a genus of trilete, acamerate, azonate miospores with a similar style of reticulation distributed proximally and distally, *Reticulitriletes* Mädler emend. being suitable.

Dictyotriletes bireticulatus (Ibrahim) emend. Smith & Butterworth 1967.

Plate 7, figure 20.

1932 *Sporonites bireticulatus* Ibrahim *in* Potonié *et al.*, p. 447, pl. 14, fig. 1.
1954 *Dictyotriletes bireticulatus* (Ibrahim) Potonié & Kremp, p. 108.
1967 *Dictyotriletes bireticulatus* (Ibrahim) Potonié & Kremp emend. Smith & Butterworth, p. 194, pl. 11, figs. 14,15.

Holotype. Potonié & Kremp (1955, pl. 16, fig. 296).

Diagnosis. See Smith & Butterworth (1967, p. 194).

Remarks. For a more complete synonymy see Ravn (1986, p. 90).

Dictyotriletes probireticulatus Butterworth & Mahdi 1982.

Plate 7, figure 19.

1982 *Dictyotriletes probireticulatus* Butterworth & Mahdi, p. 490, pl. 1, figs. 11-13.

Holotype. Butterworth & Mahdi (1982, pl. 1, fig. 11).

Diagnosis. See Butterworth & Mahdi (1982, p. 490).

Foveosporites Balme 1957.

Type species. *F. canalis* Balme 1957.

Diagnosis. See Balme (1957, p. 17).

Foveosporites sp.A.

Plate 7, figure 22.

Description. Miospores radial, trilete, acamerate. Laesurae straight, accompanied by low labra less than 2μ wide and less than 1μ high, reaching to, or almost to, equator and often accompanied by curvaturae perfectae. Equatorial outline circular to subcircular. Proximal and distal exoexine ornamented with circular, subcircular and rounded-elongate fovae, 1μ across and up to 4μ long. Fovae not reduced on contact face. Exoexine between fovae laevigate. Size of miospores 47(50)54μ; 4 specimens.

Comparison. *Anafoveosporites avcinii* (Ravn & Fitzgerald) Ravn 1986 and *"Foveosporites" pertusus* Gueinn 1969 MS. both appear similar but have fovae restricted to the distal surface and a more strongly developed equatorial curvatural feature. *F. pertusus* ought to belong to the genus *Anafoveosporites* Ravn 1986.

Marasmosporites gen nov.

Type species. *M. semiesus* sp. nov.

Diagnosis. Miospores radial, trilete, acamerate. Equatorial outline rounded triangular, sides straight or slightly convex or concave. Proximally laevigate. Distal ornament of irregular vermiculae of variable widths which anastomose to form a negative reticulum. Elements between vermiculae granulate, vermiculate and/or muronate, flat topped and all of the same height. Vermiculae rarely, if ever, approach the equator.

Derivation of name. Gr. *marasmos* - to wither away, and, in a modern sense, the wasting away of the body; in reference to the decayed appearence of the distal exoexine.

Comparison. *Convolutispora* Hoffmeister *et al.* 1955 has proximal and distal muri. *Anafoveosporites* (Ravn & Fitzgerald) Ravn 1986 has distal fovae which do not coalesce into a reticulum.

Marasmosporites semiesus sp. nov.
Plate 6, figure 25.

Diagnosis. Miospores radial, trilete, acamerate. Equatorial outline rounded triangular, sides straight or slightly convex or concave. Proximally laevigate. Distal ornament of irregular vermiculae of variable widths which anastomose to form a negative reticulum. Elements between vermiculae granulate, vermiculate and/or muronate, flat topped and all of the same height. Vermiculae rarely, if ever, approach the equator. Miospore diameter 25(28.2)30μ; 20 specimens.

Derivation of name. L. *semiesus* - half-eaten; in reference to the eaten or corroded appearence of the distal exoexine.

Type locality. 44/22-1, southern North Sea.

Type horizon. Coal in core at 11424'; middle Duckmantian.

Holotype. Plate 6, figure 25.

Comparison. See under generic Comparison.

Microreticulatisporites Knox emend. Potonié & Kremp 1954.

Type species. *M. lacunosus* (Ibrahim) Knox *ex* Potonié & Kremp 1954.

Diagnosis. See Potonié & Kremp (1954, p. 143).

Remarks. Potonié & Kremp (1954) validated the genus by photographic illustration of the type species. Unfortunately the type species (*M. lacunosus*) has an ornament which is microfoveolate rather than clearly microreticulate. In view of this, *Microreticulatisporites* appears to partially overlap with the concepts of the genera *Foveotriletes* van der Hammen *ex* Potonié 1956 and *Foveosporites* Balme 1957. Many species have sculpture intermediate between these genera (Ravn 1986, 1991). With this in mind, the following species maintained within *Microreticulatisporites* where there is an historical precedent, pending systematic clarification of the genera.

Microreticulatisporites harrisonii Peppers 1970.
Plate 7, figure 12.

1970 *Microreticulatisporites harrisonii* Peppers, p. 110, pl. 9, fig. 1.

Holotype. Peppers (1970, pl. 9, fig. 1).

Diagnosis. See Peppers (1970, p. 110.).

Microreticulatisporites hortonensis Playford 1964.

Plate 7, figure 9.

1964 *Microreticulatisporites hortonensis* Playford, p. 28, pl. 8, figs. 3, 4.

Holotype. Playford (1964, pl. 8, fig. 3).

Diagnosis. Playford (1964, p. 28).

Microreticulatisporites microreticulatus Knox 1950.

1950 *Microreticulatisporites microreticulatus* Knox, p. 321.

Neotype. Smith & Butterworth (1967, pl. 11, fig. 5).

Diagnosis. See Butterworth & Williams (1958, p. 367).

Microreticulatisporites cf. *microreticulatus*

Plate 7, figure 10.

Remarks. Specimens are larger than the type (40(55)60μ);15 specimens, but bear an almost identical miroreticulate sculpture.

Microreticulatisporites nobilis (Wicher) Knox 1950.

Plate 7, figures 5, 6.

1934 *Sporites nobilis* Wicher, p. 186, pl. 8, fig. 3.
1950 *Microreticulatisporites nobilis* (Wicher) Knox, p. 321, pl. 18, fig. 242.

Holotype. Potonié & Kremp (1955, pl. 15, fig. 279).

Diagnosis. See Potonié & Kremp (1955, p. 101).

Microreticulatisporites punctatus Knox 1950.

Plate 7, figure 11.

1950 *Microreticulatisporites punctatus* Knox, p. 321.

Neotype. Smith & Butterworth (1967, pl. 11, figs. 12, 13).

Diagnosis. See Butterworth & Williams (1958, p. 368).

Reticulitriletes Mädler 1964 emend.

Type species. *R. globosus* Mädler 1964.

Emended Diagnosis. Miospores radial, trilete, azonate, acamerate, circular or sub-circular in equatorial outline. Trilete rays simple, straight. Proximal and distal surfaces ornamented with a comprehensive reticulate sculpture of muri with height equal to or greater than their width, enclosing more or less polygonal lumina of greater width than the nuri. Reticulum may be imperfect and may be reduced or absent from areas in the immediate vicinity of the trilete mark.

Remarks. The above emended diagnosis follows closely that of the emendation by Ravn (1986). It differs in the indication that the muri may be greater in height than width. See discussion under *Dictyotriletes* Naumova *ex* Potonié & Kremp emend. Ravn 1986 above.

Reticulitriletes areolatus Guennel comb. nov.
Plate 7, figure 14.

1958 *Reticulatisporites areolatus* Guennel, p. 83-84, pl. 6, fig. 7, text-fig. 19.

Holotype. Guennel (1958, text-fig. 19).

Diagnosis. See Guennel (1958, p. 83).

Reticulitriletes distortus (Peppers) Ravn 1986.

1970 *Dictyotriletes distortus* Peppers, p. 112, pl. 9, figs. 9-11, text-fig. 24.
1986 *Reticulitriletes distortus* (Peppers) Ravn, p. 53, pl. 25, fig. 14.

Holotype. Peppers (1970, pl. 9, fig. 9).

Diagnosis. See Peppers (1970, p. 112).

Reticulitriletes aff. *distortus*
Plate 7, figure 15.

Remarks. Specimens are slightly larger (32(35.5)40μ; 10 specimens) than the type material and have more numerous muri which are slightly more densely set.

Reticulitriletes falsus (Potonié & Kremp) Ravn 1986.
Plate 7, figure 16.

1955 *Dictyotriletes falsus* Potonié & Kremp, p. 109, pl. 16, figs. 303, 304.
1986 *Reticulitriletes falsus* (Potonié & Kremp) Ravn, p. 54, pl. 25, figs. 10-12.

Holotype. Potonié & Kremp (1955, pl. 109, fig. 303).

Diagnosis. See Potonié & Kremp (1955, p. 109).

Reticulitriletes mediareticulatus (Ibrahim) Ravn 1986.
Plate 7, figure 13.

1933 *Reticulati-sporites mediareticulatus* Ibrahim, p. 34, pl. 7, fig. 62.
1955 *Dictyotriletes mediareticulatus* (Ibrahim) Potonié & Kremp, p. 110, pl. 16, figs. 314, 315.
1967 *Dictyotriletes mediareticulatus* Potonié & Kremp emend. Smith & Butterworth, p. 197, pl. 11, figs. 22-24.
1986 *Reticulitriletes mediareticulatus* (Ibrahim) Ravn, p. 54, pl. 25, figs. 5, 6.

Holotype. Potonié & Kremp (1955, pl. 16, fig. 314).

Diagnosis. See Smith & Butterworth (1967, p. 197).

Reticulitriletes muricatus (Kosanke) comb. nov.

Plate 7, figure 18.

1950 *Reticulati-sporites muricatus* Kosanke, p. 27, pl. 4, fig. 7.
1967 *Dictyotriletes muricatus* (Kosanke) Smith & Butterworth, p. 197-198, pl. 4, fig. 7.

Holotype. Kosanke (1950, pl. 4, fig. 7).

Diagnosis. See Kosanke (1950, p. 27).

Reticulitriletes reticulocingulum (Loose) Ravn 1986.

Plate 7, figure 17.

1932 *Sporonites reticulocingulum* Loose *in* Potonié *et al.*, p. 450, pl. 18, fig. 41.
1967 *Dictyotriletes reticulocingulum* (Loose) Smith & Butterworth, p. 198, pl. 11, figs. 27-29.
1986 *Reticulitriletes reticulocingulum* (Loose) Ravn, p. 54, pl. 25, figs. 7-9.

Holotype. Potonié & Kremp (1955, pl. 16, fig. 306).

Diagnosis. See Potonié & Kremp (1955, p. 113).

Remarks. For a more complete synonymy see Ravn (1986, p. 54).

Subturma ZONOTRILETES Waltz *in* Naumova 1939.

Infraturma AURICULATI Schopf emend. Dettmann 1963.

Ahrensisporites **Potonié & Kremp 1954.**

Type species. *A. guerickei* (Horst) Potonié & Kremp 1954.

Diagnosis. See Potonié & Kremp (1954, p. 155).

Ahrensisporites guerickei (Horst) Potonié & Kremp *ex* Horst 1955.

Plate 7, figure 26.

1943 *Triletes guerickei* Horst, pl. 7, figs. 58, 59, 61-64.
1954 *Ahrensisporites guerickei* (Horst) Potonié & Kremp, p. 155.
1955 *Ahrensisporites guerickei* (Horst) Potonié & Kremp ex Horst, p. 178, pl. 23, figs. 58,59, 61-64.

Holotype. Horst (1955, pl. 23, fig. 63).

Diagnosis. See Horst (1955, p. 178).

Remarks. Potonié & Kremp (1954) sought to validate this species invalidly presented by Horst (1943) in an unpublished doctoral thesis. However, they failed to figure a Holotype. The species was not validly published until Horst (1955) figured the Holotype.

Ahrensisporites ornatus (Neves) Ravn 1986.

Plate 7, figure 27.

1961 *Ahrensisporites guerickei* var. *ornatus* Neves, p. 263, pl. 32, fig. 11.
1986 *Ahrensisporites ornatus* (Neves) Ravn, p. 96, pl. 27, figs. 8-10.

Holotype. Neves (1961, pl. 32, fig. 11).

Diagnosis. Neves (1961, p. 263).

Remarks. As *A. guerickei* var. *guerickei* 1961 and *A. guerickei* var. *ornatus* Neves 1961 do not appear to intergrade morphographically (Ravn, 1986) and have different (although overlapping) stratigraphic ranges (Neves, 1961; Ravn, 1986), Ravn (1986) considered them to be distinct species and raised the latter to specific status.

Ahrensisporites sinus Neves 1959 MS.

Plate 7, figures 21, 25.

1959 *Ahrensisporites sinus* Neves, p. 107-108, pl. 13, figs. 1-9 (unpublished thesis).

Holotype. Neves (1959, pl. 13, fig. 1).

Diagnosis. See Neves (1959, p. 107).

Remarks. The species remains ineffectively published.

Tripartites Schemel 1950.

Type species. *T. vetustus* Schemel 1950.

Diagnosis. See Schemel (1950, p. 242).

Remarks. Jansonius & Hills (1976, card 2030) and Ravn (1991, p. 76) consider *Tripartites* to be a junior synonym of *Platyptera* Naumova *ex* Schulz 1967. However, given the differences between the diagnoses, it is here considered desirable to maintain the two genera as seperate until the Russian type material of *Platyptera* and the American type material of *Tripartites* can be directly compared.

Tripartites nonguerickei Potonié & Kremp *ex* Smith & Butterworth 1967.

Plate 8, figure 4.

1943 *Triletes (Zonales) guerickei* Horst, pl. 7, fig. 60 (unpublished thesis).
1955 *Ahrensisporites guerickei* Potonié & Kremp *auct. non*. Horst, p. 178, pl. 23, fig. 60.
1956 *Tripartites nonguerickei* Potonié & Kremp, p. 92.
1967 *Tripartites nonguerickei* Potonié & Kremp *ex* Smith & Butterworth, p. 207-208, pl. 13, figs. 1-3.

Holotype. Horst (1955, pl. 23, fig. 60).

Diagnosis. See Smith & Butterworth (1967, p. 207).

Remarks. The specimen figured as *Ahrensisporites guerickei* by Horst (1955) was selected by Potonié & Kremp (1956) as the type for this species. However, they failed to provide a diagnosis. The species was validated by the publication of a diagnosis by Smith & Butterworth (1967).

Tripartites vetustus Schemel 1950.

Plate 8, figure 5.

1950 *Tripartites vetustus* Schemel, p. 242, pl. 40, fig. 11.

Holotype. Schemel (1950, pl. 40, fig. 11).

Diagnosis. See Schemel (1950, p. 242).

Triquitrites Wilson & Coe emend. Potonié & Kremp 1954.

Type species. *T. arculatus* Wilson and Coe 1940.

Diagnosis. See Potonié & Kremp (1954, p. 153).

Triquitrites protensus Kosanke 1950.

Plate 7, figure 28.

1950 *Triquitrites protensus* Kosanke, p. 40, pl.8, fig. 2.

Holotype. Kosanke (1950, pl. 8, fig. 2).

Diagnosis. See Kosanke (1950, p. 40).

Triquitrites sculptilis Balme emend. Smith & Butterworth 1967.

Plate 8, figures 2, 3.

1952 *Triquitrites sculptilis* Balme, p. 181, text-fig. 1g.
1967 *Triquitrites sculptilis* Balme emend. Smith & Butterworth, p. 204, pl. 12, figs. 10-15.

Lectotype. Smith & Butterworth (1967, pl. 12, figs. 10, 11), selected by Balme.

Diagnosis. See Smith & Butterworth (1967, p. 204).

Remarks. For a more complete synonymy see Smith & Butterworth (1967, p. 204).

Triquitrites tribullatus (Ibrahim) Schopf *et al.* 1944.

Plate 8, figure 1.

1932 *Sporonites tribullatus* Ibrahim in Potonié *et al.*, p. 448, pl. 15, fig. 13.
1944 *Triquitrites tribullatus* (Ibrahim) Schopf *et al.*, p. 47.

Holotype. Potonié & Kremp (1955, pl. 17, fig. 319).

Diagnosis. See Potonié & Kremp (1956, p. 90).

Remarks. Ravn (1986) placed several species of *Triquitrites* as junior synonyms of *T. tribullatus* on the grounds that they were morphologically indistinguishable from it. Despite the difficulties created by inter-specific gradation within this group of miospores (see Smith & Butterworth, 1967, p.

202), several species may be distinguished and have useful stratigraphic distributions. Ravn's synonomies are therefore rejected here.

For a more complete synonymy see Smith & Butterworth (1967, p. 202).

Infraturma TRICRASSITI Dettmann 1963.

Diatomozonotriletes Naumova emend. Playford 1963.

Type species. *D. saetosus* (Hacquebard & Barss) Hughes & Playford 1961.

Diagnosis. See Playford (1963, p. 646).

Diatomozonotriletes rarus Playford 1963.

Plate 8, figure 6.

1963 *Diatomozonotriletes raus* Playford, p. 649-650, pl. 93, figs. 15, 16, text-fig. 11e.

Holotype. Playford (1963, pl. 93, fig. 15).

Diagnosis. See Playford (1963, p. 649-650).

Reinschospora Schopf *et al.* 1944.

Type species. *R. speciosa* (Loose) Schopf *et al.* 1944 (= *R. bellitas* Bentall, *in* Schopf *et al.* 1944).

Diagnosis. See Schopf *et al.* (1944, p. 52).

Reinschospora speciosa (Loose) Schopf *et al.* 1944.

Plate 8, figure 8.

1934 *Alati-sporites speciosus* Loose, p. 151, pl. 7, fig. 1.
1944 *Reinschospora speciosa* (Loose) Schopf *et al.*, p. 53.
1944 *Reinschospora bellita* Bentall *in* Schopf *et al.*, p. 53, fig. 2.

Holotype. Potonié & Kremp (1956, pl. 19, fig. 419).

Diagnosis. See Potonié & Kremp (1956, p. 132).

Reinschospora triangularis Kosanke emend. Ravn 1979.

Plate 8, figure 7.

1950 *Reischospora triangularis* Kosanke, p. 43, pl. 9, figs. 6, 7.
1979 *Reinschospora triangularis* Kosanke emend. Ravn, p. 36, pl. 11, figs. 3-6.

Holotype. Kosanke (1950, pl. 9, figs. 6, 7).

Diagnosis. See Ravn (1979, p. 36).

Remarks. For a more complete synonymy see Ravn (1986, p. 36).

Trinidulus Felix & Paden 1964.

Type species. *T. diamphidios* Felix and Paden 1964.
Diagnosis. See Felix & Paden (1964, p. 330).
Remarks. This genus is tentatively included in the infraturma TRICRASSITI as it bears distinctive interradial, equatorial structures, although these do not correspond exactly to "sclerine thickenings (inter radial crassitudes) or extensions (corona) in the three interradial regions of the equator" as prescribed by Dettmann (1963, p. 64).

Trinidulus diamphidios Felix & Paden 1964.
Plate 8, figure 21.

1964 *Trinidulus diamphidios* Felix & Paden, p. 330, text-figs. 1-4.

Holotype. Felix & Paden (1964, text-fig. 1).
Diagnosis. See Felix & Paden (1964, p. 330).

Infraturma CINGULATI Potonié & Klaus 1954.

Bellispores Artüz 1957.

Type species. *B. nitidus* Artüz 1957 (= *B. bellus* Artüz 1957).
Diagnosis. See Artüz (1957, p. 254).

Bellispores nitidus (Horst) Sullivan emend Smith & Butterworth 1967.
Plate 8, figure 20.

1943 *Triletes nitidus* Horst, pl. 8, fig. 81.
1964 *Bellispores nitidus* (Horst) Sullivan, p. 375.
1967 *Bellispores nitidus* (Horst) Sullivan emend. Smith & Butterworth, p. 225, pl. 15, figs. 4-7.

Holotype. Horst (1955, pl. 24, fig. 81).
Diagnosis. See Smith & Butterworth (1967, p. 225).
Remarks. Smith & Butterworth (1967) provided an expanded diagnosis based upon the diagnoses given by Horst (1955) and Artüz (1957). In my opinion this represents a *de facto* emendation of the specific diagnosis.

Knoxisporites Potonié & Kremp emend. Neves & Playford 1961.

Type species. *K. hagenii* Potonié and Kremp 1954.
Diagnosis. See Neves & Playford (1961, p. 9).

Knoxisporites biceps sp. nov.

Plate 8, figure 12.

Diagnosis. Miospores radial, trilete, acamerate, cingulate. Amb more or less circular. Laesurae difficult to identify due to presence of identical, distal, trilete-like structure. Proximal and distal structures reach to equator and are accompanied by well developed, high and narrow tapering labra 8μ to 15μ high at the poles; structures are rotated by 60° with respect to each other. Cingulum 5μ to 12μ wide, often with a gradational inner margin. Exoexine laevigate. Diameter of miospores 55(60)92μ; 20 specimens.

Derivation of name. L. *biceps* - two headed; in reference to the presence of proximal and distal triradiate "labra" and the consequent difficulty in identifying the proximal face.

Type locality. Well 44/22-3; southern North Sea.

Type horizon. Mudstones in core at 11867'; early Duckmantian.

Holotype. Plate 8, figure 12.

Comparison. *Knoxisporites seniradiatus* Neves 1961 has distal bars of thickening rotated at 60° to the trilete mark, but which are not labrate and which are easily distinguishable from the trilete structure. *Knoxisporites triradiatus* Hoffmeister *et al.* 1955 lacks prominant labra associated with the trilete mark.

Knoxisporites dissidius Neves 1961.

Plate 8, figure 13.

1961 *Knoxisporites dissidius* Neves, p. 266, pl. 33, figs. 4, 6.

Holotype. Neves (1961, pl. 33, fig. 4).

Diagnosis. See Neves (1961, p. 266).

Knoxisporites quadratus Butterworth *et al.* 1988.

Plate 8, figure 9.

1988 *Knoxisporites quadratus* Butterworth *et al.*, p. 73, pl. 5, figs. 2-4, 7.

Holotype. Butterworth *et al.* (1988, pl. 5, figs. 2, 4).

Diagnosis. See Butterworth *et al.* (1988, p. 71).

Knoxisporites seniradiatus Neves 1961.

Plate 8, figure 11.

1961 *Knoxisporites seniradiatus* Neves, p. 267-268, pl. 33, fig. 5.

Holotype. Neves (1961, pl. 33, fig. 5).

Diaghnosis. See Neves (1961, p. 268).

Knoxisporites stephanephorus Love 1960.

Plate 8, figure 14.

1960 *Knoxisporites stephanephorus* Love, p. 118, pl. 2, figs. 1, 2.

Holotype. Love (1960, pl. 2, fig. 1).

Diagnosis. See Love (1960, p. 118).

Knoxisporites triradiatus Hoffmeister *et al.* 1955.

Plate 8, figure 10.

1955 *Knoxisporites triradiatus* Hoffmeister *et al.*, p. 391, pl. 37, figs. 11, 12.

Holotype. Hoffmeister *et al.* (1955, pl. 37, fig. 12).

Diagnosis. See Hoffmeister *et al.* (1955, p. 391).

Reticulatisporites Ibrahim emend. Neves 1964a.

Type species. *Reticulatisporites reticulatus* (Ibrahim) Ibrahim 1933.

Diagnosis. See Neves (1964a, p. 1066).

Remarks. Diversity of opinion exists regarding the interpretation of the structure of the reticulate genera *Reticulatisporites* and *Dictyotriletes*. The principal division in opinion concerns the interpretation of *Reticulatisporites* as cingulate or acingulate. Workers who consider *Reticulatisporites* to be acingulate (e.g. Potonié, 1966; Playford & Helby, 1968; Playford, 1971; Urban, 1971; Ravn, 1986), tend to include azonate reticulate miospores whose muri are higher than they are wide in that genus. *Dictyotriletes* (or more recently *Dictyotriletes* and *Reticulitriletes*) is (are) then used to accommodate similar miospores whose muri are wider than they are high. Workers who consider *Reticulatisporites* to be cingulate (e.g. Neves & Playford, 1961; Hughes *et al.*, 1962; Neves, 1964a; Smith & Buttterworth, 1967) have no need to differentiate the genera on the basis of ornament height versus width as the two genera are, in this interpretation, fundamentally different in their structure.

In this account the genus *Reticulatisporites* is interpreted as cingulate based upon the photographs of the type material presented by Neves (1964a), and the microtome sections figured by Hughes *et al.* (1962). Potonié & Kremp (1954) consider the cingulum of *Reticulatisporites* to be no more than the equatorial expression of the muri of the reticulum. This interpretation can only be accepted if species of *Reticulatisporites* have a continuous equatorial murus such that no lumina are seen at the equator. Such a feature would serve to differentiate *Reticulatisporites* from *Dictyotriletes* and *Reticulitriletes*. In such case the differentiation between a cingulum and a continuous equatorial murus may be a semantical one.

Reticulatisporites danzei (Agrali) Mishell 1966 MS.

Plate 8, figures 25, 26.

1965 *Knoxisporites danzei* Agrali *in* Agrali *et al.*, p. 174, pl. 15, fig. 22.
1966 *Reticulatisporites danzei* (Agrali) Mishell, p. 290-291, pl. 10, fig. 5 (unpublished thesis).

Holotype. Agrali *et al.* (1965, pl. 15, fig. 22).

Diagnosis. See Agrali *et al.* (1965, p. 174).

Reticulatisporites polygonalis (Ibrahim) Loose emend. Smith & Butterworth 1967.

Plate 9, figure 2.

1932 *Sporonites polygonalis* Ibrahim *in* Potonié *et al.*, p. 447, pl. 14, fig. 8.
1934 *Reticulati-sporites polygonalis* (Ibrahim) Loose, p. 155, pl. 7, fig. 16.
1967 *Reticulatisporites polygonalis* (Ibrahim) Loose emend. Smith & Butterworth, p. 221, pl. 14, fig. 13.

Holotype. Potonié & Kremp (1955, pl. 16, fig. 318).

Diagnosis. See Smith & Butterworyth (1967, p. 221).

Remarks. For a more complete synonymy see Smith & Butterworth (1967, p. 221).

Reticulatisporites reticulatus (Ibrahim) Ibrahim 1933.

Plate 9, figure 1.

1932 *Sporonites reticulatus* Ibrahim *in* Potonié *et al.*, p. 447, pl. 14, fig. 3.
1933 *Reticulati-sporites reticulatus* (Ibrahim) Ibrahim, p. 33, pl. 1, fig. 3.

Holotype. Smith & Butterworth (1967, pl. 14, fig. 16).

Diagnosis. See Potonié & Kremp (1955, p. 112).

Rotaspora Schemel emend. Smith & Butterworth 1967.

Type species. *R. fracta* Schemel emend. Smith & Butterworth 1967.

Diagnosis. See Smith & Butterworth (1967, p. 226).

Rotaspora knoxii Butterworth & Williams 1958.

Plate 8, figure 22.

1958 *Rotaspora knoxi* Butterworth & Williams, p. 378, pl. 3, figs. 21-23.

Holotype. Smith & Butterworth (1967, pl. 15, fig. 15).

Diagnosis. See Butterworth & Williams (1958, p. 378).

Rotaspora? xenica Neville *in* Neves *et al.* 1973.

Plate 8, figure 23.

1973 *Rotaspora? xenica* Neville *in* Neves *et al.*, p. 38, pl. 1, figs. 26, 27.

Holotype. Neves *et al.* (1973, pl. 1, fig. 26).

Diagnosis. See Neves *et al.* (1973, p. 38).

Savitrisporites Bhardwaj 1955.

1958 *Callisporites* Butterworth and Williams, p. 376.

Type species. *S. triangulus* Bhardwaj 1955.

Diagnosis. See Bhardwaj (1955, p. 127).

Savitrisporites asperatus Sullivan 1964.

Plate 8, figure 17.

1964 *Savitrisporites asperatus* Sullivan, p. 374, pl. 60, figs. 6-8.

Holotype. Sullivan (1964, pl. 60, figs. 7, 8).

Diagnosis. See Sullivan (1964, p. 374).

Savitrisporites concavus Marshall & Smith 1965.

Plate 8, figure 18.

1965 *Savitrisporites concavus* Marshall & Smith, p. 661, pl. 99, figs. 9-12.
1971 *Callisporites concavus* (Marshall & Smith) Loboziak, p. 55, pl. 7, figs. 27-28.

Holotype. Marshall & Smith (1965, pl. 99, fig. 9).

Diagnosis. See Marshall & Smith (1965, p. 61).

Savitrisporites nux (Butterworth & Williams) Sullivan emend. Smith & Butterworth 1967.

Plate 8, figure 19.

1958 *Callisporites nux* Butterworth & Williams, p. 377, pl. 3, figs. 24, 25.
1964 *Savitrisporites nux* (Butterworth & Williams) Sullivan, p. 373, pl. 60, figs. 1-5.
1967 *Savitrisporites nux* (Butterworth & Williams) Sullivan emend. Smith & Butterworth, p. 23, pl. 15, figs. 1-3.

Lectotype. Smith & Butterworth (1967, pl. 15, figs. 1, 2).

Diagnosis. See Smith & Butterworth (1967, p. 224).

Savitrisporites semotus sp. nov.

Plate 8, figures 15, 16.

Diagnosis. Trilete, radial, acamerate, cingulate miospores. Amb broadly rounded triangular, interradial margins convex. Laesurae straight, simple, reaching to cingulum. Proximal and distal ornament of discrete, blunt or rounded baculae- and verrucae-like elements, 3μ to 8μ in diameter and 2μ to 6μ in height. Cingulum principally laevigate but with faintly developed ornamental elements at the equator giving an irregular outline to the spore. Size of miospores 42(53.1)60μ; 10 specimens.

Derivation of name. L. *semotus* - distinct, seperate; in reference to the discrete ornamental elements.

Type locality. Well 44/22-1, southern North Sea.

Type horizon. Coal in core at 11422'; middle Duckmantian.

Holotype. Plate 8, figure 16.

Comparison. Differentiated from other species of *Savitrisporites* by the isolated nature of the distal ornamental elements which do not coalesce at their bases and are not arranged into more-or-less parallel bands. *Dictyotriletes camptotus* Alpern 1960 has a cingulum and a regular distal reticulum formed by anastomosing verrucate ornament. This species should probably be transferred to the genus *Bascaudaspora* Owens 1983.

Stenozonotriletes Naumova *ex* Ischenko emend. Potonié 1958.

Type species. *S. conformis* Naumova 1953.

Diagnosis. See Potonié (1958, p. 25).

Stenozonotriletes coronatus Sullivan & Marshall 1966.

Plate 8, figure 24.

1966 *Stenozonotriletes coronatus* Sullivan & Marshall, p. 273, pl. 3, figs. 1-5.

Holotype. Sullivan & Marshall (1966, pl. 3, fig. 2).

Diagnosis. See Sullivan & Marshall (1966, p. 273).

Stenozonotriletes lycosporoides (Butterworth & Williams) Smith & Butterworth 1967.

Plate 9, figure 8.

1958 *Anulatisporites lycosporoides* Butterworth & Williams, p. 378, pl. 3, figs. 28, 29.

1967 *Stenozonotriletes lycosporoides* (Butterworth & Williams) Smith & Butterworth, p. 218, pl. 14, figs. 5, 6.

Holotype. Butterworth & Williams 1958 (pl. 3, fig. 28).

Diagnosis. See Butterworth & Williams (1958, p. 378).

Stenozonotriletes perforatus Playford 1962.

Plate 9, figure 4.

1962 *Stenozonotriletes perforatus* Playford, p. 607, pl. 86, figs. 8, 9, text-fig. 5e.

Holotype. Playford (1962, pl. 86, fig. 8).

Diagnosis. See Playford (1962, p. 607).

Infraturma PSEUDOCINGULATI Neves 1961.

Secarisporites Neves 1961.

Type species. *S. lobatus* Neves 1961.
Diagnosis. See Neves (1961, p. 260).

Secarisporites remotus Neves 1961.

Plate 9, figures 3, 7.

1961 *Secarisporites remotus* Neves, p. 262, pl. 32, figs. 8, 9.

Holotype. Neves (1961, pl. 32, fig. 9).
Diagnosis. See Neves (1961, p. 262).

Secarisporites cf. *remotus*

Plate 9, figure 6.

Remarks. Specimens are similar in size to those of the type but do not have the isolated lobate elements, the 'pseudocingulum' being usually well developed and rarely disrupted by invaginations.

Infraturma PATINATI Butterworth & Williams emend. Smith & Butterworth 1967.

Archaeozonotriletes Naumova emend. Allen 1965.

Type species. *A. variabilis* Naumova emend Allen 1965.
Diagnosis. See Allen (1965, p. 721).

Archaeozonotriletes variabilis Naumova emend. Allen 1965.

Plate 9, figure 5.

1953 *Archaeozonotriletes variabilis* Naumova, p. 30, pl. 2, figs. 12, 13, pl. 12, figs 8-11.
1965 *Archaeozonotriletes variabilis* Naumova emend. Allen, p. 721-722, pl. 100, fig3. 3-6.

Holotype. Naumova (1953, pl. 2, fig. 12).
Diagnosis. See Allen (1965, p. 721).

Infraturma ZONATI Potonié & Kremp 1954.

Fragilipollenites Konyali *ex* Konyali emend. Lentin 1971 MS.

Type species. *F. radiatus* Konyali *ex* Konyali emend. Lentin 1971 MS.
Diagnosis. See Lentin (1971, p. 221).

Fragilipollenites radiatus Konyali *ex* Konyali emend. Lentin 1971 MS.
Plate 9, figure 13.

1963 *Fragilipollenites radiatus* Konyali, p. 63, pl. 11, fig. 3 (unpublished thesis).
1965 *Fragilipollenites radiatus* Konyali *ex* Konyali *in* Agrali *et al.*, p. 180, pl. 16, fig. 24.
1971 *Fragilipollenites radiatus* Konyali *ex* Konyali emend. Lentin, p. 222, pl. 12, fig. 6 (unpublished thesis).

Holotype. Agrali *et al.* (1965, pl. 16, fig. 24).
Diagnosis. See Lentin (1971, p. 222).

Kraeuselisporites Leschik emend. Scheuring 1974.

Type species. *K. dentatus* Leschik emend. Scheuring 1974.
Diagnosis. See Scheuring (1974, p. 199).

Kraeuselisporites? crassus sp. nov.
Plate 9, figures 9, 10, 11.

Diagnosis. Radial, trilete, acamerate, zonate and cingulate miospores. Outline convexely rounded triangular. Laesurae straight, accompanied by well developed labra, c.2.5μ wide, reaching to inner margin of cingulum. Cingulum well developed, 5μ to 10μ wide, usually of uniform thickness, but may taper towards the equator. Zona variably developed on different specimens, up to 10μ wide, occasionally virtually absent. Proximal exine punctate. Distal ornament of coni and galae, 1μ to 2.5μ wide and 1μ to 2μ high; spinose tops to galae very thin and slender, less than 0.5μ wide and c.1μ high, often broken off; distal ornament evenly distributed on cingulum and inner area of spore, but rare or absent on zona. Size of miospores 50(69.7)75μ; 20 specimens.
Derivation of name. L. *crassus* - thickening; with reference to the prominent sub-equatorial crassitude.
Type locality. Well 44/22-3; southern North Sea.
Type horizon. Mudstones in sidewall core at 11558'; middle Duckmantian.
Holotype. Plate 9, figures 9, 10.

Comparison. Published species of *Kraeuselisporites* do not have a well developed cingulum. *Kraeuselisporites pseudoornatus* sp. nov. has a distal ornament of long spinae.

Remarks. The taxonomic placement of this species is questionable as the presence of a cingulum is not usual within the genus *Kraeuselisporites.*

Kraeuselisporites echinatus Owens *et al.* 1966.

Plate 9, figure 15.

1966 *Kraeuselisporites echinatus* Owens *et al.*, p. 148-153, pl. 1, figs. 1-6, pl. 2, fig. 1, text-fig. 1.

Holotype. Owens *et al.* (1966, pl. 1, fig. 2).

Diagnosis. See Owens *et al.* (1966, p. 150-152).

Kraeuselisporites ornatus (Neves) Owens *et al.* 1966.

Plate 9, figure 16.

1961 *Cirratriradites ornatus* Neves, p. 269, pl. 33, fig. 3.
1966 *Kraeuselisporites ornatus* (Neves) Owens *et al.*, p. 153-154, pl. 2, figs. 2-4.

Holotype. Neves (1961, pl. 33, fig. 3).

Diagnosis. See Owens *et al.* (1966, p. 153-154).

Kraeuselisporites? pseudoornatus sp. nov.

Plate 9, figures 12, 14.

Diagnosis. Radial, trilete, acamerate, zonate and cingulate miospores. Outline convexely rounded triangular. Laesurae straight, accompanied by well developed labra, c.2.5μ wide, reaching to inner margin of cingulum. Cingulum well developed, 10μ to 18μ wide, usually of uniform thickness, but may taper towards the equator. Zona variably developed on different specimens, up to 15μ wide. Exine laevigate or punctate. Distal ornament of prominent, tapering spinae, 1μ to 2.5μ wide at their bases and 5μ to 16μ long; most strongly developed on the cingulum and zone. Size of miospores 50(69.7)75μ; 20 specimens.

Derivation of name. The name refers to the superficial resemblence of this species to *Kraeuselisporites ornatus* (Neves) Owens *et al.* 1966.

Type locality. Well 44/22-4; southern North Sea.

Type horizon. Siltstones in core at 12155'; early Duckmantian.

Holotype. Plate 9, figure 14.

Comparison. Published species of *Kraeuselisporites* do not have a well developed cingulum. *Kraeuselisporites crassus* sp. nov. has a distal ornament of coni and galae.

Remarks. The taxonomic placement of this species is questionable as the presence of a cingulum is not usual within the genus *Kraeuselisporites.*

Suprasubturma CAMERATITRILETTES Neves & Owens 1966.

Subturma SOLUTITRILETES Neves & Owens 1966.

Infraturma PLANATI Neves & Owens 1966.

Auroraspora Hoffmeister *et al* emend. Richardson 1960.

Type species. *A. solisortus* Hoffmeister *et al.* 1955.

Diagnosis. See Richardson (1960, p. 49).

Auroraspora? pickerillensis sp. nov.

Plate 10, figure 5, 6.

Diagnosis. Radial, trilete, camerate miospores. Amb subcircular to oval. Trilete rays slightly flexuous, accompanied by narrow tapering labra, c.1μ wide, reaching to equator. Intexine circular to sucircular, laevigate, two thirds to three quarters of spore diameter. Intexine and exoexine attatched only in the region of the trilete rays. Exoexine thin, membranous, frequently folded; densely punctate giving an appearence of infrareticulation or granulation. No curvaturae developed. Size of miospores 59(69.8)82μ

Derivation of name. Named after the Pickerill Field in which the species was first recognised by McLean & Neves (1993)a.

Type locality. Well 44/22-1, southern North Sea.

Type horizon. Mudstones in core at 11878'; early Duckmantian.

Holotype. Plate 10, figure 5.

Comparison. *A? pseudogranulata* is larger and has a smaller intexine. Other species of *Auroraspora* do not have the distinctive punctate exoexine.

Remarks. The species is only questionably assigned to the genus *Auroraspora* as the distinctive, intense granular appearence of the exoexine is uncharacteristic of the genus. For further comments see under *A? pseudoreticulata.*

Auroraspora? pseudogranulata. (Neves) emend.

Plate 10, figures 1, 2.

1959 *Auroraspora pseudogranulata* Neves, p. 158, pl. 21, fig. 8 (unpublished thesis).

Holotype. Neves (1959, pl. 21, fig. 8).

Emended Diagnosis. Trilete, camerate miospores with a circular to rounded triangular equatorial outline. Trilete rays straight, simple, up to three quarters spore radius, labra, if present, up to 1μ wide. Intexine circular to sucircular, laevigate, one half to one quarter spore diameter. Intexine and exoexine attatched only in the region of the trilete rays. Exoexine thin, membranous, frequently folded; densely infrapunctate giving an appearence of infrareticulation or granulation. No curvaturae developed.

Remarks. The above is an expansion of the diagnosis given by Neves (1959) in his doctoral thesis.

Remarks. The species is only questionably assigned to the genus *Auroraspora* as the distinctive, intense granular appearence of the exoexine is uncharacteristic of the genus. The genus *Playfordiaspora* Maheshwari & Banerji 1975 may accommodate this species (Graeham Dolby, pers. comm.). However, Maheshwari & Banerji (1975, p. 158) indicate that *Playfordiaspora* only appears monosaccate but actually has an equatorial flange-like development (i.e. a zona). However, the type species of the genus (*P. cancellosa* (Playford & Dettmann) Maheshwari & Banerji 1975) was originally placed in the genus *Guthoerlisporites* Bhardwaj 1954 by Playford & Dettmann (1965, p. 147) which is reserved for circular monosaccate species. Examination of the original illustrations of the holotype of *P. cancellosa* (Playford & Dettmann (1965, pl. 14, fig. 4)) indicates that the species is probably camerate, rather than saccate or zonate. Playford & Dettman's (1965) interpretation as saccate is possibly due to the presence of intense infrapunctation, appearing as infrareticulation, in the type material. If this proves to be the case, and *Playfordiaspora* is camerate rather than zonate, then emendation of the genus to this effect would provide a suitable generic repository for *A? pseudogranulata* and *A? pickerillensis.*

Auroraspora solisortus Hoffmeister *et al.* 1955.

Plate 10, figure 7.

1955 *Auroraspora solisortus* Hoffmeister *et al.*, p. 381, pl. 37, fig. 3.

Holotype. Hoffmeister *et al.* (1955, pl. 37, fig. 3).

Diagnosis. See Hoffmeister *et al.* (1955, p. 381).

Auroraspora velata (Felix & Burbridge) Ravn 1991.

Plate 10, figures 3, 4.

1967 *Cystoptychus velatus* Felix & Burbridge, p. 413, pl. 63, fig. 5.
1991 *Auroraspora velata* (Felix & Burbridge) Ravn, p. 23, pl. 28, figs. 14-16.

Holotype. Felix & Burbridge (1967, pl. 63, fig. 5).

Diagnosis. See Felix & Burbridge (1967, p. 413).

Endosporites Wilson and Coe 1940.

Type species. *E. globiformis* (Ibrahim) Schopf *et al.* 1944 (= *E. ornatus* Wilson and Coe 1940).
Diagnosis. See Wilson & Coe (1940, p. 184).

Endosporites conarus Mishell 1966 MS.

Plate 10, figures 11, 12.

1966 *Endosporites conarus* Mishell, p. 319, pl. 13, figs. 3, 4 (unpublished thesis).

Holotype. Mishell (1966, pl. 13, fig. 3).
Diagnosis. See Mishell (1966, p. 319).
Remarks. The species remains ineffectively published.

Endosporites globiformis (Ibrahim) Schopf *et al.* 1944.

Plate 10, figure 9.

1932 *Sporonites globiformis* Ibrahim *in* Potonié *et al.*, p. 447, pl. 14, fig. 5.
1944 *Endosporites globiformis* (Ibrahim) Schopf *et al.*, p. 45.

Holotype. Potonié & Kremp (1956, pl. 20, fig. 459).
Diagnosis. See Potonié & Kremp (1956, p. 161).
Remarks. For a more complete synonymy see Ravn (1986, p. 77).

Endosporites pygmaeus sp. nov.

Plate 10, figure 8.

Diagnosis. Radial, trilete, camerate mispores. Amb subcircular to convexely rounded triangular. Laesurae straight or flexuous, accompanied by tapering labra, 1μ to 2μ high, terminating in curvaturae perfectae which forms an equatorial limbus. Intexine two thirds to three quarters of spore diameter, laevigate. Exoexine infrapunctate and may be finely granulate. Proximal surface over intexine usually laevigate but may be punctate or faintly granulate. Size of miospores 32(36)42μ; fifteen specimens.
Derivation of name. L. *pygmaeus* - pygmy; in reference to the small size of the species.
Type locality. Well 44/22-1, southern North Sea.
Type horizon. Mudstones in core at 11414.9'; early Duckmantian.
Holotype. Plate 10, figure 8.
Comparison. *Endosporites minutus* Hoffmeister *et al.* 1955 is larger in diameter (greater than 40μ) and has a relatively larger intexine (25-30μ, i.e. two thirds of the exoexine diameter).

Endosporites zonalis (Loose) Knox 1950.

Plate 10, figure 10.

1934 *Zonales-sporites zonalis* Loose, p. 148, pl. 7, fig. 5.
1950 *Endosporites zonalis* (Loose) Knox, p. 332.

Holotype. Potonié & Kremp (1956, pl. 20, fig. 455).

Diagnosis. See Potonié & Kremp (1956, p. 163).

Remarks. For a more complete synonymy see Ravn (1986, p. 77).

Spencerisporites Chaloner 1951.

Type species. *S. radiatus* (Ibrahim) Felix and Parks 1959.

Diagnosis. See Chaloner (1951, p. 861).

Spencerisporites radiatus (Ibrahim) Felix & Parks 1959.

Plate 12, figure 1.

1932 *Sporonites radiatus* Ibrahim *in* Potonié *et al.*, p. 449, pl. 16, fig. 25.
1934 *Triletes karczewskii* Zerndt, p. 27, pl. 31, fig. 3.
1951 *Spencerisporites karczewskii* (Zerndt) Chaloner, p. 862, text-figs. 1, 2, 6, 7.
1959 *Spencerisporites radiatus* (Ibrahim) Chaloner; Felix & Parks, p. 362, pl. 1, figs. 1-4, pl. 2, figs. 1-4.

Holotype. Potonié & Kremp (1955, pl. 20, fig. 400).

Diagnosis. See Chaloner (1951, p. 862, for *S. karczewskii*).

Remarks. For a more complete synonymy see Ravn (1986, p. 76).

Infraturma DECORATI Neves & Owens 1966.

Grandispora Hoffmeister *et al.* emend Neves & Owens 1966.

Type species. *G. spinosa* Hoffmeister *et al.* 1955

Diagnosis. See Neves & Owens (1966, p. 346).

Grandispora spinosa Hoffmeister *et al.* 1955.

Plate 10, figure 15.

1955 *Grandispora spinosa* Hoffmeister *et al.*, p. 388, pl. 39, figs. 10, 14.

Holotype. Hoffmeister *et al.* (1955, pl. 39, fig. 10).

Diagnosis. See Hoffmeister *et al.* (1955, p. 388).

Grumosisporites Smith & Butterworth 1967.

Type species. *G. verrucosus* (Butterworth and Williams) Smith & Butterworth 1967.

Diagnosis. See Smith & Butterworth (1967, p. 228).

Grumosisporites papillosus (Ibrahim) emend Smith & Butterworth 1967.

Plate 10, figure 13.

1933 *Verrucosi-sporites papillosus* Ibrahim, p. 25, pl. 5, fig. 44.
1967 *Grumosisporites papillosus* (Ibrahim) emend. Smith & Butterworth, p. 230, pl. 16, figs. 9-13.

Holotype. Potonié & Kremp (1955, pl. 13. fig. 206).

Diagnosis. Smith & Butterworth (1967, p. 230).

Grumosisporites varioreticulatus (Neves) emend. Smith & Butterworth 1967.

Plate 10, figure 14.

1958 *Dictyotriletees varioreticulatus* Neves, p. 8, pl. 2, figs. 1a, b.
1967 *Grumosisporites varioreticulatus* (Neves) emend. Smith & Butterworth, p. 232, pl. 17, figs. 8-10.

Holotype. Neves (1958, pl. 2, figs. 1a, b).

Diagnosis. See Smith & Butterworth (1967, p. 232).

Rugospora Neves & Owens 1966.

Type species. *R. corporata* Neves & Owens 1966.

Diagnosis. See Neves & Owens (1966, p. 350).

Rugospora corporata Neves & Owens 1966.

Plate 11, figure 12.

1966 *Rugospora corporata* Neves & Owens, p. 353, pl. 2, figs. 4-5, text-fig. 2.

Holotype. Neves & Owens (1966, pl. 2, fig. 4).

Diagnosis. See Neves & Owens (1966, p. 353).

Spelaeotriletes Neves & Owens 1966.

Type species. *S. triangulus* Neves & Owens 1966.
Diagnosis. See Neves & Owens (1966, p. 342-344).

Spelaeotriletes arenaceus Neves & Owens 1966.

Plate 11, figure 3.

1966 *Spelaeotriletes arenaceus* Neves & Owens, p. 345, pl. 2, figs. 1-3.

Holotype. Neves & Owens (1966, pl. 1, fig. 1).
Diagnosis. See Neves & Owens (1966, p. 345).

Spelaeotriletes bulboides sp. nov.

Plate 11, figures 8, 9.

Diagnosis. Radial, trilete, camerate miospores. Amb circular. Laesure straight or slightly flexuous, accompanied by weakly developed labra less than 1μ high, reaching to equator and developing into curvaturae perfectae. Intexine thin but distinct, laevigate, three quarters of spore diameter. Exoexine equatorially developed into a narrow zona 2μ to 3.5μ wide. Proximal exoexine punctate or faintly granulate. Distal ornament of densely set, faint grana, less than 0.5μ in diameter, with scattered spinae-coni, 0.5μ in diameter and 1μ to 2μ high. Size of miospores 61(66.5)69μ; 20 specimens.

Derivation of name. L. *bulbus* - onion, with reference to the appearence of the spore as having several concentrically arranged layers.

Type locality. Well 44/22-1; southern North Sea.

Type horizon. Mudstones in core at 11878'; early Duckmantian.

Holotype. Plate 11, figure 8.

Comparison. The presence of the equatorial zona differentiates this species from others of the genus.

Remarks. The presence of the narrow zona and the equatorial curvaturae may give the appearence of extra exinal layers.

Spelaeotriletes oppletus sp. nov.

Plate 11, figure 4.

Diagnosis. Radial, trilete, camerate miospores. Amb concavely rounded triangular. Laesurae straight or flexuous, accompanied by distinct labra 2μ to 4μ high, extending to equatorial margin where they develop into a distinct curvatural ridge (limbus). Intexine laevigate, more than three quarters of spore diameter. Exoexine with proximal and distal ornament of subcircular verrucae, 0.5μ to 1.5μ in diameter, usually 1μ apart or closer. Size of miospores 71(78.4)82μ; 20 specimens.

Derivation of name. L. *oppleo* - to fill up, with reference to the relatively large size of the intexine which almost fills the camera.

Type locality. 44/22-3, southern North Sea.

Type horizon. Mudstones in core at 11872'; early Duckmantian.

Holotype. Plate 11, figure 4.

Comparison. *S. asperatus* Ravn 1991 is smaller and has a less prominent intexine and less strongly developed labra. *S. crustatus* Higgs 1975 has an ornament of grana and subordinate coni and spinae. Other Carboniferous species of *Spelaeotriletes* have a relatively smaller intexine in relation to the size of the exoexine.

Spelaeotriletes cf. *oppletus.*

Plate 11, figures 5, 6.

Remarks. Specimens assigned to this taxon are similar to the type but have large, up to 3μ high, verrucae-baculae developed on the curvaturae and projecting beyond the equatorial margin.

Spelaeotriletes pretiosus (Playford) Neves & Belt 1970.

1964 *Pustulatisporites pretiosus* Playford, p. 19-20, pl. 4, figs. 5-7, pl. 5, fig. 1, text-fig. 1a.
1970 *Spelaeotriletes pretiosus* (Playford) Neves & Belt, p. 1241.

Holotype. Playford (1964, pl. 4, fig. 6).

Diagnosis. See Playford (1964, p. 19-20).

Spelaeotriletes cf. *pretiosus.*

Plate 11, figures 7, 10.

Remarks. Present specimens are smaller (55(62)67μ) than the type and bear a relatively denser ornament of verrucae 3μ to 6μ across.

Subturma MEMBRANATITRILETES Neves & Owens 1966.
Infraturma CONTINUATI Neves & Owens 1966.

Discernisporites Neves emend. Neves & Owens 1966.

Type species. *D. irregularis* Neves 1958.
Diagnosis. See Neves & Owens (1966, p. 357).

Discernisporites irregularis Neves 1958.

1958 *Discernisporites irregularis* Neves, p. 4, pl. 3, fig. 5.

Holotype. Neves (1958, pl. 3, fig. 5).
Diagnosis. See Neves (1958, p. 4).
Remarks. Upon recognition that *Discernisporites* is camerate Neves & Owens (1966) emended the generic circumscription. In so doing they presented a *de facto* emendation of the type species, *D. irregularis.* The diagnosis of the type species should, then, be read in the light of the generic emendation of Neves & Owens (1966), such that it is taken to indicate camerate miospores.

Discernisporites cf. *irregularis.*

Plate 11, figures 13-16.

Remarks. Specimens in the current study have a slightly reduced size range (47(63.5)82μ; 28 specimens) compared to that of 50-100μm quoted by Neves (1958). A plexus of forms is present in this material in which the proximal ornamental elements anastomose to varying degrees, plus the variable development of coni on and around the main rugulate/cristate elements (e.g. Plate 11, figure 13). In many specimens rugae or cristae are developed into a more or less well defined reticulum (Plate 11, figures 14-16). In some instances coni develop at the junctions of the cristae/rugae which form the reticulum (Plate 11, figures 14, 16). Furthermore, the inter-elemental exoexine may be ornamented with grana (Plate 11, figure 15)

This plexus of forms could be included in an emended *D. irregularis.* However, this would expand the concept of the species well beyond what is believed to be its original intention, and so this has been avoided.

Discernisporites micromanifestus (Hacquebard) Sabry & Neves 1971.

Plate 11, figures 11, 12.

1957 *Endosporites micromanifestus* Hacquebard, p. 317, pl. 3, fig. 16.
1971 *Discernisporites micromanifestus* (Hacquebard) Sabry & Neves, p. 1445, pl. 3, fig. 11.

Holotype. Hacquebard (1957, pl. 3, fig. 16).
Diagnosis. See Hacquebard (1957, p. 317).

Ibrahimispores Artüz emend. Artüz 1971.

Type species. *I. microhorridus* Artüz 1957.

Diagnosis. See Artüz (1971, p. 111).

Remarks. The suprageneric placement of *Ibrahimispores* is problematical as the nature of the attatchment of the intexine and exoexine is uncertain. The genus appears to be closely related to *Spinozonotriletes* Hacquebard emend. Neves & Owens 1966 as specimens of intermediate form may be found. For this reason the genus has been placed with *Spinozonotriletes* in the infraturma CONTINUATI.

Ibrahimispores brevispinosus Neves 1961

Plate 12, figure 5.

1961 *Ibrahimnispores brevispinosus* Neves, p. 254-255, pl. 31, fig. 2.

Holotype. Neves (1961, pl. 31, fig. 2).

Diagnosis. See Neves (1961, p. 255).

Ibrahimispores microhorridus Artüz 1957.

Plate 12, figure 4.

1957 *Ibrahimispores microhorridus* Artüz, p. 246, pl. 3, fig. 21a,b.

Holotype. Artüz (1957, pl. 3, fig. 21a,b).

Diagnosis. See Artüz (1957, p. 246).

Spinozonotriletes Hacquebard emend. Neves & Owens 1966.

Type species. *S. uncatus* Hacquebard 1957.

Diagnosis. See Neves & Owens (1966, p. 355).

Spinozonotriletes uncatus Hacquebard 1957.

Plate 12, figure 2.

1957 *Spinozonotriletes uncatus* Hacquebard, p. 316, pl. 3, figs. 8-10.

Holotype. Hacquebard (1957, pl. 3, fig. 8).

Diagnosis. See Hacquebard (1957, p. 316).

Spinozonotriletes cf. *uncatus.*

Plate 12, figure 3.

Remarks. Specimens assigned to this taxon are smaller than the type material having an overall diameter (inclusive of ornament) of 70(83.8)85μ; 15 specimens. In some specimens the tips of the spinae may be thickened or solid, suggesting that these may represent a morphographically intermediate form between the genera *Spinozonotriletes* and *Ibrahimispores* Artüz emend Artüz 1971.

Infraturma CINGULICAMERATI Neves & Owens 1966.

Cingulizonates Dybová & Jachowicz emend. Butterworth *et al.* 1964.

Type species. C. *Bialatus* (Waltz) Smith and Butterworth 1967. (= C. *tuberosus* Dybová and Jachowicz 1957).
Diagnosis. See Butterworth *et al.* (1957, p. 105).

Cingulizonates bialatus (Waltz) Smith & Butterworth 1967.

Plate 13, figure 3.

1938 *Zonotriletes bialatus* Waltz, *in* Luber & Waltz, p. 22, pl. 4, fig. 51.
1956 *Densosporites bialatus* (Waltz) Potonié & Kremp, p. 144.
1967 *Cingulizonates bialatus* (Waltz) Smith & Butterworth, p. 260, pl. 21, figs. 3,4.

Holotype. Not designated.
Diagnosis. See Luber & Waltz (1938, p. 22).
Remarks. For a more complete synonymy see Smith & Butterworth (1967, p. 260).

Cingulizonates loricatus (Loose) Butterworth & Smith *in* Butterworth *et al.* 1964.

Plate 13, figure 4.

1932 *Sporonites loricatus* Loose *in* Potonié *et al.*, p. 450, pl. 18, fig. 42.
1964 *Cingulizonates loricatus* (Loose) Butterworth & Smith *in* Butterworth *et al.*, p. 1053, pl. 2, fig. 4.

Holotype. Potonié & Kremp (1956, pl. 18, fig. 400).
Diagnosis. See Potonié & Kremp (1956, p. 119).
Remarks. For a more complete synonymy see Butterworth *et al.*(1964, p. 1053).

Cirratriradites Wilson & Coe 1940.

Type species. C. *maculatus* Wilson and Coe 1940.
Diagnosis. Wilson & Coe (1940, p. 183).
Remarks. Potonié & Kremp (1954) consider C. *maculatus* Wilson & Coe 1940 to be a junior synonym of C. *saturni* (Ibrahim) Schopf *et al.* 1944. However Wilson (1966) maintains the difference between C. *maculatus* and C. *saturni*.

Cirratriradites rarus (Ibrahim) Schopf *et al.* 1944.

Plate 12, figure 6.

1933 *Zonales-sporites rarus* Ibrahim, p. 29, pl. 6, fig. 35.
1944 *Cirratriradites rarus* (Ibrahim) Schopf *et al.* p. 44.

Holotype. Ibrahim (1933, pl. 6, fig. 53).

Diagnosis. See Ibrahim (1933, p. 29).

Cirratriradites saturni (Ibrahim) Schopf *et al.* 1944.

Plate 12, figure 7.

1932 *Sporonites saturni* Ibrahim *in* Potonié *et al.*, p. 448, pl. 15, fig. 14.
1944 *Cirratriradites saturni* (Ibrahim) Schopf *et al.*, p. 44.

Holotype. Potonié *et al.* (1932, pl. 15, fig. 14).

Diagnosis. See Potonié & Kremp (1956, p. 128).

Remarks. For a more complete synonymy see Ravn (1986, p. 74).

Crassispora Bhardwaj emend. Sullivan 1964.

Type species. *C. kosankei* (Potonié & Kremp) Bhardwaj 1957 emend. Smith & Butterworth 1967 (= *C. ovalis* (Bhardwaj) Bhardwaj 1957).

Diagnosis. See Sullivan (1964, p. 375).

Crassispora kosankei (Potonié & Kremp) Bhardwaj emend. Smith & Butterworth 1967.

Plate 12, figure 8.

1955 *Planisporites kosankei* Potonié & Kremp, p. 71, pl. 13, figs. 208-213.
1967 *Crassispora kosankei* (Potonié & Kremp) Bhardwaj emend. Smith & Butterworth, p. 234, pl. 19, figs. 2-4.

Holotype. Potonié & Kremp (1955, pl. 13, fig. 208).

Diagnosis. See Smith & Butterworth (1967, p. 234).

Cristatisporites Potonié & Kremp emend. Butterworth *et al.* 1964.

Type species. *C. indignabundus* (Loose) Staplin & Jansonius 1964.

Diagnosis. Butterworth *et al.* (1964, p. 108).

Cristatisporites connexus Potonié & Kremp 1955.

Plate 13, figure 9.

1955 *Cristatisporites connexus* Potonié & Kremp, p. 106, pl. 16, fig. 291.

Holotype. Potonié & Kremp (1955, pl. 16, fig. 291).

Diagnosis. Potonié & Kremp (1955, p. 106).

Cristatisporites indignabundus (Loose) Potonié & Kremp emend Staplin & Jansonius 1964.

Plate 13, figure 13.

1932 *Sporonites indignabundus* Loose *in* Potonié *et al.*, p. 451, pl. 19, fig. 51.
1954 *Cristatisporites indignabundus* (Loose) Potonié & Kremp, p. 142.
1964 *Cristatisporites indignabundus* (Loose) Potonié & Kremp emend. Staplin & Jansonius, p. 108-109. pl. 19, figs. 7-9, 12, 14, 20, text-fig. 2c.

Holotype. Potonié & Kremp (1955, pl. 16, fig. 294).

Diagnosis. See Staplin & Jansonius (1964, p. 108).

Cristatisporites splendidus Artüz 1957.

Plate 13, figures 10, 14.

1957 *Cristatisporites splendidus* Artüz, p. 247, pl. 4, fig 22.

Holotype. Artüz (1957, pl. 4, fig. 22).

Diagnosis. See Artüz (1957, p. 247).

Densosporites Berry emend. Butterworth *et al.* 1964.

Type species. *D. covensis* Berry 1937.

Diagnosis. See Butterworth *et al.* (1964, p. 101).

Densosporites anulatus (Loose) Schopf *et al.* 1944.

Plate 12, figure 13.

1932 *Sporonites anulatus* Loose *in* Potonié *et al.*, p. 451, pl. 18, fig. 44.
1934 *Zonales-sporites annulatus* (Loose) Loose, p. 151.
1944 *Denso-sporites annulatus* (Loose) Schopf *et al.*, p. 40.
1967 *Densosporites anulatus* (Loose) Smith & Butterworth, p. 239, pl. 19, figs. 5,6.

Holotype. Potonié & Kremp (1956, pl. 17, fig. 365).

Diagnosis. See Potonié & Kremp (1956, p. 112).

Remarks. Schopf *et al.* (1944) proposed *D. annulatus* as a new combination prior to Smith & Butterworth (1967). The spelling of the specific epithet is discussed by Ravn (1986, p. 69). The original spelling is followed here although the orthographic correction by Loose (1934, p. 151) may be correct.

Densosporites crassigranifer Artüz 1957.

Plate 12, figures 12, 17.

1957 Densosporites crassigranifer Artüz, p. 251, pl. 5, fig. 38.

Holotype. Artüz (1957, pl. 5, fig. 38).

Diagnosis. See Artüz (1957, p. 251).

Densosporites duriti Potonié & Kremp 1956.

Plate 12, figure 10.

1956 *Densosporites duriti* Potonié & Kremp, p. 117, pl. 18, figs. 383-384.

Holotype. Potonié & Kremp (1956, pl. 18, fig. 383).

Diagnosis. See Potonié & Kremp (1956, p. 117).

Densosporites gracilis Smith & Butterworth 1967.

Plate 12, figure 16.

1967 *Densosporites gracilis* Smith & Butterworth, p. 240, pl. 19, figs. 7,8.

Holotype. Smith & Butterworth (1967, pl. 19, fig. 7).

Diagnosis. See Smith & Butterworth (1967, p. 240).

Densosporites pseudoannulatus Butterworth & Williams 1958.

Plate 12, figure 14.

1958 *Densosporites pseudoannulatus* Butterworth & Williams, p. 379, pl. 3, fig. 42.

Holotype. Butterworth & Williams (1958, pl. 3, fig. 42).

Diagnosis. See Butterworth & Williams (1958, p. 379).

Densosporites sphaerotriangularis Kosanke 1950.

Plate 12, figure 11.

1950 *Denso-sporites sphaerotriangularis* Kosanke, p. 33, pl.6, fig. 7.

Holotype. Kosanke (1950, pl. 6, fig. 7).

Diagnosis. See Kosanke (1950, p. 33).

Densosporites spinosus Dybová & Jachowicz 1957.

Plate 13, figures 1, 2.

1957 *Densosporites spinosus* Dybová & Jachowicz, p. 164, pl. 49, figs. 1-4.

Holotype. Dybová & Jachowicz (1957, pl. 49, fig. 1).

Diagnosis. See Dybová & Jachowicz (1957, p. 164).

Densosporites tenuis Hoffmeister *et al.* 1955

Plate 12, figure 15.

1955 *Densosporites tenuis* Hoffmeister *et al.*, p. 387, pl. 36, figs. 18, 19, 23.
1958 *Densosporites intermedius* Butterworth & Williams, p. 379, pl. 3, figs. 38, 39.
non1956 *Densosporites tenuis* (Loose) Potonié & Kremp, p. 120, pl. 18, figs. 404-407.

Holotype. Hoffmeister *et al.* (1955, pl. 36, fig. 18).

Diagnosis. See Hoffmeister *et al.* (1955, p. 387).

Remarks. Smith & Butterworth (1967, p. 241) present the case for the priority of *D. tenuis* over *D. intermedius*.

Hymenozonotriletes Naumova *ex* Mehta emend. Potonié 1958.

Type species. *H. polycanthus* Naumova 1953.

Diagnosis. See Potonié (1958, p. 29).

Hymenozonotriletes explanatus (Luber) Kedo 1963.

Plate 12, figure 9.

1941 *Zonotriletes explanatus* Luber *in* Luber & Waltz, p. 10, pl. 1, fig. 4.
1963 *Hymenozonotriletes explanatus* (Luber) Kedo, p. 67, pl. 6, figs. 144-147.

Holotype. Luber & Waltz (1941, pl. 1, fig. 4).

Diagnosis. See Kedo (1963, p. 67).

Remarks. The single specimen recorded and figured is questionably assigned to *H. explanatus*.

Lycospora Schopf *et al.* emend. Somers 1972.

Type species. *L. micropapillata* (Wilson and Coe) Schopf *et al.* 1944.

Diagnosis. See Somers (1972, p. 54).

Lycospora noctuina Butterworth & Williams emend. Smith & Butterworth 1967.

Plate 13, figure 5.

1958 *Lycospora noctuina* Butterworth & Williams, p. 376, pl. 3, figs. 14, 15.

Holotype. Smith & Butterworth (1967, pl. 20, fig. 4).

Diagnosis. See Smith & Butterworth (1967, p. 248).

Remarks. Smith & Butterworth (1967) provided an expanded diagnosis based upon that of Butterworth & Williams (1958) which represents a *de facto* emendation of the species.

Lycospora orbicula (Potonié & Kremp) Smith & Butterworth 1967.

Plate 13, figure 6.

1955 *Cyclogranisporites orbiculus* Potonié & Kremp, p. 63, pl. 13, figs. 179-183.
1967 *Lycospora orbicula* (potonié & Kremp) Smith & Butterworth, p. 249-250, pl. 20, figs 179-183.

Holotype. Potonié & Kremp (1955, pl. 13, fig. 179).

Diagnosis. See Smith & Butterworth (1967, p. 249).

Lycospora pusilla (Ibrahim) Schopf *et al.* 1944

Plate 13, figure 7.

1932 *Sporonites pusillus* Ibrahim *in* Potonié *et al.*, p. 448, pl. 15, fig. 19.
1944 *Lycospora pusilla* (Ibrahim) Schopf *et al.*, p. 54.

Holotype. Potonié & Kremp (1956, pl. 17, fig. 352).

Diagnosis. See Potonié & Kremp (1955, p. 103).

Lycospora rotunda Bhardwaj 1957.

Plate 13, figure 8.

1957 *Lycospora rotunda* Bhardwaj, p. 103, pl. 27, figs. 10-12.

Holotype. Bhardwaj (1957, pl. 27, fig. 10).

Diagnosis. See Bhardwaj (1957, p. 103).

Radiizonates Staplin & Jansonius 1964.

Type species. *R. aligerens* (Knox) Staplin & Jansonius 1964.

Diagnosis. See Staplin & Jansonius (1964, p. 106).

Radiizonates aligerens (Knox) emend. Staplin & Jansonius 1964.

Plate 13, figure 11.

1950 *Cirratriradites aligerens* Knox, p. 329, pl. 19, fig. 288.
1964 *Radiizonates aligerens* (Knox) Staplin & Jansonius, p. 106, pl. 18, figs. 23-28.

Neotype. Staplin & Jansonius (1964, pl. 18, figs. 24, 25).

Diagnosis. See Staplin & Jansonius (1964, p. 106).

Remarks. Knox (1950) did not designate a Holotype.

Radiizonates difformis (Kosanke) Staplin & Jansonius 1964.

Plate 13, figure 12.

1950 *Cirratriradites difformis* Kosanke, p. 35, pl. 7, fig. 3.
1964 *Radiizonates difformis* (Kosanke) Staplin & Jansonius, p. 106.

Holotype. Kosanke (1950, pl. 7, fig. 3).

Diagnosis. See Kosanke (1950, p. 35).

Remarks. For a more complete synonymy see Ravn (1976, p. 76).

Radiizonates faunus (Ibrahim) Smith & Butterworth 1967.

Plate 13, figure 18.

1932 *Sporonites faunus* Ibrahim *in* Potonié *et al.*, p. 447, pl. 14, fig. 4.
1967 *Radiizonates faunus* (Ibrahim) Smith & Butterworth, p. 264, pl. 21, figs. 12, 13.

Holotype. Potonié & Kremp (1956, pl. 18, fig. 385).

Diagnosis. See Potonié & Kremp (1956, p. 117).

Remarks. For a more complete synonomy see Smith & Butterworth (1967, p. 264).

Radiizonates striatus (Knox) Staplin & Jansonius 1964.

Plate 13, figure 16.

1950 *Cirratriradites striatus* Knox, p. 330, pl. 19, fig. 289.
1964 *Radiizonatees striatus* (Knox) Staplin & Jansonius, p. 106.

Neotype. Butterworth & Williams (1954, pl. 18, fig. 1).

Diagnosis. See Butterworth & Williams (1954, p. 757).

Remarks. Knox (1950) failed to designate a Holotype. Butterworth & Williams validated the species by selecting two hypotypes, one of which was selected as a neotype by Smith & Butterworth (1967).

Radiizonates aff. *striatus.*

Plate 13, figure 17.

1967 *Radiizonates* cf. *straitus* (Knox) Staplin & Jansonius 1964; Smith & Butterworth, p. 266, pl. 20, figs. 20, 21.

Remarks. This species is used in the same sense that Smith & Butterworth (1967) use *R.* cf. *striatus* to include specimens which are smaller and have a relatively narrow inner zone to the cingulum than *R. striatus.* The morphographic distinction between *R. striatus* and *R.* aff. *striatus* appears to be consistent, although subtle. Furthermore, the two taxa appear to have distinct stratigraphic ranges.

Radiizonates tenuis (Loose) Butterworth & Smith in Butterworth *et al.* 1964.

Plate 13, figure 15.

1932 *Sporonites tenuis* Loose *in* Potonié *et al.*, p. 450, pl. 18, fig. 34.
1956 *Densosporites tenuis* (Loose) Potonié & Kremp, p. 120, pl. 18, figs. 404-407.
non 1955 *Densosporites tenuis* Hoffmeister *et al.*, p. 387, pl. 36, figs. 18, 19, 23.
1964 *Radiizonates tenuis* (Loose) Butterworth & Smith *in* Butterworth *et al.*, p. 1054, pl. 2, fig. 13.

Holotype. Potonié & Kremp (1956, pl. 18, fig. 404).

Diagnosis. See Potonié & Kremp (1956, p. 120).

Simozonotriletes Naumova *ex* Ischenko emend. Potonié & Kremp 1954.

Type species. *S. intortus* (Waltz) Potonié & Kremp 1954.
Diagnosis. See Potonié & Kremp (1954, p. 159).
Remarks. Staplin (1960) and other workers have considered that *Murospora* Somers 1952 has priority over this genus. However, they failed to recognise the validation of the genus by Ischenko (1952), assuming that it was not validated until the work of Potonié & Kremp (1954). A discussion regarding the confused taxonomy of this genus and its type species can be found in Jansonius & Hills (1990, cards 4766, 4767).

Simozonotriletes intortus (Waltz) Potonié & Kremp 1954.

Plate 13, figure 19.

1938 *Zonotriletes intortus* Waltz *in* Luber & Waltz, pl. 2, fig. 24.
1954 *Simozonotriletes intortus* (Waltz) Potonié & Kremp, p. 159.
1962 *Murospora intorta* (Waltz) Playford, p. 609, pl. 86, figs. 12, 13.

Lectotype. Luber & Waltz (1938, pl. 2, fig. 24).
Diagnosis. See Potonié & Kremp (1954, p. 159).

Vallatisporites Hacquebard emend. Sullivan 1964.

Type species. *V. vallatus* Hacquebard 1957.
Diagnosis. See Sullivan (1964, p. 370).

Vallatisporite vallatus Hacquebard 1957.

Plate 13, figure 20.

1957 *Vallatisporites vallatus* Hacquebard, p. 312, pl. 2, fig. 12.

Holotype. Hacquebard (1957, pl. 2, fig. 12).
Diagnosis. See Hacquebard (1957, p. 312).

Infraturma MEMBRANATI Neves 1961.

Diaphanospora Balme & Hassell emend. Evans 1970.

Type species. *D. riciniata* Balme & Hassell emend. Evans 1970.
Diagnosis. See Evans (1970, p. 68).
Remarks. Evans (1970) examined the type material of *Perotrilites* Erdtman *ex* Couper 1953 and determined that the type species (*P. granulatus* Couper 1953) was zonate rather than perinate. As such, *Perotrilites* cannot accomodate several

of the species of Carboniferous trilete, circular or subcircular miospore which have a thin, diaphanous, unornamented "perine" distinctly seperated from the main spore body over most of the surface. These species are placed within the genus *Diaphanospora*. Other species previously assigned to *Perotrilites* have been reassigned to the genera *Rugospora* Neves & Owens 1966 and *Velamisporites* Bharadwaj & Venkatachala 1962 by various authors.

Diaphanospora parvigracila (Peppers) Ravn 1979.

Plate 13, figure 21.

1970 *Perotriletes* (sic) *parvigracilus* Peppers, p. 128, pl. 13, figs. 5-7.
1979 *Diaphanospora parvigracila* (Peppers) Ravn, p. 48, pl. 18, fig. 11.

Holotype. Peppers (1970, pl. 13, fig. 5).

Diagnosis. See Peppers (1970, p. 128).

Hymenospora Neves 1961.

Type species. *H. palliolata* Neves 1961.

Diagnosis. See Neves (1961, p. 270).

Hymenospora caperata Felix & Burbridge 1967.

1967 *Hymenospora caperata* Felix & Burbridge, p. 405-406, pl. 62, fig. 12.

Holotype. Felix & Burbridge (1967, pl. 62, fig. 12).

Diagnosis. See Felix & Burbridge (1967, p. 405).

Hymenospora cf. *caperata.*

Plate 13, figure 25.

Remarks. This taxon is used *sensu* Ravn (1986).

Hymensopora murdochensis sp. nov.

Plate 13, figures 22-24.

Diagnosis. Radial, trilete, camerate miospores. Amb subcircular, broadly rounded triangular or elongate-oval. Laesurae straight, simple, reaching to margin of intexine, often difficult to discern. Intexine laevigate, three quarters radius of spore. Cameration of more or less constant width around the intexine. Exoexine finely granulate, grana largest (up to 1μ diameter) on the distal surface towards the distal pole; folded into 30 to 50, more or less radial plications on both proximal and distal faces; exoexine attatched to intexine in furrows of plications. Size of miospores $46(53.3)59\mu$; 20 specimens.

Derivation of name. Named after the Murdoch Gas Field in which the species was first recognised.
Type locality. Well 44/22-1, southern North Sea.
Type horizon. Coal in core at 12064'; late Langsettian.
Holotype. Plate 13, figure 22.
Comparison. *Hymenospora palliolata* Neves 1961 is larger, has fewer radial plications and a laevigate exoexine. *H. multirugosa* Peppers 1970 has prominent, labrate laesurae and a relatively thick, infrapunctate exoexine. *Schulzospora plicata* is consistently elongate-elliptical in outline due to the median constriction of the exoexine. It therefore does not have the consistent width of cameration of *H. murdochensis.*

Infraturma POLYCAMERATI Neves & Owens 1966.

Alatisporites Ibrahim emend. Smith & Butterworth 1967.

Type species. *A. pustulatus* (Ibrahim) Ibrahim 1933.
Diagnosis. See Smith & Butterworth (1967, p. 279).

Alatisporites hoffmeisterii Morgan 1955.

Plate 14, figure 3.

1955 *Alatisporites hoffmeisterii* Morgan, p. 37, pl. 2, figs. 1-8.

Holotype. Morgan (1955, pl. 2, fig. 1).
Diagnosis. See Morgan (1955, p. 37).

Alatisporites nudus Neves 1958.

Plate 14, figure 4.

1958 *Alatisporites nudus* Neves, p. 10, pl. 3, fig. 9.

Holotype. Neves (1958, pl. 3, fig. 9).
Diagnosis. See Neves (1958, p. 10).

Alatisporites pustulatus (Ibrahim) Ibrahim 1933.

Plate 14, figure 2.

1932 *Sporonites pustulatus* Ibrahim *in* Potonié *et al.*, p. 448, pl. 14, fig. 12.
1933 *Alati-sporites pustulatus* (Ibrahim) Ibrahim, p. 32, pl. 1, fig. 12.

Holotype. Potonié & Kremp (1956, pl. 19, fig. 445).
Diagnosis. See Potonié & Kremp (1956, p. 155).

Subturma indeterminate.
Infraturma indeterminate.

Colatisporites Williams *in* Neves *et al.* 1973.

Type species. C. *decorus* (Bharadwaj & Venkatachala) Williams *in* Neves *et al.* 1973.

Diagnosis. See Neves *et al.* (1973, p. 40).

Colatisporites decorus (Bharadwaj & Venkatachala) Williams *in* Neves *et al.* 1973.
Plate 13, figure 26.

1962 *Tholisporites decorus* Bharadwaj & Venkatachala, p. 39, pl. 10, figs. 142-146.
1973 *Colatisporites decorus* (Bharadwaj & Venkatachala) Williams *in* Neves *et al.*, p. 41, pl. 2, figs. 11-13.

Holotype. Bhardwaj & Venkatachala (1962, pl. 10, fig. 142).

Diagnosis. See Neves *et al.* (1973, p. 41).

Schulzospora Kosanke 1950.

Type species. *S. rara* Kosanke 1950.

Diagnosis. See Kosanke (1950, p. 53).

Schulzospora campyloptera (Waltz) Hoffmeister *et al.* 1955.
Plate 13, figure 27.

1938 *Zonotriletes campylopterus* Waltz *in* Luber & Waltz, p. 16, pl. 3, fig. 39, pl. A, fig. 15.
1955 *Schulzospora campyloptera* (Waltz) Hoffmeister *et al.*, p. 396.

Holotype. Not known.

Diagnosis. See Smith & Butterworth 1967, p. 274).

Remarks. See Smith & Butterworth (1967, p. 274) for a more complete synonymy.

Schulzospora rara Kosanke 1950.
Plate 13, figure 28, 29.

1950 *Schulzospora rara* Kosanke, p. 53, pl. 13, figs. 5-8.

Holotype. Kosanke (1950, pl. 13, fig. 8).

Diagnosis. See Kosanke (1950, p. 53).

Suprasubturma indeterminate.
Subturma indeterminate.
Infraturma indeterminate.

Elaterites Wilson 1943.

Type species. *E. triferens* Wilson 1943.
Diagnosis. see Wilson (1943, p. 520).

Elaterites anfractus sp. nov.

Plate 14, figures 5-8.

Diagnosis. Miospores trilete, possibly camerate. Outer exine layer developed into single elater-like structure which is arranged in a coil about the inner exine layer. Separation and uncoiling of the 'elater' variable. Laesurae straight, simple, one half of diameter of the intexine. Outer exine layer thin, punctate, occasionally faintly granular. Inner exine layer scabrate or laevigate, commonly thickened in the region of the trilete mark. Miospore size difficult to determine due to uncoiling of 'elater', overall diameter 56(60)70μ, intexine diameter 38(41.8)48μ, width of 'elater' 7μ to 16μ; 15 specimens.
Derivation of name. L. *anfractus* - orbit, round-about; in reference to the encircling nature of the single elater.
Type locality. 44/22-1, southern North Sea.
Type horizon. Mudstones in core at 12090'; Langsettian.
Holotype. Plate 14, figure 8.
Comparison. *E. triferens* Wilson 1943 has three elaters and a relatively larger intexine (58-60μ, Wilson (1943); 40(72)75μ Turner (1991b)).

Pteroretis Felix & Burbridge 1961.

Type species. *P. primum* Felix & Burbridge 1961.
Diagnosis. See Felix & Burbridge (1961, p. 491).

Pteroretis primum Felix & Burbridge 1961.

Plate 14, figure 1.

1961 *Pteroretis primum* Felix & Burbridge, p. 494, pl. 1, figs. 1-8).
Holotype. Felix & Burbridge (1961, pl. 1, fig. 2).
Diagnosis. Felix & Burbridge (1961, p. 494).

Turma MONOLETES Ibrahim 1933.
Suprasubturma ACAMERATOMONOLETES Williams 1971 MS.
Subturma AZONOMONOLETES Luber 1955.
Infraturma LAEVIGATOMONOLETI Dybová & Jachowicz 1957.

Laevigatosporites Ibrahim 1933.

Type species. *L. vulgaris* (Ibrahim) Ibrahim 1933.

Diagnosis. See Potonié & Kremp (1954, p. 165).

Laevigatosporites densus Alpern 1958.

Plate 14, figures 9, 10.

1958 *Laevigatosporites densus* Alpern, p. 80, pl. 2, fig. 32.

Holotype. Alpern (1958, pl. 2, fig. 32).

Diagnosis. Alpern (1958, p. 80).

Laevigatosporites desmoinesensis (Wilson & Coe) Schopf *et al.* 1944.

Plate 14, figure 12.

1934 *Laevigatosporites vulgaris minor* Loose, p. 158, pl. 7, fig. 12.
1940 *Phaseolites desmoinesensis* Wilson & Coe, p. 182, pl. 1, fig. 4.
1944 *Laevigato-sporites desmoinesensis* (Wilson & Coe) Schopf *et al.*, p. 37.
1956 *Laevigatosporites desmoinesensis* (Wilson & Coe) Schopf *et al.*; Potonié & Kremp, p. 139, pl. 19, figs. 425-428.
1957 *Laevigatosporites minor* (Loose) Potonié & Kremp (sic); Bhardwaj, p. 109, pl. 29, figs. 8, 9.
1967 *Laevigatosporites minor* Loose 1934; Smith & Butterworth, p. 284-285, pl. 24, fig. 3.

Holotype. Wilson & Coe (1940,.pl. 1, fig. 4).

Diagnosis. See Wilson & Coe (1940, p. 184).

Remarks. Bhardwaj (1957) attributed the raising of *L. minor* to specific status to Potonié & Kremp but failed to indicate a date for this taxonomic change. It seems likely that Bhardwaj acted in error as Potonié & Kremp (1956, p. 139) maintained the variety *L. vulgaris minor* as a synonym of *L. desmoinesensis*. In this case Bhardwaj (1957) must be attributed with raising the status of *L vulgaris minor*. Given the synonymy indicated by Potonié & Kremp (1956) priority is given to *L. desmoinesnsis*, the basionym of which was published by Wilson & Coe (1940) thus pre-dating the publication of *L. minor* as a species.

Laevigatosporites minimus (Wilson & Coe) Schopf *et al.* 1944.

Plate 14, figure 13.

1940 *Phaseolites minimus* Wilson & Coe, p. 183, fig. 5.
1944 *Laevigato-sporites minimus* (Wilson & Coe) Schopf *et al.*, p. 37.

Holotype. Wilson & Coe (1940, fig. 5).

Diagnosis. See Wilson & Coe (1940, p. 183).

Laevigatosporites vulgaris (Ibrahim) Ibrahim 1933.

Plate 14, figure 11.

1932 *Sporonites vulgaris* Ibrahim *in* Potonié *et al.*, p. 448, pl. 15, fig. 16.
1933 *Lavigato-sporites vulgaris* (Ibrahim) Ibrahim, p. 39, pl. 2, fig. 16.

Holotype. Potonié & Kremp (1956, pl. 19, fig. 429).

Diagnosis. See Ibrahim (1933, p. 39).

Latosporites Potonié & Kremp 1954.

Type species. *L. latus* (Kosanke) Potonié & Kremp 1954.

Diagnosis. See Potonié & Kremp (1954, p. 165).

Latosporites globosus (Schemel) Potonié & Kremp 1956.

Plate 14, figure 14.

1950 *Laevigto-sporites globosus* Schemel, p. 748, text-fig. 2.
1956 *Latosporites globosus* (Schemel) Potonié & Kremp, p. 140.

Holotype. Schemel (1950, text-fig. 2).

Diagnosis. See Schemel (1950, p. 746).

Infraturma SCULPTATOMONOLETI Dybová & Jachowicz 1957.

Columinisporites Peppers 1964.

Type species. *C. ovalis* Peppers 1964.

Diagnosis. See Peppers (1964, p. 15).

Columinisporites ovalis Peppers 1964.

Plate 14, figures 20, 21.

1964 *Columinisporites ovalis* Peppers, p. 16, pl. 1, figs. 11-12.

Holotype. Peppers (1964, pl. 1, fig. 11).

Diagnosis. See Peppers (1964, p. 16).

Dictyomonolites Ravn 1986.

Type species. *D. swadei* Ravn 1986.
Diagnosis. See Ravn (1986, p. 114).

Dictyomonolites swadei Ravn 1986.

Plate 14, figure 17, 18.

1986 *Dictyomonolites swadei* Ravn, p. 115, pl. 35, figs. 1-8.

Holotype. Ravn (1986, pl. 34, fig. 1).
Diagnosis. See Ravn (1986, p. 115).
Remarks. The relationship between this species and possible synonyms (*Dictyotriletes castaneaeformis* (Horst) Sullivan 1964 and *D. clatriformis* (Artüz) Sullivan 1964) is discussed by Ravn (1986).

Punctatosporites Ibrahim emend. Alpern & Doubinger 1973.

Type species. *P. minutus* Ibrahim emend. Alpern & Doubinger 1973.
Diagnosis. See Alpern & Doubinger (1973, p. 36).

Punctatosporites minutus Ibrahim emend. Alpern & Doubinger 1973.

Plate 14, figure 15.

1933 *Punctato-sporites minutus* Ibrahim, p. 40, pl. 5, fig. 33.
1973 *Punctatosporites minutus* Ibrahim emend. Alpern & Doubinger, p. 42, pl. 11, figs. 1-26.

Holotype. Ibrahim (1933, pl. 5, fig. 33).
Diagnosis. See Alpern & Doubinger (1973, p. 41).
Remarks. For a more complete synonymy see Alpern & Doubinger (1973, p. 41).

Thymospora Wilson & Venkatachala 1963b.

Type species. *T. thiessenii* (Kosanke) Wilson & Venkatachala 1963b.
Diagnosis. See Wilson & Venkatachala (1963b, p. 76).

Thymospora spp.

Plate 14, figure 22.

Remarks. Assemblages of Thymospora spp. from the S.N.S.C.B. commonly show intra-specific variation between *T. obscura* (Kosanke) Wilson &

Venkatachala 1963b and *T. pseudothiessenii* (Kosanke) Wilson & Venkatachal 1963b. The illustrated specimen is an intermediate form.

Torispora Balme emend. Doubinger & Horst 1961.

Type species. *T. securis* Balme emend Alpern *et al.* 1965.
Diagnosis. See Doubinger & Horst. (1961 p. 29).

Torispora securis Balme emend. Alpern *et al.* 1965.

Plate 14, figure 23.

1952 *Torispora securis* Balme, p. 183, text-figs. 3a-d.
1965 *Torispora securis* Balme emend Alpern *et al.*, p. 570, pl. 1, fig. 1.

Lectotype. Smith & Butterworth (1967, pl. 24, fig. 31), designated by Balme.
Diagnosis. See Alpern *et al.* (1965, p. 570).
Remarks. For a more complete synonymy see Ravn (1986, p. 113).

Turma ALETES Ibrahim 1933.
Suprasubturma ACAMERATALETES Razzo 1985 MS.
Subturma AZONALETES Luber emend. Potonié & Kremp 1954.
Infraturma PSILONAPITI Erdtmann 1954.

Fabasporites Sullivan 1964.

Type species. *F. pallidus* Sullivan 1964.
Diagnosis. See Sullivan (1964, p. 378).

Fabasporites pallidus Sullivan 1964.

Plate 14, figure 16.

1964 *Fabasporites pallidus* Sullivan, p. 379, pl. 61, figs. 9-11.

Holotype. Sullivan (1964, pl. 61, fig. 11).
Diagnosis. See Sullivan (1964, p. 379).

Turma HILATES Dettmann 1963.
Suprasubturma ACAMERATIHILATES Spode 1974 MS.
Subturma SOLUTIHILATES Spode 1974 MS.
Infraturma EPITYGMATI Spode in Smith & Butterworth 1967.

Vestispora Wilson & Hoffmeister emend. Wilson & Venkatachala 1963a.

Type species. *V. profunda* Wilson & Hoffmeister 1956.

Diagnosis. See Wilson & Venkatachala (1963a, p. 96).

Vestispora costata (Balme) Bharadwaj emend. Spode *in* Smith & Butterworth 1967.

Plate 15, figure 1.

1952 *Endosporites costatus* Balme, p. 178, text-fig. 1f.
1957 *Vestispora costata* (Balme) Bhardwaj, p. 118, pl. 24, figs. 36-40.
1967 *Vestispora costata* (Balme) Bharadwaj emend. Spode *in* Smith & Butterworth, p. 295, pl. 25, figs. 1, 2.

Lectotype. Smith & Butterworth (1967, pl. 25, fig. 1).

Diagnosis. See Smith & Butterworth (1967, p. 295).

Vestispora dubia sp. nov.

Plate 15, figures 2, 3.

Diagnosis. Radial, trilete, camerate, operculate miospores. Laesurae straight simple, two thirds radius with faint curvaturae perfectae delimiting margin of operculum. Intexine often difficult to discern. Exoexine laevigate, ornamented with straight, unbranching costae which taper at both ends. Costae often intimately associated with and difficult to differentiate from exoexinal folds. Miospore diameter 65(78.3)97μ; 20 specimens.

Derivation of name. L. *dubius* - uncertain, in reference to the poorly developed costae/folds.

Type locality. Well 44/22-1, southern North Sea.

Type horizon. Mudstones in core at 11878'; Duckmantian.

Holotype. Plate 15, figure 2.

Comparison. *V. costata* (Balme) Bhardwaj emend Spode *in* Smith & Butterworth 1967 has more prominent costae and a more prominent intexine. *V. lucida* (Butterworth & Williams) Potonié 1960 is larger and has a thin, membranous exoexine.

Remarks. The camerate and operculate nature of species is often difficult to discern. The species may represent abortive or immature specimens of other species of *Vestispora*.

Vestispora fenestrata (Kosanke & Brokaw) Wilson & Venkatachala emend. Spode *in* Smith & Butterworth 1967.

Plate 15, figure 4.

1950 *Punctati-sporites fenestratus* Kosanke & Brokaw *in* Kosanke, p. 15, pl. 2, fig. 10.
1963a *Vestispora fenestrata* (Kosanke & Brokaw) Wilson & Venkatachala, p. 99, pl. 1, figs. 13, 14.
1967 *Vestispora fenestrata* (Kosanke & Brokaw) Wilson & Venkatachala emend. Spode *in* Smith & Butterworth, p. 296, pl. 25, figs. 3-6.

Holotype. Kosanke (1950, pl. 2, fig. 10).

Diagnosis. See Smith & Butterworth (1967, p. 296).

Remarks. For a more complete synonymy see Ravn (1986, p. 63).

Vestispora magna (Butterworth & Williams) Wilson & Venkatachala emend. Spode *in* Smith & Butterworth 1967.

Plate 15, figures 5, 6.

1954 *Reticulatisporites magnus* Butterworth & Williams, p. 756, pl. 17, figs. 5, 6.
1963a *Vestispora magna* (Butterworth & Williams) Wilson & Venkatachala, p. 99.
1967 *Vestispora magna* (Butterworth & Williams) Wilson & Venkatachala emend. Spode *in* Smith & Butterworth, p. 298, pl. 25, figs. 11, 12.

Holotype. Smith & Butterworth (1967, pl. 25, fig. 11).

Diagnosis. See Smith & Butterworth (1967, p. 298).

Vestispora cf. *magna.*

Plate 15, figures 8, 9.

Remarks. Specimens which do not possess the charcteristic secondary reticulum of the type material but otherwise appear morphologically identical are included in this taxon.

Vestispora pseudoreticulata Spode *in* Smith & Butterworth 1967.

Plate 15, figure 7.

1952 *Reticulatisporites tortuosus* Balme (in part), p. 179.
1964b *Vestispora pseudoreticulata* Spode *in* Neves, p. 1233, pl. 3, figs. 1,2.
1967 *Vestispora pseudoreticulata* Spode *in* Smith & Butterworth, p. 298, pl. 25, figs. 13, 14.

Holotype. Not designated.

Diagnosis. See Smith & Butterworth (1967, p. 299).

Remarks. This species remains a *nomen nudum* as Spode *in* Neves (1964b) gave no description or typification and the designation of a holotype referred to by Smith & Butterworth (1967) (as Spode (in press)) has yet to be published.

Vestispora tortuosa (Balme) Bhardwaj emend. Spode *in* Smith & Butterworth 1967.

Plate 15, figure 10.

1952 *Reticulatisporites tortuosus* Balme (in part), text-fig. 1d.
1957 *Vestispora tortuosa* (Balme) Bhardwaj, p. 119.
1967 *Vestispora tortuosa* (Balme) Bharadwaj emend. Spode *in* Smith & Butterworth, p. 299, pl. 26, figs. 1, 2.

Lectotype. Smith & Butterworth (1967, pl. 26, fig. 1).

Diagnosis. See Smith & Butterworth (1967, p. 299).

4.2.2. Anteturma POLLENITES Potonié 1931.

Turma SACCITES Erdtmann 1947.

Subturma MONOSACCITES Chitaley emend. Potonié & Kremp 1954.

Infraturma TRILETESACCITI Leschik 1956.

Costatascyclus Felix & Burbridge emend. Urban 1971.

Type species. *C. crenatus* Felix & Burbridge emend. Urban 1971.

Diagnosis. See Urban (1971, p. 114).

Costatscyclus crenatus Felix & Burbridge emend. Urban 1971.

Plate 15, figure 11.

1967 *Costatascyclus crenatus* Felix & Burbridge, p. 411, pl. 64, fig. 6.
1971 *Costatascyclus crenatus* Felix & Burbridge emend. Urban, p. 114-115, pl. 25, figs. 4-9.

Holotype. Felix & Burbridge (1967, pl. 64, fig. 6).

Diagnosis. Urban (1971, p. 114-115).

Guthoerlisporites Bhardwaj 1954.

Type species. *G. magnificus* Bhardwaj 1954.

Diagnosis. See Bhardwaj (1954, p. 518).

Guthoerlisporites cf. *magnificus*.

Plate 15, figure 13.

Remarks. Present specimens conform to the diagnosis but do not have well developed tectae associated with the laesurae.

Tinnulisporites Dempsey 1967.

Type species. *T. microsaccus* Dempsey 1967.

Diagnosis. See Dempsey (1967, p. 114).

Tinnulisporites microsaccus Dempsey 1967.

Plate 15, figure 12.

1967 *Tinnulisporites microsaccus* Dempsey, p. 115, pl. I, figs. F-N.

Holotype. Dempsey (1967, pl. I, fig. G).

Diagnosis. See Dempsey (1967, p. 115).

Wilsonites (Kosanke) Kosanke 1959.

Type species. *W. vesicatus* (Kosanke) Kosanke 1959.

Diagnosis. See Kosanke (1950, p. 54).

Wilsonites circularis (Guennel) Peppers & Ravn *in* Ravn 1979.

Plate 16, figure 4.

1958 *Endosporites circularis* Guennel, p. 51, pl. 1, figs. 18, 19, text-fig. 12.
1979 *Wilsonites circularis* (Guennel) Peppers & Ravn *in* Ravn, p. 50, pl. 20, fig. 3.

Holotype. Guennel (1958, text-fig. 12).

Diagnosis. See Guennel (1958, p. 51).

Wilsonites delicatus (Kosanke) Kosanke 1959.

Plate 16, figure 7.

1950 *Wilsonia delicata* Kosanke, p. 54, pl. 14, figs. 1-3.
1959 *Wilsonites vesicatus* (Kosanke) Kosanke, p. 700.

Holotype. Kosanke (1950, pl. 14, fig. 1).

Diagnosis. Kosanke (1950, p. 54).

For a more complete synonymy see Ravn (1986, p. 122).

Wilsonite kosankei Bhardwaj 1957.

Plate 16, figure 1.

1957 *Wilsonites kosankei* Bhardwaj, p. 115, pl. 30, figs. 10-12.

Holotype. Bhardwaj (1957, pl. 30, fig. 10).

Diagnosis. See Bhardwaj (1957, p. 115).

Wilsonites ephemerus Tschudy & Kosanke 1966.

Plate 16, figure 3.

1966 *Wilsonites ephemerus* Tschudy & Kosanke, p. 66, pl. 2, figs. 36, 37.

Holotype. Tschudy & Kosanke (1966, pl. 2, fig. 36).

Diagnosis. See Tschudy & Kosanke (1966, p. 66).

Wilsonites vesicatus (Kosanke) Kosanke 1959.

Plate 16, figure 2.

1950 *Wilsonia vesicatus* Kosanke, p. 54, pl. 14, figsa. 1-3.
1959 *Wilsonites vesicatus* (Kosanke) Kosanke, p. 700.

Holotype. Kosanke (1950, pl. 14, fig.1).

Diagnosis. See Kosanke (1950, p. 54).

Infraturma MONOLETESACCITI Hart 1961 MS.

Paleospora Habib 1966.

Type species. *P. fragila* Habib 1966.

Diagnosis. See Habib (1966, p. 647).

Remarks. The suprageneric placement of this monospecific genus is questionable as the apparently complex structure of the type species is not completely understood.

Paleospora fragila Habib 1966.

Plate 17, figure 5.

1966 *Paleospora fragila* Habib, p. 647, pl. 108, figs. 1, 2.

Holotype. Habib (1966, pl. 108, fig. 1).

Diagnosis. See Habib (1966, p. 108).

Peppersites Ravn 1979.

Type species. *P. ellipticus* Ravn 1979.

Diagnosis. See Ravn (1979, p. 51).

Peppersites ellipticus Ravn 1979.

Plate 16, figure 5.

1979 *Peppersites ellipticus* Ravn, p. 51, pl. 21, figs. 1-4.

Holotype. Ravn (1979, pl. 21, fig. 1).

Diagnosis. See Ravn (1979, p. 51).

Potonieisporites Bhardwaj 1954.

Type species. *P. novicus* Bhardwaj 1954.
Diagnosis. See Bharadwaj (1954, p. 46).

Potonieisporites elegans (Wilson & Kosanke) Wilson & Venkatachala 1964.
Plate 16, figure 10.
1944 *Florinites elegans* Wilson & Kosanke, p. 330, fig. 3.
1964 *Potonieiesporites elegans* (Wilson & Kosanke) Wilson & Venkatachala, p. 67-68, figs. 1, 2.
Holotype. Wilson & Kosanke (1944, fig. 3).
Diagnosis. See Wilson & Kosanke (1944, p. 330).

Potonieisporites microsaccus Butterworth *et al.* 1988.
Plate 16, figure 9.
1988 *Potonieisporites microsaccus* Butterworth *et al.*, p.77, pl. 6, figs. 1, 2.
Holotype. Butterworth *et al.* (1988, pl. 6, fig. 1).
Diagnosis. See Butterworth *et al,* (1988, p. 77).

Quasillinites Ravn & Fitzgerald 1982.

Type species. *Q. diversiformis* (Kosanke) Ravn & Fitzgerald 1982.
Diagnosis. See Ravn (1979, p. 50).

Quasillinites diversiformis (Kosanke) Ravn & Fitzgerald 1982.
Plate 16, figure 6.
1950 *Florinites diversiformis* Kosanke, p. 49, pl. 12, fig. 5.
1979 *Pseudoillinites diversiformis* (Kosanke) Ravn, p. 51, pl. 21, figs. 9-11.
1982 *Quasillinites diversiformis* (Kosanke) Ravn & Fitzgerald, p. 153, pl. 13, fig. 6.
Holotype. Kosanke (1950, pl. 12, fig. 5).
Diagnosis. See Ravn (1979, p. 50).

Infraturma ALETESACCITI Leschik 1956.

Florinites Schopf *in* Schopf *et al.* 1944.

Type species. *F. mediapudens* (Loose) Potonié & Kremp 1956 (= *F. antiquus* Schopf, *in* Schopf *et al.* 1944).

Diagnosis. See Schopf *et al.* (1944, p. 56).

Florinites florini Imgrund 1960.

1960 *Florinites florini* Imgrund, p. 179, pl. 16, fig. 94.

Holotype. Imgrund (1960, pl. 16, fig. 94).

Diagnosis. See Imgrund (1960, p. 179).

Florinites cf. *florini.*

Plate 16, figure 11.

Remarks. This taxon is applied *sensu* Smith & Butterworth (1967, p. 302-303).

Florinites junior Potonié & Kremp 1956.

Plate 17, figure 2.

1956 *Florinites junior* Potonié & Kremp, p. 168, pl. 21, figs. 466-467.

Holotype. Potonié & Kremp (1956, pl. 21, fig. 466).

Diagnosis. See Potonié & Kremp (1956, p. 168).

Florinites mediapudens (Loose) Potonié & Kremp 1956.

Plate 16, figure 12.

1934 *Reticulata-sporites mediapudens* Loose, p. 158, pl. 7, fig. 8.
1944 *Florinites antiquus* Schopf *in* Schopf *et al.*, p. 58-59, fig. 4.
1956a *Florinites mediapudens* (Loose) Potonié & Kremp, p. 169, pl. 21, figs. 468-471.

Holotype. Potonié & Kremp (1956, pl. 21, fig. 468).

Diagnosis. See Potonié & Kremp (1956, p. 169).

Remarks. A more complete synonymy is presented in Ravn (1986, p. 122).

Florinites minutus Bhardwaj 1957.

Plate 16, figure 13.

1957 *Florinites minutus* Bhardwaj, p. 117, pl. 31, figs. 6,7.

Holotype. Bhardwaj (1957, pl. 31, fig. 6).

Diagnosis. See Bhadrwaj (1957, p. 117).

Florinites pumicosus (Ibrahim) Schopf *et al.* 1944.

Plate 16, figure 8.

1932 *Sporonites pumicosus* Ibrahim *in* Potonié *et al.*, p. 447, pl. 14, fig. 6.
1944 *Florinites? pumicosus* (Ibrahim) Schopf *et al.*, p. 59.

Holotype. Potonié & Kremp (1955, pl. 21, fig. 472).

Diagnosis. See Potonié & Kremp (1955, p. 169).

Florinites similis Kosanke 1950.

Plate 17, figure 3.

1950 *Florinites similis* Kosanke, p. 49, pl. 12, fig. 2.

Holotype. Kosanke (1950, pl. 12, fig. 2).

Diagnosis. See Kosanke (1950, p. 49).

Florinites? triletus Kosanke 1950.

Plate 17, figure 1.

1950 *Florinites triletus* Kosanke, p. 50, pl. 12, figs. 3-4.

Holotype. Kosanke (1950, pl. 12, figs. 3, 4).

Diagnosis. See Kosanke (1950, p. 50).

Remarks. The presence of a definite trilete mark is contrary to the definition of *Florinites* as described by Schopf *et al.* (1944) and so this species is only tentatively assigned to the genus.

Florinites visendus (Ibrahim) Schopf *et al.* 1944.

Plate 16, figure 14.

1933 *Reticulata-sporites visendus* Ibrahim, p. 39, pl. 8, fig. 66.
1944 *Florinites? visendus* (Ibrahim) Schopf *et al.*, p. 60.

Holotype. Potonié & Kremp (1956, pl. 21, fig. 477).

Diagnosis. See Potonié & Kremp (1956, p. 170).

Florinites volans (Loose) Potonié & Kremp 1956.

Plate 17, figure 4.

1932 *Sporonites volans* Loose *in* Potonié *et al.*, p. 451, pl. 18, fig. 6.
1956 *Florinites volans* (Loose) Potonié & Kremp, p. 170, pl. 21, fig. 462.

Holotype. Potonié & Kremp (1956, pl. 21, fig. 462).

Diagnosis. See Potonié & Kremp (1956, p. 170).

Infraturma indeterminate.

Indeterminate genus.

Striate monosaccate, species indeterminate.
Plate 17, figure 9.

Description. Monolete monosaccate miospores. Outline oval, intexine oval, with long axis aligned along long axis of exoexine. Exoexine infrareticulate. Laesura straight, simple, developed along the full length of the intexine. Intexine bears 6 to 8 irregular, longitudinal taeniae, 5μ to 10μ wide. Length of exoexine 57(75)98μ, width of exoexine 32(48)67μ, length of intexine 35(47)55μ, width of intexine 30(38.1)50μ; 4 specimens.

Comparison. As far as is known, no striate monosaccates have been described. The taeniae on the intexine bear a resemblance to those of *Illinites unicus* Kosanke emend Helby 1966, but that species is bisaccate.

Subturma DISACCITES Cookson 1947.
Infraturma DISACCITRILETI Leschik 1956.

Parasporites Schopf 1938.

Type species. *P. maccabei* Schopf 1938.

Diagnosis. See Schopf (1938, p. 46).

Parasporites macanensis Sabry & Neves 1971.
Plate 17, figure 6.
1971 *Paraspora* (sic) *macanensis* Sabry & Neves, p. 1445, pl. 3, figs. 12, 15.

Holotype. Sabry & Neves (1971, pl. 3, fig. 12).

Diagnosis. See Sabry & Neves (1971, p. 1445).

Parasporites cf. *macanensis.*
Plate 17, figure 11.

Remarks. Smaller (length 60(61.5)63μ, width 40(47.2)50μ; 6 specimens) than the typre material and with a less distinct trilete mark which is often obscured by folding of the sacci where they are in contact with the inner body.

Infraturma DISACCIATRILETI Leschik emend. Potonié 1958.

Limitisporites Leschik emend. Klaus 1958.

Type species. *L. rectus* Leschik 1956.
Diagnosis. See Klaus (1958, p. 283).

Limitisporites rectus Leschik 1956.

1956 *Limitisporites rectus* Leschik, p. 133, pl. 21, fig. 15.
Holotype. Leschik (1956, pl. 21, fig. 15).
Diagnosis. See Leschik (1956, p. 133).

Limitisporitese cf. *rectus*.

Plate 18, figures 1-3.

Remarks. Many specimens which are comparable to *L. rectus* Leschik 1956 were recorded. They generally have a less distinct, but longer monolete mark than the type, and this is commonly accompanied by a broad fold. The central body may be circular or oval in proximo-distal view and the sacci may be somewhat longitudinally extended in comparison to the type material.

Limitisporites latus Leschik 1956.

1956 *Limitisporites latus* Leschik. p. 133, pl. 21, fig. 16.
Holotype. Leschik (1956, pl. 21, fig. 16).
Diagnosis. See Leschik (1956, p. 133).

Limitisporites cf. *latus*.

Plate 18, figure 4.

Remarks. Specimens from this study appear similar to the type but have a less well defined monolete mark and a central body which is oval-elliptical in proximo-distal view, rather than circular.

Pityosporites Seward emend. Manum 1960.

Type species. *P. antarcticus* Seward 1914.
Diagnosis. See Manum (1960, p. 14).

Pityosporites inaequus sp. nov.

Plate 17, figures 12-14.

Diagnosis. Diploxylonoid bisaccate, egg-shaped in proximo-distal view. Central boby sub-circular to ovoid (long axis transverse), laevigate, proximally thickened. No laesura or furrow visible. Sacci of markedly different sizes. Size of palynomorphs: overall length 40(51.4)57μ, overall width 35(34.7)42, depth of large saccus 32(37.8)40μ, depth of small saccus 23(27.3)36μ; 20 specimens.

Derivation of name. L. *inaequus* - asymmetrical, with reference to the asymmetry of the sacci.

Type locality. Well 44/22-1, southern North Sea.

Type horizon. Coal in core at 11752'; Duckmantian.

Holotype. Plate 17, figure. 12.

Comparison. *P. westphalensis* Wiliams 1955 is smaller and has sacci of equal size.

Pityosporites westphalensis Williams 1955.

Plate 17, figure 10.

1955 *Pityosporites westphalensis* Williams, p. 467, pl. 6, figs. 1-6.

Holotype. Williams (1955, pl. 6, fig. 1).

Diagnosis. See Williams (1955, p. 467).

Infraturma PODOCARPOIDITI Potonié *et al.* 1950.

Platysaccus Naumova *ex* Ischenko emend. Potonié & Klaus 1954.

Type species. *P. papilionis* Potonié & Klaus 1954.

Diagnosis. See Potonié & Klaus (1954, p. 10).

Remarks. For a discussion of the taxonomy of this genus see Jansonius & Hills (1976, card 2032).

Platysaccus saarensis (Bhardwaj) Jizba 1962.

Plate 18, figure 6.

1957a *Alisporites saarensis* Bhardwaj, p. 117-118, pl. 31, figs. 14, 15.
1962 *Platysaccus saarensis* (Bhardwaj) Jizba, p. 885, pl. 124, figs. 59-61.

Holotype. Bhardwaj (1957a, pl. 31, fig. 14).

Diagnosis. See Bhardwaj (1957a, p. 117).

Infraturma STRIATITI Pant 1954.

Illinites Kosanke emend. Helby 1966.

Type species. *I. unicus* Kosanke emend. Helby 1966.
Diagnosis. See Helby (1966, p. 680).

Illinites unicus Kosanke emend. Helby 1966.
Plate 17, figures 7, 8.

1950 *Illinites unicus* Kosanke, p. 51, pl. 1, figs. 3, 4.
1962 *Complexisporites polymorphus* Jizba, p. 869, pl. 121, figs. 1-14.
1966 *Illinites unicus* Kosanke emend. Helby, p. 680, pl. 8, figs. 9-18, pl. 9, fig. 1.

Holotype. Kosanke (1950, pl. 1, figs. 1, 2).
Diagnosis. See Helby (1966, p. 680).
Remarks. For a more complete synonymy see Ravn (1986, p. 127)

Protohaploxypinus Samoilovich emend Morbey 1975.

Type species. *P. latissimus* (Luber) Samoilovich 1953.
Diagnosis. See Morbey (1975 p. 25).

Protohaploxypinua amplus (Balme & Hennelly) Hart 1964.

1955 *Lueckisporites amplus* Balme & Hennely, p. 93, pl. 3, figs. 24-28.
1964 *Protohaploxypinus amplus* (Balme & Hennelly) Hart, p. 1179-1180, fig. 10.

Holotype. None designated.
Diagnosis. See Balme & Hennelly (1955, p. 93).

Protohaploxypinus cf. *amplus*.
Plate 18, figures 12, 13.

Description. Specimens are similar to the type material and also to that figured by Hart (1960) and Utting (1970) except that that the intexine is very difficult to discern. This feature is not mentioned in the diagnosis, but Utting (1970, p. 123) remarks that the central body is often obscure.

Protohaploxypinus masonii sp. nov.
Plate 18, figures 5, 7, 10.

Diagnosis. Disacciti striatiti, diploxylonoid in outline. Central body longitudinally oval, possessing a proximal cappa ornamented by 15 to 20 longitudinal taeniae. Teaniae 2 to 6μ wide, often irregular and with occasional breaks along their length. Sacci semi-circular in outline, infra-reticulate with lumina mainly less than 2μ in diameter. Contact of sacci with central body accompanied by narrow, crescentic folds. Size of palynomorphs: overall length 85(105.4)140μ, overall width 55(63.9)82μ, central body length 64(66.9)82μ.

Derivation of name. Named in honour of Dr. M. Mason, retired Chief Operations Geologist with Conoco (UK) Ltd. in recognition of his role in supporting links between academic and applied palynology.

Type locality. 44/22-1, southern North Sea.

Type horizon. Mudstone in core at 12045'; early Duckmantian.

Holotype. Plate 18, figures 5, 7.

Comparison. Distinguished from other species of *Protohaploxypinus* by the narrow, often broken taeniae.

Turma PLICATES Naumova emend. Potonié 1960.
Subturma PRAECOLPATES Potonié & Kremp 1954.
Infraturma indeterminate.

Zonalosporites **Ibrahim 1933.**

1933 *Zonalosporites* Ibrahim, p. 40.
1936 *Monoletes* Ibrahim *ex* Schopf, p. 107.
1954 *Schopfipollenites* Potonie & Kremp, p. 180.
1963 *Cymbospora* Venkatachala, p. 180.

Type species. *Z. vittatus* Ibrahim 1933.

Diagnosis. Ibrahim (1933, p. 40).

Remarks. Potonié (1970) recognised the priority of *Zonalosporites* over *Monoletes* Ibrahim *ex* Schopf 1936, *Schopfipollenites* Potonié & Kremp 1954 and *Cymbospora* Venkatachala 1963.

Zonalosporites ellipsoides (Ibrahim) Ravn 1986.
Plate 18, figure 11.

1932 *Sporonites ellipsoides* Ibrahim *in* Potonié *et al.* (pars.), p. 449, pl. 17, fig. 29.
1954 *Schopfipollenites ellipsoides* (Ibrahim) Potonié & Kremp (pars), p. 180.
1986 *Zonalosporites ellipsoides* (Ibrahim) Ravn, p. 128, pl. 40 figs. 6, 7.

Holoytpe. Potonié & Kremp (1956, pl. 22, fig. 478).

Diagnosis. See Potonié & Kremp (1956, p. 184).

Subturma MONOCOLPATES Iversen & Troells-Smith 1950.
Infraturma indeterminate.

Cycadopites.Wodehouse emend Krutzsch 1970.

Type species. *C. follicularis* Wilson & Webster 1946.
Diagnosis. See Krutzsch (1970, p. 26).

Cycadopites sp. A.

Plate 18, figures 8, 9.

Description. Narrow, elongate, monocolpate pollen. Colpus simple, extending full length of grain, accompanied by broad (2 to 4μ wide) , well developed labra which taper towards the poles; polar extremes of colpus develops into 'teardrop-shaped' opening. Exine laevigate or finely granulate. Size of grains 25(28.6)31μ; 20 specimens.
Remarks. The occurrence of specimens assigned to this genus is considered under the Discussion.

4.2.3. Group. ACRITARCHA Evitt 1963.

Remarks. Several taxa of acritarchs were recognised in the samples studied. In all cases these are considered to be reworked (see Discussion, Chapter 5). Many of these taxa have distinctive morphographies and so may be readily identified. However, several genera are difficult to speciate in reworked material due to their simple morphographies. In the following account attention has been paid to the stratigraphic utility of acritarch taxa. Genera with numerous species and relatively simple morphographies (i.e.. *Baltisphaeridium, Cymatiosphaera, Leiosphaeridia, Micrhystridium, Multiplicisphaeridium* and *Veryhachium*) and which promise to provide little stratigraphic information have not been speciated. On the other hand, many of the distinctive acritarch taxa also have restricted startigraphic ranges and so are useful in biostratigraphy (Downie, 1984; Fensome *et al.* 1990), and so have been speciated in this account.

No suprageneric classification has been applied, and the taxa are listed alphabetically.

Acanthodiacrodium Timofeev emend. Deflandre & Deflandre-Rigaud 1962.

Type species. *A. dentiferum* Timofeev 1958.
Diagnosis. See Deflandre & Deflandre-Rigaud (1962, p. 194).

Acanthodiacrodium ignoratum (Deunff) Downie & Sarjeant 1965.
Plate 19, figure 15.
1961 *Diornatisphaera ignorata* Deunff, p. 44, pl. 3, fig. 16.
1965 *Acanthodiacrodium ignoratum* (Deunff) Downie & Sarjeant, p. 78.
Holotype. Deunff (1961, pl. 3, fig. 16).
Diagnosis. See Deunff (1961, p. 44).

Acanthodiacrodium spinum Rasul 1979.
Plate 19, figure 17.
1979 *Acanthodiacrodium spinum* Rasul, p. 66-67, pl. 3, figs. 1-7.
Holotype. Rasul (1979, pl. 3, fig. 1).
Diagnosis. See Rasul (1979, p. 66).

Acanthodiacrodium unigeminum Timofeev *ex* Downie & Sarjeant 1965.
Plate 19, figure 16.
1959 *Acanthorytidodiacrodium unigeminum* Timofeev, p. 85-86, pl. 7, fig. 24.
1965 *Acanthodiacrodium unigeminum* (Timofeev) Downie & Sarjeant, p. 81.
Holotype. Timofeev (1959, pl. 7, fig. 24).
Diagnosis. See Timofeev (1959, p. 85).

Baltisphaeridium Eisenack *ex* Eisenack emend. Eisenack 1969.

Plate 19, figures 7, 8.
Type species. *B. longispinosusm* (Eisenack *ex* Wetzel) Eisenack 1959.
Diagnosis. See Eisenack (1969, p. 249).

Biannulatisphaerites Neville *in* Neves *et al.* 1973.

Type species. *B. simplex* Neville *in* Neves *et al.* 1973.
Diagnosis. See Neves *et al.* (1973, p. 40).

Biannulatisphaerites simplex Neville *in* Neves *et al.* 1973.
Plate 19, figure 1.
1973 *Biannulatisphaerites simplex* Neville *in* Neves *et al.*, p. 40, pl. 1, figs. 1, 2.
Holotype. Neves *et al.* (1973, pl. 1, fig. 1).
Diagnosis. See Neves *et al.* (1973, p. 40).

Buedingiisphaeridium Schaarschmidt emend. Lister 1970.

Type species. *B. permicum* Schaarschmidt 1963.
Diagnosis. See Lister (1970, p. 59, 61).

Buedingiisphaeridium pyramidale Lister 1970.
1970 *Buedingiisphaeridium pyramidale* Lister, p. 61, pl. 3, figs. 11-14.
Holotype. Lister (1970, pl. 3, fig. 12).
Diagnosis. See Lister (1970, p. 61).

Buedingiisphaeridium cf. *pyramidale.*
Plate 19, figure 4.

Remarks. The specimens recovered in this study have fewer (c.75%) thickened pyramidal ornamental elements than the type material.

Chomotriletes Naumova *ex* Naumova 1953.

Type species. *C. vedugensis* Naumova 1953.
Diagnosis. See Naumova (1939, p. 355).

Chomotriletes vedugensis Naumova 1953.
Plate 19, figure 2.
1953 *Chomotriletes vedugensis* Naumova, p. 58, pl. 7, figs. 21-22.
Lectotype. Naumova (1953, pl. 7, fig. 21).
Diagnosis. See Naumova (1953, p. 58).

Cymatiogalea Deunff emend. Rasul 1974.

Type species *C. margaritata* Deunff 1961.
Diagnosis. See Rasul (1974, p. 52).

Cymatiogalea cristata (Downie) Rauscher 1973.
Plate 19, figure 21.
1958 *Baltisphaeridium cristatum* Downie, p. 338-339, pl. 16, fig. 4.
1973 *Cymatiogalea cristata* (Downie) Rauscher, p. 65-66, pl. 1, fig. 21.
Holotype. Downie (1958, pl. 16, fig. 4).
Diagnosis. See Downie (1958, p. 338-339).

Cymatiogalea cuvillierii (Deunff) Deunff 1964.

Plate 19, figure 22.

1961 *Priscogalea cuvillierii* Deunff, p. 41, pl. 1, fig. 2.
1964 *Cymatiogalea cuvillierii* (Deunff) Deunff, p. 124.

Holotype. Deunff (1961, pl. 1, fig. 2).

Diagnosis. See Deunff (1961, p. 41).

Cymatiogalea multarea (Deunff) Eisenack *et al.* 1973.

Plate 19, figure 23.

1961 *Priscogalea multarea* Deunff, p. 41, pl. 1, fig. 5.
1973 *Cymatiogalea multarea* (Deunff) Eisenack *et al.*, p. 229.

Holotype. Deunff (1961, pl. 1, fig. 5).

Diagnosis. See Deunff (1961, p. 41).

Cymatiosphaera Wetzel ex Deflandre 1954.

Plate 19, figure 13.

Type species. *C. radiata* Wetzel 1933.

Diagnosis. See Deflandre (1954, p. 257).

Cymbosphaeridium Lister 1970.

Type species. *C. bikidium* Lister 1970.

Diagnosis. See Lister (1970, p. 145).

Cymbosphaeridium bikidium Lister 1970.

Plate 19, figures 27, 30.

1970 *Cymbosphaeridium bikidium* Lister, p. 64-65, pl. 6, figs. 1-9.

Holoype. Lister (1970, pl. 6, fig. 1).

Diagnosis. See Lister (1970, p. 64).

Dasydiacrodium Timofeev *ex* Deflandre & Deflandre-Rigaud 1962.

Type species. *D. eichwaldii* Timofeev 1959.

Diagnosis. See Timofeev (1959, p. 88).

Dasydiacrodium annosum Rasul 1974.

Plate 19, figure 18.

1974 *Dasydiacrodium annosum* Rasul, p. 67-68, pl. 2, fig. 9.

Holotype. Rasul (1974, pl. 2, fig. 9).

Diagnosis. See Rasul (1974, p. 67).

Diexallophasis Loeblich 1970.

Plate 19, figure 31.

Type species. *D. denticulata* (Stockmans & Willière) Loeblich 1970.

Diagnosis. See Loeblich (1970, p. 714).

Leiosphaeridia Eisenack emend. Downie & Sarjeant 1963

Plate 19, figure 3.

Type species. *L. baltica* Eisenack 1958.

Diagnosis. See Downie & Sarjeant (1963, p. 94).

Lophosphaeridium Timofeev ex Downie emend Lister 1970.

Plate 19, figure 26.

Type species. *L. rarum* Timofeev 1959.

Diagnosis. see Lister (1970, p. 61).

Micrhystridium Deflandre emend. Lister 1970.

Plate 19, figures 5, 6.

Type species. *M. inconspicuum* (Deflandre) Deflandre 1937.

Diagnosis. See Lister (1970, p. 77).

Multiplicisphaeridium Staplin emend. Turner 1984.

Plate 19, figure 9.

Type species. *M. ramispinosum* Staplin 1961.

Diagnosis. See Turner (1984, p. 120).

Polygonium Vavrdová 1966.

Type species. *P. gracile* Varvdová 1966.
Diagnosis. See Vavrdoá (1966, p. 412-413).

Polygonium gracile Vavrdová 1966.

Plate 19, figure 11.

1966 *Polygonium gracile* Vavrdová, p. 413-414, pl. 1, fig. 3, pl. 3, fig. 1, text-figs. 3b, 4b.

Holotype. Vavrdová (1966, pl. 1, fig. 3, text-fig. 3b).
Diagnosis. See Vavrdová (1966, p. 413-414).

Priscogalea Deunff emend. Rasul 1974.

Type species. *P. barbata* Deunff 1961.
Diagnosis. See Rasul (1974, p. 47).

Priscogalea cortinula Deunff 1961.

Plate 19, figure 9.

1961 *Priscogalea cortinula* Deunff, p. 41, pl. 1, figs. 8, 10.

Holotype. Deunff (1961, pl. 1, fig. 8).
Diagnosis. See Deunff (1961, p. 41).

Priscogalea fimbria Rasul 1974.

Plate 19, figure 20.

1974 *Priscogalea fimbria* Rasul, p. 47, pl. 3, figs. 1-2.

Holotype. Rasul (1974, pl. 3, fig. 1).
Diagnosis. See Rasul (1974, p. 47).

Stelliferidium Deunff 1974.

Type species. *S. striatulum* (Vavrdová) Deunff *et al.* 1974.
Diagnosis. See Deunff (1974, p. 13).

Stelliferidium simplex Deunff emend. Deunff *et al.* 1974.

Plate 19, figures 24, 25.

1961 *Stelliferidium simplex* Deunff, p. 41, pl. 1, fig. 9.
1974 *Stelliferidium simplex* Deunff emend Deunff *et al.*, p. 15.

Holotype. Deunff (1961, pl. 1, fig. 9).
Diagnosis. See Deunff *et al.* (1974, p. 41).

Timofeevia Vanguestaine 1978.

Type species. *T. lancariae* (Cramer & Diez) Vanguestaine 1978.
Diagnosis. See Vanguestaine (1978, p. 272).

Timofeevia acremonia Rasul 1979.

Plate 19, figure 10.

1979 *Timofeevia acremonia* Rasul, p. 68-69, pl. 3, fig. 9.

Holotype. Rasul (1979, pl. 3, fig. 9).
Diagnosis. See Rasul (1979, p. 68).

Veryhachium Deunff emend. Turner 1984.

Plate 19, figure 29.

Type species. *V. trisulcum* Deunff ex Deunff 1959.
Diagnosis. See Turner (1984, p. 139).

Veryhachium wenlockianum Downie *ex* Wall & Downie 1963.

Plate 19, figure 4.

1959 *Veryhachium tetraedon* var. *wenlockium* Downie, p. 62, pl. 12, figs. 9, 11.
1963 *Veryhachium wenlockianum* Downie *ex* Wall & Downie, p. 782.

Holotype. Downie (1959, pl. 12, fig. 9).
Diagnosis. See Downie (1959, p. 62).
Remarks. For a discussion on the validation and choice of specific epithet of this species see Fensome *et al.* (1990, p. 527).

5. DISCUSSION.

5.1. PALYNOSTRATIGRAPHIC CLASSIFICATION.

5.1.1. Strengths and weaknesses.

The boundaries between biozones are marked by the appearence and/or disappearence of one or more taxa, and, in some instances, by the stratigraphic upper or lower limits of species epiboles. Consequently the assignment of a particular fossil assemblage in isolation to a biozone may be difficult, although usually not impossible provided that it has a reasonable taxonomic diversity. The biostratigraphic classification is most readily applied to a range of assemblages spread over a stratigraphic interval , such that the appearences and extinctions of taxa can be observed and this is indeed the usual situation when dealing with the biostratigraphic analysis of off-shore well sections.

When plotted against an absolute chronostratigraphic time-scale (Figure 24) it is apparent that the palynostratigraphic resolution of the biozones is variable. There is a concentration of biozones and sub-biozones in the late Langsettian and Duckmantian. Rather than representing any greater increase in the evolution and extinction of miospore species over this stratigraphic interval, this probably represents a sampling bias. As shown in Figure 12, a disproportionate number of well sections in the database provide coverage over this interval. This is due primarily to the targetting of early Duckmantian prospects (e.g. the Murdoch reservoir sandstone and approximate equivalents) by Conoco (UK) Ltd. Furthermore, the existence of potentially economic prospects in this part of the succession has meant that a disproportionate amount of core has been drilled here. Therefore, the classification over this interval is based on large amounts of high-quality data, while other intervals have less coverage based on fewer cored sections.

In other parts of the Westphalian the well coverage is not so extensive (see Figure 12). Few wells penetrate into the middle and early Langsettian, although there is excellent coverage provided by the multi-well studies in Blocks 44/28 (McLean & Neves, 1993a) and 48/11b (McLean, 1991a). The lower parts of this interval (i.e. towards the base of the Langsettian) often display a reduction in sample quality in terms of both abundance and diversity of assemblages. The reasons for this remain uncertain. The drop in assemblage quality may be due

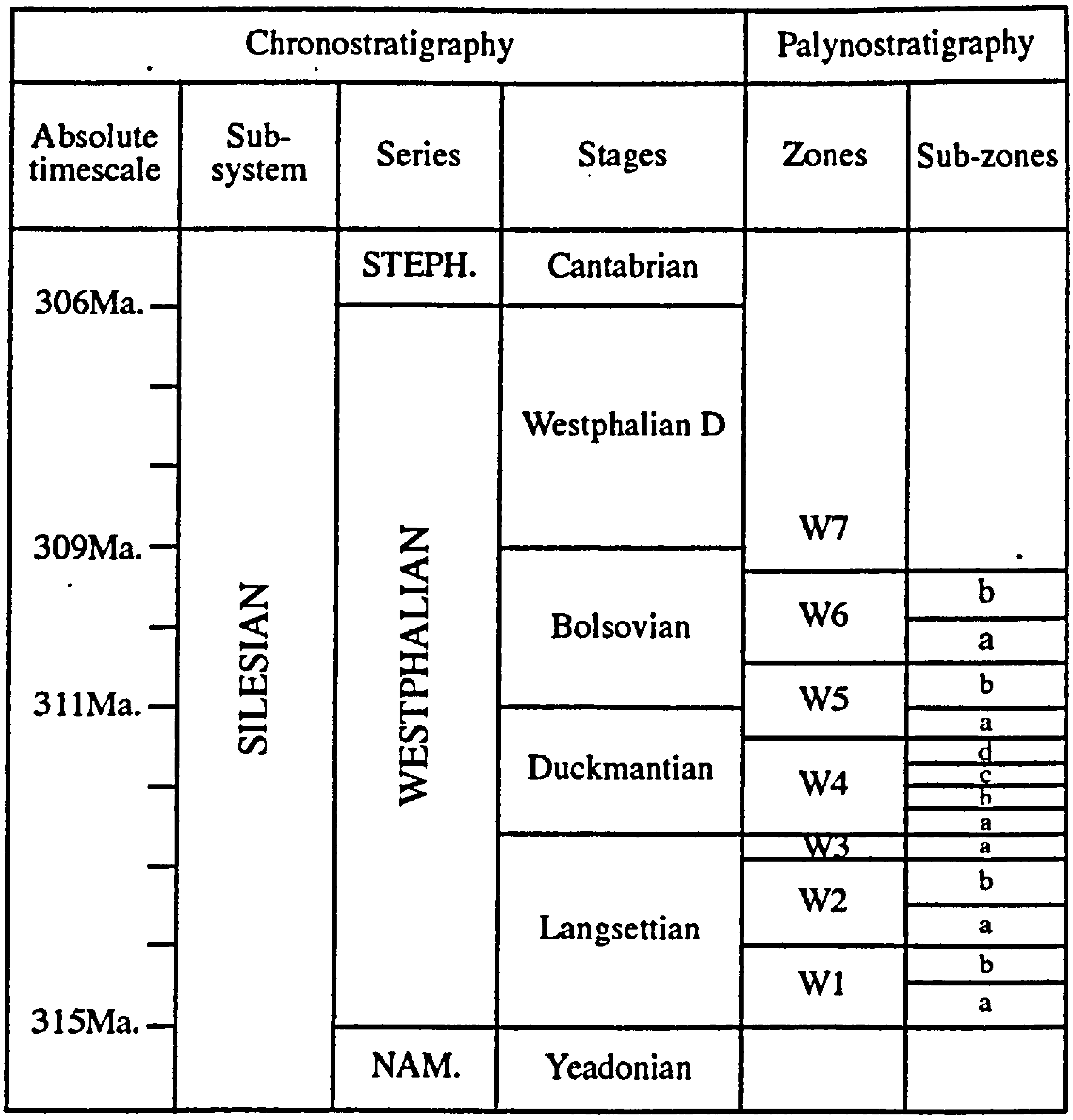


Figure 24. Summary of the Palynostratigraphic classification of the Westphalian of the Southern North Sea Carboniferous Basin. Absolute time scale after Lippolt *et al.* (1984) and Hess & Lippolt (1986).

to palaeoenvironmental or post-depositional preservational effects. In sand-prone parts of the sequence, such as often occur in the early Langsettian-late Namurian, assemblages may be locally mature, possibly due to thermal conductivity of sandbodies, or to the effects of oxidising groundwaters circulating within sandbodies. In any case, it is possible that a higher definition of biozones is not possible in the early Langsettian. Turner & Spinner (1993) suggest that the rate of evolution and extinction of microfloras in this part of the Silesian (at least in the Central Pennine Basin) is reduced, and hence less biostratigraphic resolution should be expected.

The reduction in biostratigraphic resolution above the Duckmantian is firstly due to the fact that few of the database wells penetrate the Bolsovian-Westphalian D. Until recently, exploration in the Silesian of the S.N.S.C.B. has concentrated on the structural highs where post Duckmantian section has been removed by pre-Permian erosion. With the recognition of Bolsovian-Westphalian D prospects (e.g. Besley *et al.*, 1993) it may be that more material over this interval will become available. Secondly, due to the red-bed nature of much of the sediments of this age, it seems likely that palynological resolution will remain limited. The results of careful sampling (e.g. Turner, 1990a, and, from onshore, 1991b) do hold promise for the future palynological subdivision of the Bolsovian and Westphalian D.

5.1.2. Definition of biozonal boundaries.

The published stratigraphic distributions of Silesian miospore taxa (e.g. Clayton *et al.*, 1977) show that changes in miospore assemblages are gradational. Range charts of species distributions characteristically have an ascending (or descending) sequence of miospore range tops and bases (e.g. see Figure 14c for a limited number of taxa). This may seem to indicate that the choice of inception or extinction datums which are selected to define biozone boundaries is therefore somewhat arbitrary. However, there are certain levels at which significant numbers of species appear and/or disappear which provide useful biostratigraphic markers and which are taken to define the biozonal boundaries. In reality, and on a small (centimetre) scale, the precise position of biozonal boundaries may be difficult to identify consistently and may be influenced by 'external' factors such as sample spacing. In practice it is generally preferable to define the biozonal boundaries as coincident with the bases of marine bands where possible. This achieves two things. Firstly, it means that the biozones may be relatable directly to the series and stages of the

Silesian, the stratotypes of which are defined by the bases of particular goniatite-bearing marine bands (Ramsbottom, 1981; Owens *et al.*, 1985). Secondly, because of this, much confusion caused by overlap of chronostratigraphic and biostratigraphic units and terminology is avoided.

It must be stressed that this apparent simplification of the positioning of the biozonal boundaries is justified by the actual stratigraphic distribution of miospores which appears to indicates a relationship between the development of marine bands and the evolution and extinction of miospore species. Neves and Ramsbottom (*in* Owens *et al.*, 1977) suggest that miospore evolution is related to competition for ecological niches as delta top environments expand and contract as a response to marine transgressions and regressions. It is probable that these fluctuating sea levels are of glacio-eustatic origin, driven by expansion and contraction of the Gondwanaland ice sheets (e.g. Heckel, 1990; Ross & Ross, 1985). There is therefore likely to be an element of evolutionary stress on the miospore-producing vegetation imparted by climatic oscillations, as well as by niche competition. Recent studies of Quaternary palaeoenvironments in the tropics suggest that glacial and interglacial floras were markedly different in their composition, and that changing tropical climatic conditions have had a profound effect upon evolutionary pressure and niche competition (Paul Colinvaux, *pers. comm.*). As research into tropical Quaternary palynology advances it is possible that this may provide an analogue for the palaeotropical (i.e. Euramerian) Carboniferous palynology which may aid the interpretation of Westphalian palynostratigraphic changes.

5.1.3. Comparison with other classifications.

Assemblages from the database well sections are correlatable with the onshore chronostratigraphy by reference to the regional palynostratigraphic classifications of Smith & Butterworth (1967) and Clayton *et al.* (1977). Several taxa (e.g. *Schulzospora rara, Radiizonates aligerens, Triquitrites sculptilis, Vestispora magna*) have directly comparable homotaxial stratigraphic ranges allowing a relatively simple correlation between on-shore and off-shore biozones (Figure 25). However, several of the critical taxa used in the S.N.S.C.B. classification have different stratigraphic ranges from those recognised onshore and, in some cases (e.g. *Anafoveosporites avcinii, Sinuspores* cf. *sinuatus Hymenospora murdochensis* sp. nov.), the taxa have not been reported previously from northwest Europe. A comparison of the ranges of critical miospore taxa from onshore and off-shore is shown in Figure 26. The existence of disparate

	Great Britain		Southern North Sea		Netherlands		Belgium	Ruhr	Northern France		Illinois	Iowa
SERIES	Clayton *et al*, (1977)	Smith & Butterworth (1967)	This study		van Wijhe & Bless (1974)	van der Laar & Fermont (1989)	Somers (1971)	Grebe (1972)	Loboziak (1971)	Coquel (1976)	Peppers (1985)	Ravn (1986)
Westphalian D (pars.)	OT	XI	W7		VI						MI	PD
Bolsovian	SL	X	W6	b	V	*V. fenestrata*	SC4	VII		Vb	RD	
				a					c1	Va		SG
		IX	W5	b	IV	*V. magna*	SC3	VI	b3		SF	
Duckmantian	NJ			a				V			NG	VA
		VIII	W4	d	III			IV	b2	IVc		
				c		*D. bireticulatus*	SC2	III	b1	IVb		
				b						IVa		
				a								
Langsettian	RA	VII	W3	a		*R. aligerens*	SC1	II	a1	III	SR	EP
		VI	W2	b	II			I		II		
				a								
	SS	V	W1	b	I				an	Ib	LP	
				a								
Yeadonian	FR									Ia		

Figure 25. Comparison of palynostratigraphic classifications of the Westphalian of northwest Europe and eastern U.S.A. Unnamed biozones of Loboziak (1971) are numbered C2 to C11 in ascending sequence.

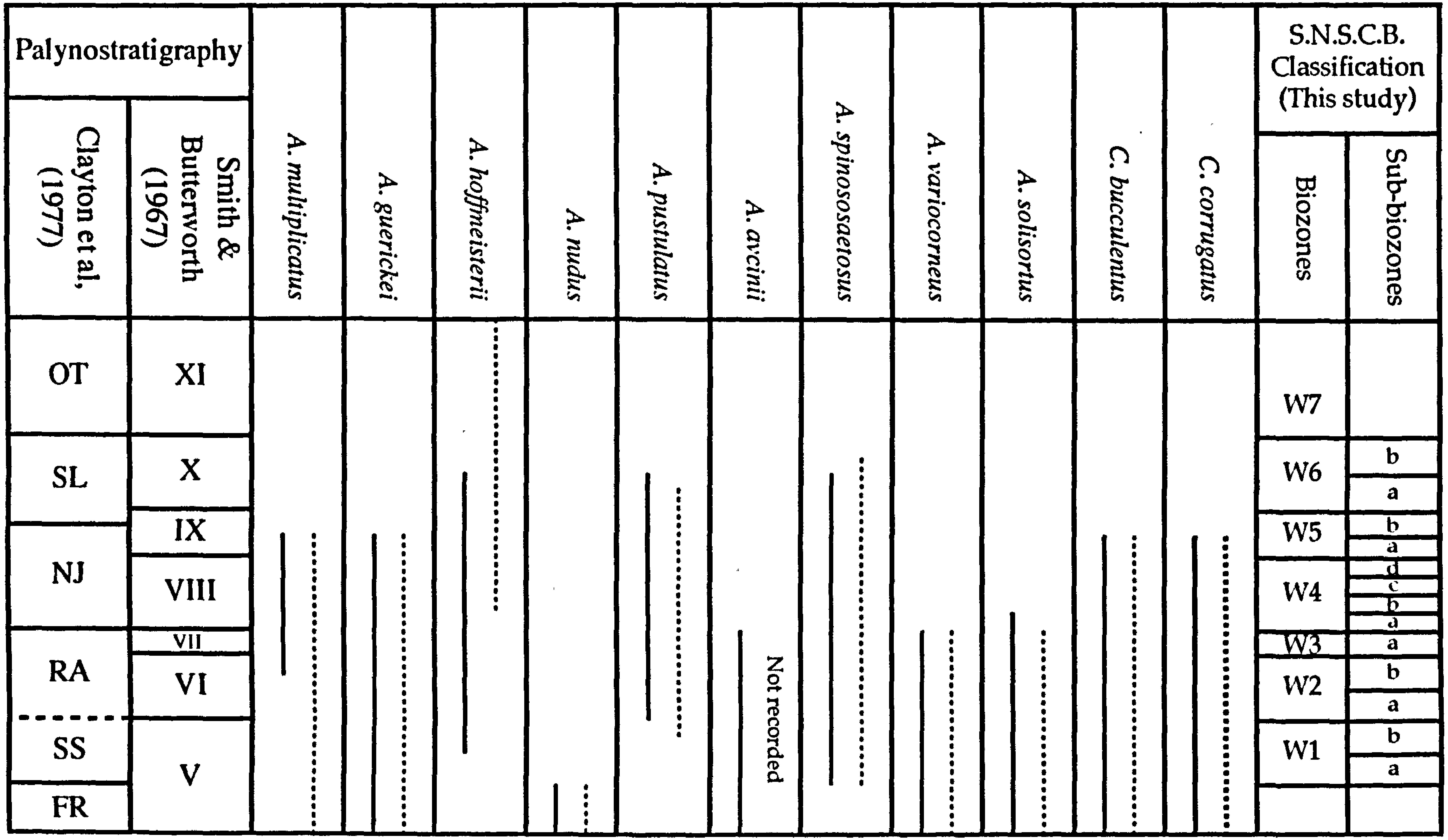


Figure 26a. Comparison of composite ranges of critical taxa in S.N.S.C.B. (solid line) with published ranges from onshore U.K. (dotted line). Onshore ranges from Smith & Butterworth (1967) and Butterworth (1984).

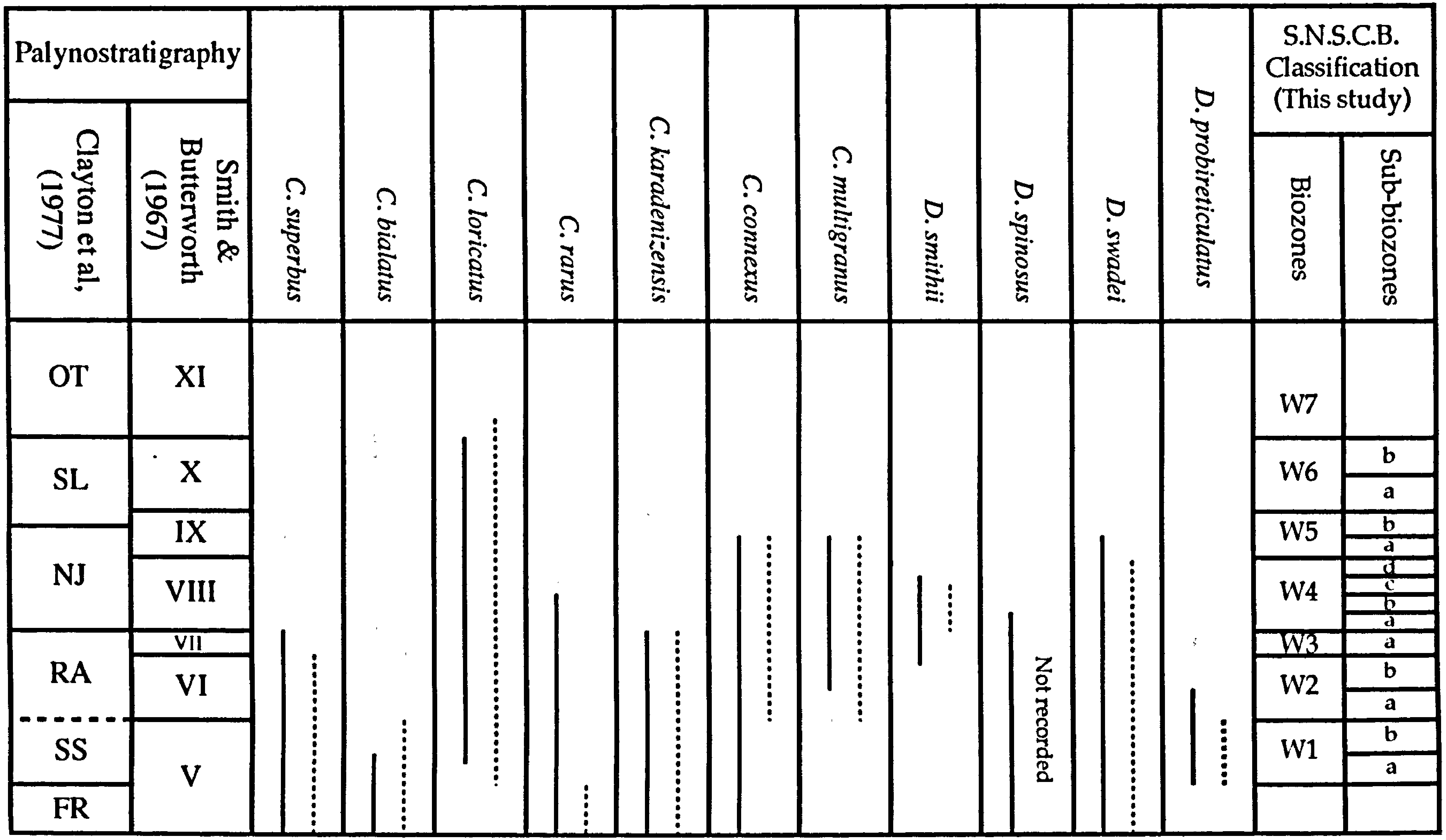


Figure 26b. Comparison of composite ranges of critical taxa in S.N.S.C.B. (solid line) with published ranges from onshore U.K. (dotted line). Onshore ranges from Smith & Butterworth (1967) and Butterworth (1984).

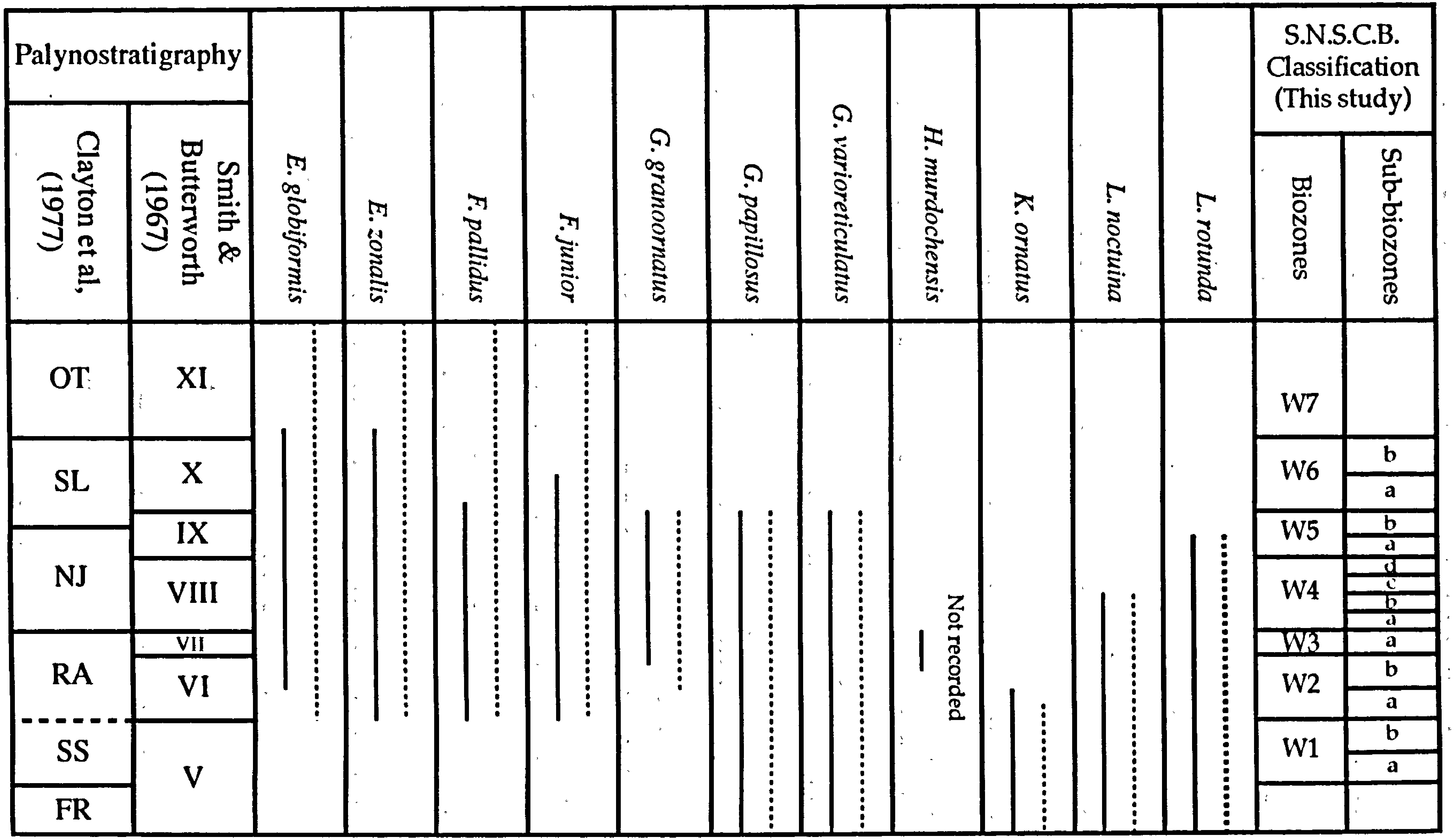


Figure 26c. Comparison of composite ranges of critical taxa in S.N.S.C.B. (solid line) with published ranges from onshore U.K. (dotted line). Onshore ranges from Smith & Butterworth (1967) and Butterworth (1984).

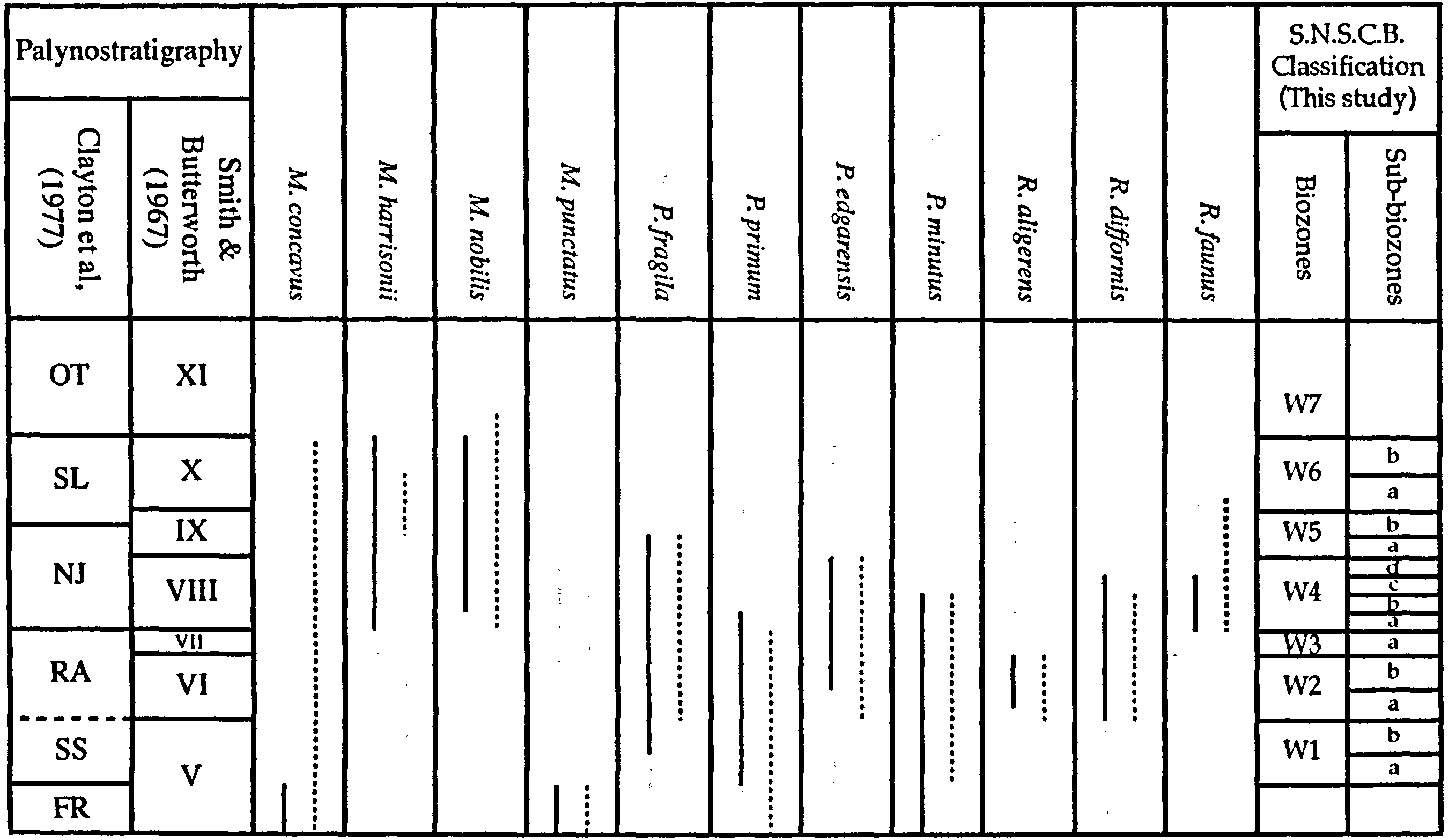


Figure 26d. Comparison of composite ranges of critical taxa in S.N.S.C.B. (solid line) with published ranges from onshore U.K. (dotted line). Onshore ranges from Smith & Butterworth (1967) and Butterworth (1984).

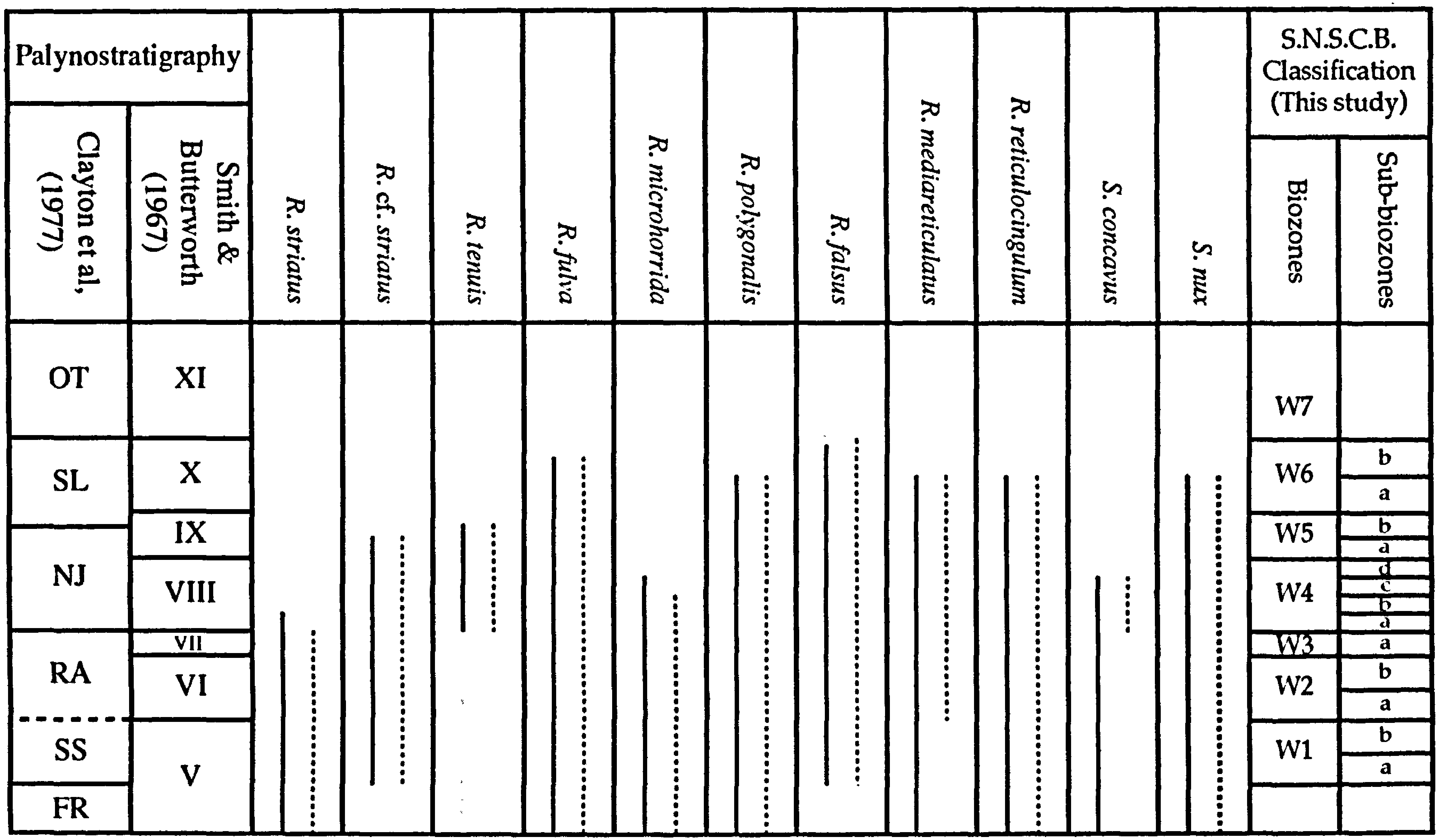


Figure 26e. Comparison of composite ranges of critical taxa in S.N.S.C.B. (solid line) with published ranges from onshore U.K. (dotted line). Onshore ranges from Smith & Butterworth (1967) and Butterworth (1984).

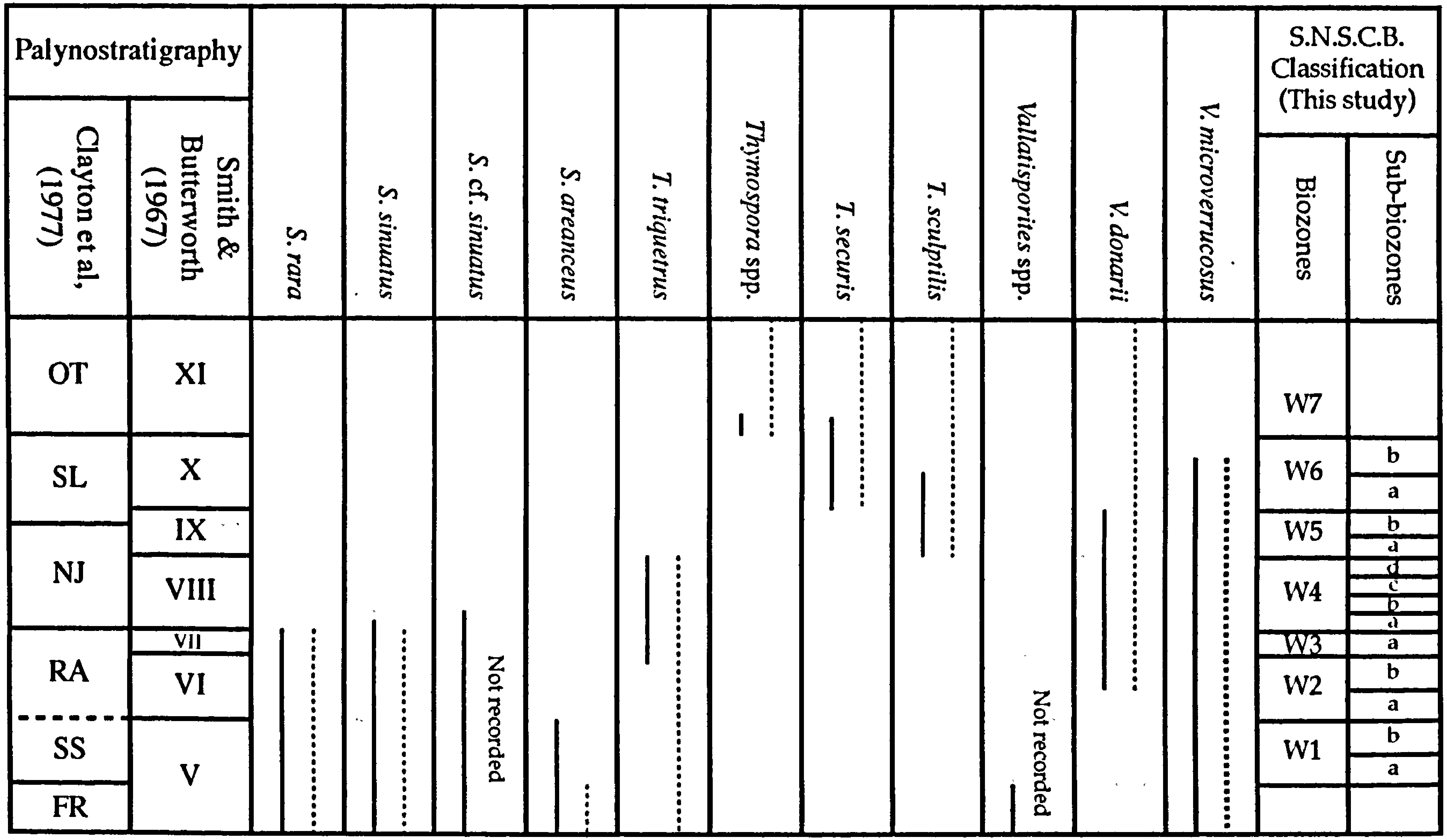


Figure 26f. Comparison of composite ranges of critical taxa in S.N.S.C.B. (solid line) with published ranges from onshore U.K. (dotted line). Onshore ranges from Smith & Butterworth (1967) and Butterworth (1984).

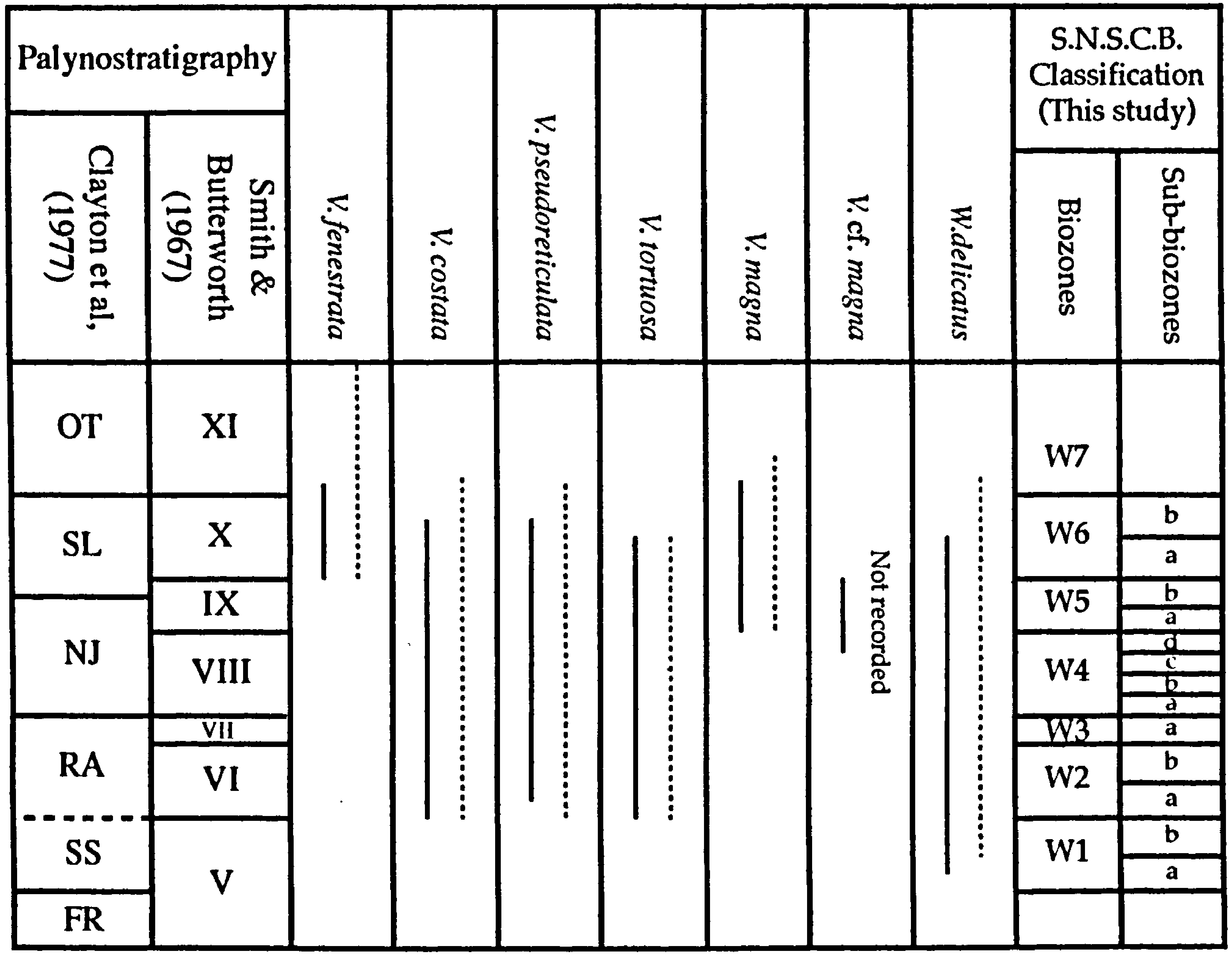


Figure 26g. Comparison of composite ranges of critical taxa in S.N.S.C.B. (solid line) with published ranges from onshore U.K. (dotted line). Onshore ranges from Smith & Butterworth (1967) and Butterworth (1984).

stratigraphic ranges in neighbouring sub-basins is, to some extent, to be expected as local palaeoenvironmental and sedimentological factors may conspire to extend or contract the apparent stratigraphic range of a particular taxon. It is hoped that the size of the data base is such as to present the true stratigraphic range of taxa on a sub-basinal scale but the existence of intra-basinal geographic and stratigraphic variation cannot be ruled out. Furthermore, the presence of conspicuous reworking of material into the S.N.S.C.B. (as discussed below) indicates the possibility of atrificially extended stratigraphic ranges.

5.2. ASPECTS OF THE PALYNOSTRATIGRAPHY OF THE MURDOCH GAS FIELD.

5.2.1. Stratigraphically restricted taxa.

Several of the taxa recorded from the well sections in the Murdoch Gas Field appear to have stratigraphically restricted ranges with range tops or bases encountered within the interval studied (Figure 27). Of particular note are the stratigraphic range tops of the taxa *Auroraspora? pickerillensis, Deltoidospora* aff. *tumida, Spelaeotriletes* cf. *oppletus,* and *Knoxisporites biceps,* and the stratigraphic range bases of *Pityosporites inaequus* and *Vestispora dubia,* which may help to define the base of the W4b sub-biozone. The base of the W4a sub-biozone may be further identified by the stratigraphic range bases of the taxa *Reticulitriletes* aff. *distortus, Protohaploxypinus* spp., *Raistrickia parvula, R. subcrinata, R. virgultorum, Spelaeotriletes* cf. *pretiosus, Endosporites pygmaeus, Converrucosisporites* aff. *vermiformis, Calamospora obtecta* and *Cycadopites* sp. A. It is possible that the ranges of these taxa may be useful in further defining or refining the palynostratigraphic subdivision of the S.N.S.C.B. Westphalian, although it should be recognised that further studies may extened these ranges.

5.2.2. Reworked taxa.

Palynological assemblages commonly contain reworked material although this is often overlooked or ignored (Streel & Bless, 1980). There are few published European records of palynomorphs reworked into sediments of Westphalian age. Bless & Streel (1976) described reworked middle Devonian to early Westphalian miospores from Bolsovian deposits of South Limburg. The

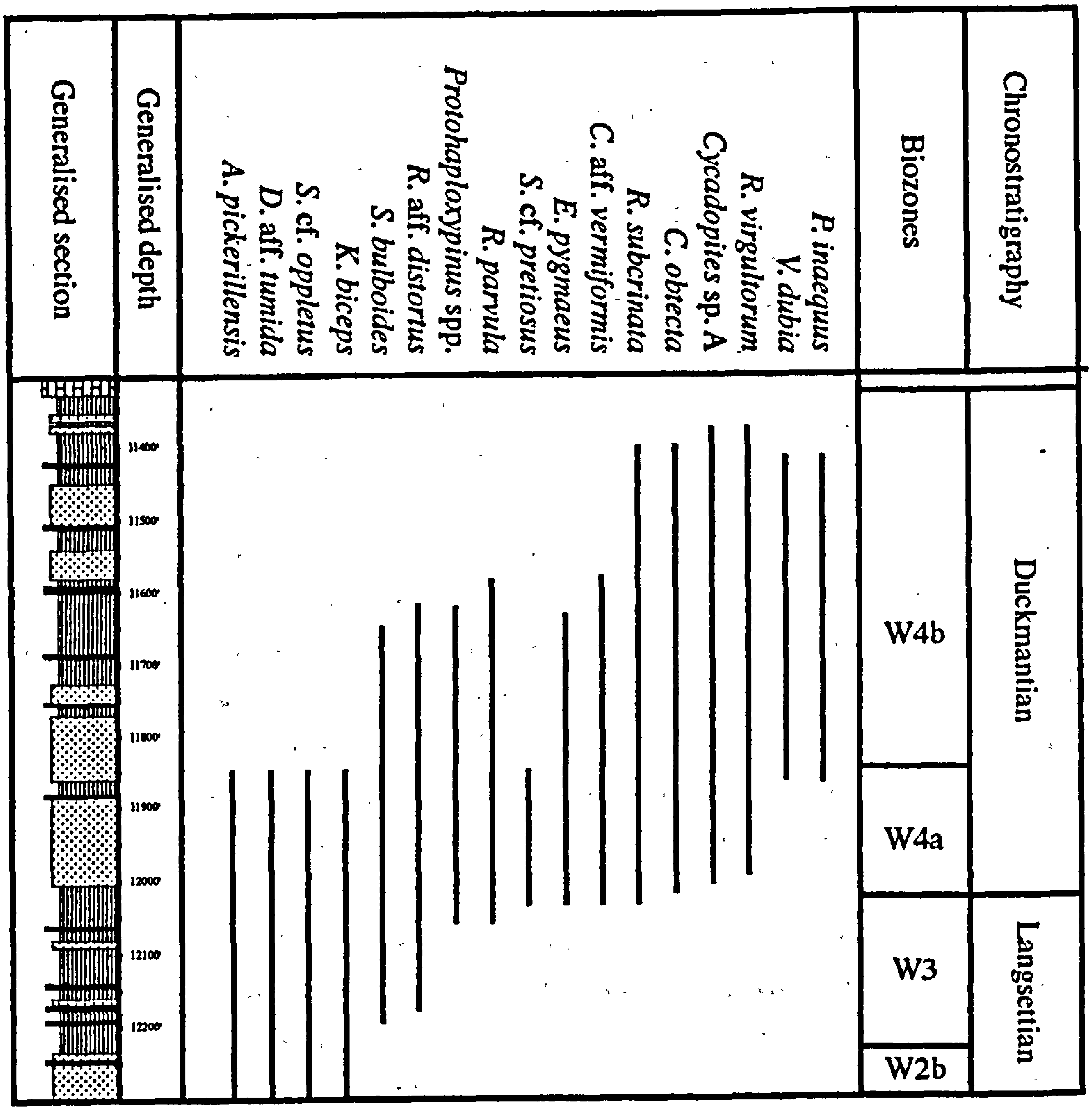


Figure 27. Generalised stratigraphic distribution of selected taxa in the Murdoch Field wells.

Netherlands, and also recorded reworked acritarchs. Van der Laar & Fermont (1989) described reworked miospores and acritachs from Langsettian to Bolsovian sequences of the same area. McLean (1992g) described acritachs and miospores of Tremadoc to Namurian age reworked into Langsettian sandstones in the Central Pennine Basin. Early Namurian miospores have been recovered from reworked coal pebbles in Duckmantian to Bolsovian deposits in Poland (Dembowski & Jachowicz, 1964). There are no published records of reworked palynomorphs from the S.N.S.C.B. although many industrial reports recognise the occurrence of reworking (e.g. Neves 1985b; McLean, 1992b).

Several taxa recovered from samples from the Murdoch Field wells may be considered to be reworked. This interpretation is made on the basis of anomalous spore (or acritarch) colour, indicative of higher thermal maturity of the reworked palynomorphs (Staplin, 1969; Legall *et al.*, 1981), and/or the recognition of distinctive morphographic types which are known to occur only in strata of a different age. In practice, the sole use of the latter criterion can lead to circular logic in the definition of the stratigraphic ranges of taxa and/or the identification of reworking. Therefore, in this study, taxa identified as reworked solely on the basis of their morphography are considered to be "possible reworking". Another indication of the presence of reworking is the recognition of marine palynomorphs (in this case acritarchs) in non-marine sediments. Due to the nature of dispersal of terrestrial palynomorphs into marine environments this is not applicable to the recognition of terrestrial palynomorphs in marine sediments. Finally, the recognition of a taxon in coal is taken to indicate that it is unlikely to be reworked, as sediment input (and hence the possibility of introduction of reworked material) into raised coal mires is limited (e.g. Spears, 1987). The potential for identifying contemporaneous taxa from their presence in coals is, however, limited by the fact that many taxa are rarely, if ever, represented in coal seam assemblages but may be common in non-coal lithologies (e.g. Neves, 1961).

Taxa which are considered to be reworked or possibly reworked are listed in Tables 3 and 4, with their likely original stratigraphic provenance. This list indicates that there are two principal ages of reworked material: Lower Palaeozoic (mainly Ordovician - Silurian) and Viséan to mid Namurian; with less well represented Cambrian and possible Devonian - Tournaisian ages.

Mapping of the pre-Permian subcrop in the southern North Sea indicates the presence of extensive exposures of Devonian to Namurian sediments around

TAXA	Present in Coals	Over-mature	Stratigraphic age
Verrucosisporites cf. *eximius*			Viséan
Tricidarisporites arcuatus		X	Viséan - Arnsbergian
Diatomozonotriletes rarus			Viséan
Bellispores nitidus		X	Viséan - early Langsettian
Rotaspora knoxii		X	Viséan - mid Pendleian
Rotaspora? xenica			Viséan
Stenozonotriletes coronatus	X		Viséan - Pendleian
Stenozonotriletes perforatus	X		Viséan
Kraeuselisporites echinatus			Viséan - mid Marsdenian
Kraeuselisporites ornatus			Viséan - mid Langsettian
Grandispora spinosa			Viséan - Arnsbergian
Rugospora corporata		X	Viséan - Marsdenian
Hymenozonotriletes explanatus		X	Tournaisian
Densosporites spinosus	X		Pendleian - Marsdenian
Vallatisporites vallatus		X	Viséan - Chokierian
Schulzospora campyloptera			Viséan - Marsdenian

Table 3. Reworked and possibly reworked miospore taxa encountered in the Murdoch Gas Field. Stratigraphic ages after Playford (1962), Neves *et al.* (1973), Butterworth (1984) & Higgs (1988).

TAXA	Present in Coals	Over-mature	Stratigraphic age
Acanthodiacrodium ignoratum			mid Cambrian
Acanthodiacrodium spinum		X	Tremadoc
Acanthodiacrodium unigminum		X	Cambrian
Baltisphaeridium spp.		X	Cambrian - Recent
Biannulatisphaerites simplex			Viséan - mid Pendleian
Buedingiisphaeridium pyramidale			Ludlow
Chomotriletes vedugensis		X	Frasnian
Cymatiogalea cristata		X	Early Ordovician
Cymatiogalea cuvillierii		X	Tremadoc
Cymatiogalea multarea		X	Tremadoc
Cymbosphaeridium bikidium		X	Ludlow
Dasydiacrodium annosum		X	Tremadoc
Diexallophasis spp.			Silurian - Viséan
Leiosphaeridia spp.		X	Precambrian - Recent
Micrhystridium spp.		X	Precambrian - Recent
Multiplicisphaeridium spp.			Cambrian - Triassic
Polygonium gracile		X	Arenig
Priscogalea cortinula		X	Tremadoc
Priscogalea fimbria		X	Tremadoc
Stelliferidium simplex		X	Tremadoc
Timofeevia acrimonia			Tremadoc
Veryhachium wenlockianum			Wenlock

Table 4. Reworked and possibly reworked acritarch taxa encountered in the Murdoch Gas Field. Stratigraphic ages after Fensome *et al.* (1990).

the margins of the Westphalian depositional centres in the S.N.S.C.B. (Leeder & Hardman, 1990) (Figure 28). These, no doubt to some extent reflect the Westphalian outcrop patterns although extensive thicknesses of Westphalian cover must have been removed beforehand. The presence of Viséan to mid-Namurian reworking in the Langsettian - Duckmantian sediments indicates that there was considerable erosion of sediments of these ages by the river systems which fed the S.N.S.C.B. from the North (Leeder, 1988a; Leeder & Hardman, 1990). Erosion was presumably concentrated around the basin margins whilst sediment was accumulating within the subsiding basin centre. The presence of Lower Palaeozoic reworking is somewhat more problematic. Seismic mapping indicates the possiblity that there are isolated outcrops of Lower Palaeozoic strata exposed though the Devonian cover in Quadrant 37 (Leeder & Hardman, 1990) and these, although relatively small, may have provided the source for the reworked material. Alternatively, the material may be far-travelled, being derived from Scandinavian Lower Palaeozoic outcrops. It is also possible that the Lower Palaeozoic material has undergone several cycles of reworking and redeposition, having been first reworked into Viséan-Namurian sediments and subsequently reworked (together with Upper Palaeozoic palynomorphs) into the Westphalian.

5.2.3. Striate Bisaccate and monocolpate palynomorphs.

Several taxa recorded from the Murdoch sections appear to have anomalous stratigraphic occurrences. Other than the reworked material described above, these belong to the morphographically distinct striate bisaccate (*Protohaploxypinus*) and monocolpate (*Cycadopites*) groups of palynomorphs. These morphographic types are more usually associated with sediments of Permian age or younger, and so their occurrence in Duckmantian strata deserves comment. It is possible that these palynomorphs represent contamination, either by downhole caving of material in cuttings samples, injection of contaminated drilling mud in core and sidewall core samples, and by intra-sample contamination in the laboratory. However, as striate bisaccate and monocolpate palynomorphs were recovered from core samples it is highly unlikely that their presence is due to downhole caving. In order to discount the possibilities of contaminated mud injection or laboratory contamination several samples of compact, relatively impermeable mudstones and claystones were carefully examined and found to contain no visible traces of injected mud. These samples were carefully reprocessed and were still found to contain striate bisaccate and monocolpate specimens. Furthermore, the preservation of

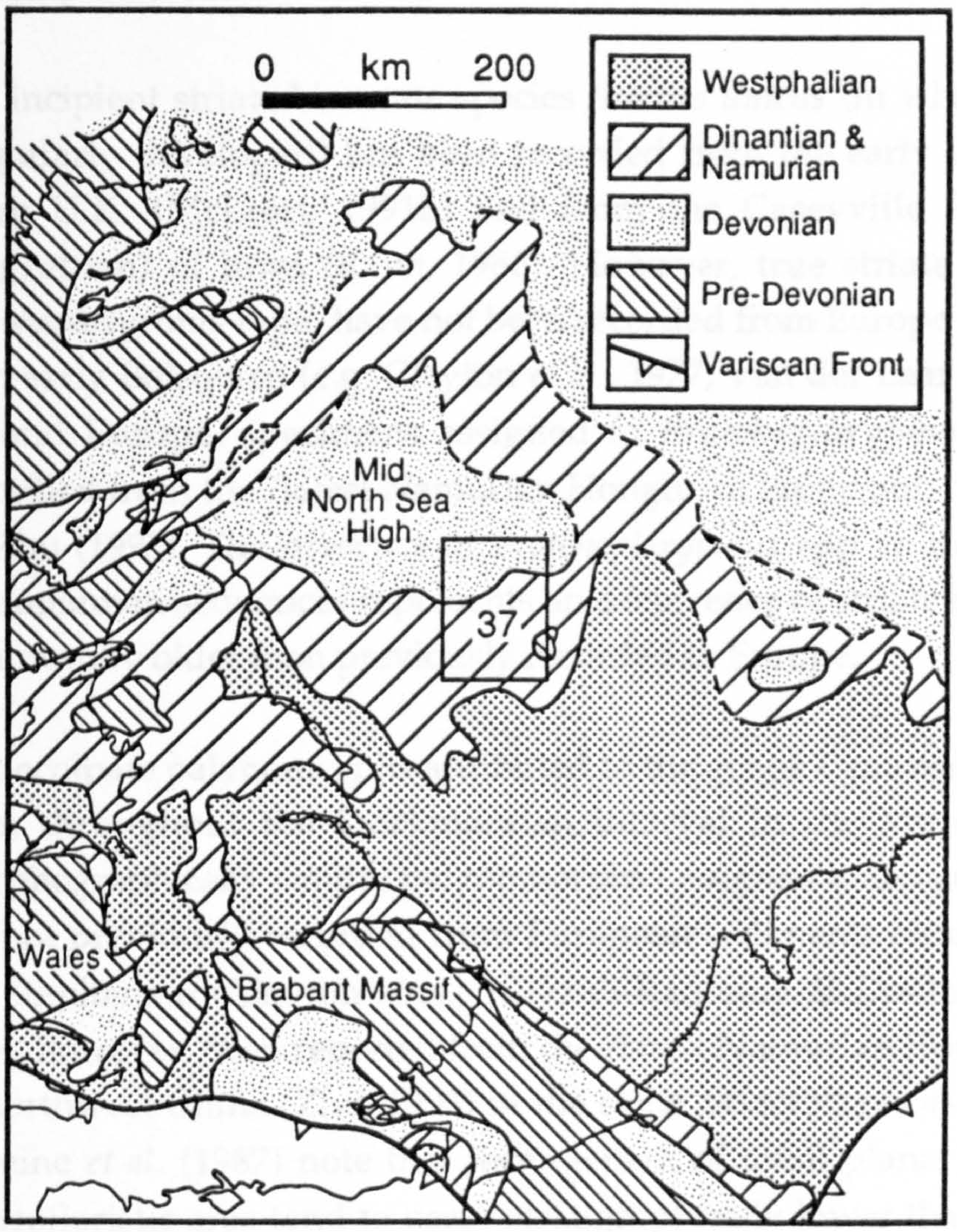


Figure 28. Pre-Permian subcrop map (after Leeder & Hardman, 1990).

the material is identical to that of the *in situ* Silesian material. i.e. it is of the same thermal maturity and has similar microbial or pyrite damage effects to other palynomorphs in the same assemblage. It seems likely that this material is contemporaneous.

The incipient striate bisaccate species *Illinites unicus* (in which the taeniae are irregularly developed) has been recorded from the early Langsettian of on-shore U.K. (McLean, 1991b) and from the Caseyville Formation (= late Langsettian) of Iowa (Ravn, 1986). However, true striate bisaccates, of the *Protohaploxypinus* type, have not been recorded from Europe in sediments older than early Bolsovian (e.g. Clayton *et al.*, 1977; Van der Laar & Fermont, 1989). Beyond Europe, specimens assigned to *Protohaploxypinus* sp. have been described from the ?latest Namurian Hongtuwa Formation of northwest China by Zhu (1993). The presence of *Protohaploxypinus* spp. in the Murdcoch Field Duckmantian sequences represents an occurrence of striate bisaccates which is significantly older than previously recorded in Europe.

Monocolpate palynomorphs attributed to the genus *Cycadopites* were recovered from throughout the Duckmantian interval in the Murdoch Field wells. Morphographically similar palynomorphs (assigned to the genus *Cheileidonites*) are not previously recorded from European sediments older than the base of the Stephanian (Clayton *et al.*, 1977; Pi-Radondy & Doubinger, 1968). They have, however, been reported from the ?latest Namurian Hongtuwa Formation of northwest China (Zhu, 1993) in the same assemblages as *Protohaploxypinus*. Laveine *et al.* (1987) note that form-genera of fossil plants in the Cathaysian palaeofloristic area tend to occur stratigraphically lower than in other parts of the Euramerian palaeofloristic kingdom (which includes northwest Europe). It would seem reasonable to suggest that this would also be true of dispersed palynomorph taxa. This, however, does not help to explain the apparently anomalous presence of these forms in the S.N.S.C.B.

Three possible explainations for this anomaly are suggested. 1. Specimens have gone unrecognised (unlikely due to their highly distinctive morphographies) or have been attributed to contamination by one method or another. 2. The microfloras in the Duckmantian of the S.N.S.C.B. in part represent an unusual vegetation which has not been represented in other northwest European basins. Given the palaeoenvironmental and sedimentological similarities of the on- and off-shore European Carboniferous basins, and the potential of bisaccate pollen grains for long distance distribution, this also seems unlikely. In any event, if this was the case striate bisaccate and monocolpate pollen would have been reported from the S.N.S.C.B. 3. The forms have been recognised but, due to the confidential and competetive nature of much of the biostratigraphy carried out in the S.N.S.C.B., have gone unreported in the public domain.

6. CONCLUSIONS.

The Westphalian successions in the Southern North Sea Carboniferous Basin have been divided into 7 biozones and 12 sub-biozones defined by the stratigraphic range tops and bases and epibole tops and bases of 77 critical miospore taxa. Due to the nature of the well database, these biozones are most refined in the late Langsettian and Duckmantian. Bolsovian and Westphalian D biozones are relatively coarsely defined due to poor representation of sections of this age in the database, and also to the red-bed nature of sediments of this age, which often precludes the recovery of good palynological assemblages. Early Langsettian biozones are of relatively low resolution, but this may be related to a reduced rate of species turnover at this time.

The biozones are relatable to onshore chronostratigraphic Stages via regional palynostratigraphic schemes. Analysis of the palynology of three Westphalian well sections in the Murdoch Gas Field (Block 44/22), coupled with the recognition of macrofossil faunas indicative of the Vanderbeckei Marine Band, allows direct calibration of part of the classification with the chronostratigraphy. It is to be hoped that future recognition of marine band faunas will allow the calibration of other parts of the classification. The ultimate test of the classification will be in its applicability to further well sections in the S.N.S.C.B.

Westphalian palynological assemblages from the Murdoch Field are well preserved and diverse. Reworked palynomorphs (mainly of Tremadoc Silurian and Namurian ages) are common. Unusually old specimens of striate bisaccate (*Protohaploxypinus*) and monocolpate (*Cycadopites*) pollen are recorded from the Duckmantian of these well sections.

7. REFERENCES.

ABBOTTS, I.L., (1991) (ed.). *United Kingdom oil and gas fields 25 years commemorative volume.* Geological Society Memoir, No. 14, The Geological Society, Bath, 1-573.

AGER, D.V., (1993). *The nature of the stratigraphic record.* John Wiley & Sons, Chichester, 1-151.

AGRALI, B., AKYOL, E., KONYALI, Y., CORSIN, P.M. & LAVEINE, J.P., (1965). Nouvelles formes des spores et pollens provant de charbons primaires et tertiaires de divers gisements turcs. *Annales de la Societé de Géologie du Nord,* 85, 169-176.

ALLEN, K.C., (1965). Lower and Middle Devonian spores of North and Central Vestspitsbergen. *Palaeontology,* 8, 687-748.

ALPERN, B., (1958). Description de quelque miospores du Permo-Carbonifère française. *Revue de Micropaléontologie,* 1, 75-86.

ALPERN, B., (1959). Contribution à l'étude palynologique et pétrographique des charbons française. *Privately published Ph.D. thesis, Université de Paris,* 1-314.

ALPERN, B. & DOUBINGER, J., (1973). Les microspores monolètes de Paleozoique. *C.I.M.P., Spores. Éditions du Centre National de la Recherche Scientifique, Paris,* 6, 1-3.

ALPERN, B., DOUBINGER, J. & HORST, U., (1965). Révision du genre *Torispora* Balme. *Pollen et Spores,* 7, 565-572.

ANDERSON, F.W., (1970). Carboniferous ostracoda - the genus *Carbonita* Strand. *Bulletin of the Geological Survey of Great Britain,* 32, 69-121.

ANDERSON, W. & DUNHAM, K.C., (1953). Reddened beds in the Coal Measures beneath the Permian of Durham and South Northumberland. *Proceedings of the Yorkshire Geological Society,* 29, 21-32.

ANDERTON, R., BRIDGES, H.P., LEEDER, M.R. & SELLWOOD, B.W., (1979). *A dynamic stratigraphy of the British Isles: a study in crustal evolution.* George Allen & Unwin, London, 1-301.

ARCHARD, G. & TRICE, R., (1990). A preliminary investigation into the spectral radiation of the Upper Carboniferous Marine Bands and its stratigraphic application. *Newsletter on Stratigraphy*, **21**, 167-173.

ARTÜZ, S., (1957). Die sporae dispersae der Turkischen Steinkohle von Zonguldak-Gebiet (mit besonderer Beachtung der neuen Arten und Genera). *Istanbul Üniversitesi fen Fakültesi Mecmuasi B*, **22**, 239-263.

ARTÜZ, S., (1971). A revision of the genus *Ibrahimispores* Artüz 1957 and its distributiion. *Istanbul Üniversitesi fen Fakültesi Mecmuasi B*, **36**, 107-113.

AZCUY, C.L., (1975). Miosporas del Namuriano y Westfaliano de la comarca Malanzan-Loma Larga, Provincia de la Rioja, Argentina. *Ameghiniana*, **12**, 1-163.

BAILEY, J.B., ARBIN, P., DAFFINOTTI, O., GIBSON, P.W. & RITCHIE, J.S., (1993). Permo-Carboniferous plays of the Silver Pit Basin. *In* PARKER, J.R. (ed.) *Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference.* The Geological Society, London, 707-715.

BALME, B.E., (1952). On some spore specimens from British Upper Carboniferous coals. *Geological Magazine*, **89**, 175-184.

BALME, B.E., (1957). Spores and pollen grains from the Mesozoic of Western Australia. *Commonwealth Science and Industrial Research Organisation. Fuel Research. Coal Section Technical Communication*, **25**, 1-48.

BALME, B.E. & HENNELLEY, J.P.F., (1955). Bisaccate sporomorphs from Australian Permian coals. *Australian Journal of Botany*, **3**, 89-98.

BARKLEY, F.A., (1934). The statistical theory of pollen analysis. *Ecology*, **15**, 283-289.

BENGTSON, P., (1988). Open nomenclature. *Palaeontology*, **31**, 223-227.

BERRY, W., (1937). Spores from the Pennington Coal, Rhea County, Tennessee. *American Midland Naturalist*, **18**, 155-160.

BESLEY, B.M., (1987). Sedimentological evidence for Carboniferous and early Permian palaeoclimates of Europe. *Annales de la Societé de Géologie du Nord*, **106**, 131-143.

BESLEY, B.M., (1988). Palaeogeographic implications of late-Westphalian to early Permian red beds, central England. *In*, BESLEY, B.M. & KELLING, G. (eds.), *Sedimentation in a synorogenic basin complex: the Upper Carboniferous of NW Europe*, Blackie, Glasgow, 200-221.

BESLEY, B.M., (1990). Carboniferous. *In* GLENNIE, K.W. (ed.), *Introduction to the petroleum geology of the North Sea*, Blackwell, Oxford, 3rd edition, 90-119.

BESLEY, B.M., BURLEY, S.D. & TURNER, B., (1992). The Late Carboniferous Red Bed play of the Southern North Sea. (Abstract). *4th Conference on the Petroleum Geology of NW Europe*, 144.

BESLEY, B.M., BURLEY, S.D. & TURNER, B., (1993). The late Carboniferous 'Barren Red Bed' play of the Southern North Sea. *In* PARKER, J.R. (ed.). *Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference*. The Geological Society, London, 727-740.

BHARADWAJ, D.C. & VENKATACHALA, B.S., (1962). Spore assemblages out of a Lower Carboniferous shale from Spitzbergen. *The Palaeobotanist*, **10**, 18-47.

BHARDWAJ, D.C., (1954). Einige neue Sporengattungen des Saarkarbons. *Neues Jahrbuch für Geologie und Paläontologie Monatschefte*, **11**, 512-525.

BHARDWAJ, D.C., (1955). The spore genera from the Upper Carboniferous coals of the Saar and their value in stratigraphical studies. *The Palaeobotanist*, **4**, 119-149.

BHARDWAJ, D.C., (1957). The palynological investigations of the Saar coals. *Palaeontographica B*, **101**, 73-125.

BLESS, M.J.M. & STREEL, M., (1976). The occurrence of reworked miospores in a Westphalian C microflora from South Limburg (The Netherlands) and its bearing on palaeogeography. *Mededelingen Rijks Geologische Dienst, Nieuwe Serie,* 27, 1-39.

BOTT, M.H., (1967). Geophysical investigations of the Northern Pennine basement rocks. *Proceedings of the Yorkshire Geological Society,* 36, 139-168.

BOWEN, J.M., (1991). 25 years of UK North Sea exploration. *In* ABBOTTS, I.L. (ed.) (1991). *United Kingdom Oil and Gas Fields, 25 Years Commemorative Volume,* Geological Society Memoir No. 14, 1-7.

BRAMAN, D.R. & HILLS, L.V., (1977). Palynology and paleoecology of the Mattson Formation, Northwest Canada. *Bulletin of Canadian Petroleum Geology,* 25, 582-630.

BROOKS, D. & THOMAS, K.W., (1967). The distribution of pollen grains on microscope slides. Part I. The non-randomness of the distribution. *Pollen et Spores,* 9, 621-629.

BUCK, S. & CUBITT, J.M., (1986). A comparison of the sedimentology and petrology of the Upper Carboniferous (Westphalian) strata in wells 44/22-1, 44/22-3 and 44/23-5 southern North Sea. *Unpublished report of The Geochem Group, report 1592, part 2,* 1-24.

BUTTERWORTH, M.A., (1984). Stratigraphical distribution of British Silesian miospore taxa (Abstract). *Pollen and Spore Biostratigraphy of the Phanerozoic in north-west Europe. Meeting of the British Micropalaeontological Society Palynology Group, Cambridge, 1984,* 2-9.

BUTTERWORTH, M.A., JANSONIUS, J., SMITH, A.H.V. & STAPLIN, F.L., (1964). *Densosporites* (Berry) Potonié and Kremp, and related genera. Report of C.I.M.P. working group no. 2. *5ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Paris, 1963,* 3, 1049-1057.

BUTTERWORTH, M.A. & MAHDI, S.A., (1982). Namurian and basal Westphalian A miospore assemblages from the Featherstone area, Northern England. *Pollen et Spores,* 24, 481-510.

BUTTERWORTH, M.A., MAHDI, S.A. & NADER, A.D., (1988). Miospores from the Westphalian A and B of northern England. *Pollen et Spores*, **30**, 57-80.

BUTTERWORTH M.A. & MILLOTT, J. O'N., (1954). Microspore distribution in the seams of the North Staffordshire, Cannock Chase and North Wales Coalfields. *Transactions of the Institute of Mining Engineers, London*, **114**, 501-520.

BUTTERWORTH, M.A. & MILLOTT, J.O'N., (1960). Microspore distribution in the coalfields of Britain. *Proceedings of the International Committee for Coal Petrology*, **3**, 157-163.

BUTTERWORTH, M.A. & WILLIAMS, R.W., (1954). Descriptions of nine species of small spores from the British Coal Measures. *Annals and Magazine of Natural History*, **7**, 753-764.

BUTTERWORTH, M.A. & WILLIAMS, R.W. (1958). The small spore floras of coals in the Limestone Coal Group and Upper Limestone Group of the Lower Carboniferous of Scotland. *Transactions of the Royal Society of Edinburgh*, **63**, 353-392.

CALVER, M.A., (1956). Die stratigraphische Verbreitung der nichtmarinen Muscheln in den penninischen Kohlenfeldern Englands. *Zeitschrift Deutsche Geologische Gesellschaft*, **107**, 26-39.

CALVER, M.A., (1968). Distribution of Westphalian marine faunas in northern England and adjoining areas. *Proceedings of the Yorkshire Geological Society*, **37**, 1-37.

CALVER, M.A., (1969). Westphalian of Britain. *Compte rendu, 6ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Sheffield, 1967*, **1**, 233-245.

CALVER, M.A., (1973). Marine fauna of the Westphalian B and C of the British Pennine coalfield. *Compte rendu, 7ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Krefeld, 1971*, **2**, 253-266.

CHADWICK, A.V., (1983). *Cappasporites*: a common Middle Pennsylvanian palynomorph. *Palynology*, **7**, 205-210.

CHALONER, W.G., (1951). On *Spencerisporites* gen. nov. and *S. karczewskii* (Zerndt), the isolated spores of *Spencerites insignis* Scott. *Annals and Magazine of Natural History*, **4**, 861-873.

CLAYTON, G., COQUEL, R., DOUBINGER, J., GUEINN, K.J., LOBOZIAK, S., OWENS, B. & STREEL, M., (1977). Carboniferous miospores of Western Europe: illustration and zonation. *Mededelingen Rijks Geologische Dienst*, **29**, 1-71.

CLEAL, C.J., (1991). Carboniferous and Permian biostratigraphy. *In* CLEAL, C.J. (ed.) *Plant fossils in Geological Investigations. The Palaeozoic.* Ellis Horwood, Chichester, 182-215.

CLIFT, S.G. & TRUEMAN, A.E., (1929). The sequence of non-marine lamellibranchs in the Coal Measures of Nottinghamshire and Derbyshire. *Quarterly Journal of the Geological Society*, **85**, 77-108.

COLLINSON, J.D., HOLDSWORTH, B.K., JONES, C.M. & MARTINSEN, O.J., (1992). Discussion of: 'The Millstone Grit (Namurian) of the southern Pennines viewed in the light of eustatically controlled sequence stratigraphy' by W.A. Read. *Geological Journal*, **27**, 173-180.

COLLINSON, J.D., JONES, C.M., BLACKBOURNE, C.A., BESLEY, B.M., ARCHARD, G.M. & McMAHON, A.H., (1993). Carboniferous depositional systems of the Southern North Sea. *In* PARKER, J.R. (ed.) *Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference.* The Geological Society, London, 677-687.

COOKSON, I.C., (1947). Plant microfossils from the lignites of Kergyelen Archipeligo. *British, Australian and New Zealand Antarctic Research Expedition 1929-31, Report A2*, 127-142.

COPE, J.C.W., INGHAM, J.K. & RAWSON, P.F. (eds.), (1992). *Atlas of palaeogeography and lithofacies.* Memoir of the Geological Society, No. 13, The Geological Society, London, 1-153.

COQUEL, R., (1976). Etude palynologique de la Série houillère dans l'unité de production de Valenciennes du Basin Houiller du Nord de la France. *Palaeontographica, B*, **156**, 12-64.

COQUEL, R., DOUBINGER, J. & LOBOZIAK, S., (1976). Les microspores-guides du Westphalien à l'Autunien de Europe occidentale. *Revue de Micropaléontolgie.*, 18, 200-212.

CORNFORD, C., (1984). Source rocks and hydrocarbons of the North Sea. *In* GLENNIE, K. (ed.), *Introduction to the Petroleum Geology of the North Sea.* Blackwells, Oxford, 171-205.

COUPER, R.R., (1953). Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *New Zealand Geological Survey Palaeontology Bulletin*, 22, 1-77.

COWAN, G, (1989). Diagenesis of Upper Carboniferous sandstones: southern North Sea Basin. *In* WHATELEY, M.K.G. & PICKERING, K.T. (eds.) (1989). *Deltas: Sites and Traps for Fossil Fuels.* Geological Society Special Publication No. 41, 57-73.

COWARD, M.P., (1990). The Precambrian, Caledonian and Variscan framework to NW Europe. *In* HARDMAN, R.F.P. & BROOKS, J. (eds.), *Tectonic Events Responsible for Britain's Oil and Gas Reserves*, Geological Society Special Publication, No. 55, 1-34.

CROOKALL, R., (1955). Fossil plants of the Carboniferous rocks of Great Britain. *Memoirs of the Geological Survey of Great Britain*, 4, 1-84.

DAVIES, J.H. & TRUEMAN, A.E., (1927). A revision of the non-marine lamellibranchs of the Coal Measures and a discussion of their zonal sequence. *Quarterly journal of the Geological Society of London*, 83, 210-259

DEFLANDRE, G., (1937). Microfossiles des silex crétacés. Deuxième partie. Flagellé incertae sedis. Hystrichosphaeridés. Sarcodinés. Organismes divers. *Annales de Paléonotologie*, 26, 51-103.

DEFLANDRE, G., (1954). Systématique des Hystrichospaeridés: sur l'acception du *Cymatiosphaera* O. Wetzel. *Compte rendu sommaire et bulletin de la Société de France*, 4, 257-258.

DEFLANDRE, G. & DEFLANDRE-RIGAUD, M., (1962). Nomenclature et systématique des Hystrichosphères (sens. lat.), observations et rectifications. *Revue de Micropaléontologie*, **4**, 190-196.

DELCOURT, A.F. & SPRUMONT, G., (1955). Les spores et grains de pollen du Wealdien du Hainaut. *Memoires de la Société Belge de Géologie, neue serie*, **4**, 1-73.

DEMBOWSKI, Z. & JACHOWICZ, A., (1964). Redeposited coal fragments and pebbles in the sandstones of the Orzez/Sze and Laziska Beds in the Miedzyrece Ig borehole. *Instytut Geologiczny Biuletyn*, **184**, 125-176.

DEMPSEY, J.E., (1967). Sporomorphs from Lower and Upper McAlester Coals (Pennsylvanian) of Oklahoma: An interim report. *Review of Palaeobotany and Palynology*, **5**, 111-118.

DETTMANN, M.E., (1963). Upper Mesozoic microfloras from southeastern Australia. *Proceedings of the Royal Society of Victoria*, **77**, 1-148.

DEUNFF, J., (1961). Un microplancton à Hystrichosphères dans le Tremadoc du Sahara. *Revue de Micropaléontologie*, **4**, 37-52.

DEUNFF, J., (1964). Systématique de microplancton fossile à Acritarches; révision de deux genres da l'Ordovicien inférieur. *Revue de Micropaléontologie*, **7**, 119-124.

DEUNFF, J., LEFORT, J-P. & PARIS, F., (1974). Le microplancton Ludlovien des Formations Immergées des Minquieres (Manche) et sa place dans la distribution du plancton Silurien. *Bulletin de la Société Géologique et Mineralogique de Bretagne, Séries C*, **3**, 9-28.

DEWEY, J.F., (1982). Plate tectonics and the evolution of the British Isles. *Journal of the Geological Society, London*, **139**, 371-412.

DIX, E., (1934). The sequence of floras in the Upper Carboniferous with special reference to South Wales. *Transactions of the Royal Society of Edinburgh*, **57**, 789-821.

DONATO, J.A., (1993). A buried granite batholith and the origin of the Sole Pit Basin, UK Southern North Sea. *Journal of the Geological Society, London*, **150**, 255-258.

DONATO, J.A. & MEGSON, J.B., (1990). A buried granite batholith beneath the East Midlands Shelf of the Southern North Sea Basin. *Journal of the Geological Society, London*, **147**, 133-140.

DÖRING, H., (1965). Die sporenpaläontologische Gliederung des Wealden in Westmecklenburg (Struktur Werle). *Geologie*, **47**, 1-118.

DOUBINGER, J. & HORST, U., (1961). *Torispora, Crassosporites* and *Bicolaria. CIMP, Krefeld, Compte rendu*, 29.

DOWNIE, C., (1958). An assemblage of microplankton from the Shineton Shales (Tremadocian). *Proceedings of the Yorkshire Geological Society*, **31**, 331-349.

DOWNIE, C., (1959). Hystrichospheres from the Silurian Wenlock Shale of England. *Palaeontology*, **2**, 56-71.

DOWNIE, C. & SARJEANT, W.A.S., (1963). On the interpretation and status of some hystrichosphere genera. *Palaeontology*, **6**, 83-96.

DOWNIE, C. & SARJEANT, W.A.S., (1965). Bibliography and index of fossil dinoflagellates and acritarchs. *Geological Society of America Memoir*, **94**, 1-180.

DYBOVÁ, S. & JACHOWICZ, A., (1957). Microspores of the Upper Silesian coal measures. *Prace Instytut Geologiczne*, **23**, 1-328.

EAGER, R.M.C., (1956). Additions to the non-marine fauna of the Lower Coal Measures of the North-Midlands coalfields. *Liverpool and Manchester Geological Journal*, **1**, 328-269.

EAGER, R.M.C., (1960). A summary of results of recent work on the palaeoecology of Carboniferous non-marine lamellibranchs. *Compte Rendu, 4eme Congrès International de Stratigraphie et de Géologie du Carbonifère, Heerlen, 1958*, **1**, 137-149.

EAGER, R.M.C., CHISHOLM, J.I., VARKER, W.J. & WILLIAMSON, I.A., (1991). A newly discovered Coal Measures marine band in Billinge Beacon Quarry, Lancashire and its stratigraphical significance. *Geological Journal*, **26**, 203-208.

EAMES, T.D., (1975). Coal rank and gas source relationships - Rotligendes reservoirs. *In* WOODLAND, A.W. (ed.), *Petroleum Geology and the continental shelf of NW Europe*. Applied Science Publishers, Barking, 191-201.

EBDON, C.C., FRASER, A.J., HIGGINS, A.C., MITCHENER, B.C. & STRANK, A.R.E., (1990). The Dinantian stratigraphy of the East Midlands: a seismostratigraphic approach. *Journal of the Geological Society, London*, **147**, 519-536.

EDEN, R.A., ELLIOTT, R.W., ELLIOTT, R.E. & YOUNG, B.R., (1963). Tonstein bands in the coalfields of the East Midlands. *Geological Magazine*, **100**, 47-58.

EISENACK, A., (1958). *Tasmanites* Newton 1875 und *Leiosphaeridia* n.g. als Gattungen der Hystrichosphaeridea. *Palaeontographica, A*, **110**, 1-19.

EISENACK, A., (1959). Neotypen baltischer Silur-Hystrichosphären und neue Arten. *Palaeontographica, A*, **112**, 193-211.

EISENACK, A., (1969). Zur systematik einiger paläozoischer Hystrichosphären (Acritarcha) des baltischen Gebietes. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **133**, 245-266.

EISENACK, A., CRAMER, F.H. & DIEZ, M. del C.R., (1973). *Katalog der fossilen Dinoflagellaten und verwandten Mikrofossilien. III Acritarcha 1*, E. Scweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1-1104.

ELLIOTT, R.E., (1968). Facies, sedimentation successions and cyclothems in productive Coal Measures in the East Midlands, Great Britain. *Mercian Geologist*, **2**, 351-371.

ERDTMAN, G., (1947). Suggestions for the classification of fossil and recent pollen grains and spores. *Svensk botanisk Tidskrift*, **41**, 104-114.

ERDTMAN, G., (1954). Some remarks on terms, diagnoses, classifications and methods in palynology. *Svensk botanisk Tidskrift*, **48**, 471-489.

EVANS, D.J., MENEILLY, A. & BROWN, G., (1992). Seismic facies analysis of Westphalian sequences of the southern North Sea. *Marine and Petroleum Geology*, **9**, 578-589.

EVANS, P.R., (1970). Revision of the miospore genera *Perotrilites* Erdtm. ex Couper 1953 and *Diaphanospora* Balme and Hassell 1962. *Australian Bureau of Mineral Resources, Geology and Geophysics Bulletin*, **116**, 65-82.

EVITT, W.R., (1963). A discussion and proposals concerning fossil dinoflagellates, hystrichospheres, and acritarchs. I. *Proceedings of the National Academy of Sciences of the United States of America*, **49**, 158-164.

FELIX, C.J. & BURBRIDGE, P.P., (1961). *Pteroretis*, a new Mississippian spore genus. *Micropaleontology*, **7**, 491-495.

FELIX, C.J. & BURBRIDGE, P.P., (1967). Palynology of the Springer Formation of southern Oklahoma, U.S.A., *Palaeontology*, **10**, 394-425.

FELIX, C.J. & PADEN, P., (1964). A new Lower Pennsylvanian spore genus. *Micropaleontology*, **10**, 330-332.

FELIX, J., (1894). Studien über fossile Pilze. *Zeitschrift Deutsche Geologische Gesellschaft*, **46**, 269-280.

FENSOME, R.A., WILLIAMS, G.L., BARSS, M.S., FREEMAN, J.M. & HILL, J.M. (1990). Acritarchs and fossil prasinophytes: an index to genera, species and infraspecific taxa. *American Association of Stratigraphic Palynologists Contributions Series*, **25**, 1-771.

FIELDING, C.R., (1982). Sedimentology and stratigraphy of the Durham Coal Measures and comparison with other British Coalfields. *Unpublished Ph.D. thesis, University of Durham.*

FIELDING, C.R., (1984)a. A coal depositional model for the Durham Coal Measures of N.E. England. *Journal of the Geological Society of London*, **141**, 919-931.

FIELDING, C.R., (1984)b. Upper delta plain lacustrine and fluviolacustrine facies from the Westphalian of the Durham Coalfield. *Sedimentology*, **31**, 547-564.

FIELDING, C.R., (1986). Fluvial channel and overbank deposits from the Westphalian of the Durham Coalfield, N.E. England. *Sedimentology*, **33**, 119-140.

FRANCIS, E.H., (1956). The economic geology of the Stirling and Clackmannon Coalfield, Scotland. Area North of the River Forth. *Coalfield Papers of the Geological Survey of Great Britain*, **1**, 1-36.

FRASER, A.J. & GAWTHORPE, R.L., (1990). Tectono-stratigraphic development and hydrocarbon habitat of the Carboniferous in northern Britain. *In*: HARDMANN, R.F.P. & BROOKS., J. (eds.), *Tectonic Events Responsible for Britain's Oil and Gas Reserves*, Geological Society Special Publication No. 55, 49-86.

FRASER, A.J., NASH, D.F., STEELE, R.P. & EBDON, C.C., (1990). A regional assessment of of the intra-Carboniferous play of northern England. *In*: BROOKS, J. (ed.), *Classic Petroleum Provinces*. Geological Society Special Publication No 50, 417-440.

FROST, R.T.C., FITCH, F.J. & MILLER, J.A., (1981). The age and nature of the crystalline basement of the North Sea Basin. *In* ILLING, L.V. & HOBSON, G. (eds), *The Petroleum Geology of the Continental Shelf of NW Europe*, Heyden, London, 43-57.

FULTON, I.M. & WILLIAMS, H., (1988). Palaeogeographical change and controls on Namurian and Westphalian A/B sedimentation at the southern margin of the Pennine Basin, Central England. *In* BESLEY, B.M. & KELLING, C.R. (eds.), *Sedimentation in a Synorogenic Basin Complex - The Carboniferous of Northwest Europe*. Blackie, Glasgow & London, 178-199.

GAO, L. & WANG, S., (1984). Carboniferous and Permian spores and pollen. *In Palaeontological Atlas of North China III*. Tianjing Institute of Geology & Mineral Resources, Geological Publishing House, Beijing, 313-440; english summary 709-710.

GEORGE, T.N., (1928). *Spirifer pennystonensis* sp. nov. from the Coal Measures of Coalbrookdale. *Annals and Magazine of Natural History*, **1**, 108-112.

GEORGE, T.N., JOHNSON, G.A.L., MITCHELL, M., PRENTICE, J.E., RAMSBOTTOM, W.H.C., SEVASTOPULO, G.D. & WILSON, R.B., (1976). A correlation of Dinantian rocks in the British Isles. *Geological Society of London, Special Report*, **7**, 1-87.

GEORGE, T.N. & WAGNER, R.H., (1972). I.U.G.S. Subcommission on Carboniferous Stratigraphy. Proceedings and report on the general assembly at Krefeld, August 21-22. *Compte Rendu, 7ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Krefeld, 1981*, **1**, 139-147.

GIBBS, A.D., (1986). Strike-slip basins and inversion: a possible model for the southern North Sea gas areas. *In* BROOKS, J., GOFF, J.C. & VAN HOORNE, B. (eds.), *Habitat of Palaeozoic Gas in Northwest Europe.* Geological Society Special Publication No. 23, 23-35.

GLENNIE, K.W., (1986). The structural framework and the pre-Permian history of the North Sea area. *In* GLENNIE, K.W. (ed.) *Introduction to the Petroleum Geology of the North Sea*. Blackwell Scientific Publications, Oxford, 2nd edition, 25-62.

GLENNIE, K.W., (1990). Outline of North Sea history and structural framework. *In* GLENNIE, K.W. (ed.) *Introduction to the Petroleum Geology of the North Sea*. Blackwell Scientific Publications, Oxford, 3rd edition, 34-77.

GLENNIE, K.W., BROOKS, J. & BROOKS, J.R.V., (1987). Hydrocarbon exploration and geological history of North West Europe. *In* BROOKS, J. & GLENNIE, K.W. (eds.). *Petroleum Geology of North West Europe*, Graham & Trotman, London, vol. 1, 1-10.

GLENNIE, K.W. & BOEGNER, P.L.E., (1981). Sole Pit inversion tectonics. *In* ILLING, L.V. & HOBSON, D.G., (eds), *Petroleum Geology of the continental Shelf of North West Europe*, Institute of Petroleum, London, 25-34.

GREBE, H., (1971). A recommended terminology and descriptive method for spores. *C.I.M.P., Spores. Éditions du Centre National de la Recherche Scientifiques*, **4**, 7-34.

GREBE, H., (1972). Die Verbreitung der Mikrosporen im Ruhrkarbon von den Bochumer Schichten bis zu den Dorstener Schichten (Westfal A-C). *Palaeontographica, B,* **140**, 27-115.

GREEN, C. & SLATT, R.M., (1992). Complex braided stream depositional model for the Murdoch Field Block 44/22 UK Southern North Sea (Abstract). *Braided rivers. Form process and economic applications,* Geological Society, London, 16.

GREUTER, W. & McNEILL, J. (eds.), 1988. *International Code of Botanical Nomenclature (adopted by the Fourteenth International Congress, Berlin, July-August 1987).* Regnum Vegetale, 118, Koeltz Scientific Books, Koehigstein, Gemany, 1-328.

GORE, A.J.P., (1983). Introduction. *In* GORE, A.J.P. (ed.) *Ecosystems of the world. Volume 4a, mires: swamp, bog, fen and moor, general studies,* Elsevier, Amsterdam, 1-34.

GUEINN, K.J., (1969). An investigation into the Namurian and Westphalian spores and pollen of the Midland Valley of Scotland. *Unpublished Ph.D. thesis, University of Sheffield,* 1-296.

GUENNEL, G.K., (1958). Miospore analysis of the Pottsville Coals of Indiana. *Bulletin Indiana Department of Conservation Geological Survey,* **13**, 1-101.

GUION, P.D., (1978). Sedimentation of interseam strata and some relationships with coal seams in the East Midlands Coalfield. *Unpublished Ph.D. thesis, Council for National Academic Awards.*

GUION, P.D. & FIELDING, C.R., (1988). Westphalian A and B sedimentation in the Pennine Basin, UK. *In* BESLEY, B.M. & KELLING, C.R. (eds.), *Sedimentation in a Synorogenic Basin Complex - The Carboniferous of Northwest Europe.* Blackie, Glasgow & London, 153-177.

GUNN, R., HWANG, N.J., MURRAY, I. & REZIGH, A., (1993). Teamwork brings success in Quad 44 - the Murdoch Field development. *Newsletter of the Petroleum Exploration Society of Great Britain, February, 1993,* 4-7.

HABIB, D., (1966). Distribution of spore and pollen assemblages in the Lower Kittanning Coal of western Pennsylvania. *Palaeontology*, **9**, 629-666.

HACQUEBARD, P.A., (1957). Plant spores in coal from the Horton Group (Mississippian) of Nova Scotia. *Micropaleontology*, **3**, 301-324.

HAGEMANN, H.W., (1966). Vergleichende mikropetrographische und sporologische Untersuchungen der Flöze Zollverein 105 aus den Mittleren Essener Schichten (Westfal B) des Ruhrkarbons im Rahmen der Flözparallelisierung. *Fortschritten in der Geologie von Rheinland und Westfalen*, **13**, 787-860.

HANCOCK, J.M., (1977). The historic development of biostratigraphic correlation. *In* KAUFFMAN, E.G. & HAZEL, J.E. (eds.), *Concepts and methods of biostratigraphy*. Dowden, Hutchinson & Ross, Stroudsburg, Pennsylvania, 3-22.

HARLAND, W.B., COX, A.V. LLWELLYN, P.G., PICKTON, C.A.G., SMITH, A.G. & WALTERS, R., (1982). *A Geologic Time Scale.* Cambridge University Press, Cambridge, 1-131.

HART, G.F., (1961). Microfloral assemblages from the Ketewaka-Mchuchuma and Songwe-Kiwira Coalfields, Tanganyika, East Africa. *Unpublished Ph.d. thesis, University of Sheffield*, 1-162.

HART, G.F., (1964). A review of the classification and distribution of the Permian miospore: *disaccate striatiti. Compte Rendu, 5éme Congrès International de Stratigraphie et de Géologie du Carbonifère, Paris, 1963*, **3**, 1171-1199.

HASZELDINE, R.S., (1984). Carboniferous North Atlantic palaeogeography: stratigraphic evidence for rifting, not megashear or subduction. *Geological Magazine*, **121**, 442-463.

HASZELDINE, R.S. & ANDERTON, R. (1980). A braidplain facies model for the Westphalian B Coal Measures, North East England. *Nature*, **243**, 51-53.

HECKEL, P.H., (1990). Evidence for global (glacio-eustatic) control over upper Carboniferous (Pennsylvanian) cyclothems in midcontinent North America. *In* HARDMANN, R.F.P. & BROOKS, J., (eds.), *Tectonic Events Responsible for Britain's Oil and Gas Reserves*, Geological Society Special Publication, No. 55, 33-47.

HEDBERG, H.D. (ed.), (1976). *International Stratigraphic Guide.* John Wiley & Sons, London, 1-200.

HEDEMANN, H.A., (1985). Importance of Carboniferous rocks for the production of hydrocarbons in the North Sea Basin and adjacent onshore areas. *Compte Rendu, 9éme Congrès International de Stratigraphie et de Géologie du Carbonifère, Washington & Champagne-Urbana, 1979*, **4**, 81-98.

HELBY, R.J., (1966). Sporologische Untersuchungen an der Karbon/Perm-Grenze im Pfälzer Bergland. *Fortschritten in der Geologie von Rheinland und Westfalen*, **13**, 645-704.

HERRON, M.M. & HERRON, S.L., (1990). Geological applications of geochemical well logging. *In* HURST, A., LOVELL, M.A. & MORTON, A.C. (eds.), *Geological Applications of Wireline Logs.* Geological Society Special Publication No. 48, 165-175.

HESS, J.C. & LIPPOLT, H.J., (1986). ^{40}Ar/^{39}Ar ages of tonstein and tuff sanidines: new calibration points for the improvement of the Upper Carboniferous time scale. *Isotope Geoscience*, **59**, 143-154.

HIGGS., K. (1975). Upper Devonian and Lower Carboniferous miospore assemblages from Hook Head, County Wexford, Ireland. *Micropalaeontology*, **21**, 393-419.

HIGGS, K., (1988). *Stratigraphic and systematic palynology of the Tournaisian rocks of Ireland.* The Geological Survey of Ireland Special Publication No. 7, 1-93.

HIGGINS, A.C., (1975). Conodont zonation of the late Viséan - early Westphalian strata of the south and central Pennines of Northern England. *Bulletin of the Geological Survey of Great Britain*, **53**, 1-90.

HIGGINS, A.C., (1985). The Carboniferous System: Part 2 - Conodonts of the Silesian Subsystem from Great Britain and Ireland. *In* HIGGINS, A.C. & AUSTIN, R.L. (eds.) *A stratigraphical index of conodonts.* British Micropalaeontological Society Series, Ellis Horwood Ltd., Chichester, 210-227.

HOFFMEISTER, W.S., STAPLIN, F.L. & MALLOY, R.E., (1955). Mississippian plant spores from the Hardinsburg Formation of Illinois and Kentucky. *Journal of Paleontology*, **29**, 372-399.

HOLLYWOOD, J. & WHORLOW, C., (1993). Structural development and hydrocarbon occurrence of the Carboniferous in the UK southern North Sea Basin. *In* PARKER, J.P. (ed.). *Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference,* The Geological Society, London, 689-696.

HORST, U., (1943). Mikrostratigraphischer Beitrag zum Vergleich des Namurs von West-Oberschleisen und Märisch-Ostrau. Die Mega- und Mikrosporen der hauptsächlichen Flöze beide Reviere. *Thesis, Technische Hochschule, Berlin.*

HORST, U., (1955). Die sporae dispersae des Namurs von Westoberschlesien und Mährisch-Ostrau. *Palaeontographica, B*, **98**, 137-236.

HUDSON, R.G.S., (1945). The goniatite zones of the Namurian. *Geological Magazine*, **82**, 1-9.

HUDSON, R.G.S. & TURNER, J.S., (1930). Early and mid-Carboniferous earth movements in Great Britain. *Proceedings of the Leeds Philosophical Society (Science Section)*, **2**, 455-466.

HUGHES, N.F., DETTMANN, M.E. & PLAYFORD, G., (1962). Sections of some Carboniferous dispersed spores. *Palaeontology*, **5**, 247-252.

HUGHES, N.F. & PLAYFORD, G., (1961). Palynological reconnaissance of the Lower Carboniferous of Spitsbergen. *Micropaleontology*, **7**, 27-44.

HURST, A., LOVELL, M.A. & MORTON, A.C., (EDS.) (1990) *Geological applications of wireline logs*. The Geological Society Special Publication No. 48, 1-357.

IBRAHIM, A.C., (1933). *Sporenformen des Ägirhorizonts des Ruhr-Reviers.* Konrad Triltsch, Würzburg, 1-47.

IMGRUND, R., (1960). Die Sporites des Kaipingbeckens, ihre paläontologische und stratigraphische Bearbeitung im Hinblick auf eine Parallelisierung mit dem Ruhrkarbon und dem Pennsylvanian von Illinois. *Geologisches Jahrbuch*, **77**, 143-204.

ISCHENKO, A.M., (1952). Atlas of the microspores and pollen of the Middle Carboniferous of the western part of the Donets Basin. *Izdatel'stvo Akademii Nauk Ukrainskoy S.S.R.*, 1-83.

ISCHENKO, A.M., (1956). Spores and pollen of the Lower Carboniferous deposits of the western extension of the Donets Basin and their stratigraphical importance. *Trudy Instituta Geologicheskikh Nauk, Akademiya Nauk Ukrinskoy S.S.R., Seriya Stratigrafii i Paleontologii*, **11**, 1-185.

IVERSEN, J. & TRØELS-SMITH, J, (1959). Pollenmorphologiske defenitioner og typer. *Danmarks geologiske undersogelse, IV raekke*, **3**, 1-54.

JANSONIUS, J., (1962). Palynology of Permian and Triassic sediments, Peace River area, western Canada. *Palaeontographica, B*, **110**, 35-98.

JANSONIUS, J., (1992). New requirements in the International Code of Botanical Nomenclature. *Review of Palaeobotany and Palynology*, **71**, 297-298.

JANSONIUS, J. & HILLS, L.V., (1976). *Genera File of fossil spores.* Special Publication of the Department of Geology, University of Calgary, Canada.

JANSONIUS, J. & HILLS, L.V., (1990). *Genera file of fossil spores, supplement 10.* Special Publication of the Department of Geology, University of Calgary, Canada.

JEFFORDS, R.M. & JONES, D.H., (1959). Preparation of slides for spores and other microfossils. *Journal of Paleontology*, **33**, 344-350.

JIZBA, K.M.M., (1962). Late Paleozoic bisaccate pollen from the United States midcontinent area. *Journal of Paleontology*, **36**, 871-887.

JONES, J.M., (1980). Carboniferous Westphalian (Coal Measures) rocks. *In* ROBINSON, D.A. (ed.), *Geology of Northest England.* Special Publication of the Natural History Society of Northumberland and Durham, 23-36.

JONGMANS, W.E. & GOTHAN, W., (1937). Betrachtungen über die Ergebnisse des Zweiten Kongresses für Karbonstratigraphie. *Compte Rendu, 2ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Heerlen, 1935,* **1**, 1-40.

KARA-MURZA, E.N., (1954). Spore pollen complexes of Triassic deposits in the Cape Tsvetkov region. *Nauchno-Issledovatelskii Institut Geologii Arktiki, Leningrad, Sbornik Statei po Paleontologii i Biostratigrafii,* **8**, 33-58.

KEATING, J.M., (1991). A palynological study of the Jurassic (Pliensbachian to Oxfordian) strata of the North West Hutton Field, northern North Sea. Volume 1. *Unpublished Ph.D. thesis, University of Sheffield,* 1-203.

KEDO, G.I., (1963). Tournaisian spores of the Pripyat depression and their stratigraphic significance. *Paleontologiya i Stratigrafiya BSSR, Minsk,* **4**, 3-121.

KENT, P.E., (1985). UK on-shore oil exploration 1930-1964. *Marine and Petroleum Geology,* **2**, 56-64.

KLAUS , W., (1958). Some lower Mesophytic microspores of Europe with remarks on their relation to the Gondwana microflora. *Journal of the Palaeontological Society of India,* **3**, 151-155.

KNOX, E.M., (1950). The spores of *Lycopodium, Phylloglossum, Selaginella* and *Isoëtes* and their value in the study of microfossils of Palaeozoic age. *Transactions and Proceedings of the Botanical Society of Edinburgh,* **35**, 209-357.

KONYALI, Y., (1963). Contribution a l'etude des microspores du Baissin Houllier d'Amasra (Secteur Sud). *Unpublished thesis, University of Lille,* 1-127.

KOSANKE, R.M., (1950). Pennsylvanian spores of Illinois and their use in correlation. *Illinois State Geological Survey Bulletin,* **74**, 1-128.

KOSANKE, R.M., (1959). *Wilsonites,* new name for *Wilsonia* Kosanke 1950. *Journal of Paleontology,* **33**, 700.

KOSANKE, R.M., (1982). Illustration and comments concerning the type specimens of *Calamospora, Florinites* and *Raistrickia*. *Journal of Paleontology*, **56**, 1171-1176.

KREMP, G.O.W., (1952). *Morphologic encyclopedia of palynology*. University of Arizona Press, Tucson, 1-163.

KRUTZSCH, W., (1959). Mikropaläontologische (sporen paläontologische) Untersuchungen in der Braunkohle des Geiseltales. *Geologie*, **8**, 1-245.

KRUTZSCH, W., (1970). *Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas, Lief VII*. VEB Gustav Fischer Verlag, Jena, 1-175.

LANE, H.R. & MANGER, W.L., (1985). Toward a boundary in the middle of the Carboniferous (1975-1985): ten years of progress. *In* LANE, H.R. & ZIEGLER, W. (eds.) Toward a boundary in the middle of the Carboniferous: Stratigraphy and Palaeontology, *Courier Forschungsinstitut Senckenberg*, **74**, 15-34.

LAVEINE, J.-P., LEMOIGNE, Y, LI, X., WU, X., ZHANG, S., ZHAO, X, ZHU, W. & ZHU, J., (1987). Paléogéographie de la Chine au Carbonifère à la lumière des donnés paléobotaniques, par comparaison avec les assemblages carbonifères d'Europe occidentale. *Compte rendu, Academie des Sciences, Paris*, **304**, 391-394.

LEEDER, M.R., (1988)a. Devono-Carboniferous river systems and sediment dispersal from the orogenic belts and cratons of NW Europe. *In* HARRIS, A.L. & FETTES, D.J. (eds.), *The Caledonian - Appalachian Orogen*, Geological Society Special Publication No. 38, 549-558.

LEEDER, M.R., (1988)b. Recent developments in Carboniferous geology: a critical review with implications for the British Isles and N.W. Europe. *Proceedings of the Geologists Association*, **99**, 73-100.

LEEDER, M.R. & HARDMAN, M., (1990). Carboniferous geology of the Southern North Sea Carboniferous Basin and controls on hydrocarbon prospectivity. *In* HARDMAN, R.F.P. & BROOKS, J. (eds.) *Tectonic Events Responsible for Britain's Oil and Gas Reserves*, Geological Society Special Publication No. 55, 87-105.

LEEDER, M., RAISWELL, R., AL-BIATTY, H., McMAHON, A. & HARDMAN, M., (1990). Carboniferous stratigraphy, sedimentation and correlation of well 48/3-3 in the southern North Sea Basin: integrated use of palynology, natural gamma/sonic logs and carbon/sulphur geochemistry. *Journal of the Geological Society, London*, **147**, 287-300.

LEES, G.M. & COX, P.T., (1937). The geological results of the search for oil in Great Britain by the D'Arcy Exploration Company Limited. *Quarterly Journal of the Geological Society, London*, **93**, 156-194.

LEGALL, F.D., BARNES, C.R. & MacQUEEN, R.W., (1981). Thermal maturation, burial history and hotspot development, Paleozoic strata of southern Ontario - Quebec, from conodont and acritarch colour alteration studies. *Bulletin of Canadian Petroleum Geology*, **29**, 492-539.

LENTIN, J.K., (1971). An investigation of some aspects of the palynofacies at the Namurian-Westphalian boundary in the southern Pennines. *Unpublished Ph.D. thesis, University of Sheffield*, 1-270.

LESCHIK, G., (1956). Sporen aus dem Salzton des Zechsteins von Neuhof (bei Fulda). *Palaeontographica B*, **100**, 122-142.

LIPPOLT, H.J., HESS, J.C. & BURGER, K., (1984). Isotopische alter von pyroklastischen sanidinen aus kaolin-Kohlentonstein als korrelationsmarken fur das mittelueroaische Oberkarbon. *Fortschritten in der Geologie von Rheinland und Westfalen*, **32**, 119-150.

LISTER, T.R., (1970). The acritarchs and chitinozoa from the Wenlock and Ludlow Series of the Ludlow and Millichope areas, Shropshire. *Palaeontographical Society Monographs*, **124**, 1-100.

LOBOZIAK, S., (1971). Les micro- et mégaspores de la partie occidentale du bassin houiller du Nord de la France. *Palaeontographica B*, **132**, 1-127.

LOBOZIAK, S., COQUEL, R. & JACHOWICZ, A., (1976). Stratigraphie du Westphalien d'Europe occidentale et de Pologne à la lumiere des etudes palynologiques (microspores). *Annales de la Societé de Géologie du Nord*, **96**, 157-172.

LOEBLICH, A.R., (1970). Morphology, ultrastructure and distribution of Paleozoic acritarchs. *Proceedings of the North American Paleontological Convention, Chicago, 1969, part G*, **2**, 705-788.

LOOSE, F., (1934). Sporenformen aus dem Flöz Bismarck des Ruhrgebietes. *Arbeiten aus dem Institut für Paläobotanik und Petrographie der Brennsteine*, **4**, 127-164.

LOVE, L.G., (1960). Assemblages of small spores from the Lower Oil Shale Group of Scotland. *Proceedings of the Royal Society of Edinburgh B*, **67**, 99-126.

LUBER, A.A., (1955). Atlas of the spore and pollen grains of the Palaeozoic deposits of Kazakhstan. *Akademiya Nauk Kazakhskoi SSR, Alma-Ata*, 1-125.

LUBER, A.A., & WALTZ, I.E., (1938). Classification and stratigraphic value of spores of some Carboniferous coal deposits in the U.S.S.R. *Trudy Tsentralnogo Nauchno-Issledovatelskogo Geologorazvedochnogo Instituta (TSNIGRI), Gorno-Toplivnoi i Geologo, Razvedochnoi Literatury, Leningrad, Moskva*, 1-43.

LUBER, A.A. & WALTZ, I.E., (1941). Atlas of microspores and pollen grains of the Palaeozoic of the U.S.S.R. *Vsesoyuznyi Nauchno-Issledovatelskii Geologicheskii Institut, Leningrad (VSEGEI), Trudy*, **139**, 1-107.

MÄDLER, K., (1964). Die geologische Verbreitung von Sporen und Pollen in der Deutschen Trias. *Geologisches Jahrbuch*, **65**, 3-147.

MAHESHWARI & BANERJI, (1975). Lower Triassic palynomorphs from the Maitur Formation, West Bengal, India. *Palaeontographica B*, **152**, 149-190.

MANSON, W., (1957). On the occurrence of a marine band in the *Anthraconaia modiolaris* Zone of the Scottish Coal Measures. *Bulletin of the Geological Survey of Great Britain*, **12**, 66-86.

MANUM, S., (1960). On the genus *Pityosporites* Seward 1914 with a new description of *Pityosporites antarcticus* Seward. *Nytt Magasin für Botanikk (Oslo)*, **8**, 11-15.

MARSHALL, A.E. & SMITH, A.H.V., (1965). Assemblages of miospores from some Upper Carboniferous coals and their associated sediments in the Yorkshire coalfield. *Palaeontology*, **7**, 656-673.

MAYNARD, J.R., WIGNALL, P.B. & VARKER, W.J., (1991). A 'hot' new shale facies from the Upper Carboniferous of Northern England. *Journal of the Geological Society, London*, **148**, 805-808.

McGREGOR, D.C., (1973), Lower and Middle Devonian spores of eastern Gaspé, Canada. I, Systematics. *Palaeontographica B*, **142**, 1-77.

McLEAN, D., (1991)a. A palynological review of Carboniferous sections in the southern North Sea Block 48/10b. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, August, 1991*, 1-23.

McLEAN, D., (1991)b. Miospore assemblages from the *Gastroceras listeri* Marine Band and associated Coal Measures, Sheffield, England (abstract). *Palynology*, **15**, 248.

McLEAN, D., (1992)a. A report on the palynological analysis of the interval 11210 feet to 12430 feet in well 44/22a-d1. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, February, 1992*, 1-8.

McLEAN, D., (1992)b. A report on the palynological analysis of the interval 12424' to 13915' in well 43/15b-3a. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, June, 1992*, 1-9.

McLEAN, D., (1992)c. A report on the palynological analysis of the interval 12230 feet to 13630 feet in wells 44/22a-d2 and 44/22a-d2z. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, August, 1992*, 1-12.

McLEAN, D., (1992)d. A report on the palynological analysis of the interval 11590 feet to 12190 feet in well 44/22a-d3. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, August, 1992*, 1-9.

McLEAN, D., (1992)e. A report on the palynological analysis of the Carboniferous intervals in wells 48/15b-7, 49/6a-4 and 49/6a-4z. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, October, 1992,* 1-12.

McLEAN, D., (1992)f. A report on the palynological analysis of the interval 14130 feet to 16515 feet in well 44/22a-d4. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, November, 1992,* 1-10.

McLEAN, D., (1992)g, Provenance of reworked palynomorphs from the Greenmoor Rock (Langsettian, Late Carboniferous), Sheffield, England (abstract). *8th International Palynological Congress, Program and Abstracts, Aix-en-Provence, September, 1992,* 94.

McLEAN, D., (1993). A report on the palynological analysis of the interval 12960 feet to 14659 feet in well 44/22a-d5. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, February, 1993,* 1-10.

McLEAN, D. & NEVES, R., (1992)a. A palynological review of Carboniferous sections in the southern North Sea Block 44/28. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, February, 1992,* 1-25.

McLEAN, D. & NEVES, R., (1992)b. A report on the palynological analysis of the interval 12772 feet to 14420 feet in well 48/4-1. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, July,* 1992, 1-12.

McLEAN, D. & NEVES, R., (1993)a. A palynostratigraphic correlation of the Carboniferous sections in wells from the Pickerill Field, Southern North Sea. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, April, 1993,* 1-65.

McLEAN, D. & NEVES, R., (1993)b. A report on the palynological analysis of the intervals 12643 feet to 12651 feet and 12674 feet to 14014 feet in well 44/21a-9. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, June, 1993,* 1-19.

McLEAN, D. & TURNER, N., (1990)a. A final report on the palynological correlation of coal seams within the Murdoch Field wells: 44/22-1, 44/22-3, 44/22-4, 44/22-5, 44/22-6z, 44/22-7. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, January, 1990,* 1-21.

McLEAN, D. & TURNER, N., (1990)b. An interim report on the palynological correlation of coal seams within the Block 44/23 wells: 44/23-4, 44/23-5, 44/23-6, 44/23-7, 44/23-8, 44/23-9. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, February, 1990,* 1-13.

MENENDEZ, C.A. & AZCUY, C.L., (1969). Microflora carbónica de la localidad de Paganzo, Provincia de La Rioja, Parte I. *Ameghiniana,* **6,** 77-97.

MINER, E.L., (1935). Paleobotanical examination of Cretaceous and Tertiary coals. *American Midland Naturalist,* **16,** 585-625.

MISHELL, D., (1966). Namurian and Westphalian miospores from the Bowland Fells and Ingleton Coalfield. *Unpublished Ph.D. thesis, University of Sheffield,* 1-452.

MOORE, P.D., (1987). Ecological and hydrological aspects of peat formation. *In* SCOTT, A.C. (ed.), *Coal and coal bearing strata: recent advances,* Geological Society Special Publication No. 32, Blackwell, Oxford, 7-15.

MORBEY, S.J., (1975). The palynostratigraphy of the Rhaetian Stage, Upper Triassic, in the Kendelbachgraben, Austria. *Palaeontographica, B,* **152,** 1-75.

MORGAN, J.L., (1955). Spores of McAlester Coal. *Oklahoma Geological Survey Circular,* **36,** 1-52.

MYKURA, W., (1960). The replacement of coal by limestone and the reddening of Coal Measures in the Ayrshire Coalfield. *Bulletin of the Geological Survey of Great Britain,* **16,** 69-109.

NAUMOVA, S.N., (1938). Microspores from the coals of the Moscow Basin. *Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Instituts Geologii i Mineralogii Syr'ya,* **119,** 21-32.

NAUMOVA, S.N., (1939). Spores and pollen of the coals of the U.S.S.R. *Report of the XVII International Congress, 1937*, 1, 353-364.

NAUMOVA, S.N., (1953). Spore-pollen complexes of the Upper Devonian of the Russian Platform and their significance for stratigraphy. *Akademiya Nauk SSR, Institut Geologischekikh Nauk, Trudy, Seriya Geologicheskaya*, **60**, 1-154.

NEVES, R., (1958). Upper Carboniferous plant spore assemblages from the *Gastrioceras subcrenatum* horizon, North Staffordshire. *Geological Magazine*, **95**, 1-19.

NEVES, R., (1959). An investigation into the Namurian microflora of parts of the southern Pennine Basin. *Unpublished Ph.D. thesis, University of Sheffield*, 1-257.

NEVES, R., (1961). Namurian plant spores from the southern Pennines, England. *Palaeontology*, 4, 247-279.

NEVES, R., (1964)a. *Knoxisporites* (Potonié and Kremp) Neves 1961. *5ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Paris, 1963*, 3, 1063-1069.

NEVES, R., (1964)b. The stratigraphic significance of the small spore assemblages of the La Camocha Mine, Gijon, N. Spain. *5ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Paris*, 1963, 3, 1229-1238.

NEVES, R., (1973)a. 47/13-2. Palynological dating of the Carboniferous between 9000 and 9200 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, August, 1973*, 1-4.

NEVES, R., (1985)a. Conoco (UK) Limited: well 44/22-3. A palynostratigraphic account of the Carboniferous interval 11343 to 12610 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, August, 1985*, 1-7.

NEVES, R., (1985)b. Well 44/22-1: a report on the palynologically based stratigraphy of the interval 11351 to 13940 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, September, 1985*, 1-13.

NEVES, R., (1987)a. Well 44/22-4. A palynostratigraphic account of the interval 11680 to 12350 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, September, 1987,* 1-5.

NEVES, R., (1988)a. Conoco (UK) Limited: well 44/22-5. A report on the palynolgically based biostratigraphy of the interval 11830 to 12680 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, March, 1988,* 1-8.

NEVES, R., (1988)b. Conoco (UK) Limited: well 44/22-6z. A palynologically based biostratigraphic report for the interval 12231.9 to 12880 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, July, 1988,* 1-12.

NEVES, R., (1988)c. Conoco (UK) Limited: well 44/22-7. A report on the palynologically determined stratigraphy for the interval 12780 to 13660 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, July, 1988,* 1-5.

NEVES, R., (1990). 44/17-1. A biostratigraphic report based on the palynology of the interval 12240 to 16083 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, June, 1990,* 1-18.

NEVES, R. & BELT, E., (1970). Some observations on Viséan and Namurian spores from Nova Scotia, Britain and northern Spain. *6ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Sheffield, 1967,* **3**,1233-1249.

NEVES, R. & DALE, B., (1963). A modified filtration system for palynological preparations. *Nature,* **198**, 775.

NEVES, R. & DOWNIE, C., (1992). 44/17-2. An updated biostratigraphic report based on the palynology of the intervals 3680 to 4220 and 12404 to 13017 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, March, 1992,* 1-10.

NEVES, R., DOWNIE, C., RAMSBOTTOM, W.H.C. & MASON, M.H., (1989). Palaeontological evidence for the Vanderbeckei Marine Band in wells of the 44 Quadrant. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit*, 1-1-4.

NEVES, R., GUEINN, K.J., CLAYTON, G., IOANNIDES, N.S., NEVILLE, R.S.W. & KRUSZEWSKA, K., (1973). Palynological correlations within the Lower Carboniferous of Scotland and northern England. *Transactions of the Royal Society of Edinburgh*, **69**, 23-70.

NEVES, R. & McLEAN, D., (1989). North Sea Well 48/8a-1. A report on the palynologically based biostratigraphy of the interval 9940 to 10290 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, March, 1989*, 1-6.

NEVES, R., McLEAN, D. & TURNER, N., (1989). North Sea well 48/15a-6. A report on the palynologically based biostratigraphy of the interval 9800 - 11494 feet.*Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, February, 1989*, 1-7.

NEVES, R. & OWENS, B., (1966). Some Namurian camerate miospores from the English Pennines. *Pollen et Spores*, **8**, 337-360.

NEVES, R. & PLAYFORD, G., (1961). The dispersed spore genus *Knoxisporites* Potonié and Kremp 1954. *C.I.M.P., Krefeld, Compte rendu*, 9.

NEVES, R. & QUINCEY, J.M., (1986). 47/13a-3. A report on the palynostratigraphy of the intervals 2700 to 4220 feet and 9200 to 10641 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, January, 1986*, 1-18.

NEVES, R. & TURNER, N., (1989)a. Total well 44/23-8. A palynological report on the Carboniferous interval 3892.30 to 3997.00 metres. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, June, 1989*, 1-5.

NEVES, R. & TURNER, N., (1989)b. Total well 44/23-9. A palynological report on the Carboniferous interval 4261.30 to 4323.91 metres. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, June, 1989*, 1-7.

NOREM, W.L., (1956). A new method for separating fossil spores and pollen from silicious rocks. *Journal of Paleontology*, **30**, 1258-1274.

OWENS, B., (1963). A palynological investigation of the Namurian and Westphalian sediments of the Stainmore outlier, Westmoreland. *Unpublished Ph.D. thesis, University of Sheffield*, 1-312.

OWENS, B., (1983). *Bascaudaspora* gen. nov., a new reticulate miospore genus from the Namurian of Northern England. *Report of the Institute of Geological Sciences*, **83/10**, 45-49.

OWENS, B., LOBOZIAK, S. & TETERIUK, V.K., (1978). Palynological subdivision of the Dinantian to Westphalian deposits of northwest Europe and the Donetz Basin of the U.S.S.R., *Palynology*, **2**, 69-91.

OWENS, B., MISHELL, D.R.F. & MARSHALL, J., (1966). *Kraeuselisporites* from the Namurian of Northern England. *Pollen et Spores*, **18**, 145-156.

OWENS, B., NEVES, R., GUEINN, K.J., MISHELL, D.R.F., SABRY, H.S.M.Z. & WILLIAMS, J.E., (1977). Palynological division of the Namurian of northern England and Scotland. *Proceedings of the Yorkshire Geological Society*, **41**, 381-398.

OWENS, B., RILEY, N.J. & CALVER, M.A., (1985). Boundary stratotypes and new stage names for the Lower and Middle Westphalian sequences in Britain. *10ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Madrid, 1983*, 4, 461-472.

PANT, D.D., (1954). Suggestions for the classification and nomenclature of fossil spore and pollen grains. *Botanical Review*, **20**, 33-60.

PANTANO, J. & LERCHE, I., (1989). Stratigraphic age determination from inversion of vitrinite reflectance data and sterane isomerisation data: correlation at its best and worst. *In* COLLINSON, J.D. (ed.), *Correlation in Hydrocarbon Exploration*, Graham & Trotman, London, 33-44.

PAPROTH, E., DUSAR, M., BLESS, M.J.M., BOUCKAERT, J., DELMER, A., FAIRON-DEMART, M., HOULLEBERGHS, E., LALOUX, M., PIERART, P., SOMERS, Y., STREEL, M., THOREZ, J. & TRICORT, J., (1983). Bio- and lithostratigraphic subdivision of the Silesian in Belgium, a review. *Annales de la Société Géologique de Belgique,* **106**, 241-283.

PARSLEY, A.J., (1986). North Sea Carboniferous plays. *In* GLENNIE, K.W. (ed.), *Introduction to the petroleum geology of the North Sea,* Blackwell Scientific, Oxford, 237-263.

PASTIELS, A., (1956). Contribution à l'étude des foraminifères du Namurien et du Westphalien de la Belgique. *Publication de l'Association de l'Etude Paléontologique et Stratigraphique Houiller,* **27**, 1-32.

PEPPERS, R.,A. (1964). Spores in strata of late Pennsylvanian cyclothems in the Illinois Basin. *Illionis State Geological Survey Bulletin,* **90**, 1-89.

PEPPERS, R.A., (1970). Correlation and palynology of coals in the Carbondale and Spoon Formations (Pennsylvanian) of the northeastern part of the Illinois Basin. *Illinois State Geological Survey Bulletin,* **93**, 1-173.

PEPPERS, R.A., (1979). Development of coal forming floras during the early part of the Pennsylvanian in the Illinois Basin. *In* PALMER, J.E. & DUTCHER, R.R. (eds.) *Depositional and structural history of the Pennsylvanian System of the Illinois Basin,* Illinois State Geological Survey Guidebook Series, 15a, 8-14.

PEPPERS, R.A., (1985). Comparison of miospore assemblages in the Pennsylvanian System of the Illinois Basin with those in the Upper Carboniferous of Western Europe. *9ème Congrés International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Washington & Champaign-Urbana, 1979,* **2**, 483-502.

PHARAOH, T.C., MERRIMAN, R.J., WEBB, P.C. & BECKINSALE, R.D., (1987). The concealed Caledonides of eastern England: preliminary results of a multidisciplinary study. *Proceedings of the Yorkshire Geological Society,* **46**, 355-370.

PHIPPS, D. & PLAYFORD, G., (1984). Laboratory techniques for the extraction of palynomorphs from sediments. *Papers of the Department of Geology, University of Queensland*, **11**, 1-23.

PIÉRART, P., (1962). Observations sur la palynologie du Westphalien B et C de la partie occidentale du Massif du Borinage. *Centre Nationale Géologique Houiller*, **5**, 103-110.

PI-RADONDY, M. & DOUBINGER, J., (1968). Spores nouvelles de Stéphanien (Massif Centrale française). *Pollen et Spores*, **10**, 411-430.

PLAYFORD, G., (1962). The Lower Carboniferous microfloras of Spitsbergen, part 1. *Palaeontology*, **5**, 550-618.

PLAYFORD, G., (1963). The Lower Carboniferous microfloras of Spitsbergen, part 2. *Palaeontology*, **5**, 619-678.

PLAYFORD, G., (1964). Miospores from the Mississippian Horton Group, eastern Canada. *Bulletin of the Canadian Geological Survey*, **107**, 1-47.

PLAYFORD, G., (1971). Lower Carboniferous spores from the Bonaparte Gulf Basin, Western Australia and Northern Territory. *Australian Bureau of Mineral Resources Bulletin*, **115**, 1-104.

PLAYFORD, G. & DETTMANN, M., (1965). Rhaeto-Liassic plant microfossils from the Leigh Creek Coal Measures, South Australia. *Senckenbergiana Lethaea*, **46**,

PLAYFORD, G. & HELBY, R., (1968). Spores from a Carboniferous section in the Hunter Valley, New South Wales. *Journal of the Geological Society of Australia*, **15**, 103-119.

PLAYFORD, G. & SATTERTHWAITE, D.F., (1985). Lower Carboniferous (Viséan) spores of the Bonaparte Gulf Basin, northwest Australia: Part one. *Palaeontographica B*, **195**, 129-152.

POLLARD, J.E., (1969). Three ostracod-mussel bands in the Coal Measures (Westphalian) of Northumberland and Durham. *Proceedings of the Yorkshire Geological Society*, **37**, 239-276.

POTONIÉ, H., (1893). Die Flora des Rotliegenden von Thüringen. *Kongelige Preussische Geologie*, 9, 1-298.

POTONIÉ, H., (1931). Pollenformen aus tertiären Braunkohlen. *Jahrbuch für Preussische Geologie und Landesanstalt.*

POTONIÉ, R., (1956). Synopsis der Gattungen der Sporae dispersae. Teil I. Sporites. *Geologisches Jahrbuch*, 23, 1-103.

POTONIÉ, R., (1958). Synopsis der Gattungen der Sporae dispersae. Teil II. Saccites, Aletes, Praecolpates, Polyplicates, Monocolpites. *Geologisches Jahrbuch*, 31, 1-114.

POTONIÉ, R., (1960). Synopsis der Gattungen der Sporae dispersae. Teil III. Nachträge Sporites, Fortsetzung Pollenites mit General-register zu Teil I-III. *Geologisches Jahrbuch*, 39, 1-189.

POTONIÉ, R., (1966). Synopsis der Gattungen die Sporae dispersae. Teil IV. Nachträge zu allen Gruppen (Turmae). *Geologisches Jahrbuch*, 52, 1-60.

POTONIÉ, R., (1970). Synopsis der Gattungen der Sporae dispersae. Teil VI. *Geologisches Jahrbuch*, 94, 3-18.

POTONIÉ, R., IBRAHIM, A.C. & LOOSE, F., (1932). Sporenformen aus den Flözen Ägir und Bismarck des Ruhrgebietes. *Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie*, B, 67, 483-544.

POTONIÉ, R. & KLAUS, W., (1954). Einige Sporengattungen der alpinen Salzgebirges. *Geologisches Jahrbuch*, 68, 517-544.

POTONIÉ, R. & KREMP, G.O.W., (1954). Die Gattungen der palaeozoischen Sporae dispersae und ihre stratigraphie. *Geologisches Jahrbuch*, 69, 111-194.

POTONIÉ, R. & KREMP, G.O.W., (1955). Die sporae dispersae des Ruhrkarbons, ihre Morphographie und Stratigraphie mit Ausblicken auf Arten andere Gebeite und Zeitabschnitte: Teil I. *Palaeontographica B*, 98, 1-136.

POTONIÉ, R. & KREMP, G.O.W., (1956). Die sporae dispersae des Ruhrkarbons, ihre Morphographie und Stratigraphie mit Ausblicken auf Arten andere Gebeite und Zeitabschnitte: Teil II. *Palaeontographica B*, **99**, 85-191.

POTONIE, R., THOMPSON, P. & THIERGART, F., (1950). Zur Nomenklatur und Klassifikation der neogenen Sporomorphae (Pollen und Sporen). *Geologisches Jahrbuch*, **65**, 35-70.

QUIRK, D.G., (1993). Interpreting the Upper Carboniferous of the Dutch Cleaver Bank High. *In* PARKER, J.R. (ed.) *Petroleum Geology of Northwest Europe: proceedings of the 4th Conference*. The Geological Society, London, 697-706.

RAMSBOTTOM, W.H.C., (1969)a. Interim report of the Namurian working group. *Compte rendu, 6ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Sheffield, 1967*, **1**, 71-77.

RAMSBOTTOM, W.H.C., (1969)b. The Namurian of Britain. *Compte rendu, 6ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Sheffield, 1967*, **1**, 219-232.

RAMSBOTTOM, W.H.C., (1973). Transgressions and regressions in the Dinantian: a new synthesis of British Dinantian stratigraphy. *Proceedings of the Yorkshire Geological Society*, **39**, 567-607.

RAMSBOTTOM, W.H.C., (1974). Namurian. *In* RAYNER, D.H. & HEMINGWAY, J.E. (eds.). *The geology and mineral resources of Yorkshire*. Yorkshire Geological Society, Leeds, 73-87.

RAMSBOTTOM, W.H.C., (1977). Major cycles of transgression and regression (mesothems) in the Namurian. *Yorkshire Geological Society Proceedings*, **41**, 261-291.

RAMSBOTTOM, W.H.C., (1979). Rates of transgression and regression in the Carboniferous of NW Europe. *Journal of the Geological Society of London*, **136**, 147-153.

RAMSBOTTOM, W.H.C., (1981) (ed.). *Field guide to the boundary stratotypes of the Carboniferous stages in Britain*. IUGS subcommission on Carboniferous Stratigraphy, Leeds, 1981, 1-105.

RAMSBOTTOM, W.H.C., CALVER, M.A., EAGAR, R.M.C., HODSON, F., HOLLIDAY, D.W., STUBBLEFIELD, C.J. & WILSON, R.B., (1978). *A correlation of Silesian rocks in the British Isles.* Geological Society of London, Special Report No. 10, 1-81.

RAMSBOTTOM, W.H.C. & SAUNDERS, W.B., (1985). Evolution and evoltionary biostratigraphy of Carboniferous ammonoids. *Journal of Paleontology,* 59, 123-139.

RASUL, M.J.H., (1985). The Westphalian palynomorphs from selected sequences in the Nottinghamshire and Yorkshire coalfields. *Unpublished Ph.D. thesis, Univesity of Sheffield,* 1-330.

RASUL, S.M., (1974). The Lower Palaeozoic acritarchs *Priscogalea* and *Cymatiogalea. Palaeontology,* 17, 41-63.

RASUL, S.M., (1979). Acritarch zonation of the Tremadoc Series of the Shineton Shales, Wrekin, Shropshire, England. *Palynology,* 3, 53-72.

RAUSCHER, R., (1973). Recherches micropaléontologiques et stratigraphiques dans l'Ordovicien et le Silurien en France. Étude des acritarches, des chitinozoaires et des spores. *Sciences Géologiques, Université Louis Pasteur de Strasbourg, Institut de Géologie, Memoire,* 38, 1-224.

RAVN, R.L., (1979). An introduction to the stratigraphic palynology of the Cherokee Group (Pennsylvanian) coals of Iowa. *Iowa Geological Survey Technical Paper,* 6, 1-117.

RAVN, R.L., (1986). Palynostratigraphy of the lower and middle Pennsylvanian coals of Iowa. *Iowa Geological Survey Technical Paper,* 7, 1-245.

RAVN, R.L., (1991). Miospores of the Kekiktuk Formation (Lower Carboniferous), Endicott Field area, Alaska North Slope. *American Association of Stratigraphic Palynologists Contributions Series,* 27, 1-173.

RAVN, R.L., BUTTERWORTH, M.A., PHILLIPS, T.L. & PEPPERS, R.A., (1986). Proposed synonomy of *Granasporites* Alpern 1959 emend. and *Cappasporites* Urban emend. Chadwick 1983, miospore genera from the Carboniferous of North America and Europe, *Pollen et Spores*, **28**, 421-434.

RAVN, R.L. & FITZGERALD, D.J., (1982). A Morrowan (Upper Carboniferous) miospore flora from eastern Iowa, U.S.A. *Palaeontographica B*, **183**, 108-172.

RAYMOND, A., (1985). Floral diversity, phytogeography and climatic ameleoration during the early Carboniferous (Dinantian). *Paleobiology*, **11**, 293-309.

RAYNER, D.H., (1953). The Lower Carboniferous rocks in the north of England: a review. *Proceedings of the Yorkshire Geological Society*, **28**, 231-315.

RAZZO, M.J.H., (1985). The Westphalian palynomorphs from selected sequences in the Nottinghamshire and Yorkshire Coalfields. *Unpublished Ph.D. thesis, University of Sheffield*, 1-330.

READ, W.A., (1988). Controls on Silesian sedimentation in the Midland Valley of Scotland. *In* BESLEY, B.M. & KELLING, G. (eds.) *Sedimentation in a synorogenic basin complex: the Upper Carboniferous of Northwest Europe*. Blackie, Glasgow, 222-241.

RICHARDS, P.C., (1990). Devonian. *In* GLENNIE, K.W. (ed.), *Introduction to the petroleum geology of the North Sea*, Blackwell, Oxford, 3rd edition, 78-89.

RICHARDSON, G. & FRANCIS E.H., (1970). Fragmental clayrock (FCR) in coal-bearing sequences in Scotland and north-east England. *Proceedings of the Yorkshire Geological Society*, **38**, 229-259.

RICHARDSON, J.B., (1960). Spores from the Middle Old Red Sandstone of Cromarty, Scotland. *Palaeontology*, **3**, 45-63.

RICHARDSON, J.B., (1965). Middle Old Red Sandstone spore assemblages from the Orcadian Basin, north-east Scotland. *Palaeontology*, **7**, 559-605.

RICHARDSON, J.B. & McGREGOR, D.C., (1986). Silurian and Devonian spore zones of the Old Red Sandstone continent and adjacent regions. *Bulletin of the Geological Survey of Canada,* **364,** 1-79.

RILEY, N.J., (1993). Dinantian (Lower Carboniferous) biostratigraphy and chronostratigraphy in the British Isles. *Journal of the Geological Society,* **150,** 427-446.

RILEY, N.J., VARKER, W.J., OWENS, B., HIGGINS, A.C. & RAMSBOTTOM, W.H.C., (1987). Stonehead Beck, Cowling, North Yorkshire, England: a British proposal for the mid-Carboniferous boundary stratotype. *Courier Forschungsinstitut Senckenberg,* **98,** 157-177.

RITCHIE, J.S. & PRATSIDES, P., (1993). The Caister Fields, Block 44/23a, UK North Sea. *In* PARKER, J.R. (ed.). *Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference,* The Geological Society, London, 759-769.

ROSS, C.A. & ROSS, J.P.R., (1985). Late Paleozoic sequences are synchronous and worldwide. *Geology,* **13,** 194-197.

SABRY, H.S.M.Z. & NEVES, R., (1971). Palynololgical evidence concerning the unconformable Carboniferous basal measures in the Sanquhar Coalfield, Dumfriesshire, Scotland. *6ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Sheffield, 1967,* **4,** 1441-1458.

SAKSENA, S., (1971). On fossil flora of Ganjra Nalla Beds: Part II - Microflora (A) Dispersed spores and pollen grains. *The Palaeobotanist,* **18,** 237-257.

SAMOILOVICH, S.R., (1953). Pollen and spores from the Permian deposits of the Cherdinsk and Aktyubinsk areas in the Lower Urals. *Vsesoyuznyi Neftyanoi Nauchno-Issledovatelskii Geologorazvedochnyi Institut, Leningrad (VNIGRI), Trudy, Paleobotanicheskii Sbornik,* **75,** 5-57.

SCHAARSCHMIDT, F., (1963). Sporen und Hystrichosphaerideen aus dem Zechstein von Büdingen in der Wetterau. *Palaeontographica, B,* **113,** 38-91.

SCHEMEL, M.P., (1950). Carboniferous plant spores from Daggett County, Utah. *Journal of Paleontology,* **24,** 232-244.

SCHEURING, B.W., (1974). *Kraeuselisporites* Leschik and *Thompsonisporites* Leschik - a revision of the type material of two disputed genera. *Review of Palaeobotany and Palynology*, 17, 187-203.

SCHOPF, J.M., (1936). The paleobotanical significance of plant structure in coal. *Transactions of the Illinois State Academy of Science*, 28, 106-110.

SCHOPF, J.M., (1938). Spores from the Herrin (No. 6) Coal bed of Illinois. *Illinois Geological Survey Report of Investigations*, 50, 1-55.

SCHOPF, J.M., WILSON, L.R. & BENTALL, R., (1944). An annotated synopsis of Paleozoic fossil spores and the definition of generic groups. *Illinois Geological Survey Report of Investigations*, 91, 1-73.

SCHULZ, E., (1967). Sporenpaläontologische Untersuchungen rätoliassischer Schichten im Zentralteil des germanischen Beckens. *Paläontologische Abhandlung B*, 3, 427-633.

SCOTT, G.H., (1965). Homotaxial stratigraphy. *New Zealand Journal of Geology and Geophysics*, 8, 859-862.

SEWARD, A.C., (1914). Antarctic fossil plants. *British Antarctic (Terra Nova) Expedition, 1910. Natural History Report, Geology*, 1, 1-49.

SMITH, A.H.V., (1971). Genus *Verrucosisporites* Ibrahim 1933 emend. *C.I.M.P. Spores*, 4, 35-87.

SMITH, A.H.V., BUTTERWORTH, M.A., KNOX, E. & LOVE, L.G., (1964). Report of C.I.M.P. Working Group No. 6. *Verrrucosisporites* (Ibrahim) emend. *5ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Paris, 1963*, 3, 1071-1078.

SMITH, A.H.V. & BUTTERWORTH, M.A., (1967). Miospores in the coal seams of the Carboniferous of Great Britain. *Special Papers in Palaeontology*, 1, 1-324.

SMITH, E.G., RHYS, G.H. & EDEN, R.A., (1967). *Geology of the country around Chesterfield, Matlock and Mansfield.* Memoir of the Geological Survey of Great Britain, HMSO, London, 1-430.

SMITH, N.J.P., (1985). *British Geological Survey 1:1,000,000 Pre-Permian Geology of the United Kingdom (South)*, British Geological Survey, Keyworth.

SOMERS, G., (1952). Fossil spore content of the Lower Jubilee Seam of the Sydney Coalfield, Nova Scotia. *Nova Scotia Research Foundation*, 1-30.

SOMERS, Y., (1971). Etude palynologique de Westphalien du Bassin de Campine et révision de genre *Lycospora. Unpublished Ph.D. thesis, University of Liege.*

SOMERS, Y., (1972). Révision du genre *Lycospora* Schopf, Wilson and Bentall. *C.I.M.P., Spores. Éditions du Centre National de la Recherches Scientifiques*, **5**, 1-110.

SOPER, N.J., WEBB, B.C. & WOODCOCK, N.H., (1987). Late Caledonian (Acadian) transpression in north-west England: timing, geometry and geotectonic significance. *Proceedings of the Yorkshire Geological Society*, **46**, 175-192

SPEARS, D.A., (1987). Mineral matter in coals, with special reference to the Pennine Coalfields. *In* SCOTT, A.C. (ed.), *Coal and Coal-bearing Strata: Recent Advances*, Geological Society Special Publication No. 32, 171-185.

SPEARS, D.A. & KANARIS-SITIRIOU, R., (1979). A geochemical and mineralogical investigation of some British and other European tonsteins. *Sedimentology*, **26**, 407-425.

SPODE, F, (1974). A micropalaeontological investigation of the Mansfield Marine Band. *Unpublished Ph.D. thesis, University of Sheffield*, 1-315.

SRIVASTAVA, S.K., (1977). Microspores from the Fredericksberg Group (Albian) of the southern United States. *Paleobiologie Continentale*, **6**, 1-119.

STAPLIN, F.L., (1960). Upper Mississippian plant spores from the Golata Formation, Alberta, Canada. *Palaeontographica B*, **107**, 1-40.

STAPLIN, F.L., (1961). Reef controlled distribution of Devonian microplankton in Alberta. *Palaeontology*, **14**, 1-11.

STAPLIN, F.L., (1969). Sedimentary organic matter, organic metamorphism, and oil and gas occurrence. *Bulletin of Canadian Petroleum Geology*, **17**, 47-66.

STAPLIN, F.L. & JANSONIUS, J., (1964). Elucidation of some Palaeozoic densospores. *Palaeontographica B*, **114**, 95-117.

STOCKMANS, F., (1962). Paléobotanique et stratigraphie. *Compte rendu, 4ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Heerlen, 1958*, **3**, 657-682.

STREEL, M., (1964). Une association de spores du Givétian inférieur de la Vesdre, à Goé (Belgique). *Annales de la Société géologique de Belgique*, **87**, B1-B30.

STREEL, M., (1967). Associations de spores du Dévonien inférieur belge et leur signification stratigraphique. *Annales de la Société géologique de Belgique*, **90**, 13-54.

STREEL, M. & BLESS, M.J.M., (1980). Occurrence and significance of reworked palynomorphs. *Mededelingen Rijks Geologische Dienst*, **32**, 69-80.

SULLIVAN, H.J., (1958). The microspore genus *Simozonotriletes*. *Palaeontology*, **1**, 125-138.

SULLIVAN, H.J., (1964). Miospores from the Drybrook Sandstone and associated measures in the Forest of Dean Basin, Gloucestershire. *Palaeontology*, **7**, 351-392.

SULLIVAN, H.J. & MARSHALL, A.E., (1966). Viséan spores from Scotland. *Micropaleontology*, **12**, 265-285.

TETERIUK, V.K., (1976). Namurian Stage analogues in the Carboniferous period of the Donetz Basin (based on palynological data). *Geological Journal*, **36**, 110-122.

TIMOFEEV, B.V., (1958). Über das Alter sächsischer Grauwacken Mikropaläophytologische Untersuchungen von Proben aus der Weesensteiner und Lausitzer Grauwacke. *Geologie*, **7**, 826-845.

TIMOFEEV, B.V., (1959). Drevneishaya flora Pribaltiki i ee stratigraficheskoe znachenie. *Vsesoyuznyi Neftyanoi Nauchno-Issledovatelskii Geologorazvedochnyi Institut, Leningrad (VGIRINI), Trudy*, **129**, 1-136.

TRUEMAN, A.E. & WIER, J., (1946-58). A monograph on British Carboniferous non-marine Lamellibranchia. *Palaeontographical Society Monographs.*

TSCHUDY, R.H. & KOSANKE, R.M., (1966). Early Permian vesciculate pollen from Texas, USA. *The Palaeobotanist*, **15**, 59-71.

TUBB, S.R., SOULSBY, A. & LAWRENCE, S.R., (1986). Palaeozoic prospects on the north flank of the London-Brabant massif. *In* BROOKS, J., GOFF, J.C. & VAN HOORN, B. (eds.) *Habitat of Palaeozoic Gas in N.W. Europe*, Geological Society of London, Special Publication, 23, 55-72.

TURNER, N., (1989). Conoco well 48/25b-5. A palynological report on the Carboniferous interval 9010 to 9080 feet. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, April, 1990,* 1-11.

TURNER, N., (1990)a. A report on the palynological examination of the interval 3840.25 to 4306 metres in Well 44/21-3. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, April, 1990,* 1-11.

TURNER, N. (1990)b. An interim report on the palynological correlation of coal seams within the Block 44/21 North Sea wells: 44/21-2, 44/21-3, 44/21-4. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, July, 1990,* 1-17.

TURNER, N., (1990)c. A report on the palynological examination of the interval 13630 to 16480 feet in well 44/27-1. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, August, 1990,* 1-6.

TURNER, N., (1990)d. A report on the palynological examination of the interval 12820.2 to 15650 feet in Well 44/21a-6. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, December, 1990,* 1-18.

TURNER, N., (1991)a. A report on the palynological examination of the interval 12572.0 to 14960.5 feet in well 44/21a-7. *Unpublished report to Conoco (UK) Ltd. of Sheffield University Industrial Palynology Unit, April, 1991,* 1-18.

TURNER, N., (1991)b. The occurrence of *Elaterites triferens* Wilson 1943 in miospore assemblages from Coal Measures of Westphalian D age, North Staffordshire, England. *Palynology*, **15**, 35-46.

TURNER, N. & SPINNER, E., (1992). Palynological evidence for the early Namurian age of the "Millstone Grit" and Upper Limestone Group around Longhoughton Steel, Northumberland. *Proceedings of the Yorkshire Geological Society*, **49**, 11-22.

TURNER, N. & SPINNER, E., (1993). A palynostratigraphic study of Namurian - Westphalian deltaic sequences of the southern central Pennine Basin, Derbyshire, England. *Review of Palaeobotany and Palynology*, **77**, 23-43.

TURNER, R.E., (1984). Acritarchs from the type area of the Ordovician Caradoc Series, Shropshire, England. *Palaeontographic, B*, **190**, 87-157.

URBAN, J.B., (1971). Palynology and the Independence Shale of Iowa, *Bulletins of American Paleontology*, **60**, 103-189.

URBAN, L.L., (1966). *Cappasporites* - a new Pennsylvanian spore genus from the Des Moines Series of Oklahoma. *Oklahoma Geology Notes*, **26**, 111-114.

UTTING, J., (1970). Karroo stratigraphy and palynology of the Upper Luangwa Valley and Lower Karroo palynology of the Mid-Zambezi Valley, Zambia. *Unpublished Ph.D. thesis, University of Sheffield*, 1-233.

VAN DER LAAR, J.G.M. & FERMONT, W.J.J., (1989). On-shore Carboniferous palynology of the Netherlands. *Mededelingen Rijks Geologische Dienst*, **43**, 35-73.

VANGUESTAINE, M., (1978). Critères palynostratigraphiques conduisant a la reconnaissance d'un pli couche revinien dans le sondage de Grand-Halleux. *Annales de la Société géologique de Belgique*, **100**, 249-276.

VAN LECKWIJK, W.P., (1960). Report of the subcommission on Carboniferous stratigraphy. *4ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte rendu, Heerlen, 1958*, **1**, 24-25.

VAN LECKWIJK, W.P. (1964). Le Namurien en Belgique et dans les régions limitrophes (Stratigraphie, Paléogéographie, Paléontologie, Sédimentologie, Puissances). *Académie Royal de Belgique, Classe des Sciences, Mémoires*, **16**, 1-58.

VAN WIJHE, D.H. & BLESS, M.J.M., (1974). The Westphalian of the Netherlands, with special reference to miospore assemblages. *Geologie en Mijnbouw*, **53**, 295-328.

VAVRDOVÀ, M., (1966). Palaeozoic microplankton from central Bohemia. *Casopis pro Mineralogii a Geologii*, **11**, 409-414.

VENKATACHALA, B.S., (1963). On some new spore genera from the Upper Carboniferous coals of the Lothringen-Saar-Pfalz Basin. *The Palaeobotanist*, **11**, 38-42.

WAGNER, R.H., (1974). The chronostratigraphic units of the Upper Carboniferous in Europe. *Bulletin de la Société Belge de Géologie, de Paleontologie et d'Hydrologie*, **83**, 235-253.

WAGNER, R.H., (1984). Megafloral zones of the Carboniferous. *Compte rendu, 9ème Congrès International de Stratigraphie et de Géologie du Carbonifère, Washington & Champagne-Urbana, 1979*, **2**, 109-134.

WALL, D. & DOWNIE, C., (1963). Permian hystrichospheres from Britain. *Palaeontology*, **5**, 770-784.

WETZEL, O., Die organischer Substanz erhaltenen Mikrofossilien des baltischen Kreide-Feuersteins mit einem sediment-petrographischen und stratigraphischen Anhang. *Palaeontographica, A*, **77**, 141-186.

WHITTAKER, A., HOLLIDAY, D.W. & PENN, I.E., (1985). *Geophysical logs in British stratigraphy*. The Geological Society Special Report No. 18, 1-74.

WHITTAKER, A., COPE, J.C.W., COWIE, J.W., GIBBONS, WA., HAILWOOD, E.A., HOUSE, M.R., JENKINS, D.G., RAWSON, P.F., RUSHTON, A.W.A., SMITH, D.G., THOMAS, A.T. & WIMBLEDON, W.A., (1991). A guide to stratigraphic procedure. *Journal of the Geological Society, London*, **148**, 813-824.

WHITAKER, M.F. & EASTERFIELD, D., (1987)a. A palynological and lithostratigraphical evaluation of the Conoco well 44/22-1. *Unpublished report of The Geochem Group, project number 147/6,* 1-43.

WHITAKER, M.F. & EASTERFIELD, D., (1987)b. A palynological and lithostratigraphical evaluation of the Conoco well 44/22-3. *Unpublished report of The Geochem Group, project number 158/S,* 1-38.

WHITAKER, M.F. & EASTERFIELD, D., (1987)c. A lithostratigraphical and palynostratigraphical correlation of the Conoco wells 44/22-1 and 44/22-3. *Unpublished report of The Geochem Group, project number 159/S,* 1-31.

WHITAKER, M.F., EASTERFIELD, D. & CAMPION, N.P. (1987). A palynological and lithostratigraphical evaluation of the Conoco well 44/22-4. *Unpublished report of The Geochem Group, project number 156/S,* 1-31.

WICHER, C.A., (1934). Sporenformen der Flammkohle des Ruhrgebietes. *Arbeiten aus dem Institut für Paläobotanik und Petrographie der Brennersteine,* **4,** 165-212.

WILLIAMS, J.E., (1971). Carboniferous miospores from the Brampton district, northern England and Archerbeck borehole, Dumfriesshire. *Unpublished Ph.D. thesis, University of Sheffield,* 1-441.

WILLIAMS, R.W., (1955). *Pityosportes westphalensis* sp. nov., an abietineous type pollen grain from the Coal Measures of Britain. *Annals and Magazine of Natural History,* **8,** 465-473.

WILLIAMSON, I.A., (1961). Tonsteins: a possible aid to coalfield correlation. *Mining Magazine, London,* **104,** 9-14.

WILSON, L.R., (1943). Elater bearing spores from the Pennsylvanian strata of Iowa. *American Midland Naturalist,* 30, 518-523.

WILSON, L.R., (1966). Type species of *Cirratriradites* Wilson and Coe 1940. *Oklahoma Geology Notes,* **26,** 38-42.

WILSON, L.R. & COE, E.A., (1940). Description of some unassigned plant microfossils from the Des Moines Series of Iowa. *American Midland Naturalist*, **23**, 182-186.

WILSON, L.R. & HOFFMEISTER, W.S., (1956). Plant microfossils of the Croweburg Coal. *Oklahoma Geological Survey Circular*, **32**, 1-57.

WILSON, L.R. & KOSANKE, R.M., (1944). Seven new species of unassigned plant microfossils from the Des Moines Series of Iowa. *Proceedings of the Iowa Academy of Science*, **51**, 329-333.

WILSON, L.R. & VENKATACHALA, B.S., (1963)a. An emendation of *Vestispora* Wilson and Hoffmeister 1956. *Oklahoma Geology Notes*, **23**, 94-100.

WILSON, L.R. & VENKATACHALA, B.S., (1963)b. *Thymospora*, a new name for *Verrucososporites*. *Oklahoma Geology Notes*, **23**, 75-79.

WILSON, L.R. & VENKATACHALA, B.S., (1964). *Potonieisporites elegans* (Wilson and Kosanke) comb. nov. *Oklahoma Geology Notes*, **24**, 67-68,

WILSON, L.R. & WEBSTER, R.M., (1946). Plant microfossils from a Fort Union coal of Montana. *American Journal of Botany*, **33**, 271-278.

WINSLOW, M.R., (1962). Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Iowa. *U.S. Geological Survey Professional Paper*, **364**, 1-93.

ZERNDT, J., (1934). Les Mégaspores du bassin houiller polonais. I. Les couches anticlinales. *Prace Instytut Geologiczne*, **1**, 1-56.

ZHU, H., (1993). A revised sub-division of the Namurian of Jingyuan, northwest China. *Review of Palaeobotany and Palynology*, **77**, 273-300.

ZIEGLER, P.A., (1981). Evolution of sedimentary basins in North-West Europe. *In* ILLING, L.V. & HOBSON, D.G., (eds), *Petroleum Geology of the continental Shelf of North West Europe*, Institute of Petroleum, London, 25-34.

ZIEGLER, P.A., (1982). Faulting and graben formation in Western and Central Europe. *Philosophical Transactions of the Royal Society, London, A*, **305**, 113-143.

ZIEGLER, P.A., (1990). *Geological atlas of Western and Central Europe.* 2nd revised edition. Shell Internationale Petroleum Maatschappij, The Hague, 1-239.

PLATES.

All figured specimens are recovered from wells 44/22-1, 44/22-2 and 44/22-3 except for specimens of those taxa used in the biostratigraphic classification which were not encountered in the 44/22 study. Such figured specimens wells are indicated by an asterisk.

Specimens are identified by well number; sample depth; slide number; England Finder reference.

All specimens are illustrated at a magnification of x500 unless otherwise stated.

PLATE 1.

1. *Adelisporites multiplicatus*. Laevigate form. 44/22-1, 11414.9', 1, F45.
2. *Adelisporites multiplicatus*. Granulate form. 44/22-1, 11685', 1, T66.1.
3. *Calamospora parva*. 44/22-1, 11375.5', 1, K53.1.
4. *Calamospora straminea*. 44/22-1, 11685', 2, R46.
5. *Calamospora multiplicata*. 44/22-1, 11414.9', 1, K32.1.
6. *Calamospora breviradiata*. 44/22-1, 11610', 3, Q31.4.
7. *Calamospora hartungiana*. 44/22-1, 11758', 1, F47.4.
8. *Calamospora pedata*. 44/22-1, 11878', 2, P31.
9. *Calamospora majus*. 44/22-1, 11753', 2, P41.3.
10. *Calamospora magnifica*. 44/22-3, 11458', 1, J52.3.
11. *Calamospora* cf. *laevigata*. 44/22-3, 12016', 1, G43.1.

PLATE 1

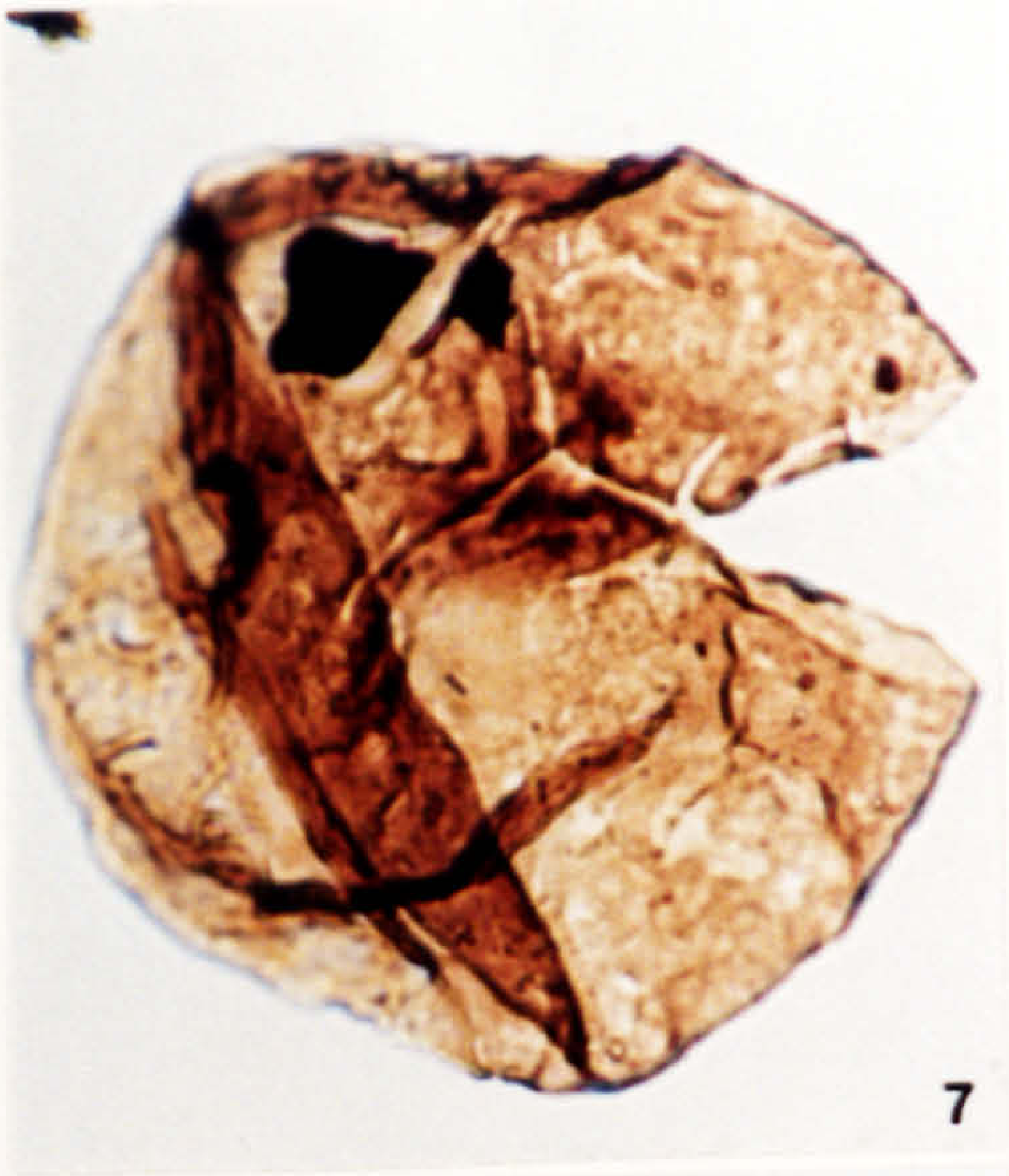

1


3

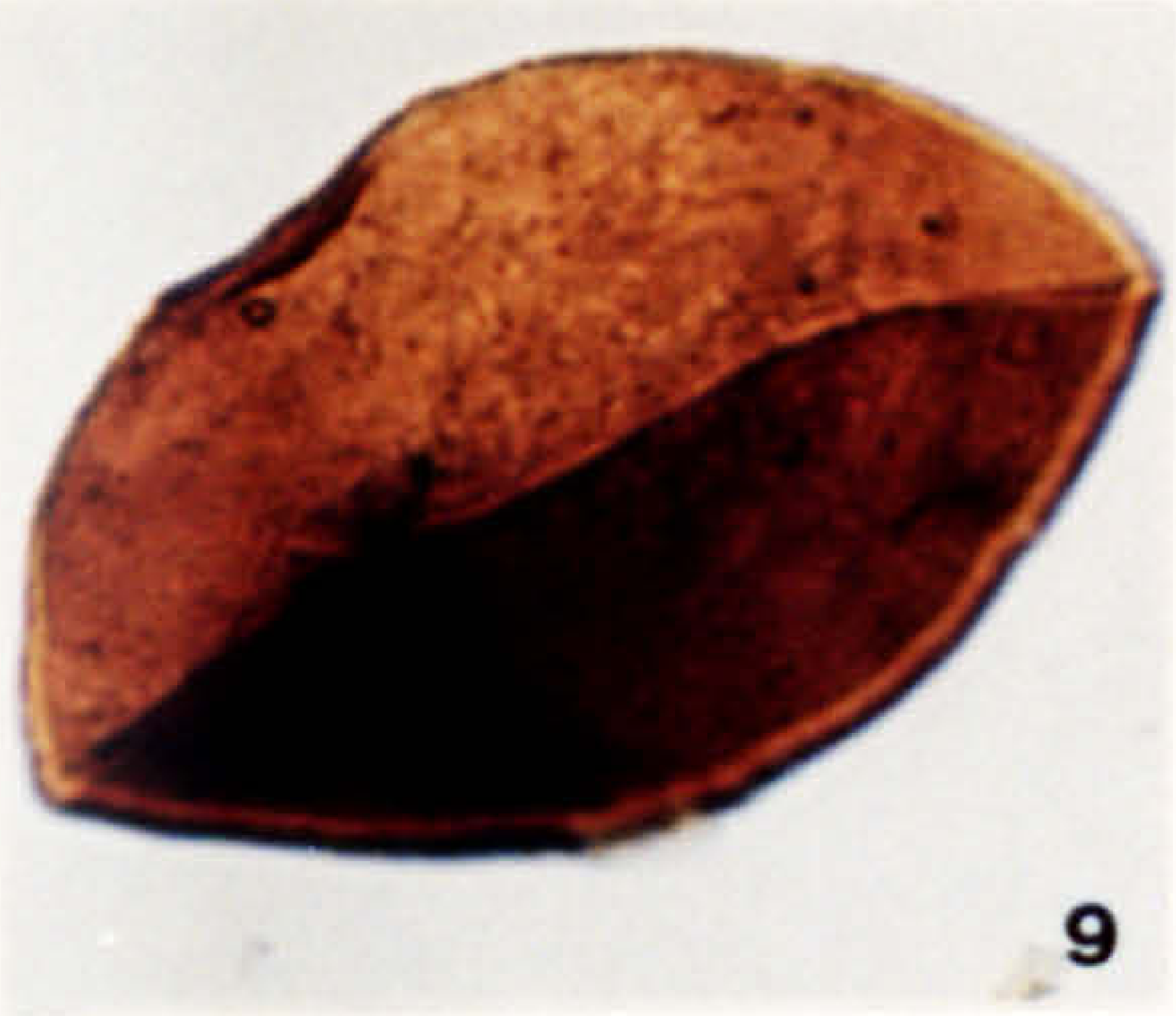

4

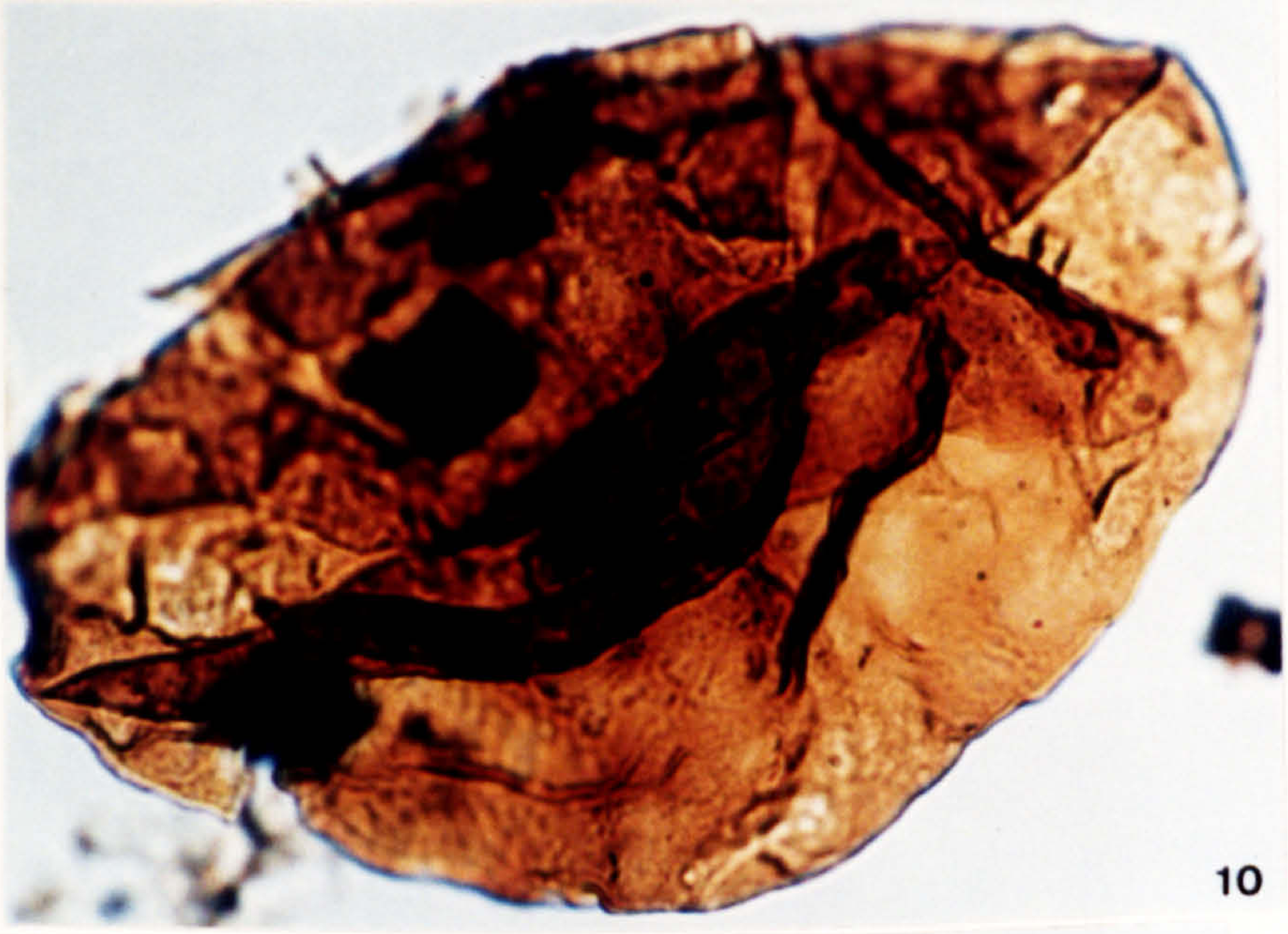

5


6


7


8


9


10


11

PLATE 2.

1. *Calamospora perrugosa*. 44/22-1, 11685', 1, J38.1.
2. *Calamospora* cf. *pallida*. 44/22-1, 11878', 1, K44.4.
3. *Calamospora pallida*. 44/22-1, 11424.9', 2, O55.
4. *Calamospora labiata*. 44/22-1, 11506', 1, V52.
5. *Calamospora microrugosa*. 44/22-1, 11752', 2, S37.2.
6. *Calamospora liquida*. 44/22-1, 11393', 1, T54.4.
7. *Calamospora mutabilis*. 44/22-1, 11393', 1, G62.3.
8. *Calamospora obtecta*. 44/22-1, 11878', 2, G42.
9. *Deltoidospora subadnatoides*. 44/22-3, 11920', 1, V45.4.
10. *Deltoidospora adnata*. 44/22-1, 11758', 1, Q54.4.
11. *Deltoidospora inerma*. 44/22-4, 12252.6', 2, L47.1.
12. *Waltzispora polita*. 44/22-1, 11758', 1, W36.3.
13. *Deltoidospora subintorta*. 44/22-4, 12095', 1, J36.
14. *Deltoidospora levis*. 44/22-1, 11752', 1, F48.3.
15. *Deltoidospora convexa*. 44/22-1, 11414.9', 1, T37.
16. *Deltoidospora ornata*. 44/22-4, 12253.7', 1, O49.4.
17. *Deltoidospora smithii*. 44/22-3, 11855', 2, C61.3.

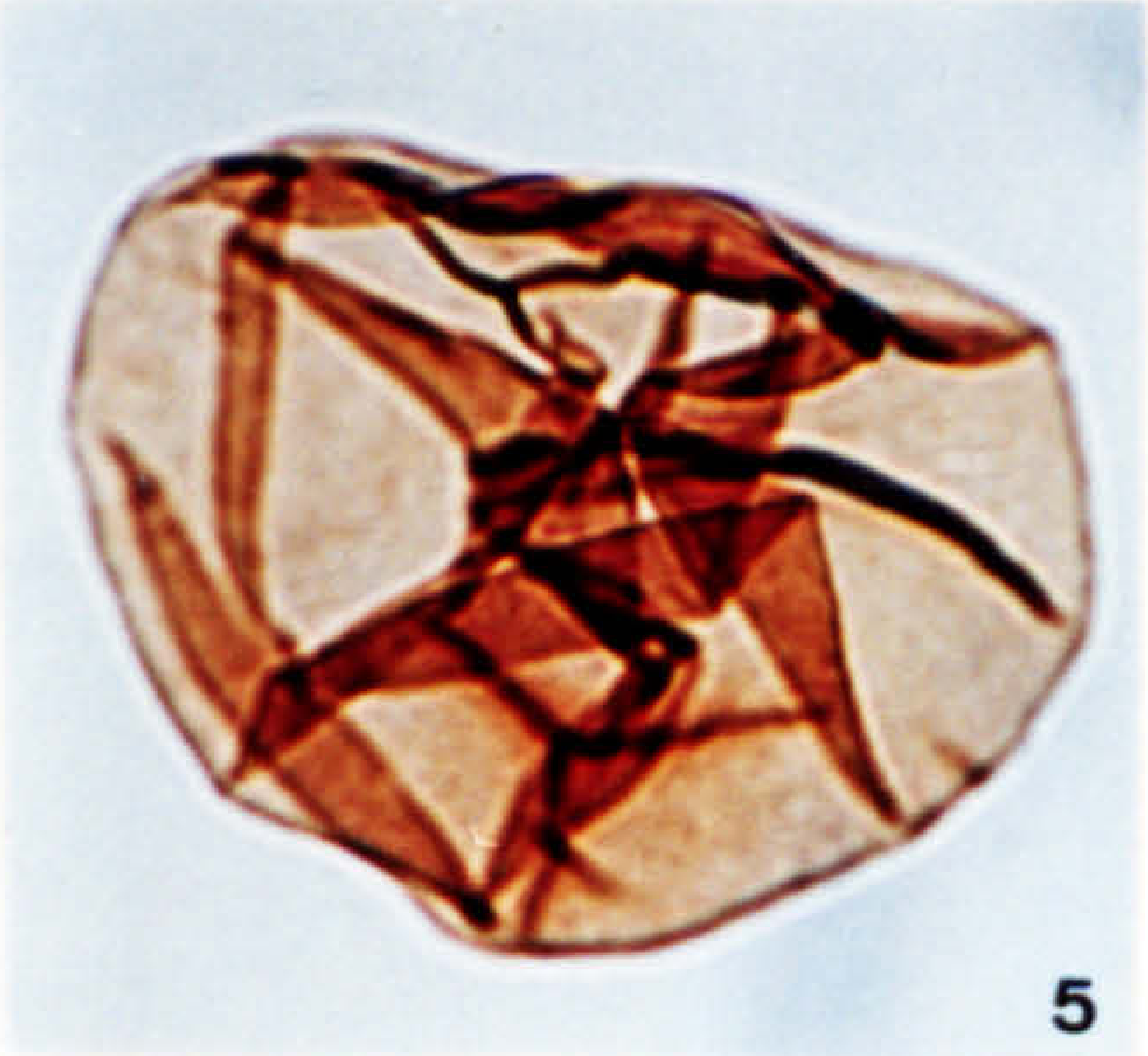
PLATE 2


1


2

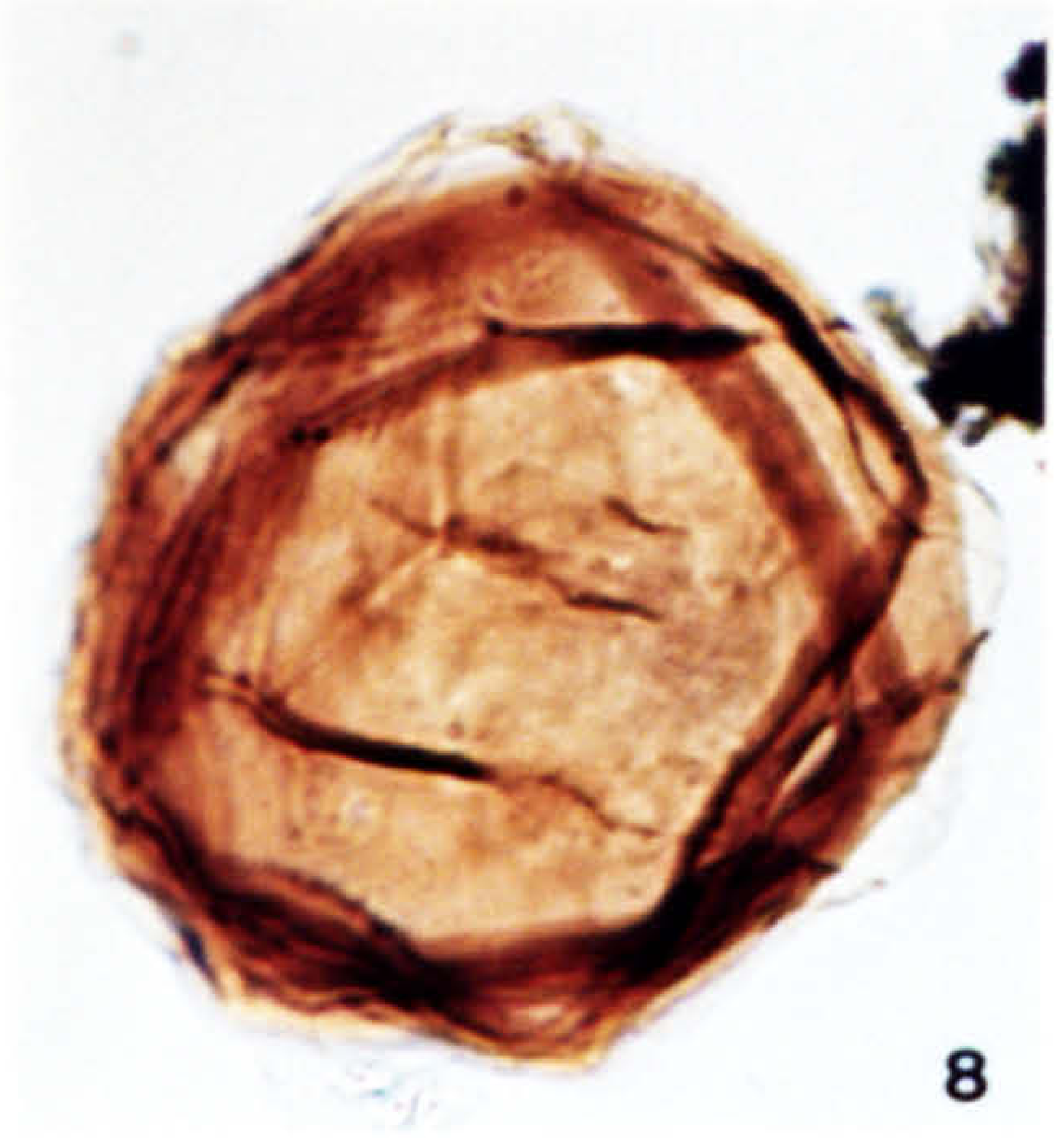

3


4


5


6


7


8

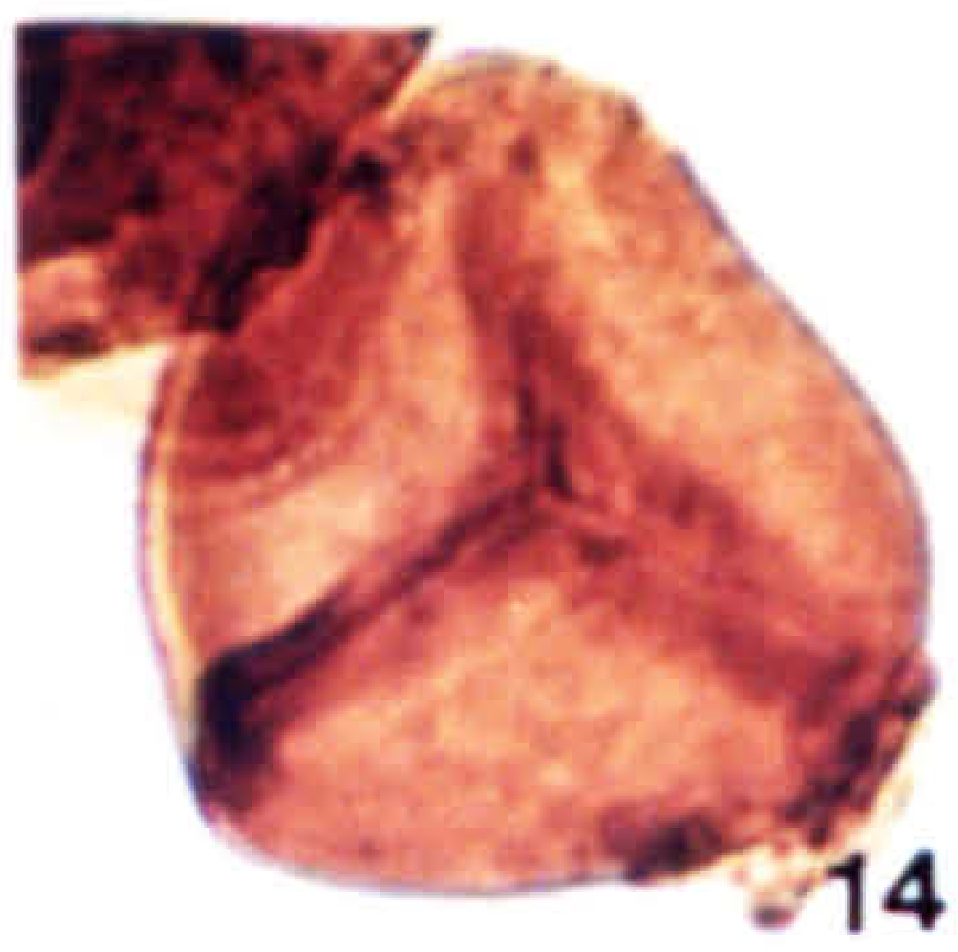

9


10


11


12


13


14


15


16

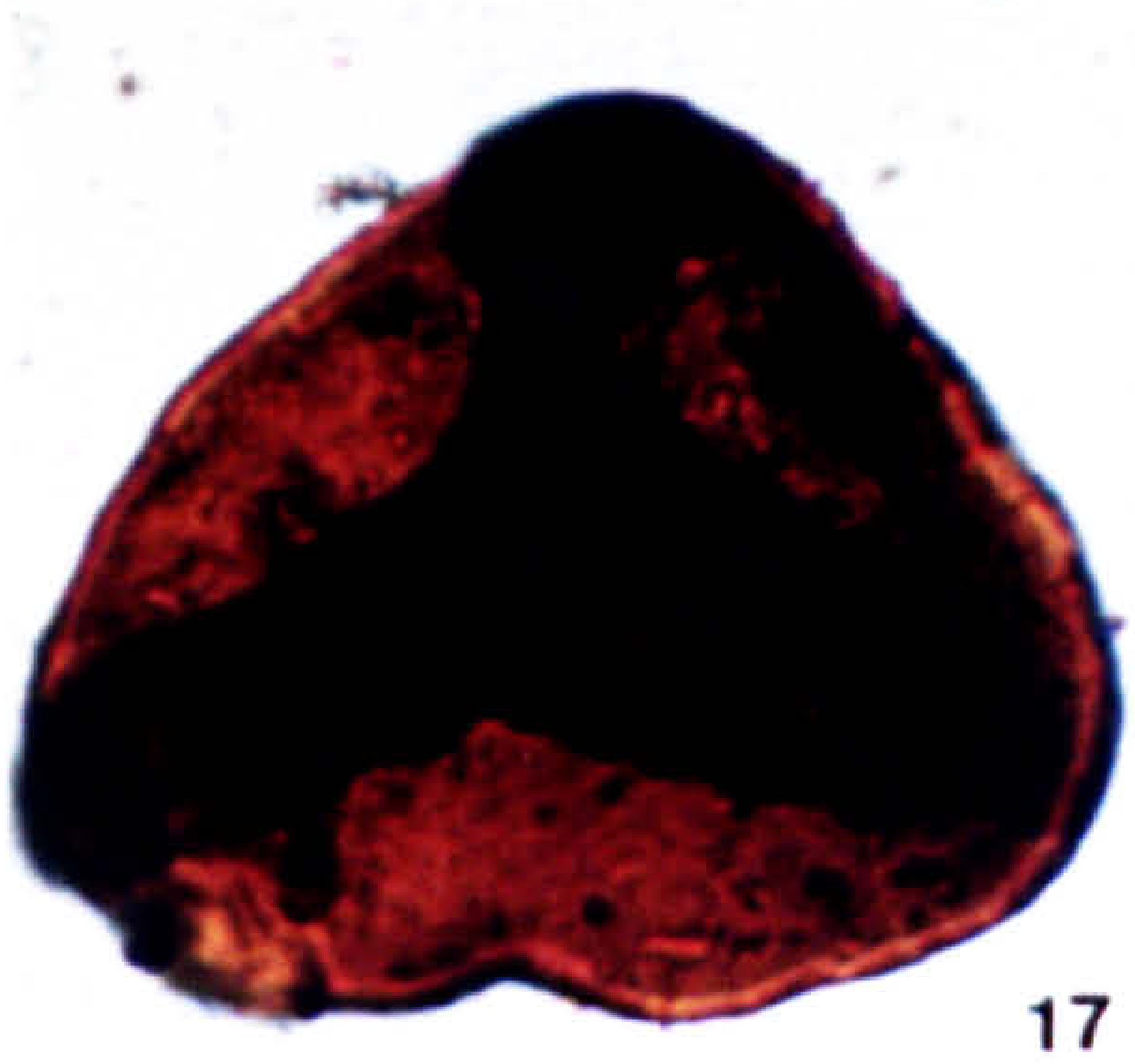

17

PLATE 3.

1. *Deltoidospora minuta*. 44/2-1, 11683', 1, P30.

2. *Deltoidospora priddyi*. 44/22-1, 11880', 1, X67.4.

3. *Deltoidospora sphaerotriangula*. 44/22-1, 11785', 1, F48.4.

4. *Retusotriletes minutus*. 44/22-1, 11375.5', 1, G29.3.

5. *Retusotriletes minutus*. 44/22-1, 11414.9', 1, C34.4.

6. *Deltoidospora* aff. *tumida*. 44/22-1, 12060', 2, S38.1.

7. *Deltoidospora* aff. *tumida*. 44/22-1, 12060', 1, U45.

8. *Punctatisporites minutus*. 44/22-1, 11414.9', 2, R46.4.

9. *Punctatisporites minutus*. 44/22-1, 11414.9', 2, L50.3.

10. *Punctatisporites glaber*. 44/22-3, 11876', 1, E50.

11. *Deltoidospora* aff. *tumida*. 44/22-1, 12031', 1, E43.

12. *Punctatisporites edgarensis*. 44/22-1, 11878', 2, J56.4.

13. *Punctatisporites nitidus*. 44/22-1, 12031', 2, P43.

14. *Punctatisporites glaber*. 44/22-1, 11753', 1, P37.

15. *Punctatisporites punctatus*. 44/22-3, 11855', 4, X49.2.

16. *Punctatisporites aerarius*. 44/22-1, 12064', 1, C63.3.

17. *Punctatisporites flavus*. 44/22-1, 11389', 1, H59.4.

18. *Punctatisporites obesus*. 44/22-1, 12242', 2, P39.4.

19. *Punctatisporites pseudopunctatus*. 44/22-1, 11600', 2, R55.2.

20. *Punctatisporites flavus*. 44/22-1, 11878', 2, R35.

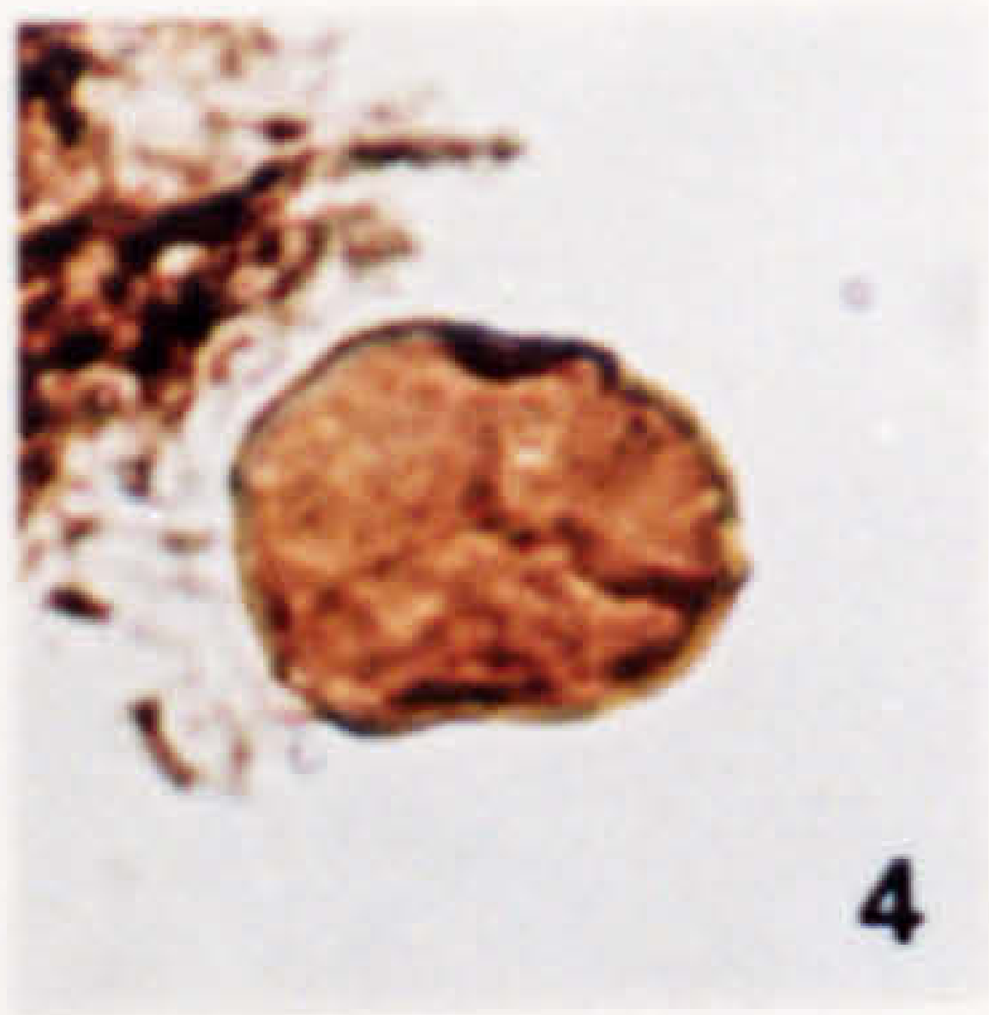
21. *Sinuspores* cf. *sinuatus*. 44/22-4, 12130', 1, H56.

PLATE 3


1


2


3


4


5


6


7


8

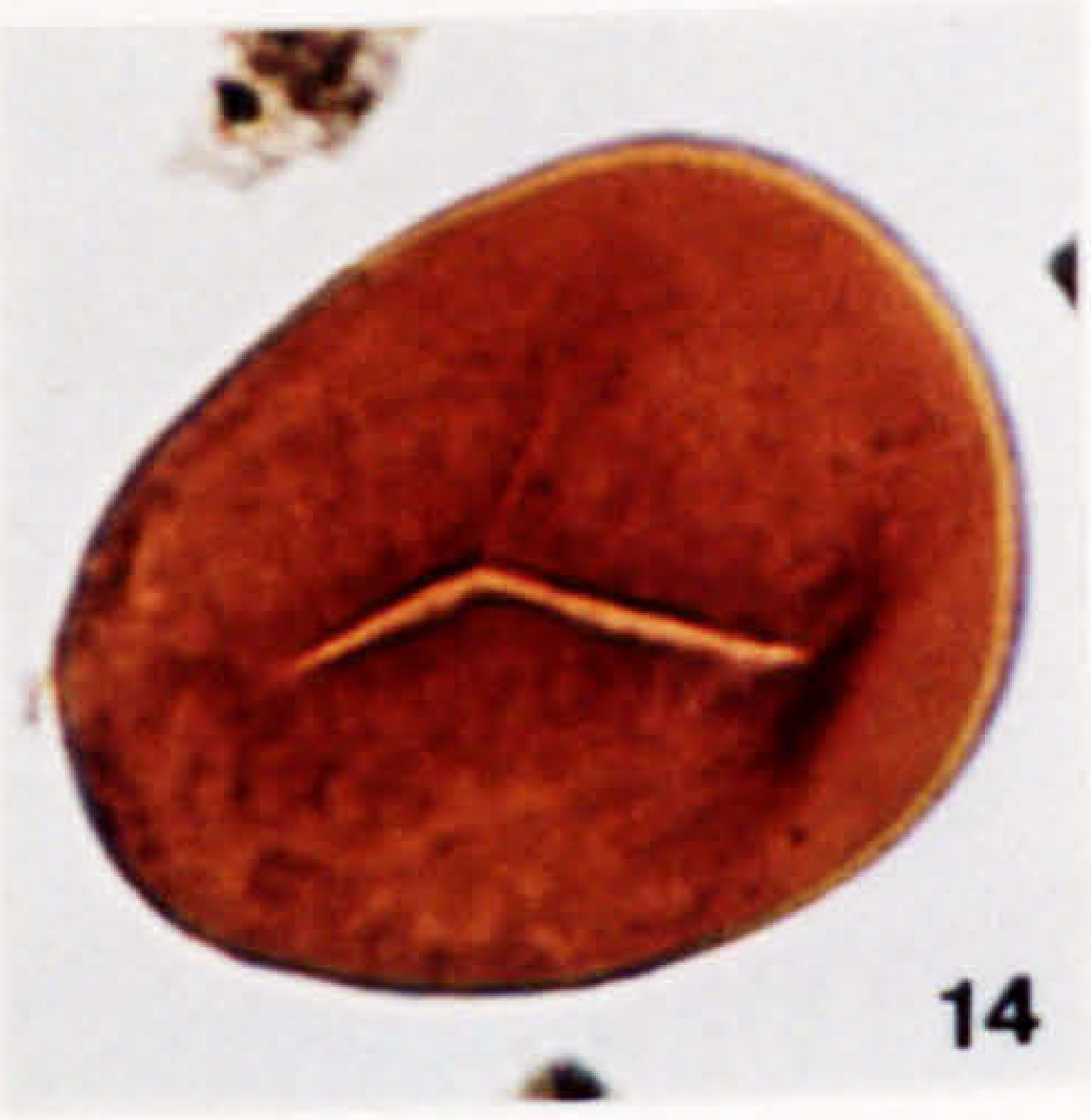

9

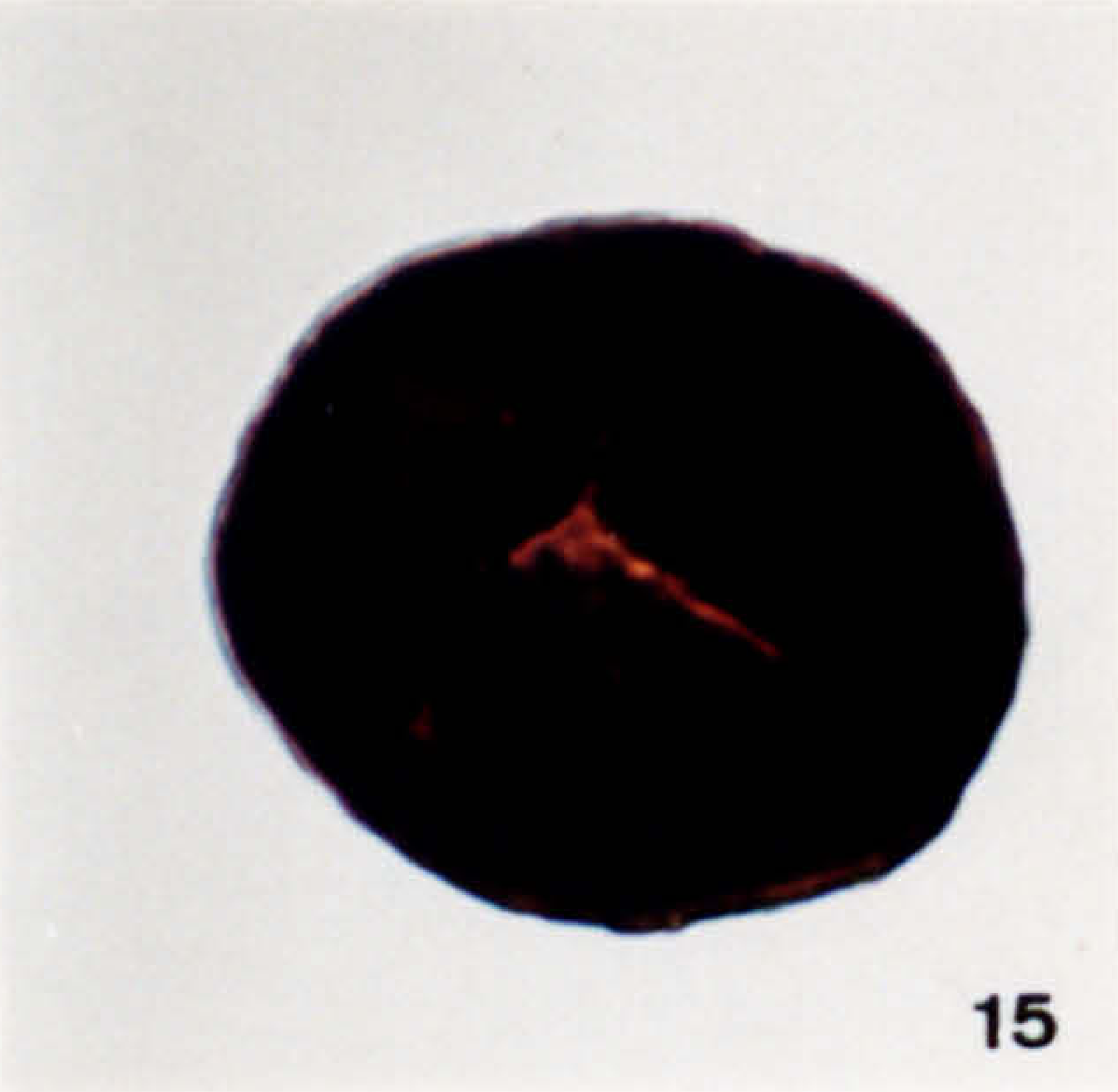

10


11


12

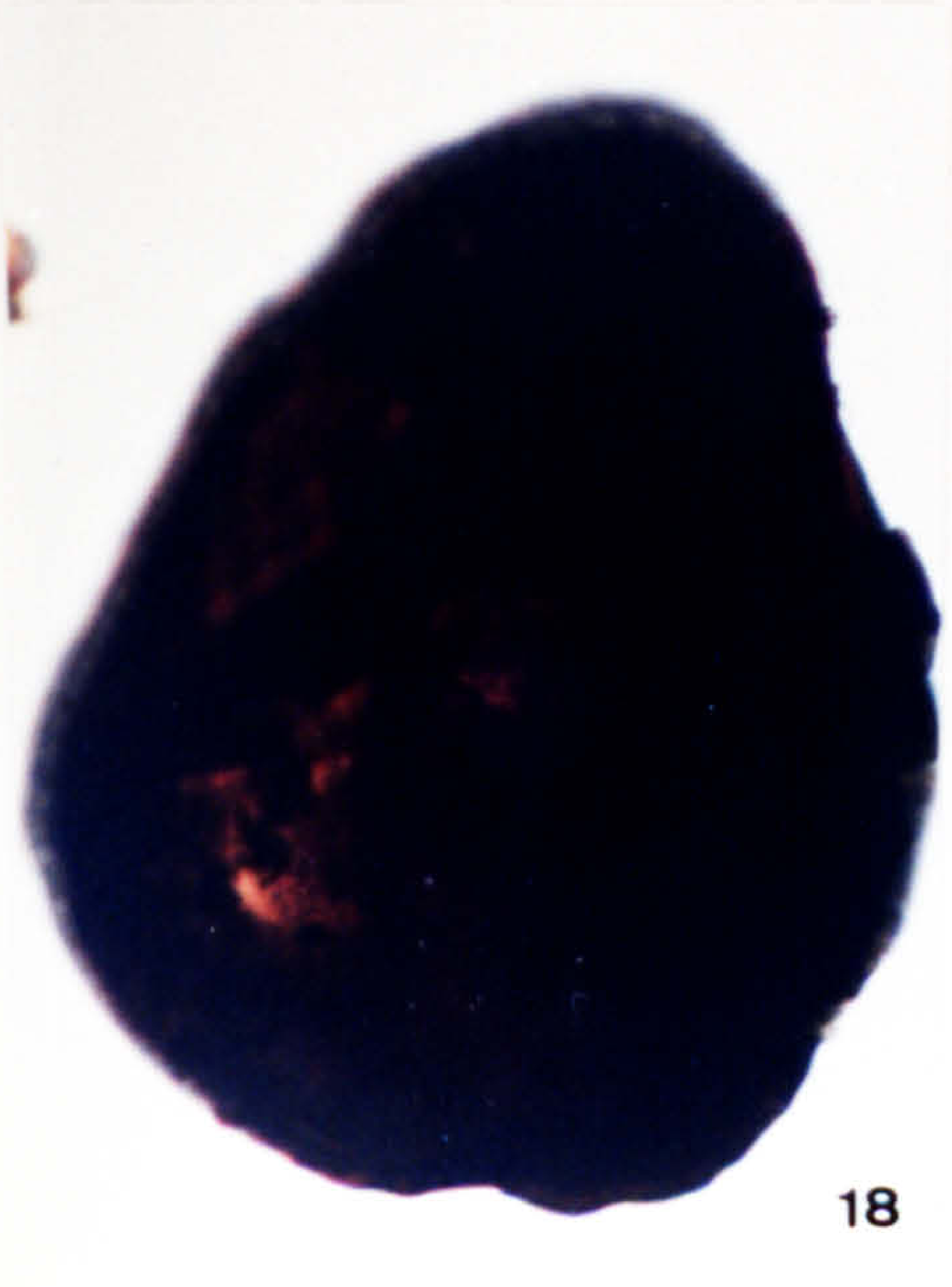

13

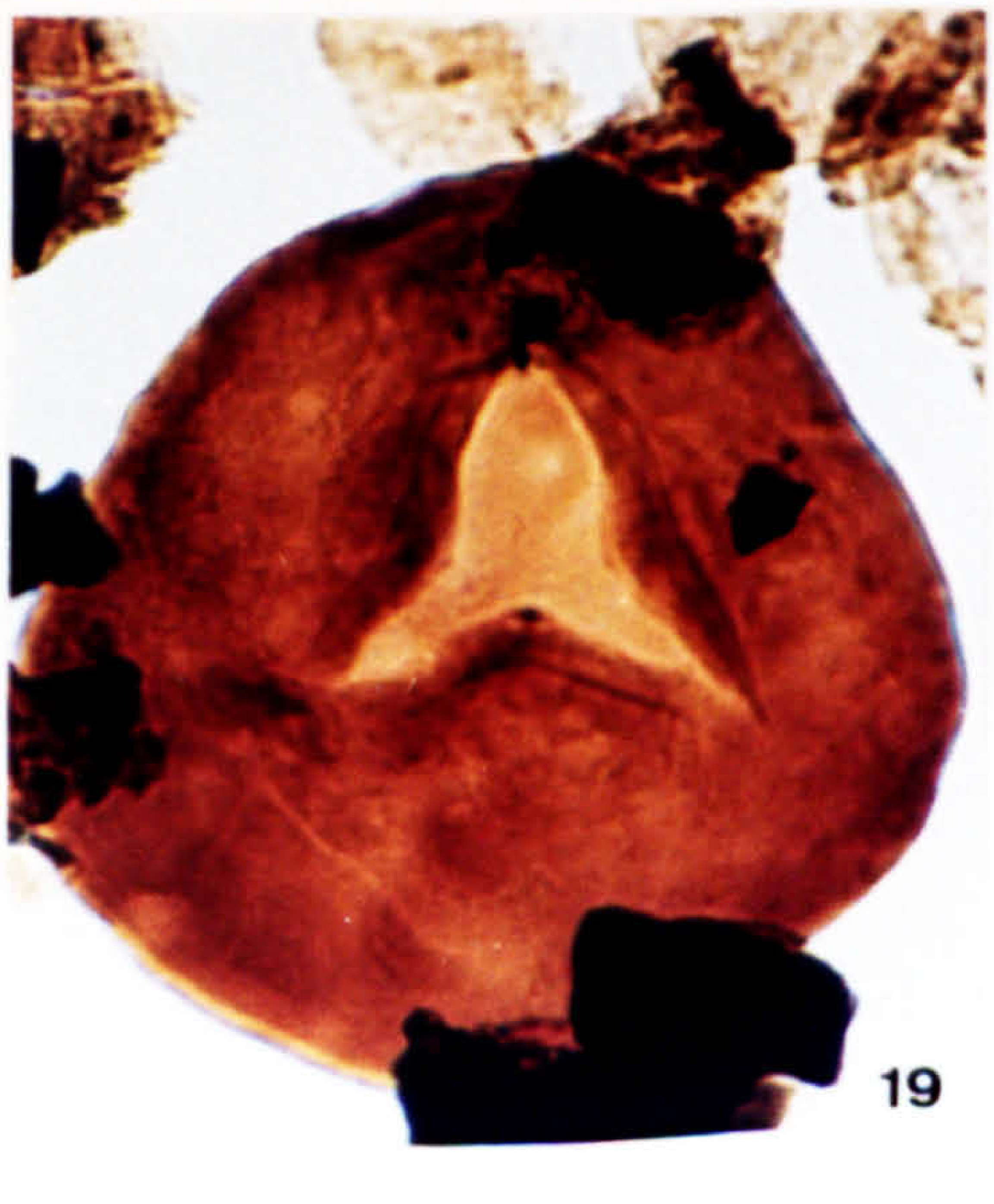

14


15


16


17


18


19

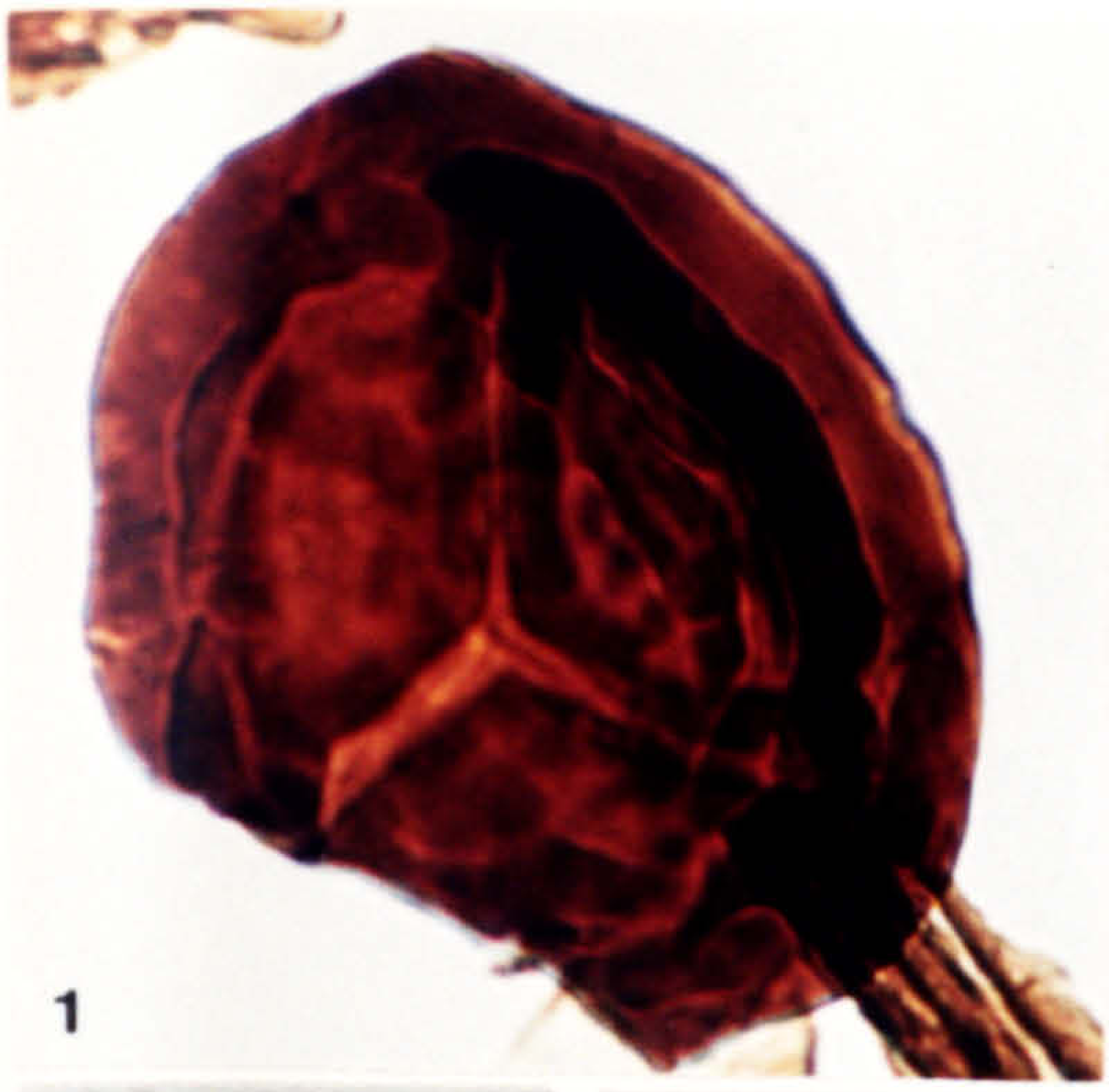

20

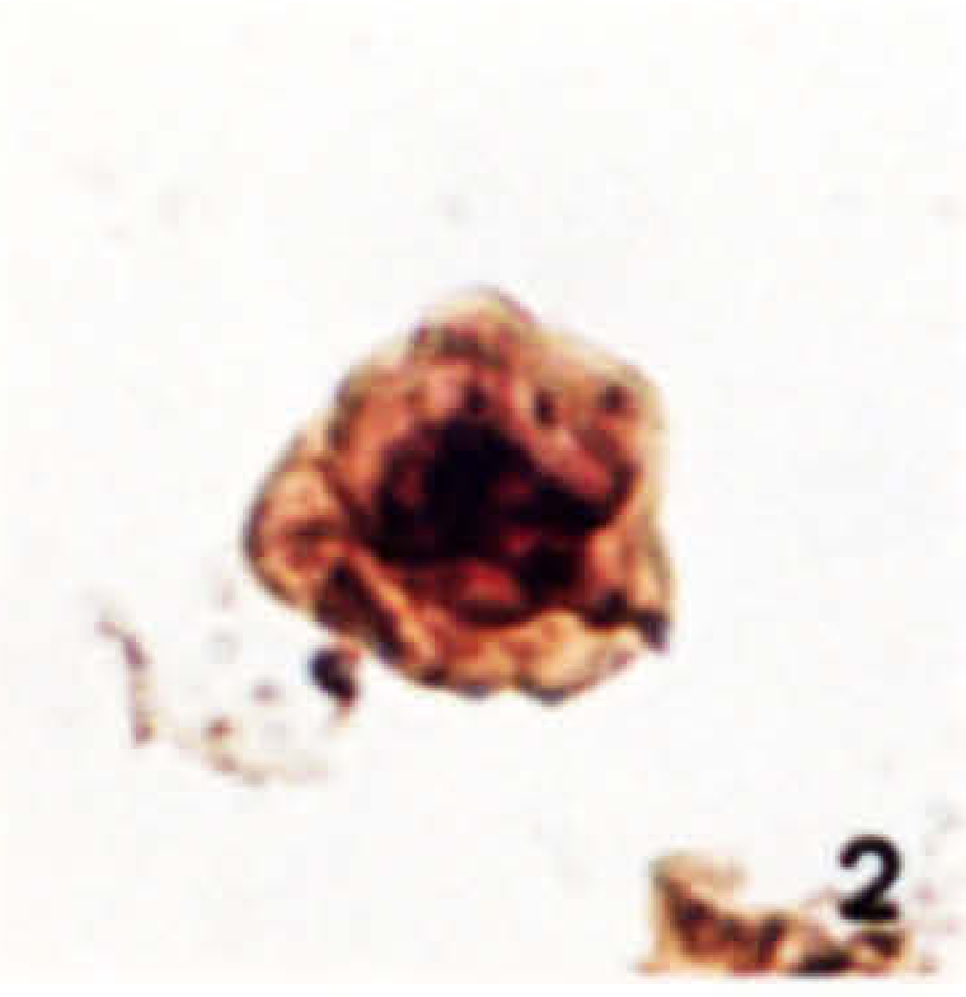

21

PLATE 4.

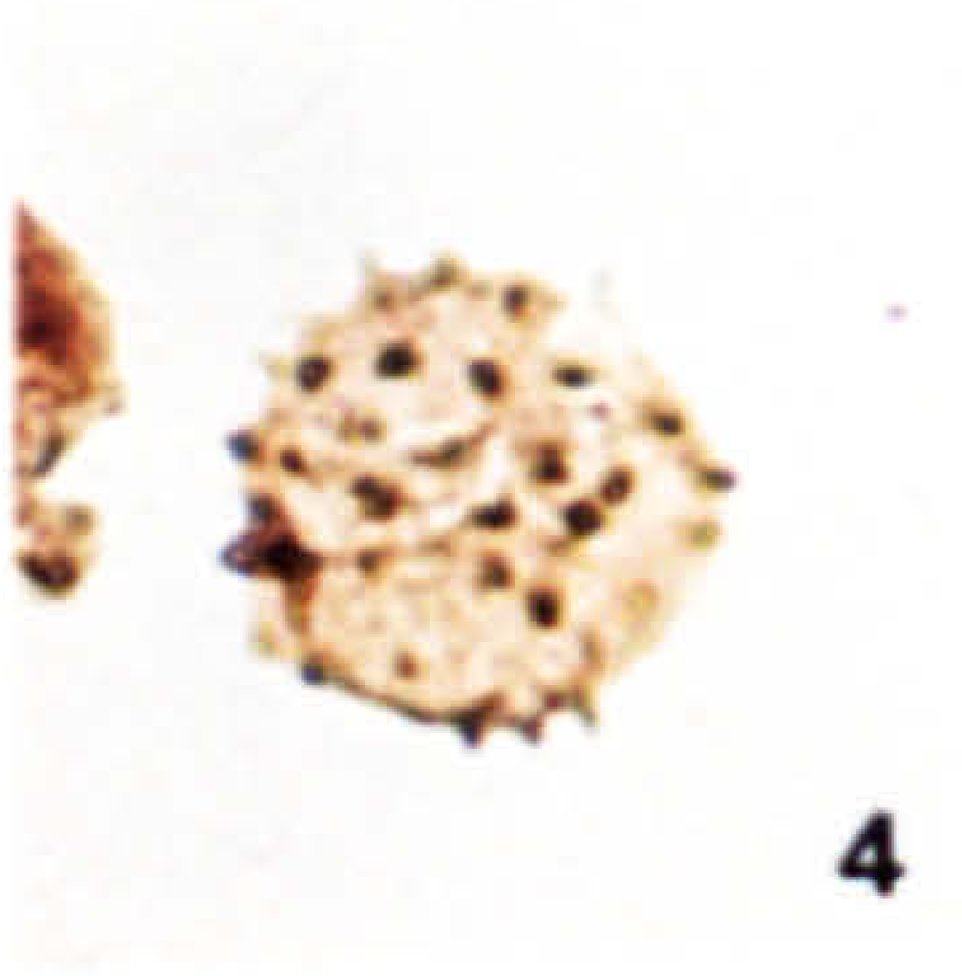
1. *Sinuspores sinuatus*. Broken specimen. 44/22-4, 12430', 2, K40.3.
2. *Scutulum pusillum*. 44/22-1, 11375.5', 1, V39.3.
3. *Anapiculatisporites northumbriensis*. 44/22-1, 11414.9', 1, S39.
4. *Anapiculatisporites protuberatus*. 44/22-1, 11683', 1, C47.
5. *Spinositriletes paucispinosus*. 44/22-1, 12060', 3, L36.
6. *Spinositriletes minor*. 44/22-3, 12019', 2, L49.4.
7. *Anapiculatisporites baccatus*. 44/22-1, 11422', 1, H40.3.
8. *Apiculiretusispora granulata*. 44/22-3, 11458', 1, E60.
9. *Apiculiretusispora minuta*. 44/22-1, 11422', 1, C60.4.
10. *Lophotriletes pseudaculeatus*. 44/22-1, 11685', 2, F43.
11. *Lophotriletes commissuralis*. 44/22-1, 11753', 1, R53.
12. *Lophotriletes gibbosus*. 44/22-1, 12242', 1, F48.
13. *Lophotriletes ibrahimii*. 44/22-1, 12028', 2, H51.4.
14. *Lophotriletes mosaicus*. 44/22-1, 12060', 3, L53.3.
15. *Lophotriletes microsaetosus*. 44/22-1, 12242', 1, S57.
16. *Lophotriletes* cf. *microsaetosus*. 44/22-1, 11393', 1, R58.
17. *Tantillus triquetrus*. 44/22-1, 11600', 1, G51.1.
18. *Apiculatasporites aculeatus*. 44/22-1, 11422', 1, Q40.3.
19. *Apiculatasporites spinulistratus*. 44/22-1, 12064', 2, K48.2.
20. *Apiculatasporites latigranifer*. 44/22-1, 11506', 2, O52.2.
21. *Apiculatasporites latigranifer*. 44/22-4, 12102', 2, Q36.3.
22. *Apiculatasporites spinososaetosus*. 44/22-3, 11458', 1, K48.3.
23. *Apiculatasporites setulosus*. 44/22-4, 12380', 1, O44.2.
24. *Apiculatasporites variocorneus*. 44/22-1, 12119', 2, O33.3.
25. *Dibolisporites ranunculioides*. Tetrad. 44/22-1, 11878', 2, L37.
26. *Pilosisporites microspinosus*. 44/22-1, 11414.9', 1, H34.2.
27. *Pilosisporites aculeolatus*. 44/22-1, 11878', 1, H31.4.
28. *Pilosisporites williamsii*. 44/22-1, 11433', 2, N47.4.
29. *Dibolisporites ranunculioides*. Holotype. 44/22-1, 11878', 2, N46.1.
30. *Dibolisporites ranunculioides*. Specimen with visible trilete mark. 44/22-1, 12032', 2, F51.3.

PLATE 4


1

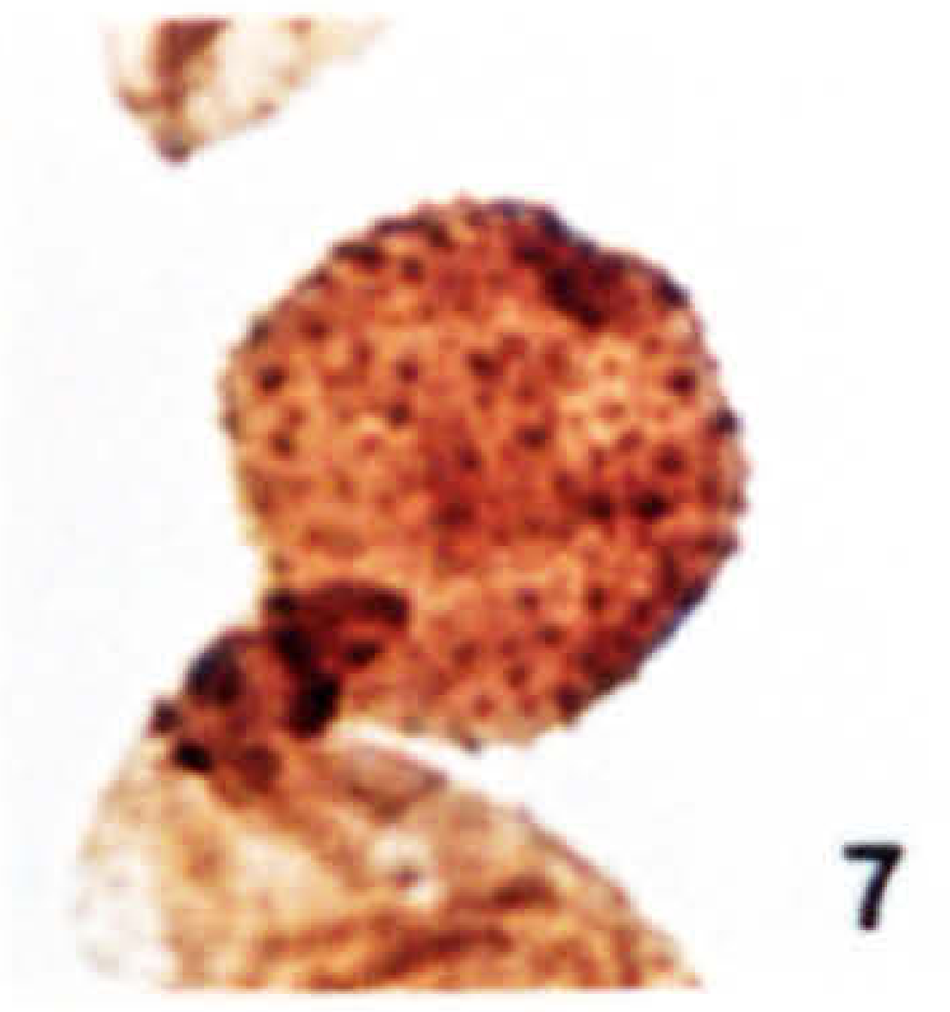

2


3

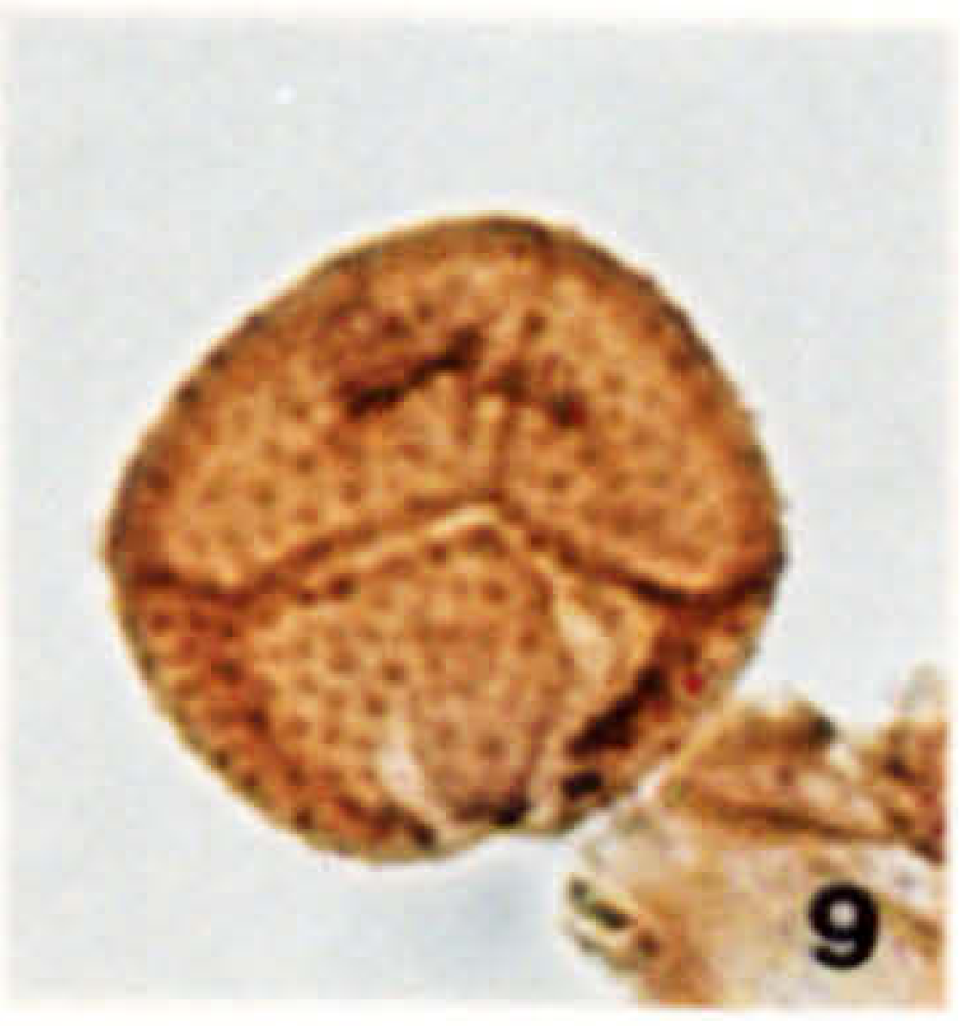

4


5


6


7


8


9


10


11


12

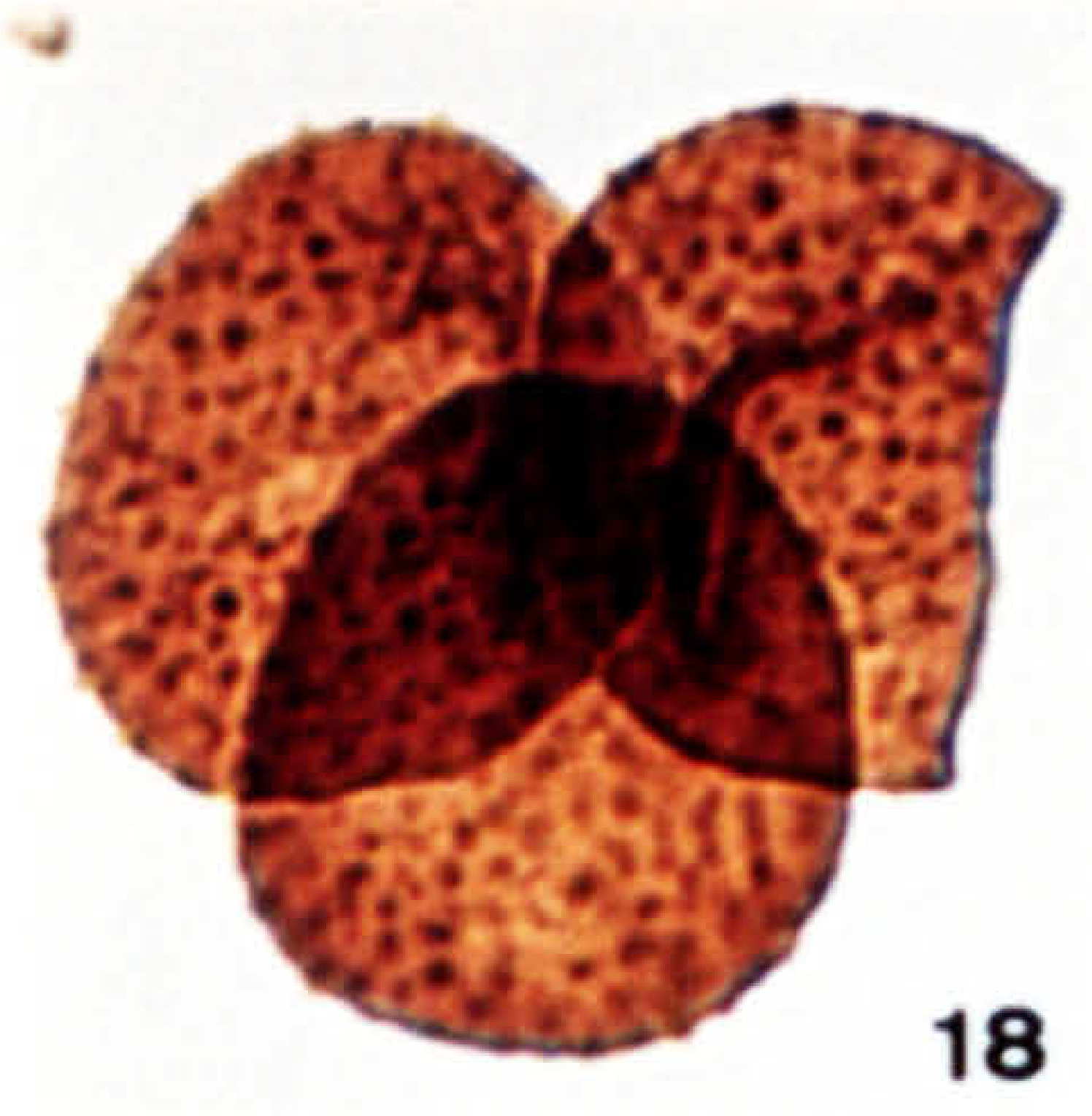

13

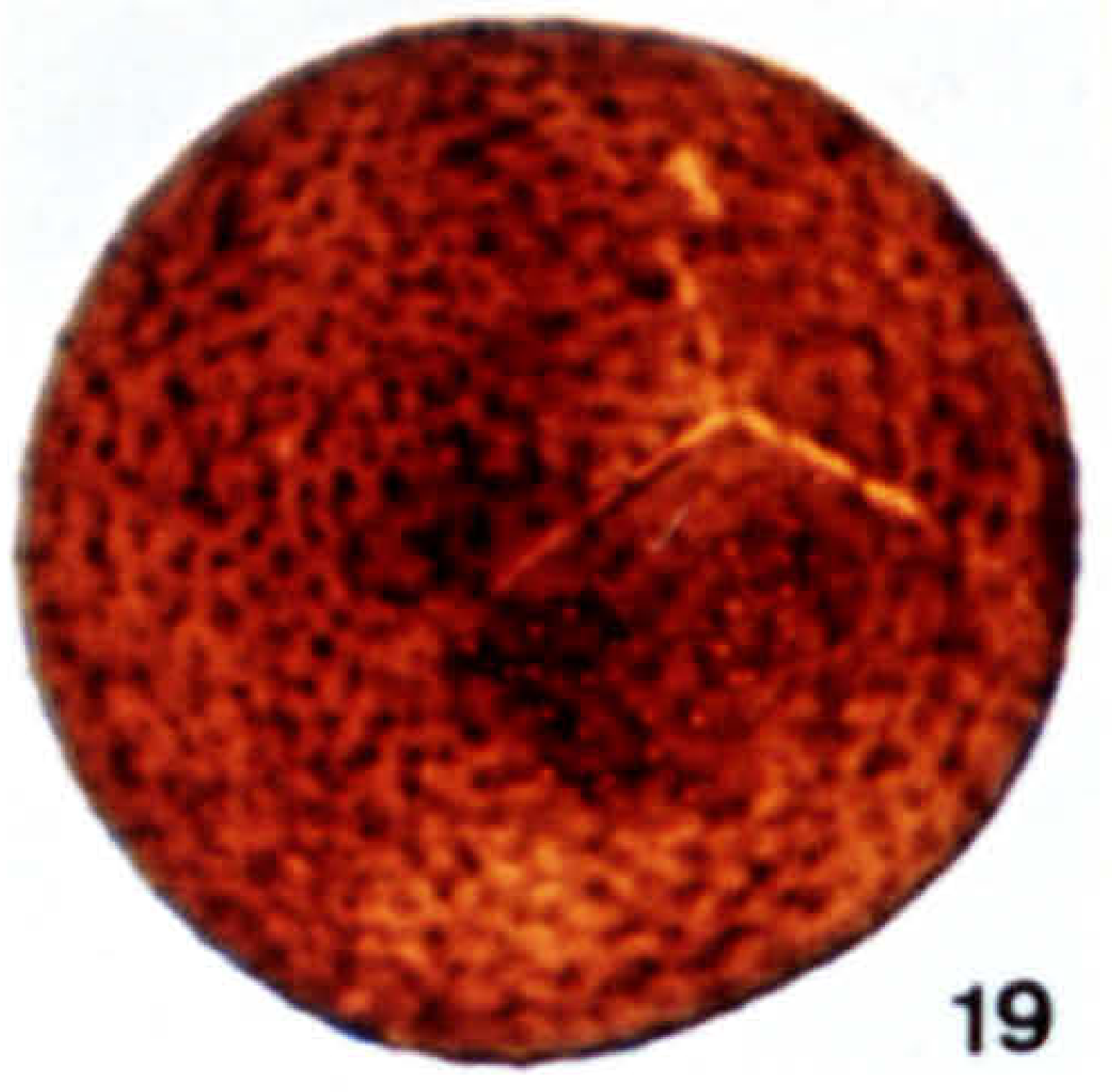

14


15


16


17

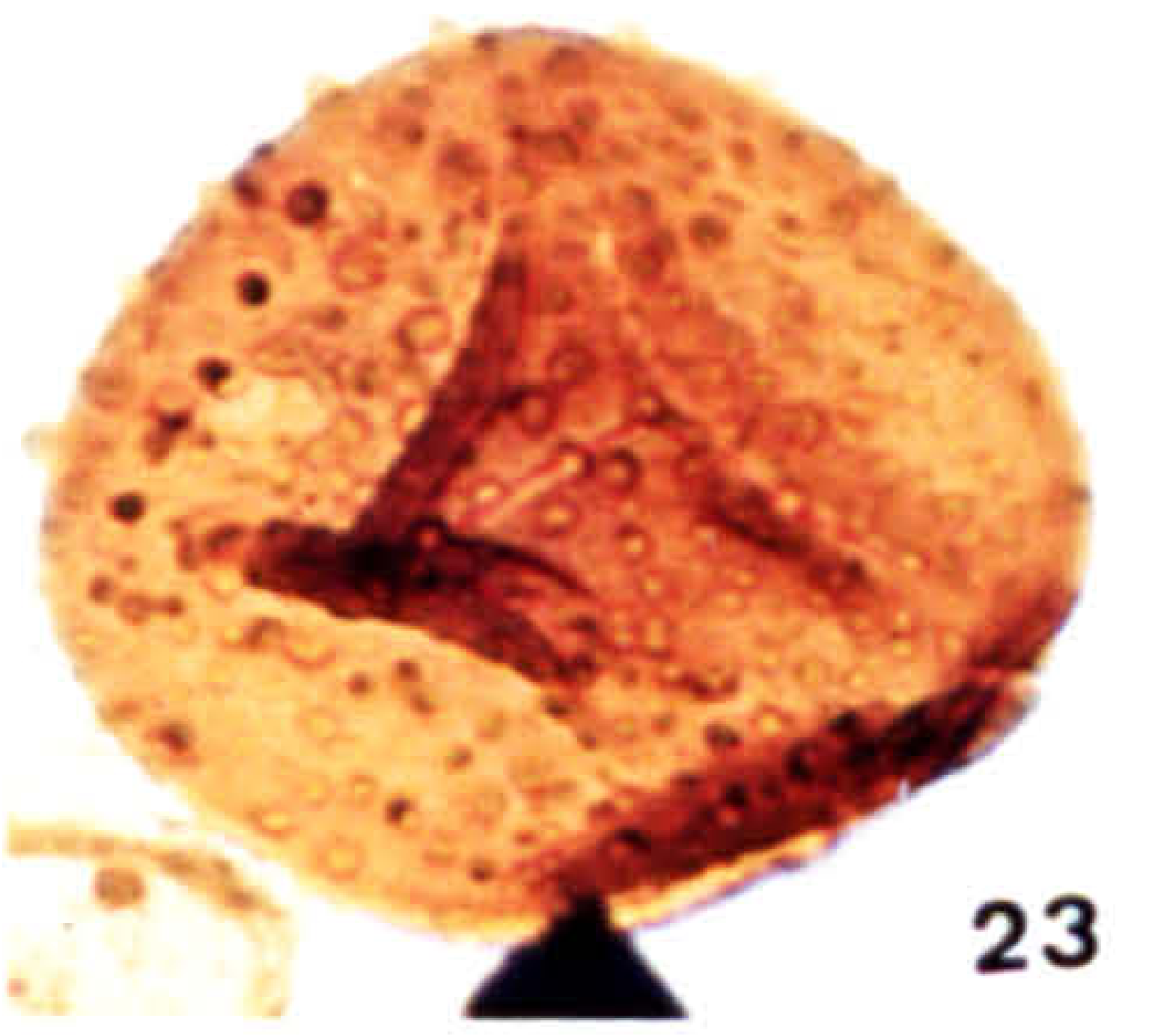

18

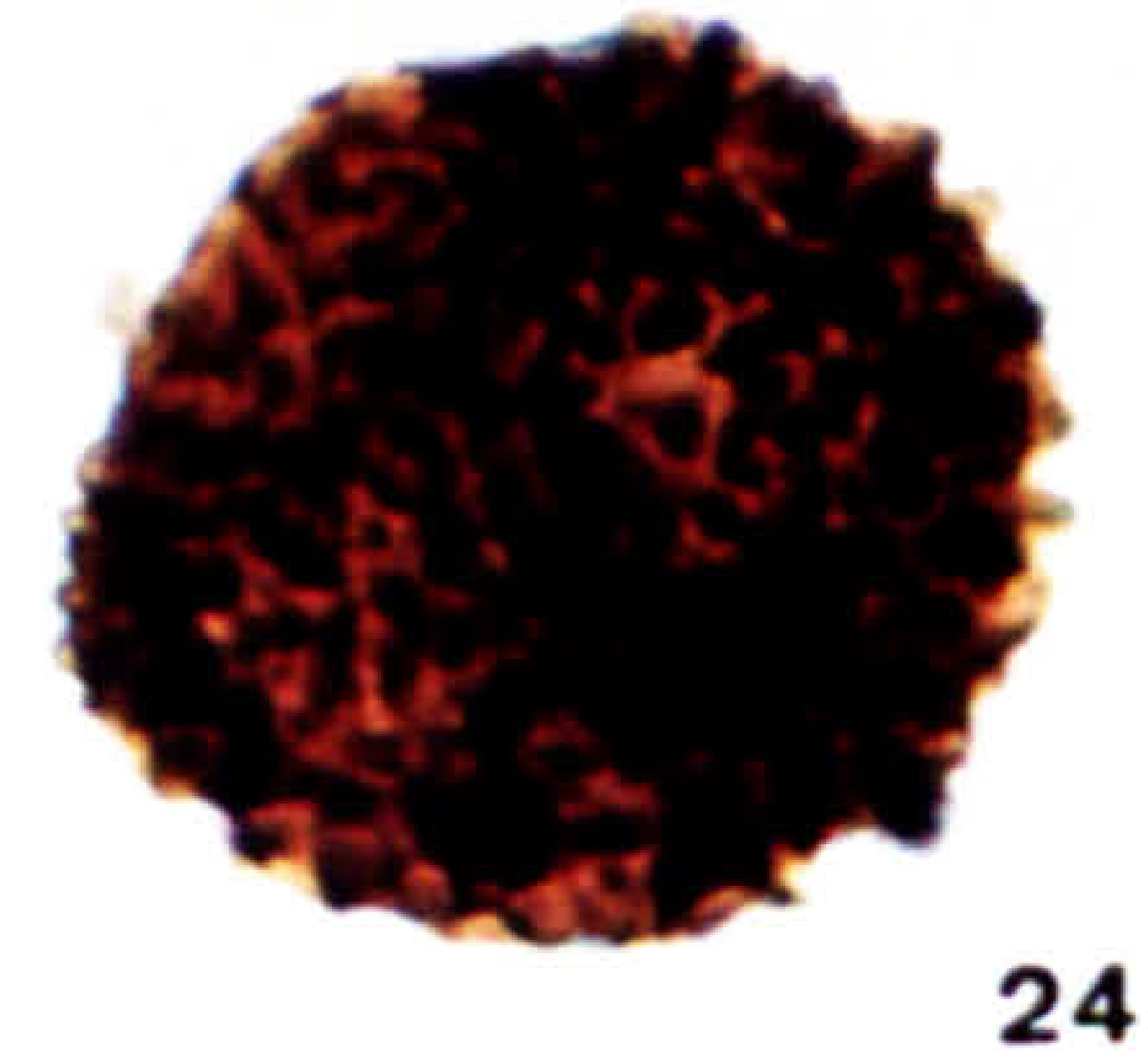

19


20


21

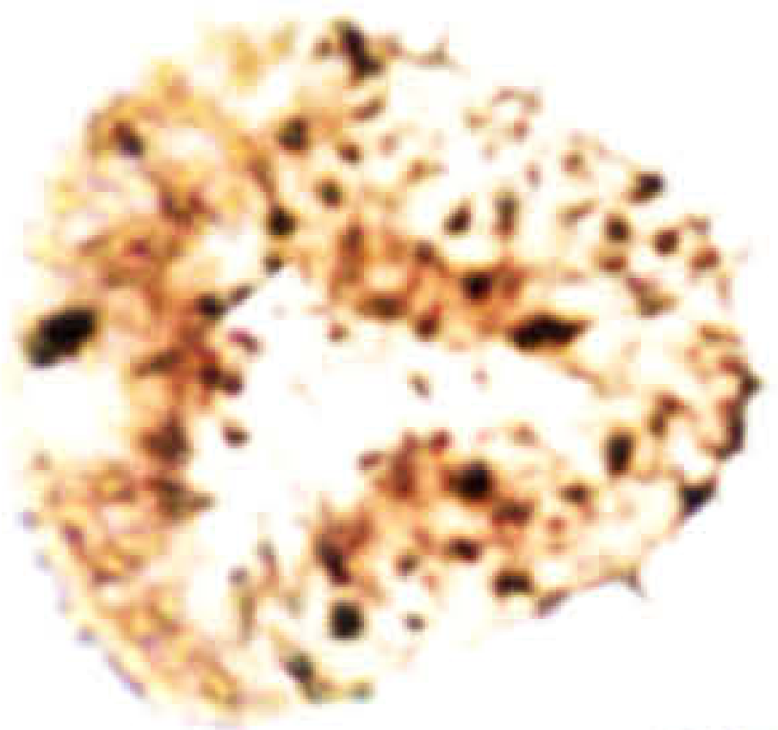

22


23


24


25


26


27


28


29


30

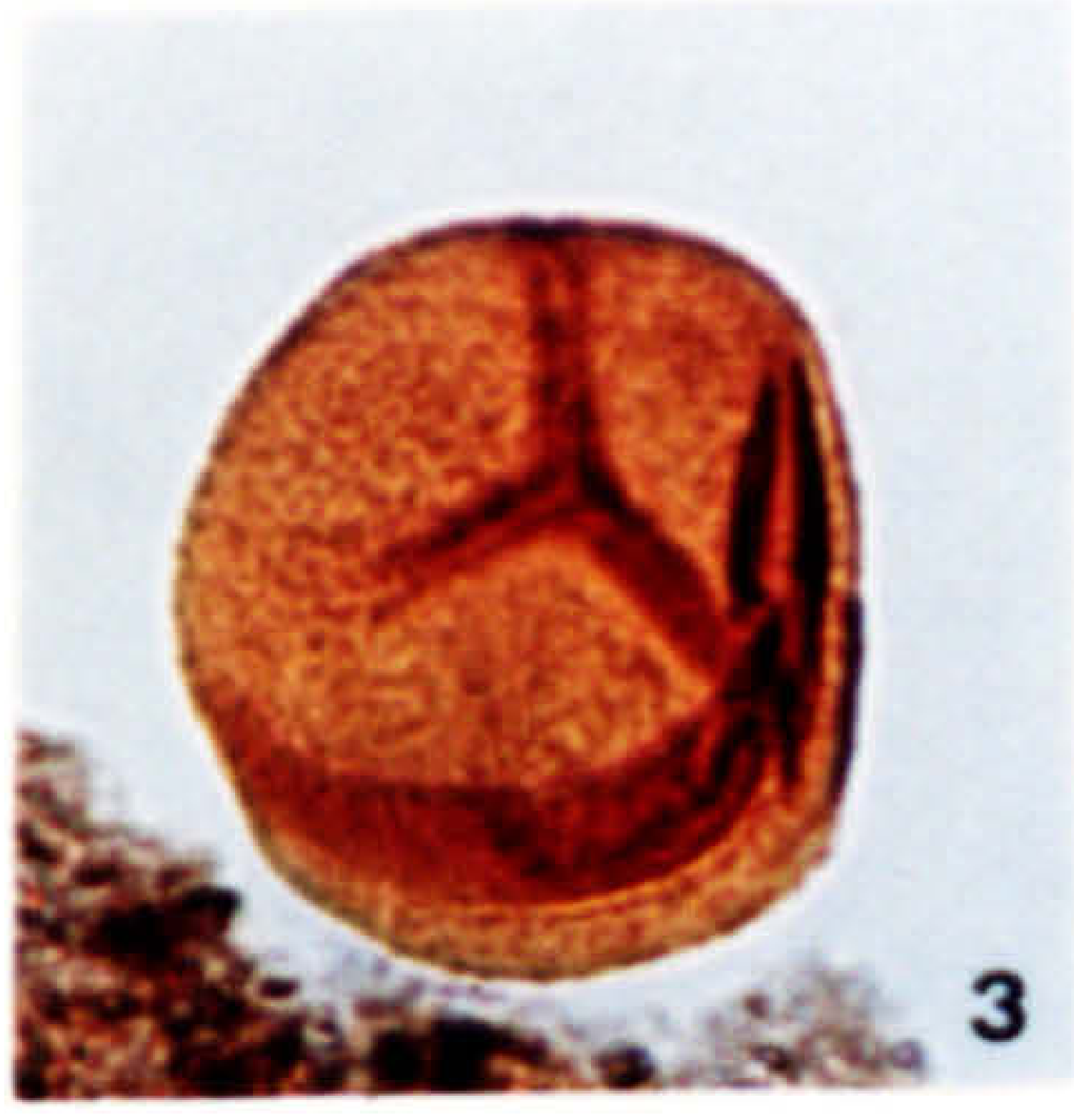
PLATE 5.

1. *Granasporites medius*. 44/22-1, 11389', 1, K40.1.
2. *Cyclogranisporites aureus*. 44/22-1, 11506', 1, K35.4.
3. *Cyclogranisporites multigranus*. 44/22-1, 11685', 1, Q62.1.
4. *Cyclogranisporites minutus*. 44/22-1,11506', 1, X60.1.
5. *Cyclogranisporites leopoldii*. 44/22-1, 12045', 1, N52.2.
6. *Granulatisporites granoornatus*. 44/22-1, 11393', 1, T59.
7. *Granulatisporites adnatoides*. 44/22-1, 11600', 1, S51.
8. *Granulatisporites* cf. *piroformis*. 44/22-3, 12013', 1, X63.1.
9. *Granulatisporites microgranifer*. 44/22-1, 12045', 1, X29.
10. *Granulatisporites granulatus*. 44/22-3, 11600', 2, R38.
11. *Converrucosisporites* aff. *vermiformis*. 44/22-1, 11414.9', 1, H38.
12. *Spackmanites habibii*. 44/22-1, 11375.5', 1, H55.
13. *Pustulatisporites crenatus*. 44/22-1, 11425', 2, C54.4.
14. *Pustulatisporites crenatus*. 44/22-1, 11389', 1, U38.3.
15. *Pustulatisporites pustulatus*. 44/22-3, 11886', 1, M47.2.
16. *Converrucosisporites* aff. *vermiformis*. 44/22-1, 11414.9', 1, K46.
17. *Converrucosisporites armatus*. 44/22-3, 11975, 2, O49.
18. *Verrucosisporites donarii*. 44/22-4, 12155', 1, U56.3.
19. *Verrucosisporites* aff. *gobbettii*. 44/22-3, 11872', 1, O45.
20. *Verrucosisporites perverrucosus*. 11393', 1, T61.
21. *Planisporites granifer*. 44/22-1, 11685', 2, O50.
22. *Verrucosisporites* cf. *cerosus*. 44/22-1, 12119', 2, C45.4.
23. *Verrucosisporites* aff. *gobbettii*. 44/22-1, 12064', 1, G61.
24. *Verrucosisporites perverrucosus*. Two attatched specimens. 44/22-1, 11878', 1, D38.3.
25. *Verrucosisporites cumbriensis*. 44/22-1, 12032', 3, B44.4.
26. *Verrucosisporite microtuberosus*. 44/22-4, 12130', 2, O44.2.
27. *Verrucosisporites verrucosus*. 44/22-1, 11685', 1, G57.4.

PLATE 5


1


2


3


4


5

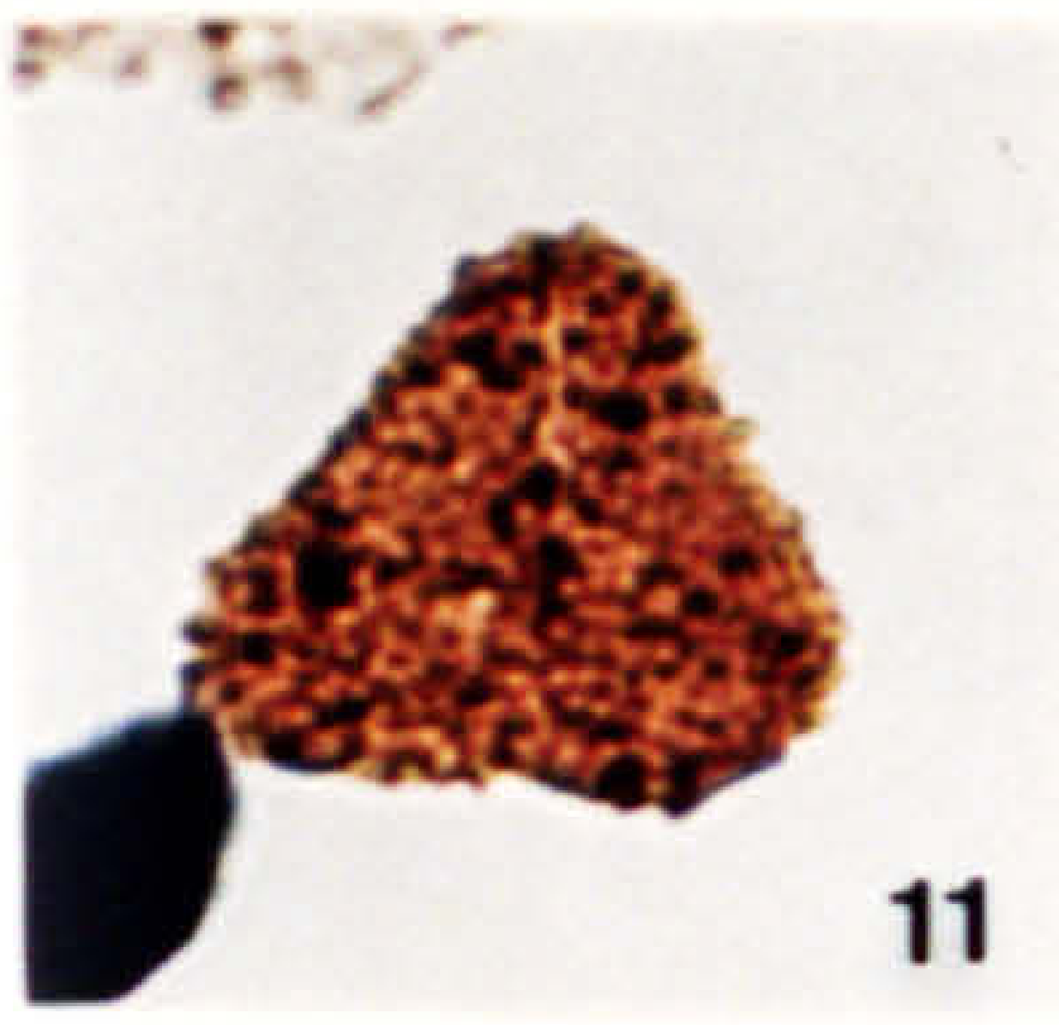

6


7

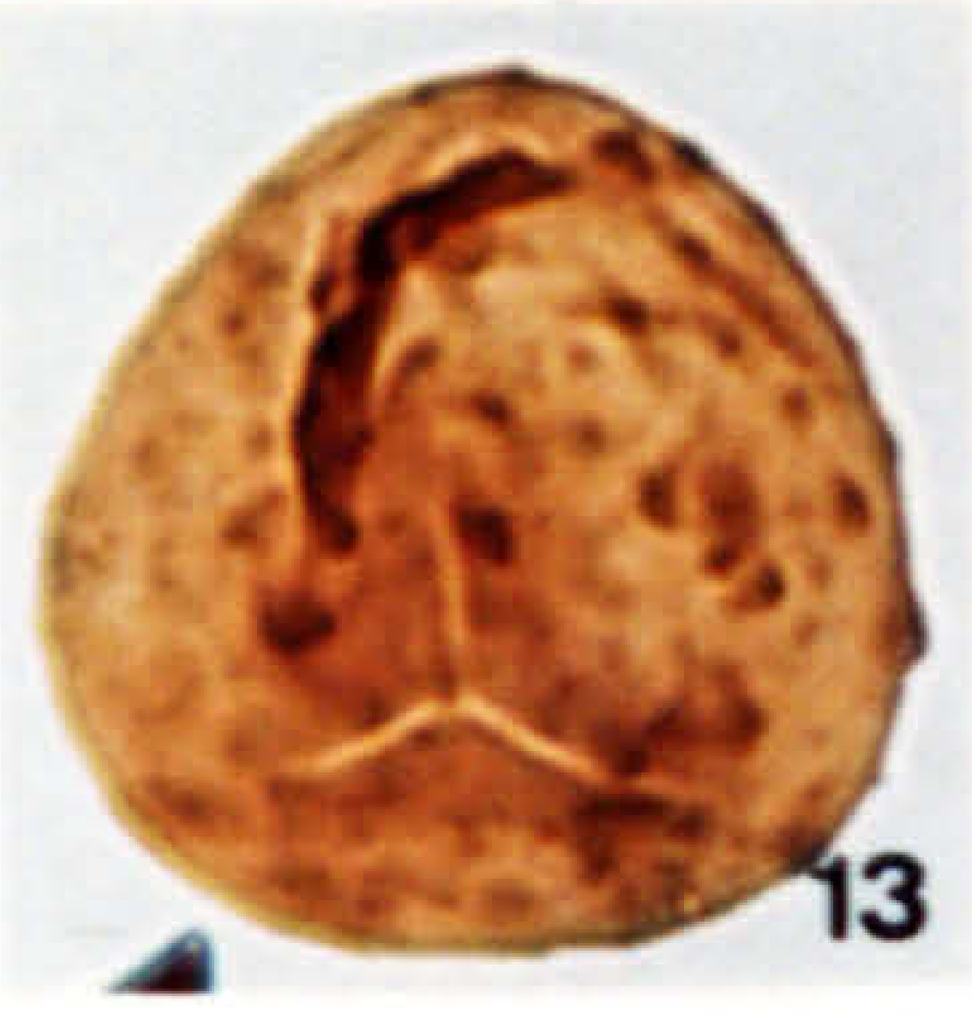

8


9


10

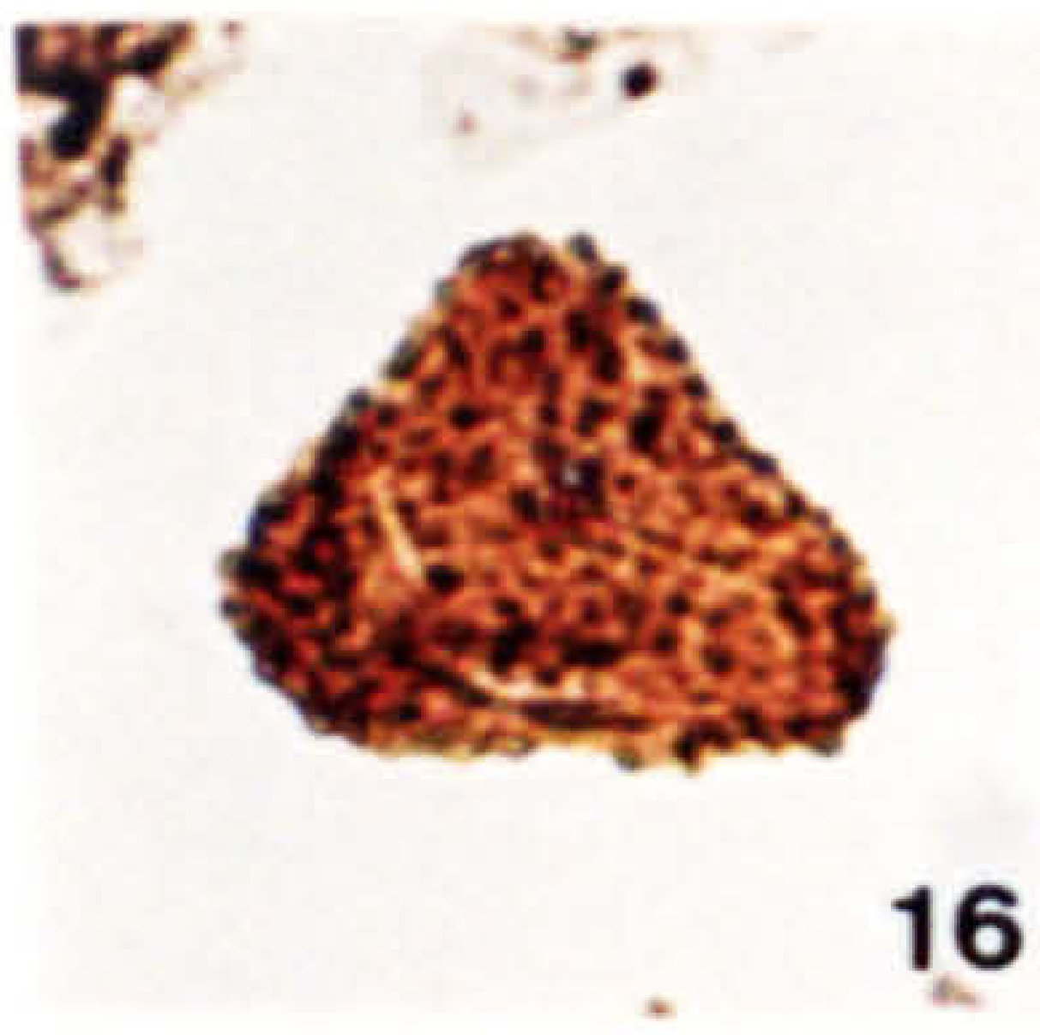

11


12


13


14


15

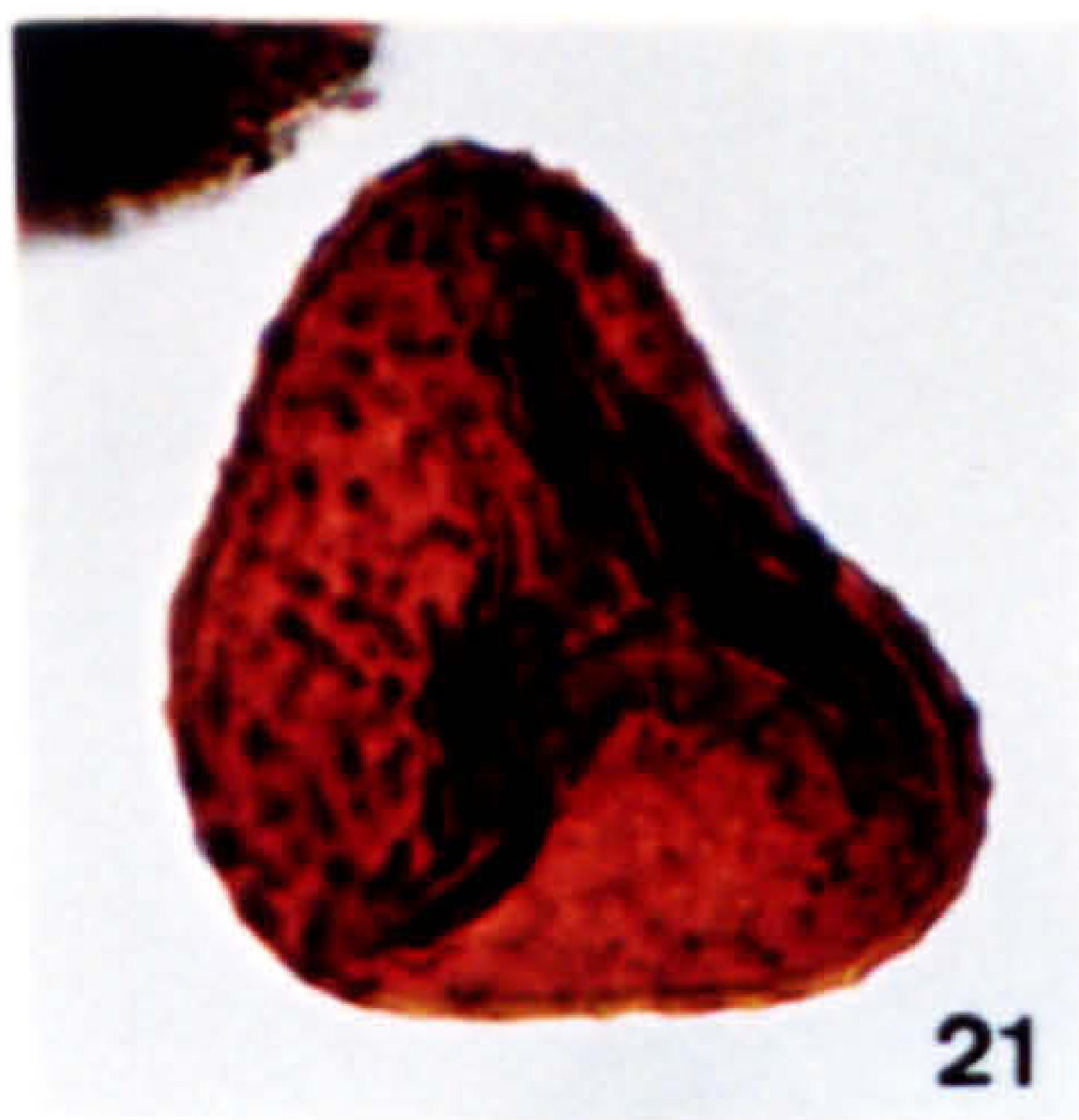

16


17

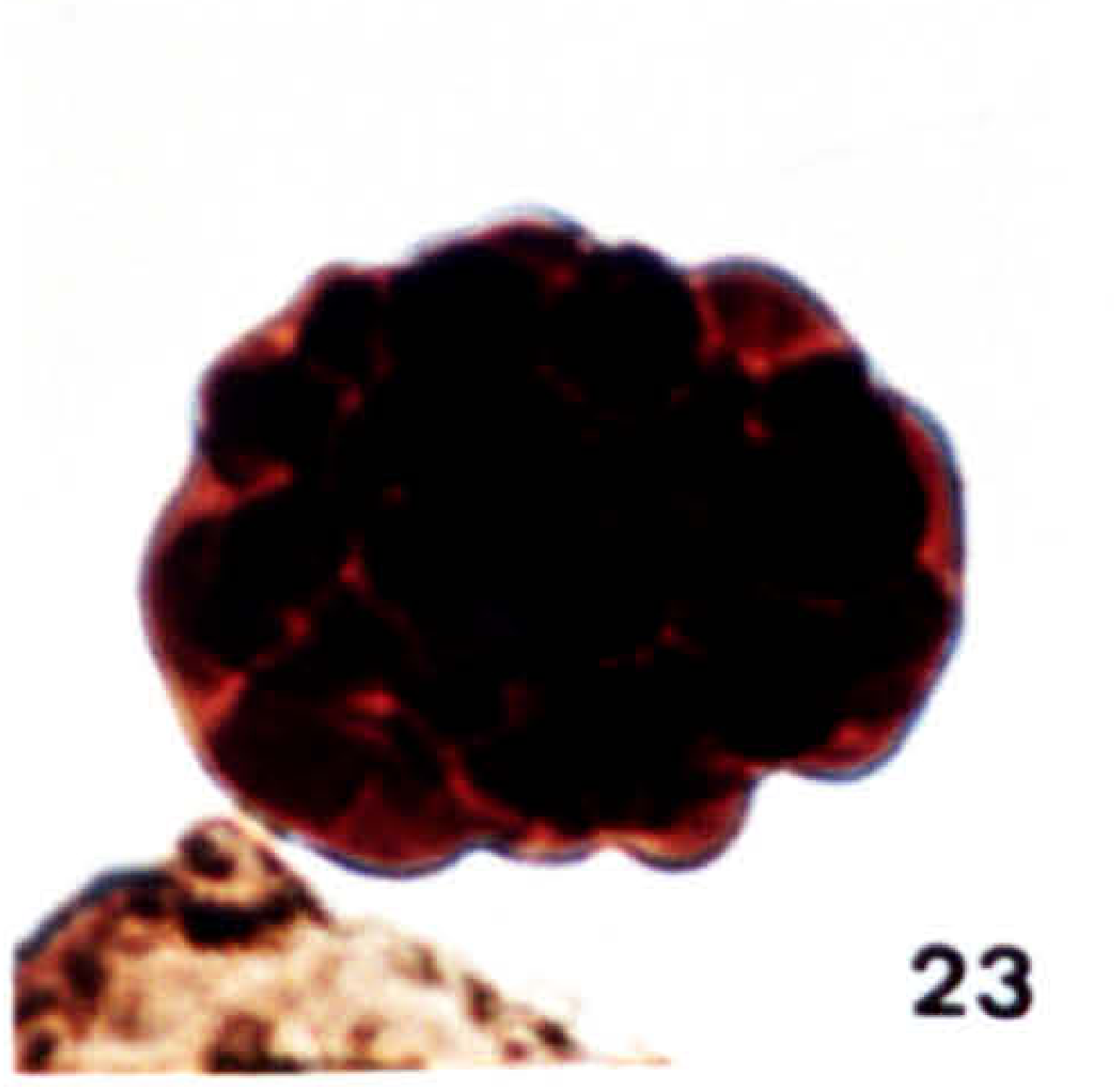

18


19


20


21


22


23


24


25


26

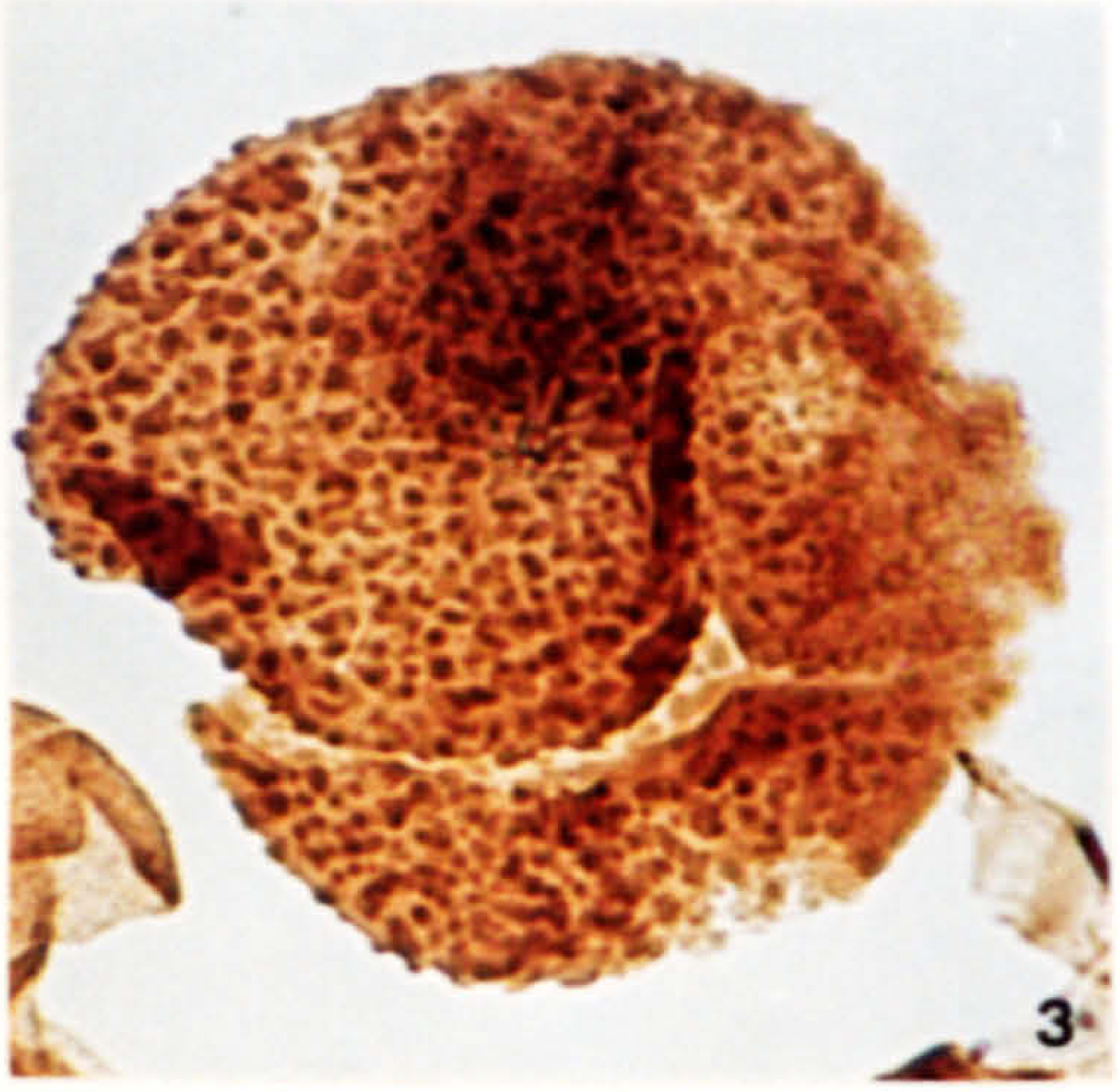

27

PLATE 6.

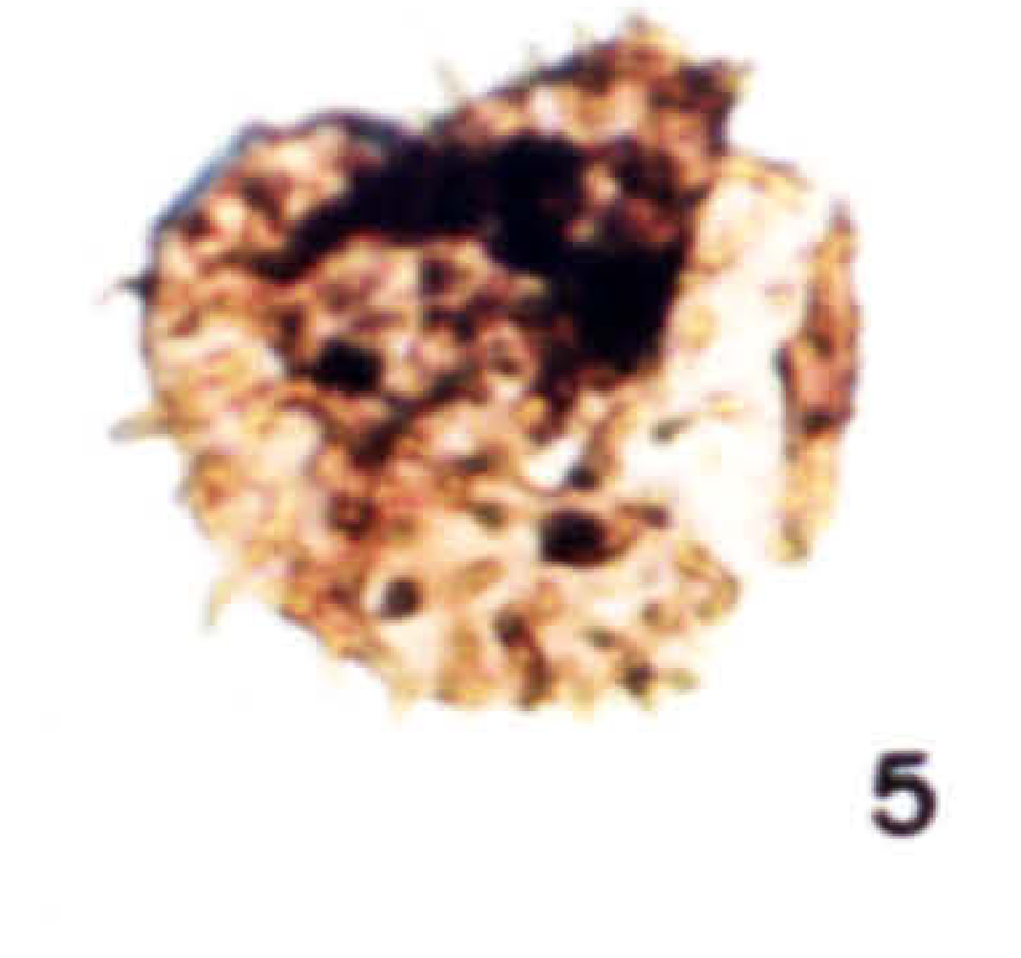
1. *Verrucosisporites* cf. *eximius*. 44/22-1, 11878', 2, T43.
2. *Verrucosisporites microverrucosus*. 44/22-4, 12104', 2, O51.2.
3. *Verrucosisporites sifati*. 44/22-1, 11506', 2, K58.1.
4. *Raistrickia parvula*. Holotype. 44/22-4, 12104', 1, Q45.
5. *Raistrickia subcrinata*. 44/22-1, 12030', 1, P48.1.
6. *Raistrickia lowellensis*. 44/22-3, 11867', 1, M58.2.
7. *Raistrickia microhorrida*. 44/22-1, 11683', 2, F45.3.
8. *Raistrickia? abdita*. 44/22-1, 11393', 1, L46.
9. *Raistrickia crinata*. 44/22-1, 11685', 2, O55.
10. *Raistrickia saetosa*. 44/22-1, 11393', 1, P51.2.
11. *Raistrickia microhorrida*. 44/22-1, 11393', 1, V47.1.
12. *Raistrickia fulva*. 44/22-1, 11424', 2, C42.2.
13. *Raistrickia digitosa*. 44/22-1, 11685', 1, Q50.2.
14. *Pileatisporites bakerii*. 44/22-1, 12242', 1, S47.4.
15. Same specimen as above, detail of pilose ornament. Magnification x1300
16. *Raistrickia breveminens*. 44/22-1, 11393', 1, K67.
17. *Raistrickia superba*. 44/22-1, 11685', 1, C46.
18. *Neoraistrickia exigua*. Holotype. 44/22-1, 11506', 2, R69.
19. Same specimen as above, detail of baculate ornament. Magnification x1300.
20. *Neoraistrickia exigua*. 44/22-1, 11414.9', 1, P38.
21. *Neoraistrickia virgultorum*. Holotype. 44/22-4, 12138', 2, P46.2.
22. *Neoraistrickia virgultorum*. 44/22-4, 12138', 2, F50.2.
23. *Tricidarisporites arcuatus*. 44/22-1, 12242', 1, J43.3.
24. *Echinatisporis knoxiae*. 44/22-1, 11453', 2, L62.
25. *Marasmosporites semiesus*. Holotype. 44/22-1, 11422', 1, D48.1.
26. *Corrugitriletes radiatus*. 44/22-4, 12410', 2, P49.
27. *Corrugitriletes radiatus*. 44/22-1, 11878', 2, H36.2.
28. *Convolutispora cerina*. 44/22-1, 11527', 2, G68.4.
29. *Convolutispora cerina*. 44/22-3, 11867', 3, D59.
30. *Convolutispora florida*. 44/22-1, 11424.9', 2, V29.4.

PLATE 6

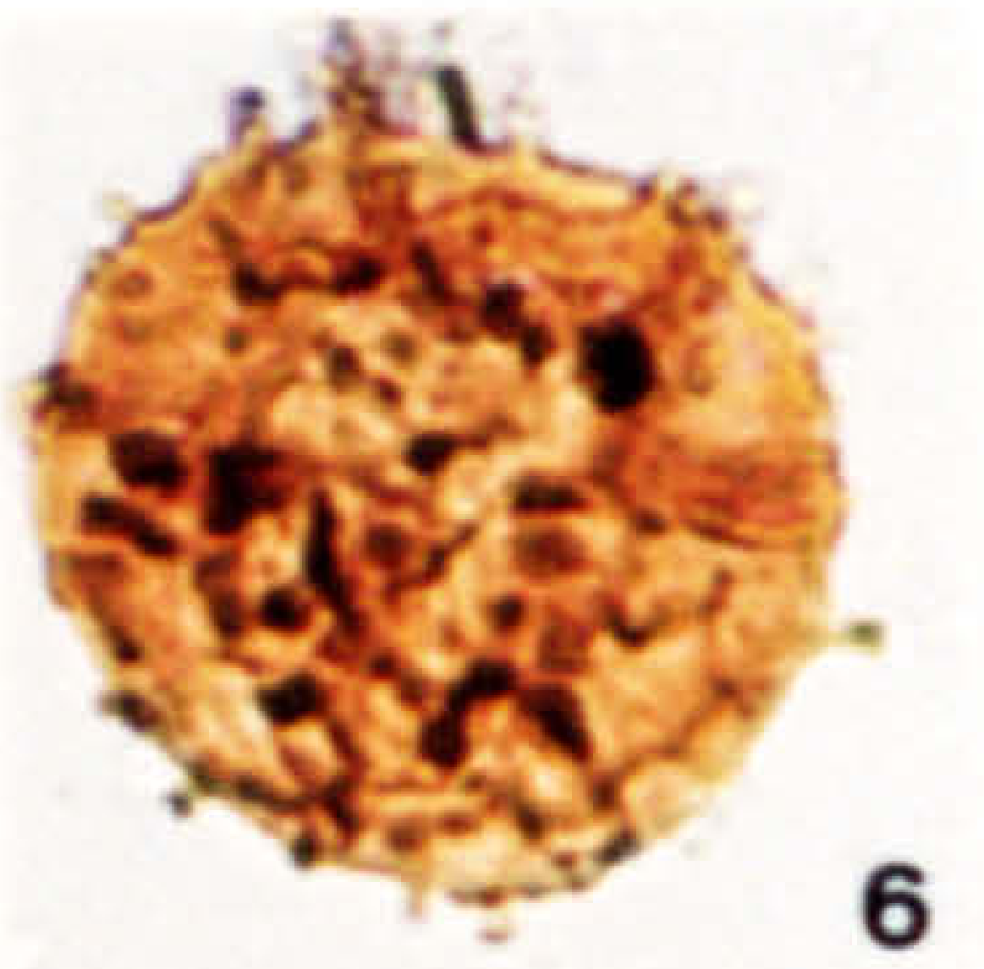

1


3

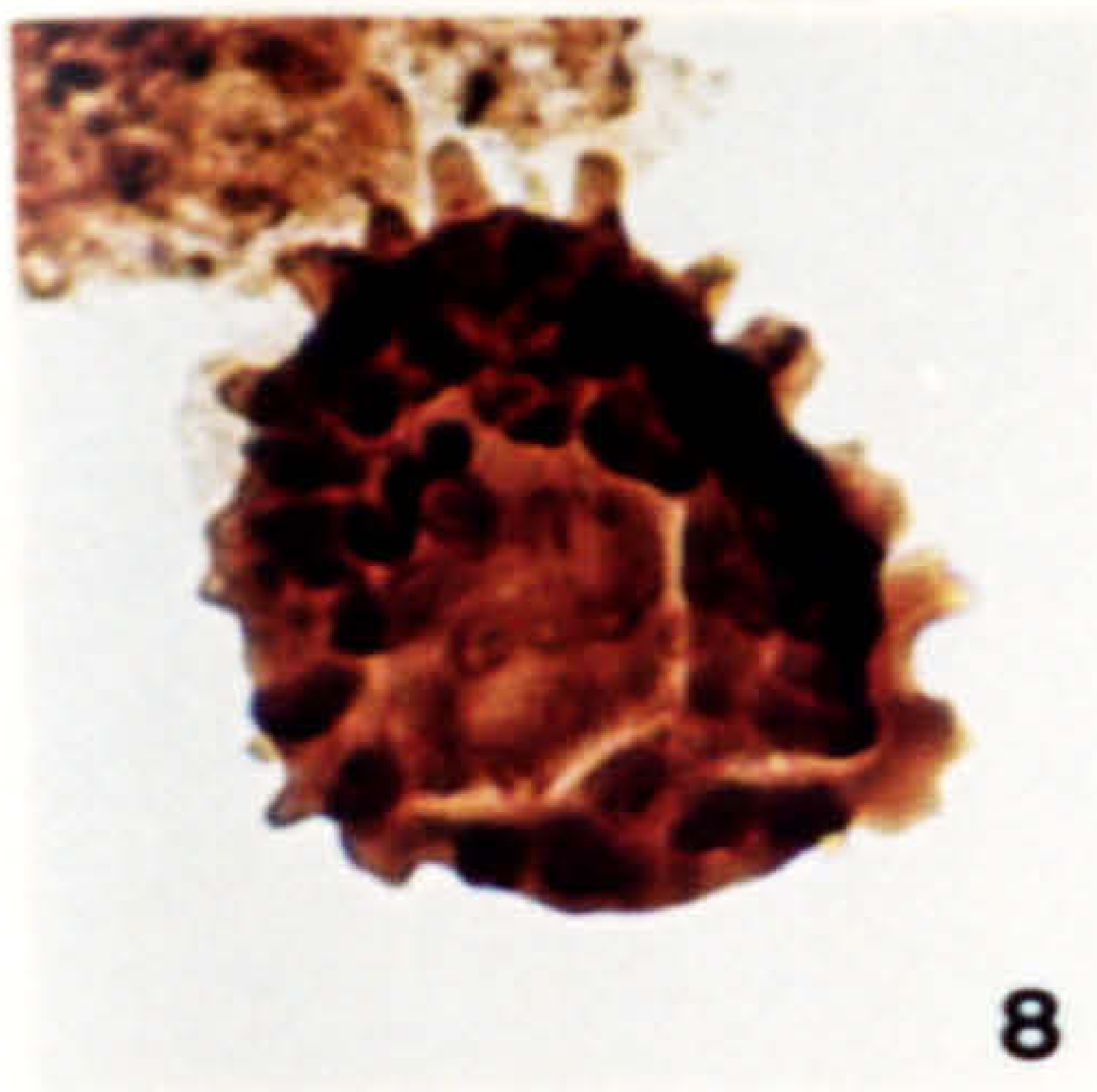

4


5

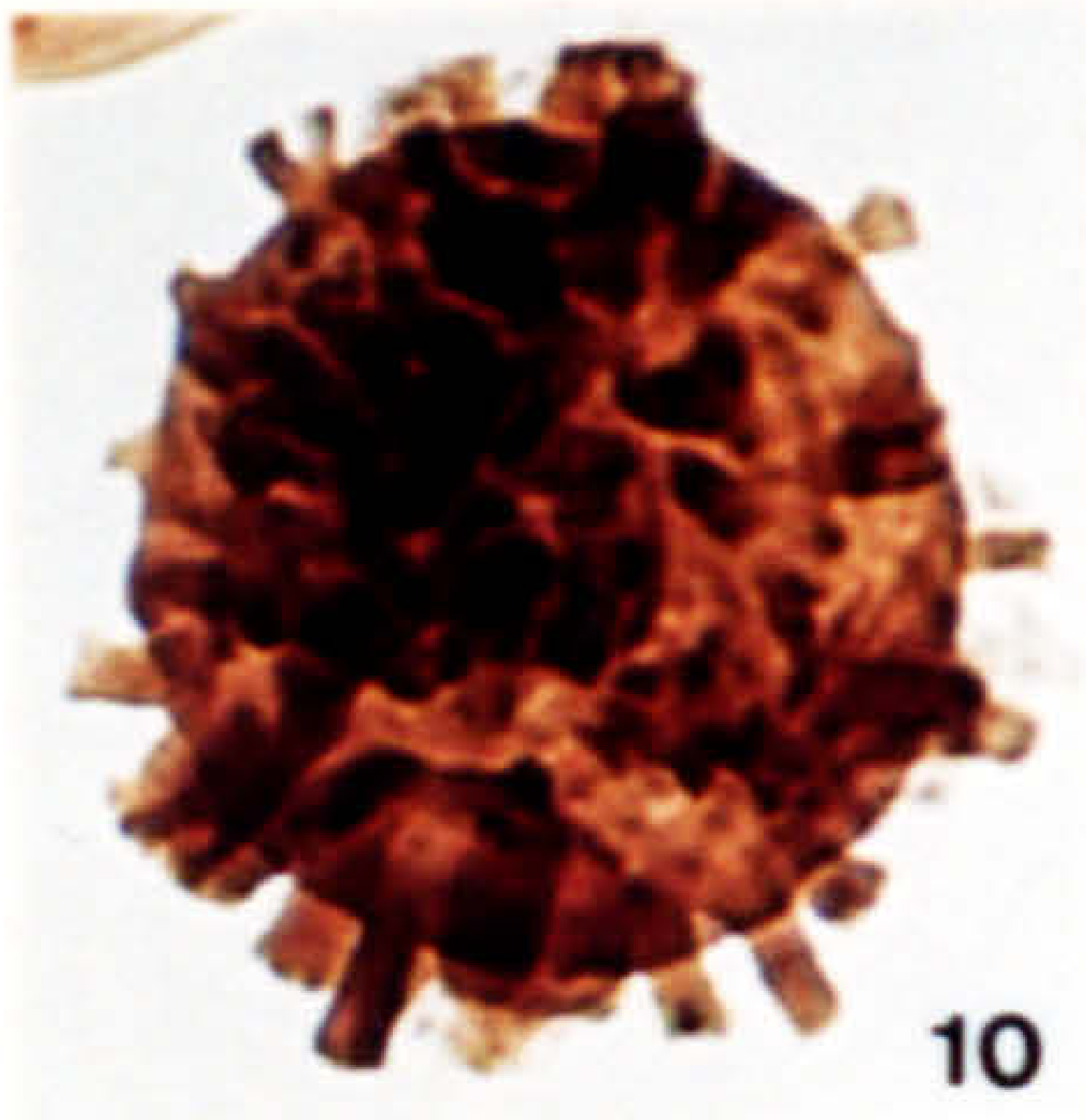

2


6


7

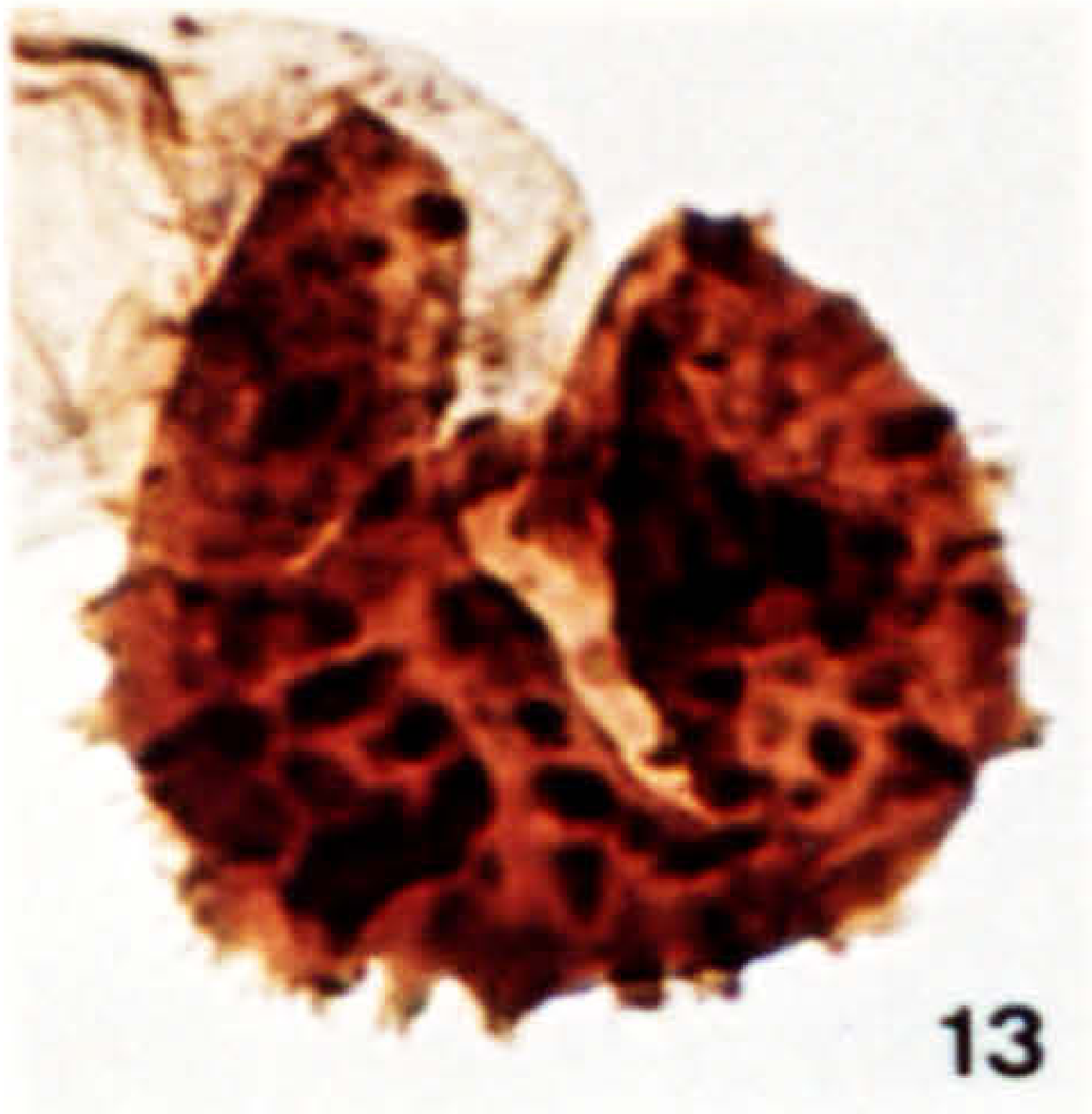

8


9

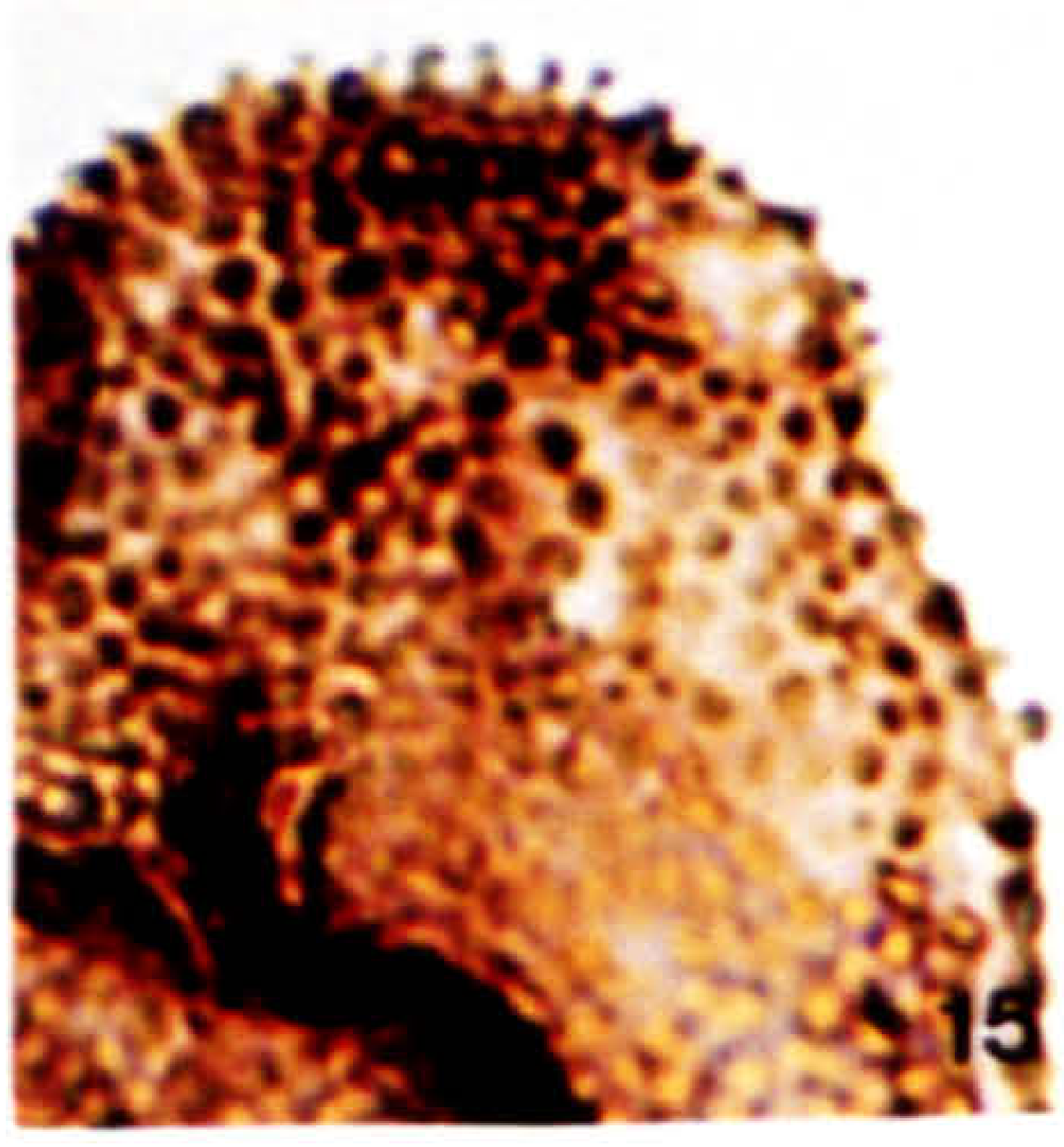

10

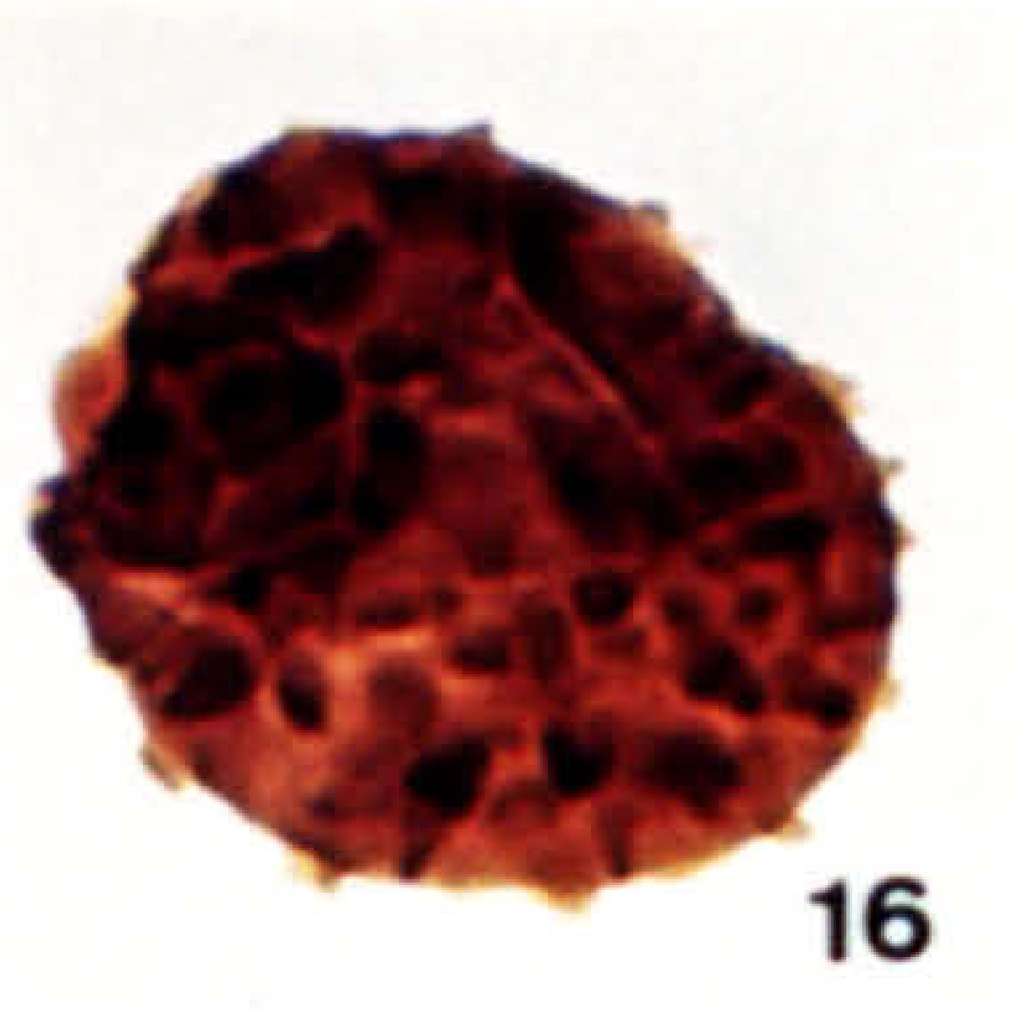

11


12


13

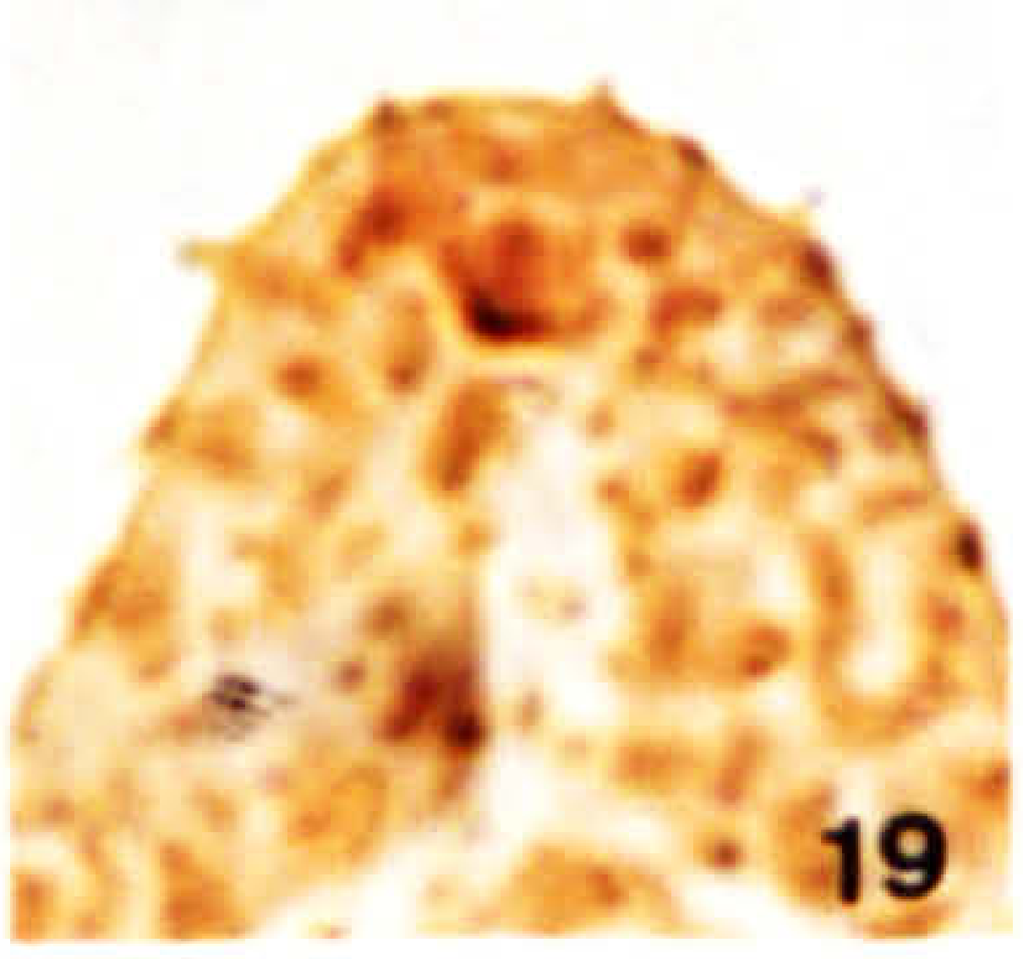

14

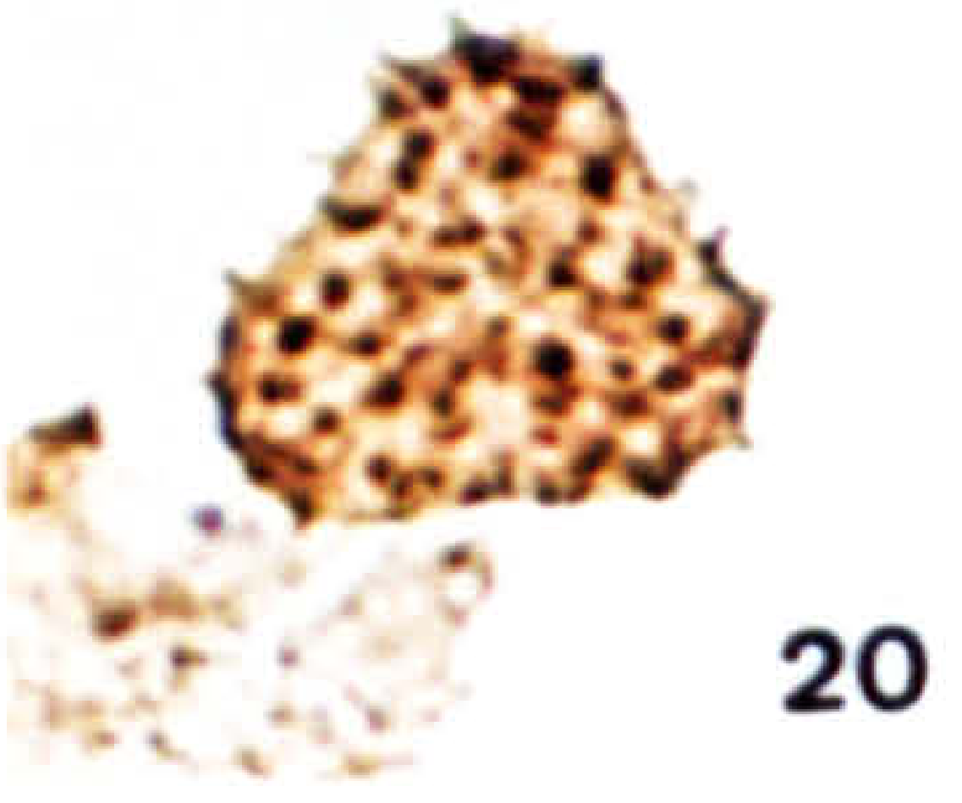

15


16


17


18


19


20

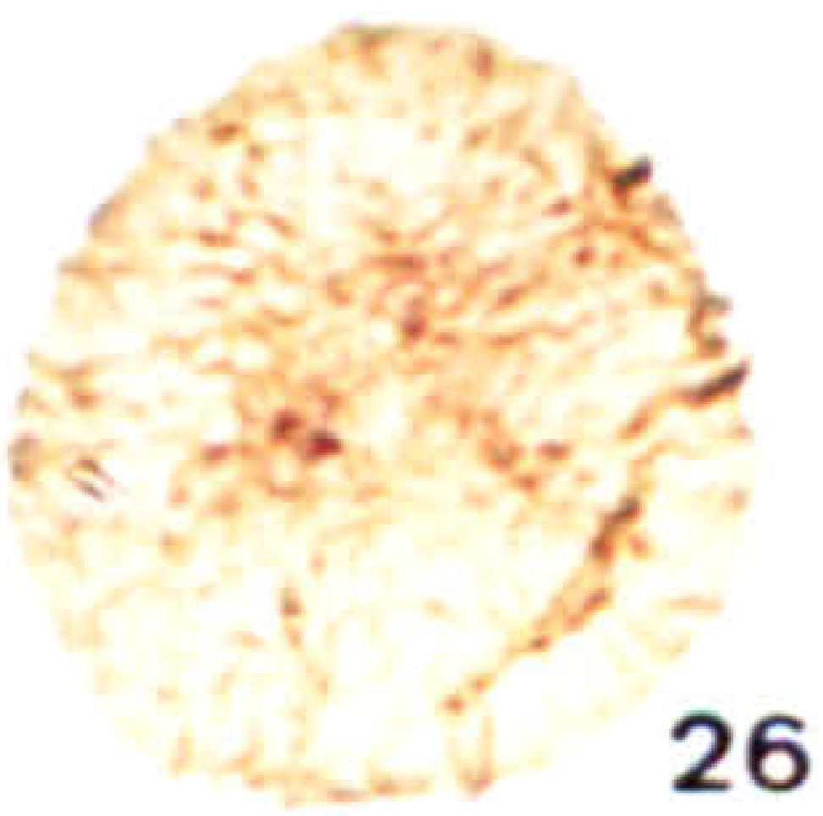

21

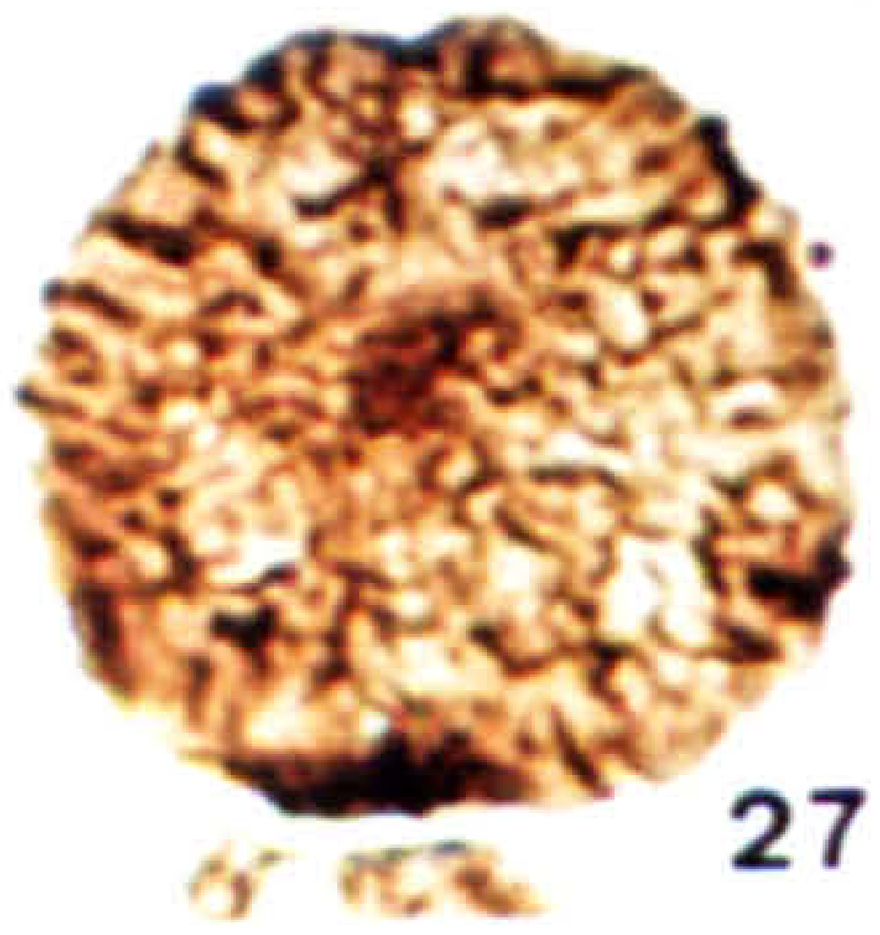

22

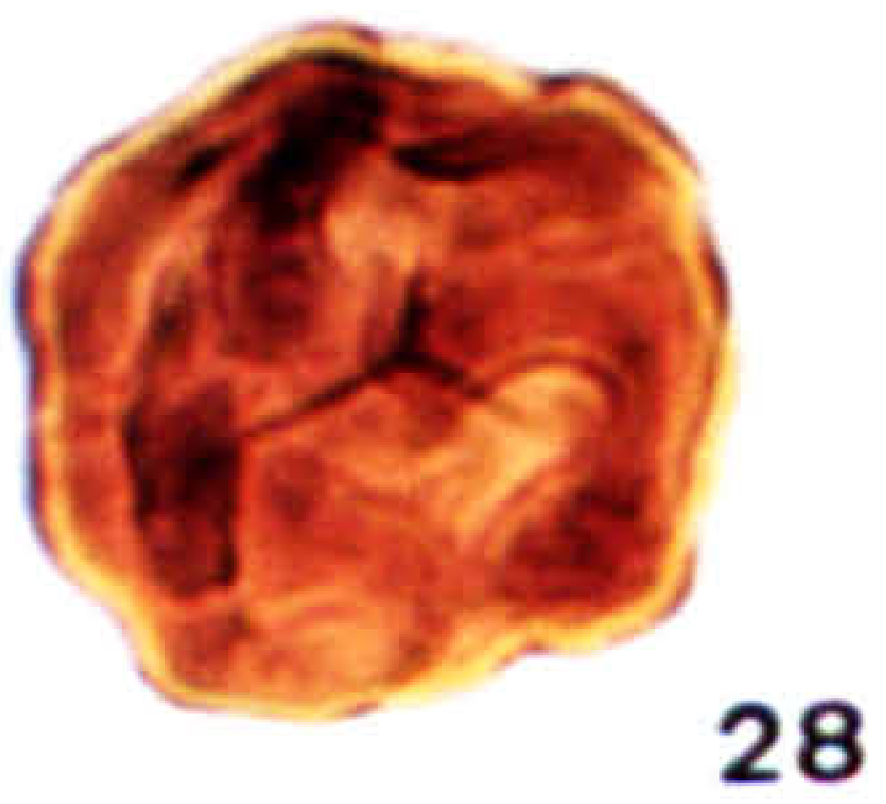

23

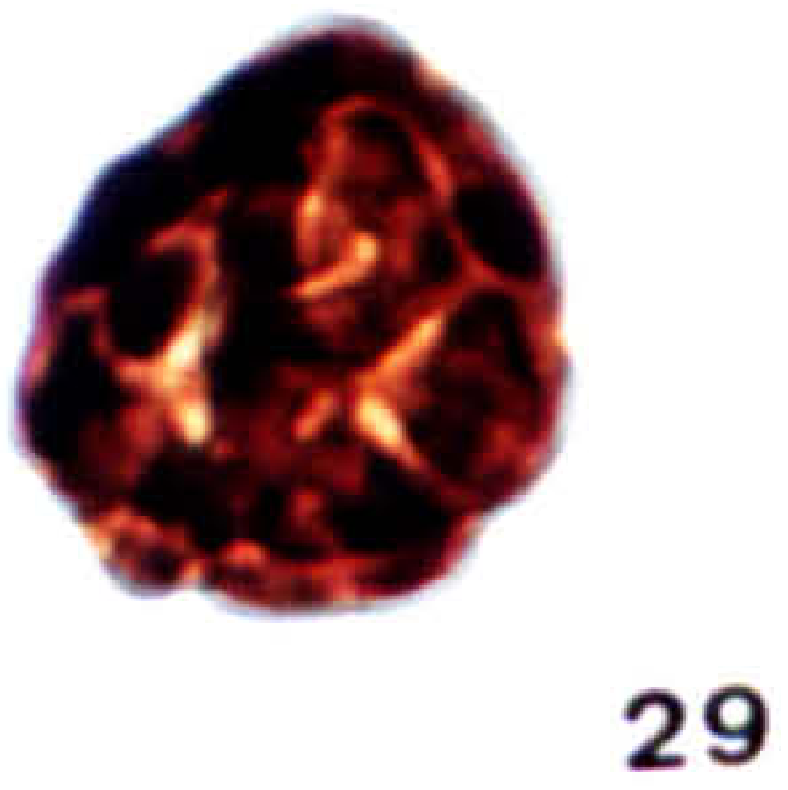

24


25


26


27


28


29

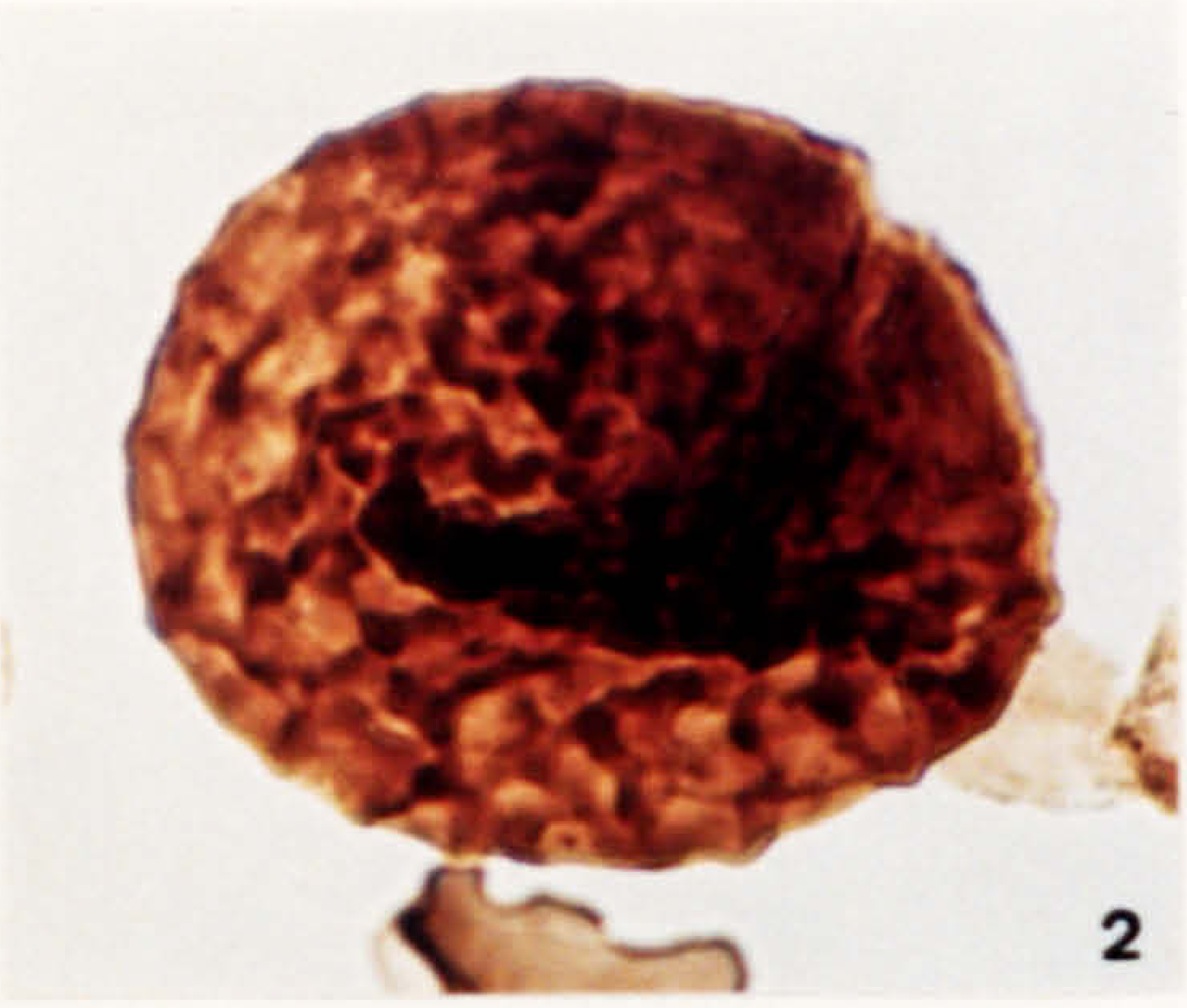

30

PLATE 7.

1. *Convolutispora tessellata.* 44/22-4, 12133', 1, P44.1.
2. *Camptotriletes superbus**. 48/11b-4, 8750', 2, K6.3.
3. *Camptotriletes bucculentus.* 44/22-1, 11422', 1, E47.
4. *Convolutispora mellita.* 44/22-4, 12257', 4, F55.3.
5. *Microreticulatisporites nobilis.* 44/22-1, 12253.7', 1, S47.
6. *Microreticulatisporites nobilis.* 44/22-4, 12253.7', 1, T54.2.
7. *Camptotriletes triangularis.* 44/22-1, 11600', 1, G51.1.
8. *Camptotriletes corrugatus.* 44/22-3, 11570', 1, P39.4.
9. *Microreticulatisporites hortonensis.* 44/22-1, 11389', 1, R38.1.
10. *Microreticulatisporites* cf. *microreticulatus.* 44/22-1, 12045', 1, H44.4.
11. *Microreticulatisporites punctatus.* 44/22-1, 12045', 1, C41.
12. *Microreticulatisporites harrisonii.* 44/22-1, 11414.9', 2, N35.
13. *Reticulitriletes mediareticulatus.* 44/22-1, 11393', 1, M47.3.
14. *Reticulitriletes areolatus.* 44/22-1, 11878', 1, C40.3.
15. *Reticulitriletes* aff. *distortus.* 44/22-1, 11878', 1, V38.
16. *Reticulitriletes falsus.* 44/22-1, 11393', 1, D63.1.
17. *Reticulitriletes reticulocingulum.* 44/22-1, 12028', 2, Q64.
18. *Reticulitriletes muricatus.* 44/22-3, 11867', 3, B44.
19. *Dictyotriletes probireticulatus**. 43/15b-3a, 13109', 1, Y58.1.
20. *Dictyotriletes bireticulatus.* 44/22-4, 12130', 1, H56.
21. *Ahrensisporites sinus.* 44/22-4, 12133', 1, K37.1.
22. *Foveosporites* sp. A. 44/22-1, 12032', 1, T50.
23. *Cordylosporites karadenizensis**. 43/15b-3a, 13109', 1, S52.4.
24. *Anafoveosporites avcinii.* 44/22-1, 12032', 2, Q64.2.
25. *Ahrensisporites sinus.* 44/22-4, 12133', 1, N54.3.
26. *Ahrensisporites guerickei.* 44/22-4, 12080', 2, E54.1.
27. *Ahrensisporites ornatus.* 44/22-4, 12257', 4, M53.
28. *Triquitrites protensus.* 44/22-4, 11880', 2, J47.4.

PLATE 7


1


2


3


4


5


6

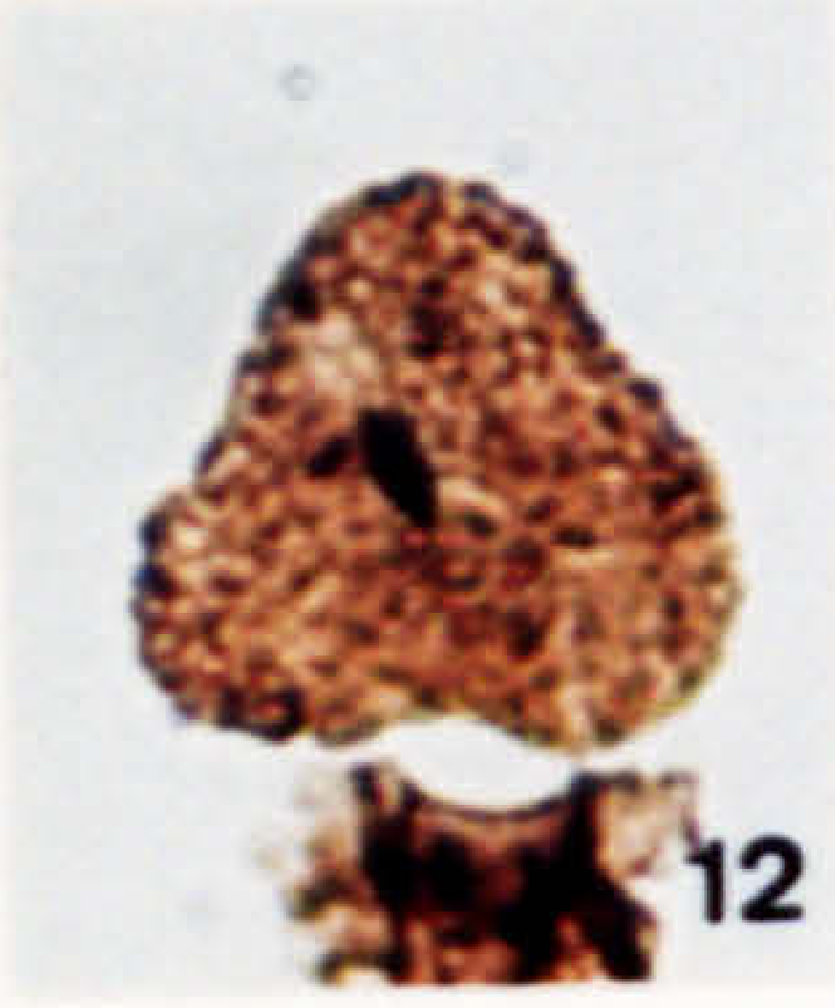

7


8


9


10


11


12


13


14

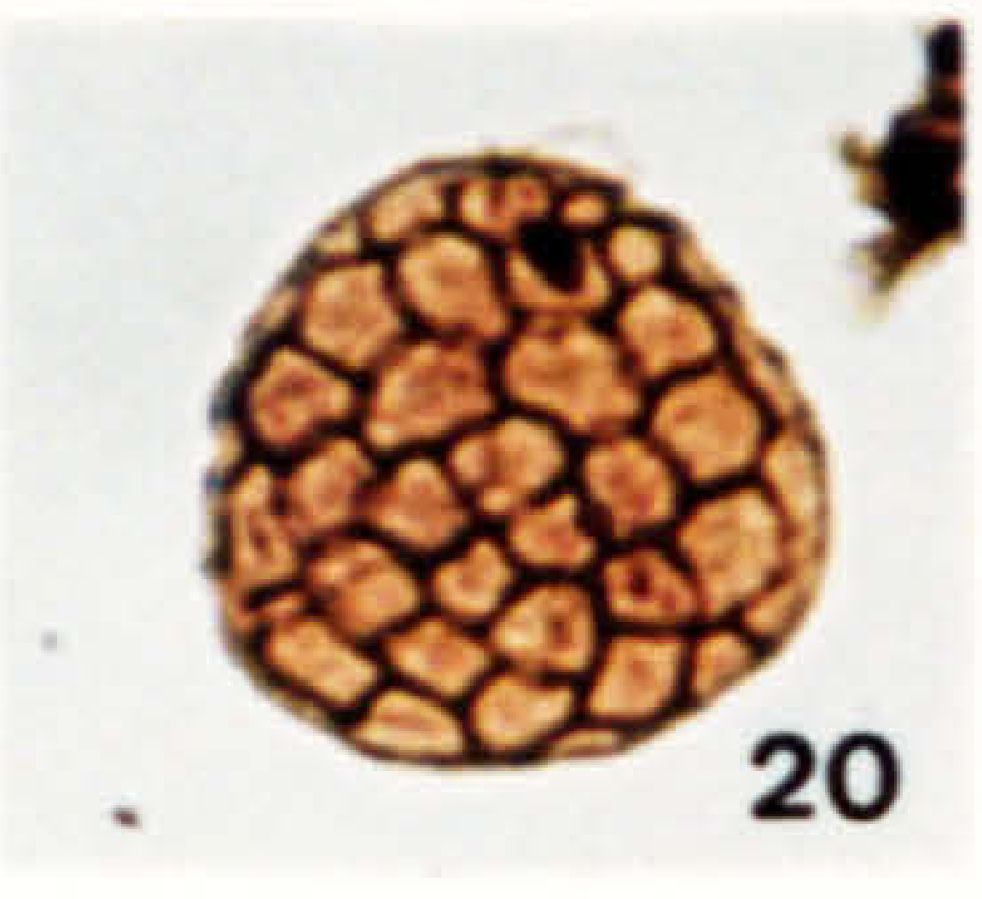

15


16


17


18


19

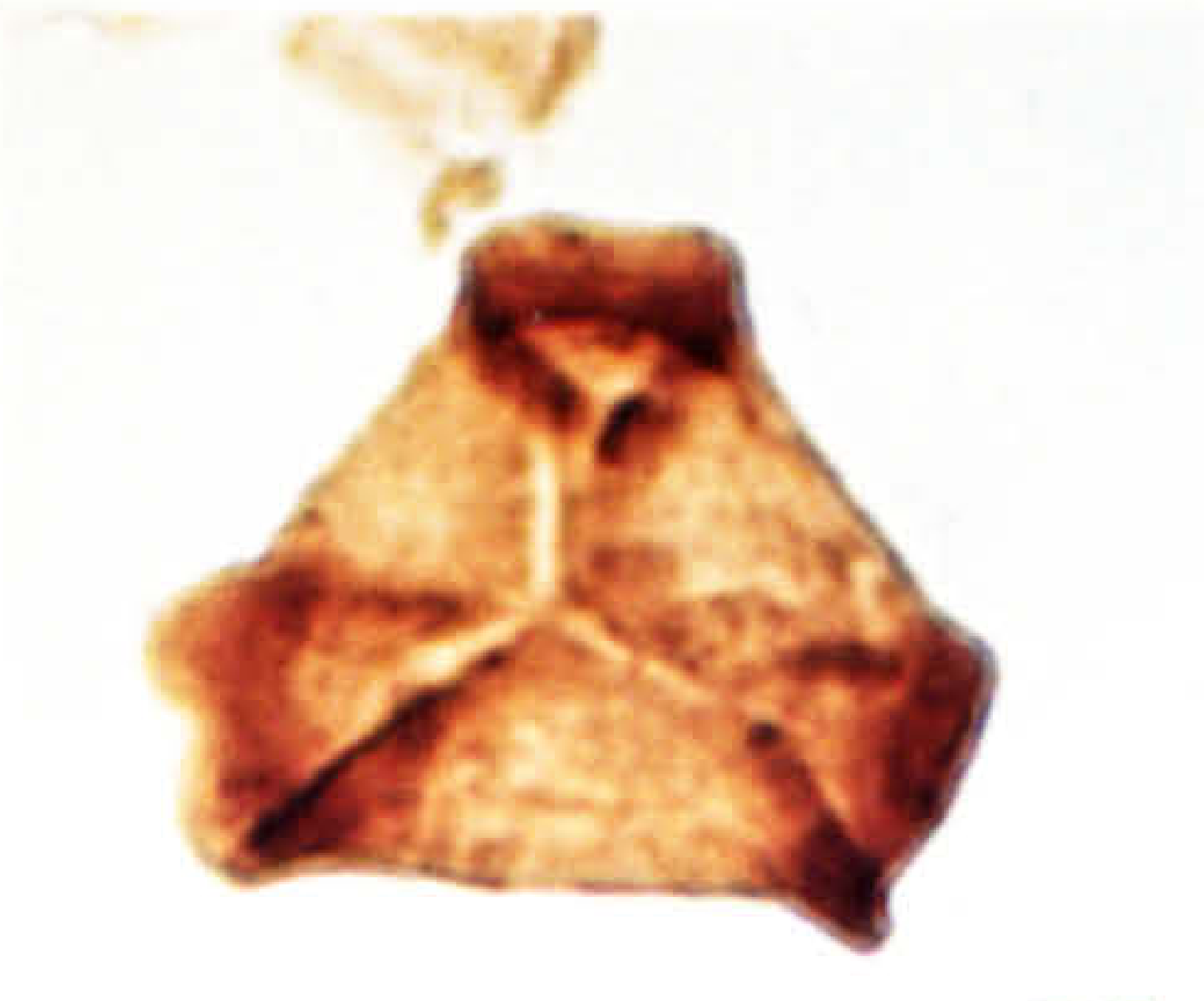

20


21


22


23


24


25


26


27

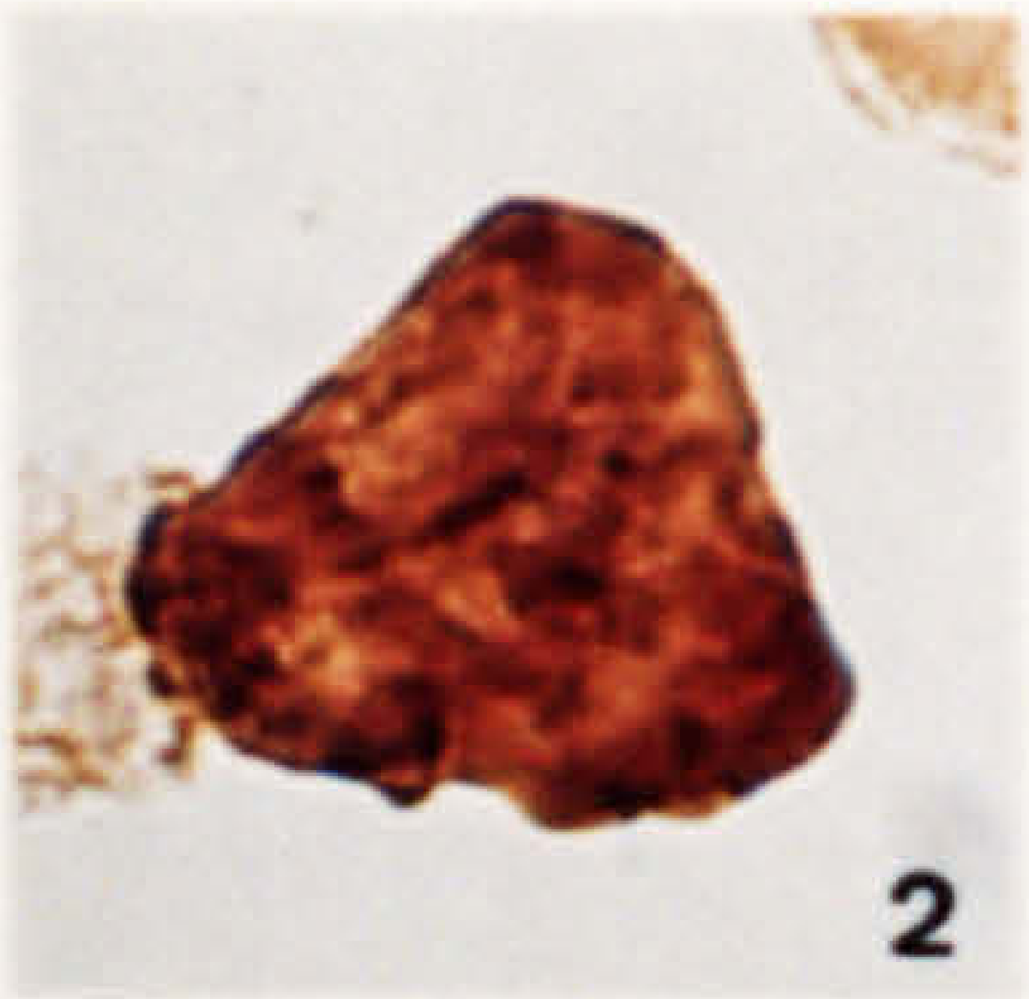

28

PLATE 8.

1. *Triquitrites tribullatus.* 44/22-1, 11878', 1, R51.
2. *Triquitrites sculptilis**. 44/21-4, 3888m., 1, J51.3.
3. *Triquitrites sculptilis**. 44/21-3, 4228m., 1. L50.1.
4. *Tripartites nonguerickei.* 44/22-1, 12055', 1, E47.1.
5. *Tripartites vetustus.* 44/22-1, 12045', 1, Q36.4.
6. *Diatomozonotriletes rarus.* 44/22-4, 12017', 1, V56.
7. *Reinschospora triangularis.* Broken specimen. 44/22-1, 11414.9', 1, K32.1.
8. *Reinschospora speciosa.* 44/22-1, 11880', 1, J45.1.
9. *Knoxisporites quadratus.* 44/22-3, 11872', 2, N51.3.
10. *Knoxisporites triradiatus.* 44/22-3, 11886', 1, N64.
11. *Knoxisporites seniradiatus.* 44/22-3, 12013', 1, U64.4.
12. *Knoxisporites biceps.* Holotype. 44/22-3, 11867', 3, R54.
13. *Knoxisporites dissidius.* 44/22-1, 12023', 1, G51.1.
14. *Knoxisporites stephanephorus.* 44/22-4, 12138', 2, D58.2.
15. *Savitrisporites semotus.* 44/22-1, 11422', 1, S58.
16. *Savitrisporites semotus.* Holotype. 44/22-1, 11422', 1, K51.
17. *Savitrisporites asperatus.* 44/22-1, 11878', 2, J59.4.
18. *Savitrisporites concavus.* 44/22-1, 11878', 1, S37.1.
19. *Savitrisporites nux.* 44/22-1, 11685', 1, P67.
20. *Bellispores nitidus.* 44/22-1, 12055', 1, N49.1.
21. *Trinidulus diamphidios.* 44/22-1, 12242', 1, Q48.2.
22. *Rotaspora knoxii.* 44/22-4, 12261.6', 1, U40.2.
23. *Rotaspora? xenica.* 44/22-4, 12017', 2, V46.3.
24. *Stenozonotriletes coronatus.* 44/22-3, 12120', 1, V67.
25. *Reticulatisporites danzei.* 44/22-1, 11683', 1, H40.1.
26. *Reticulatisporites danzei.* 44/22-1, 11928', 2, K31.4.

PLATE 8

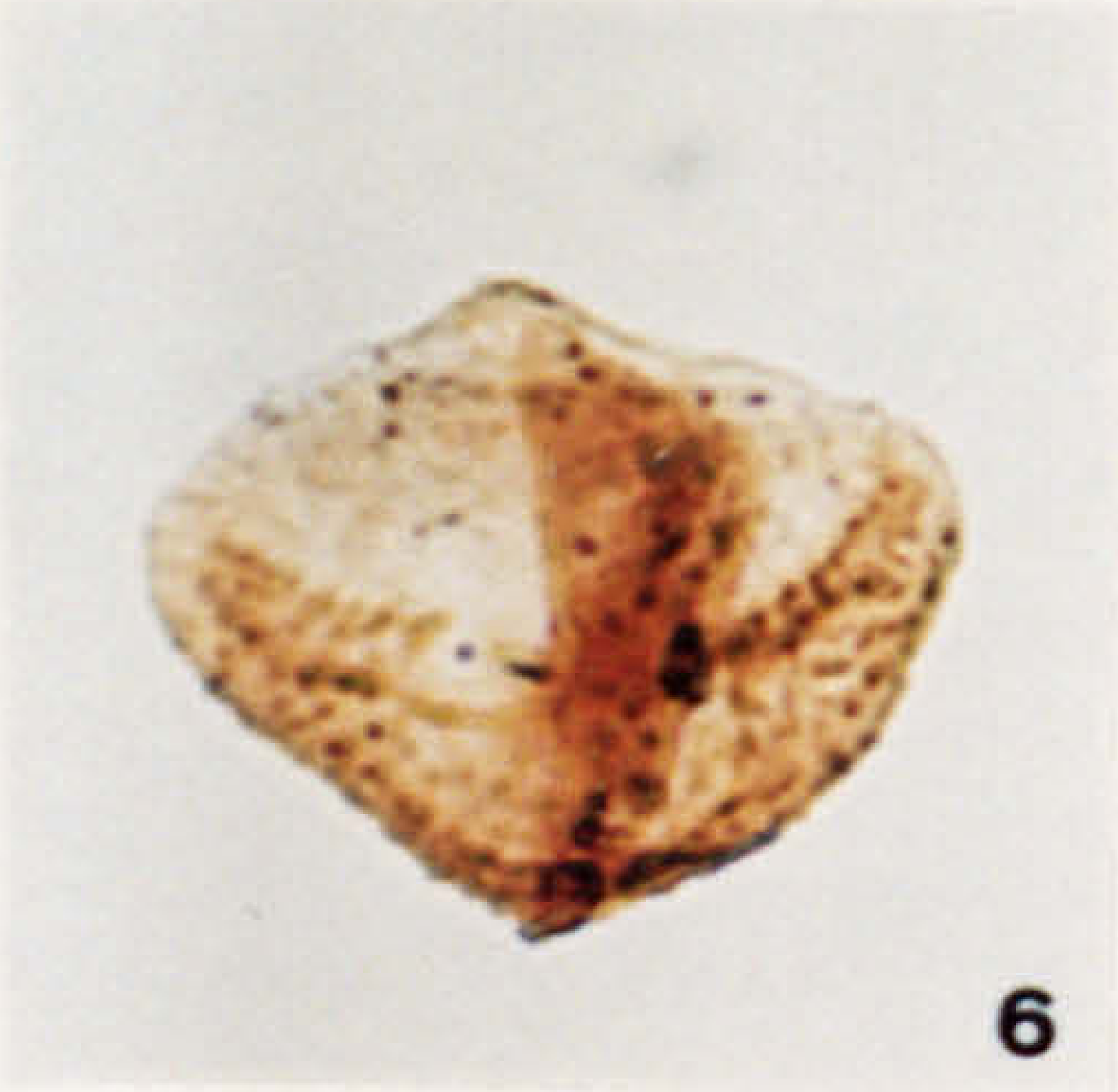

1


2

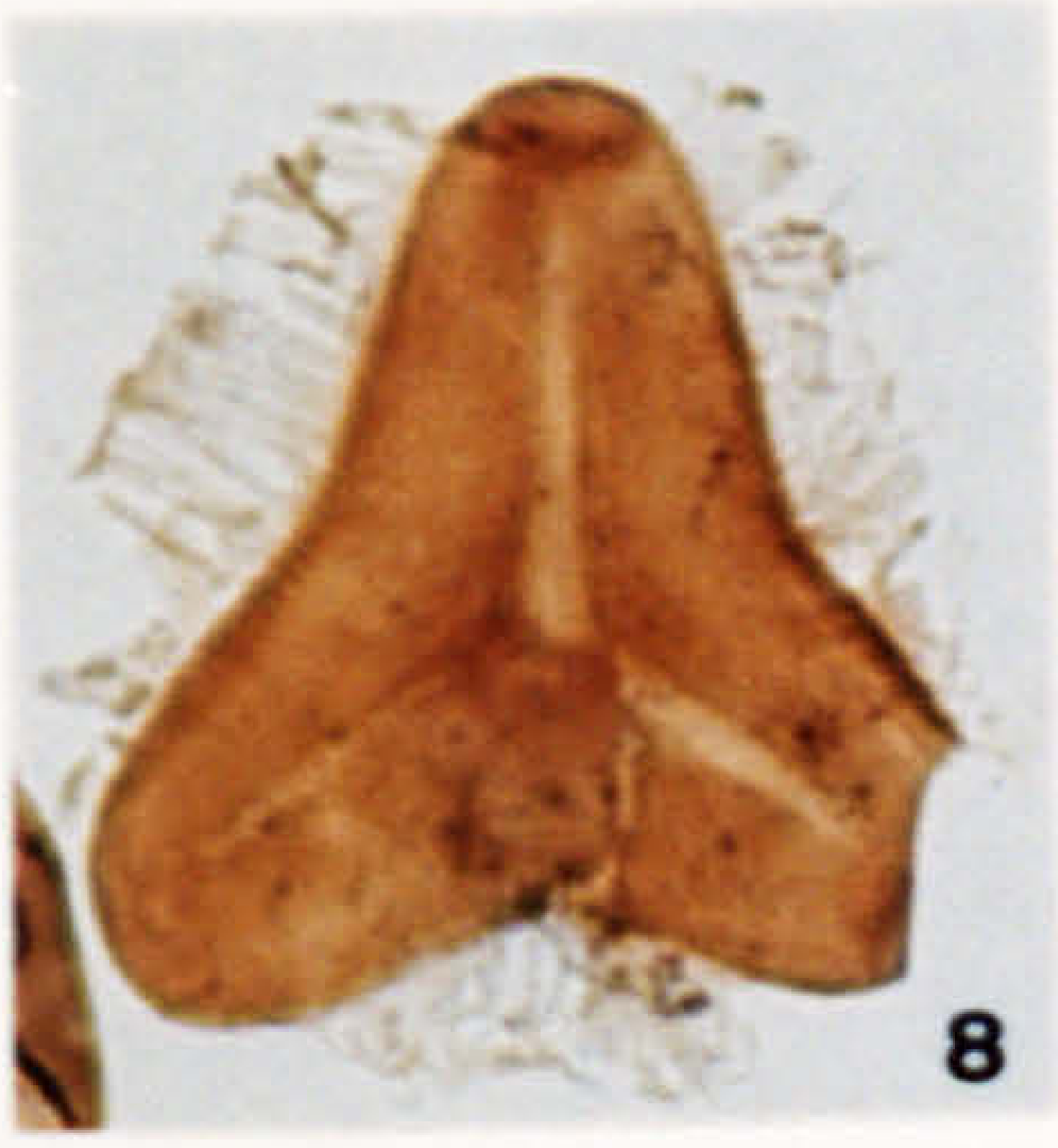

3


4


5


6


7

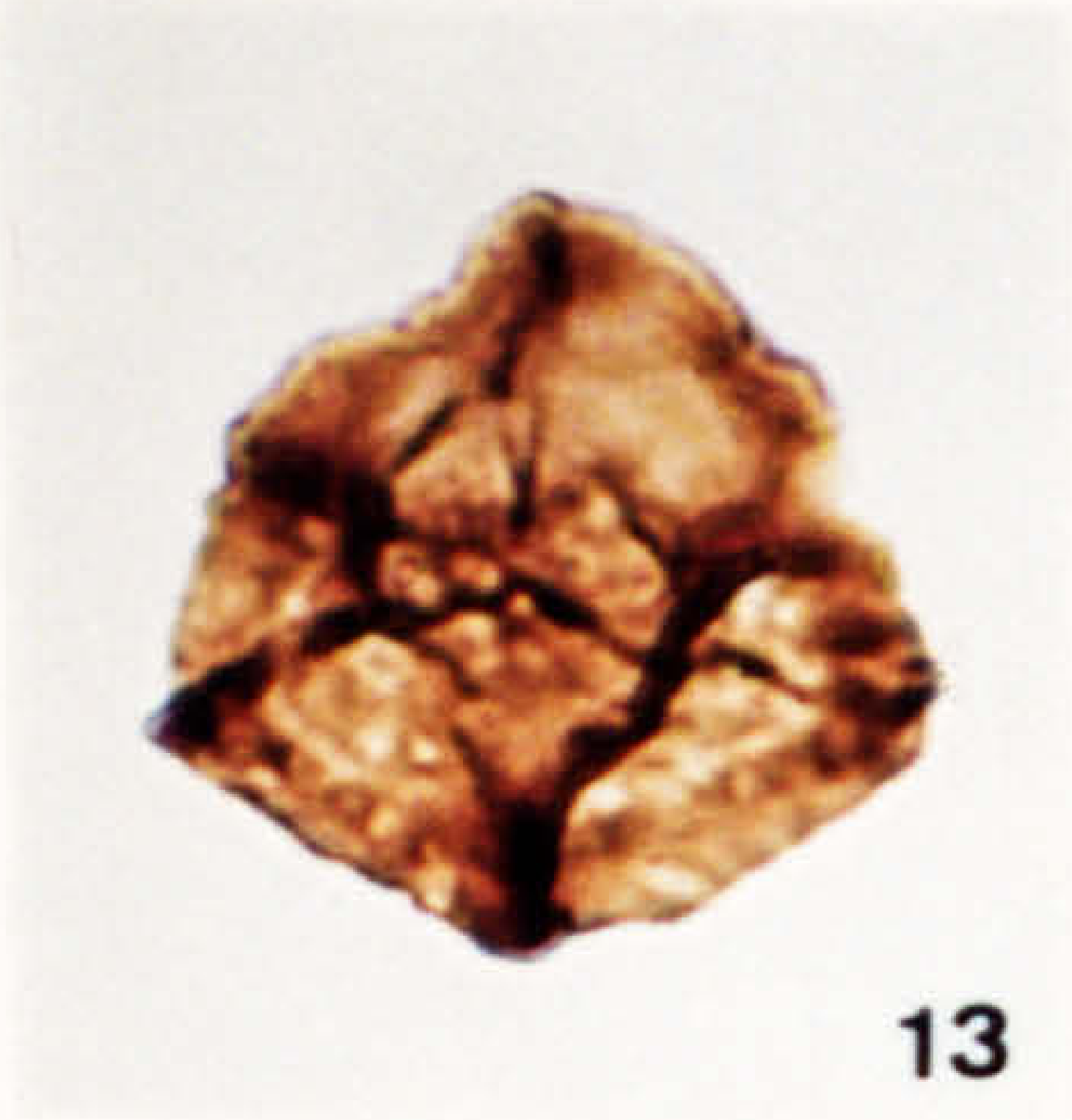

8


9


10

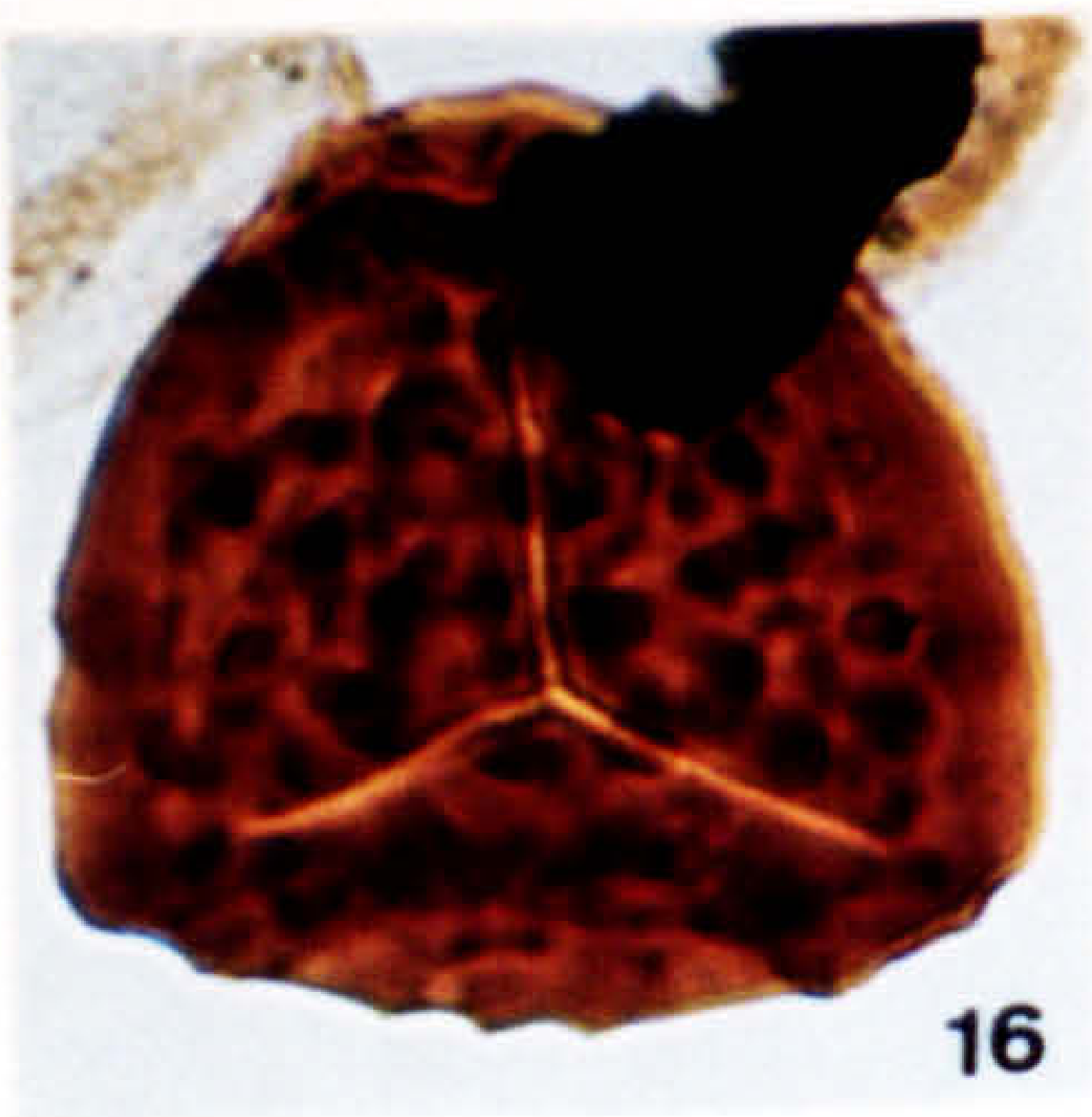

11


12


13

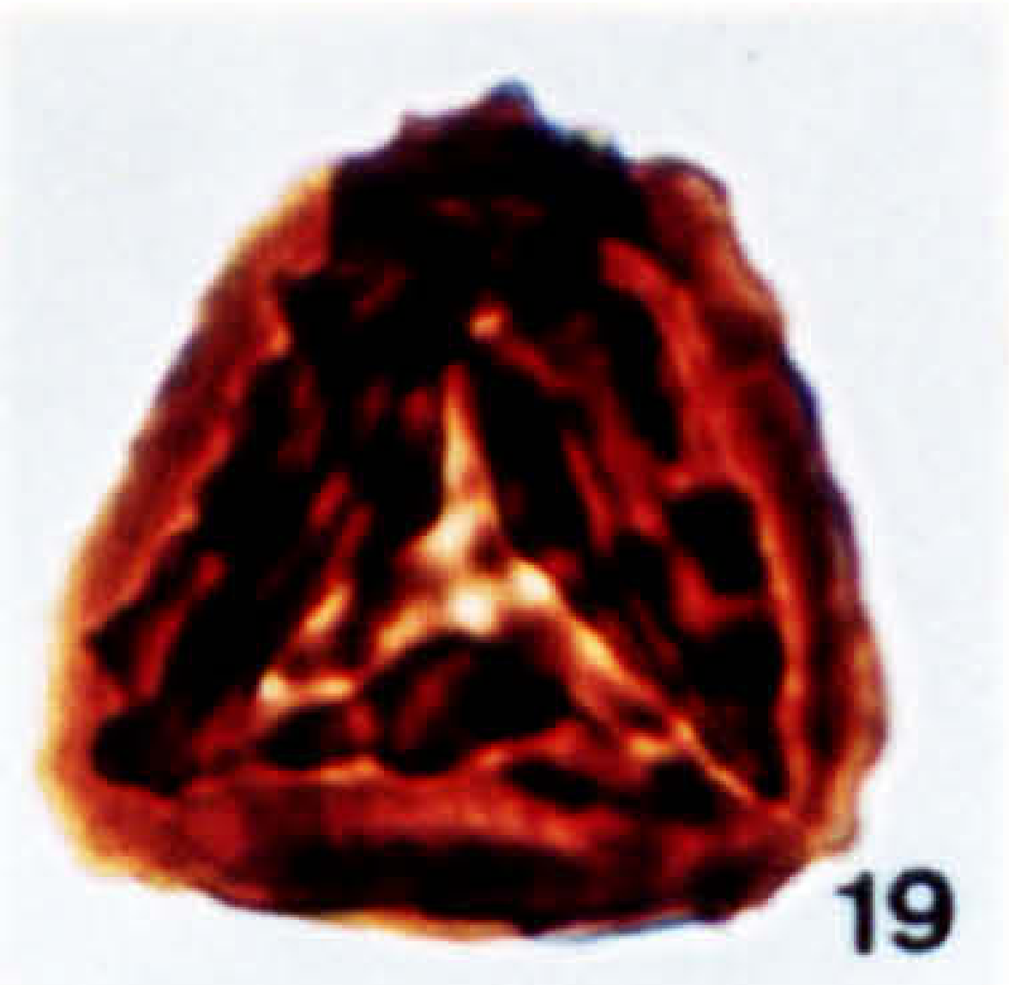

14

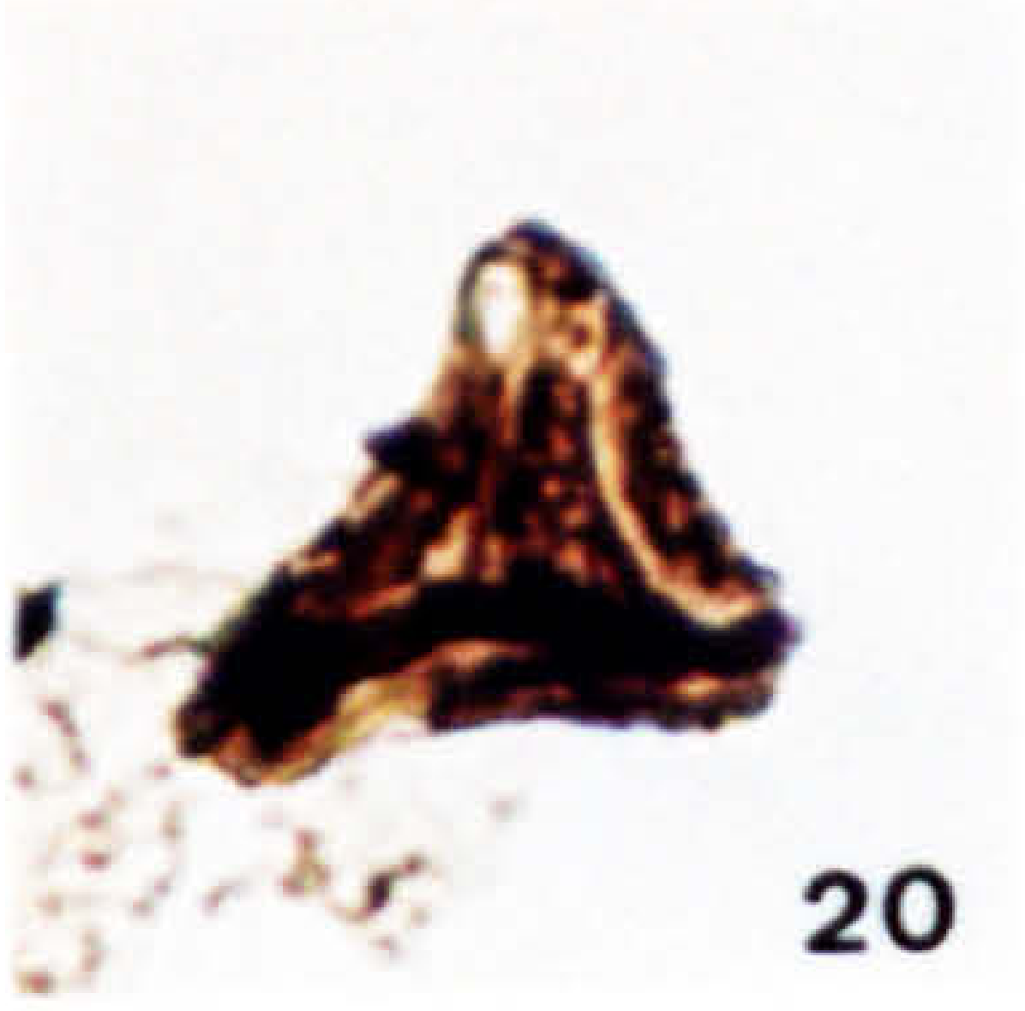

15


16


17


18

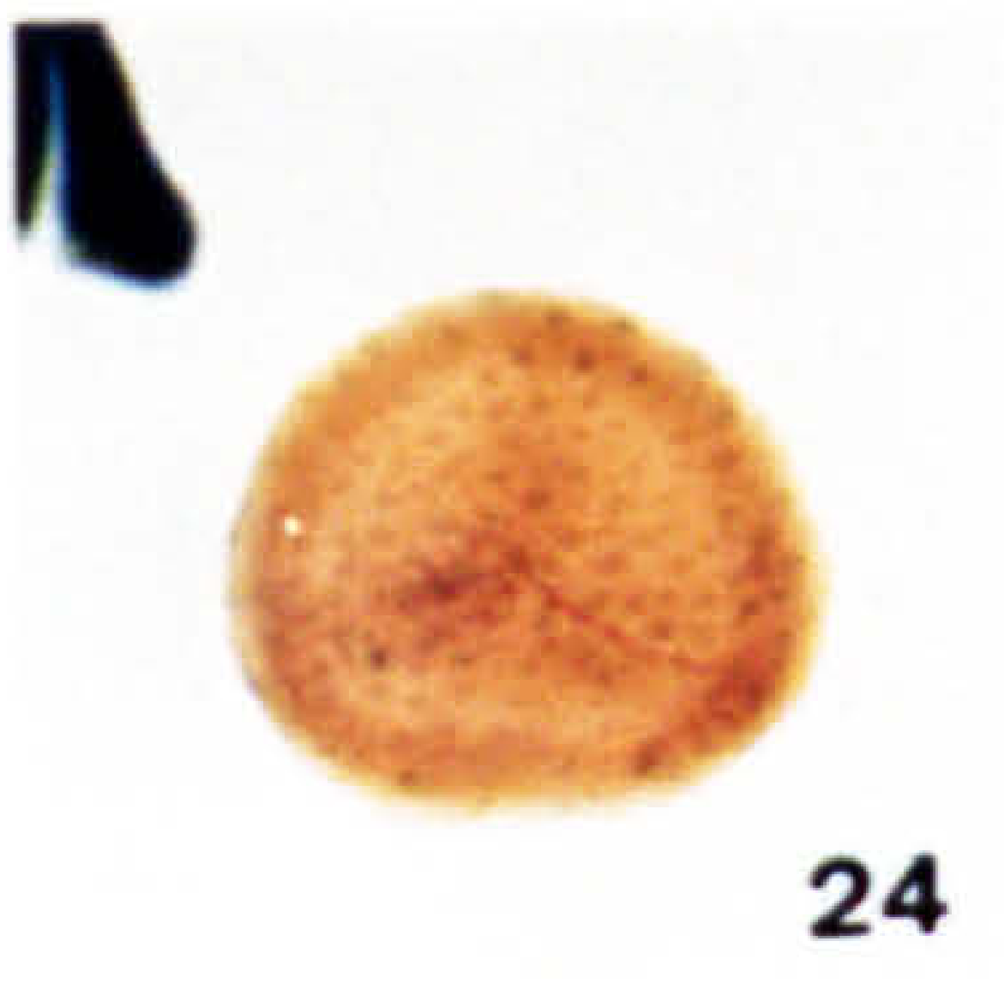

19

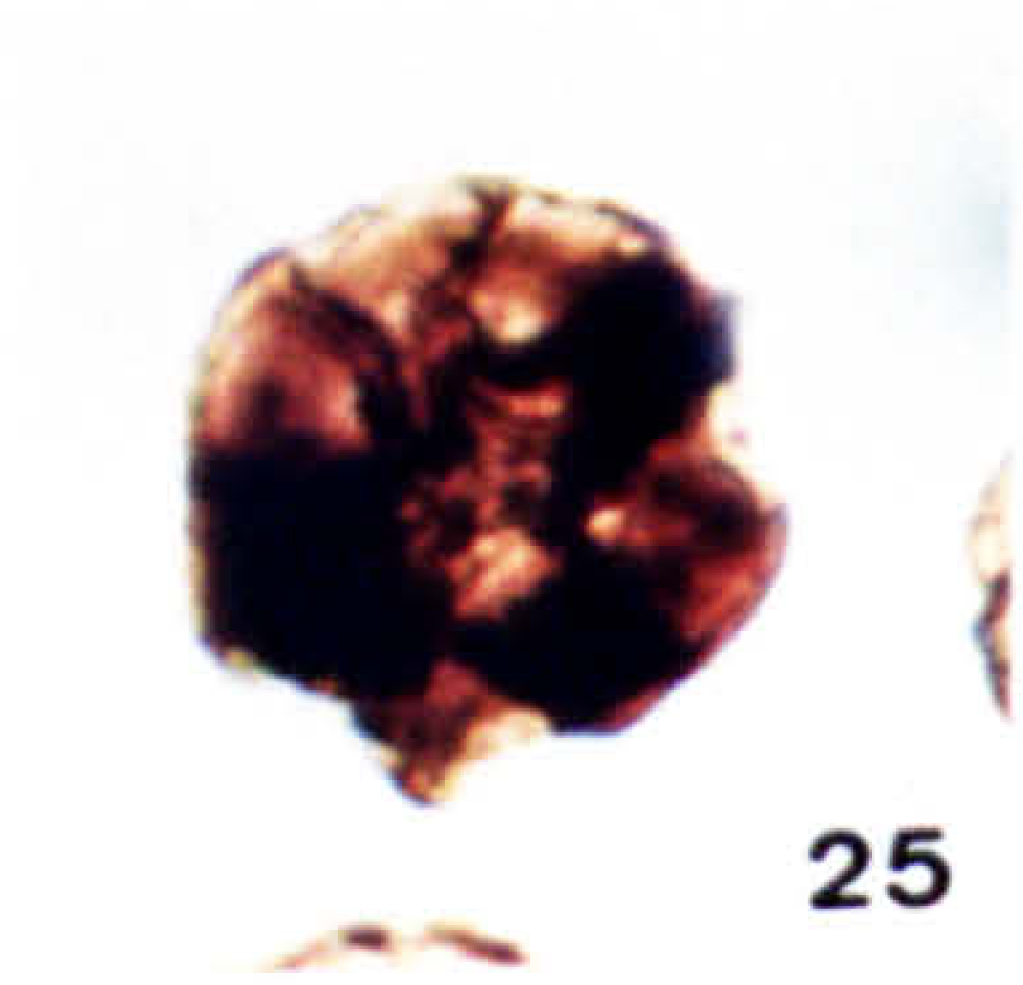

20


21


22


23


24

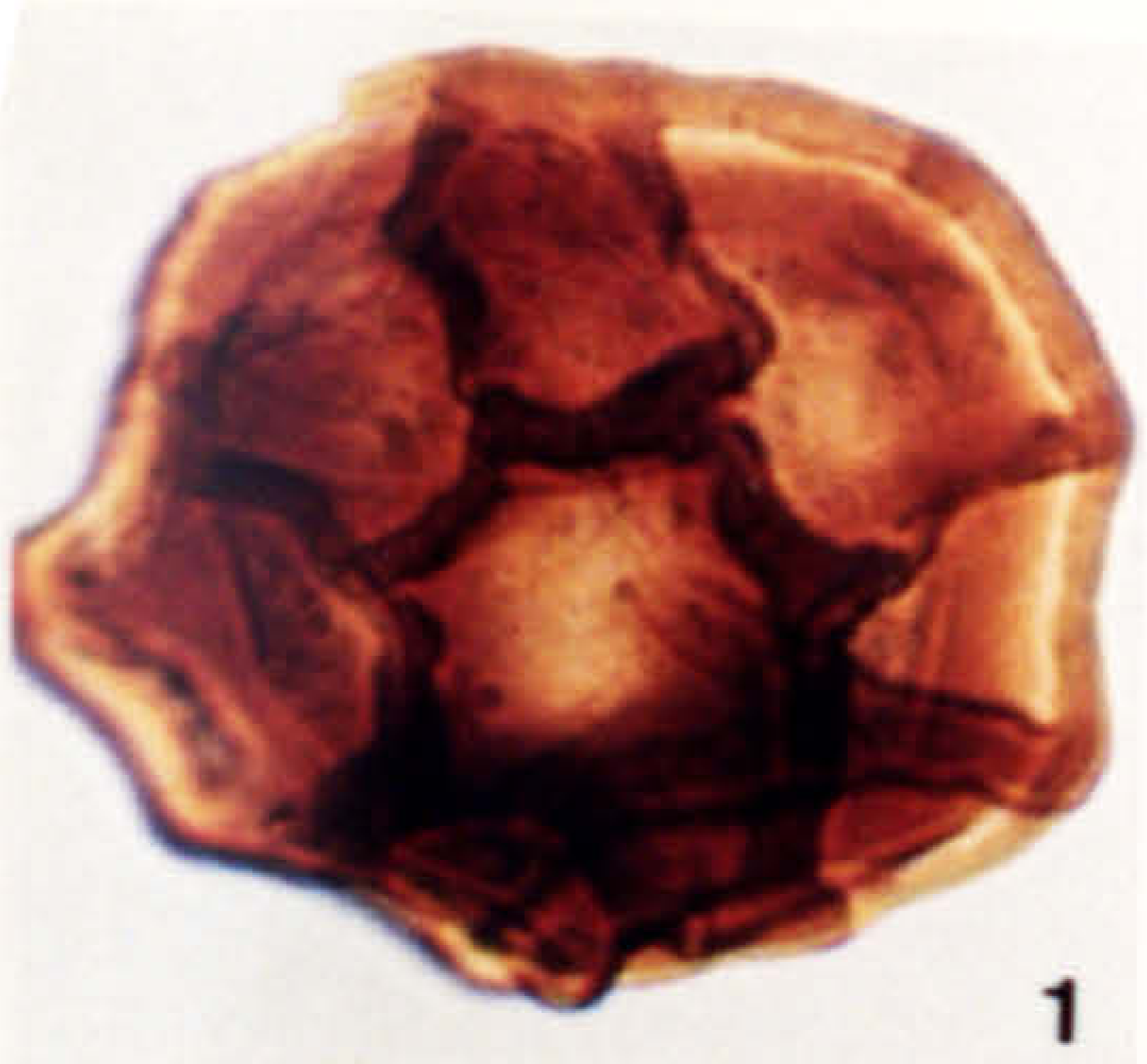

25


26

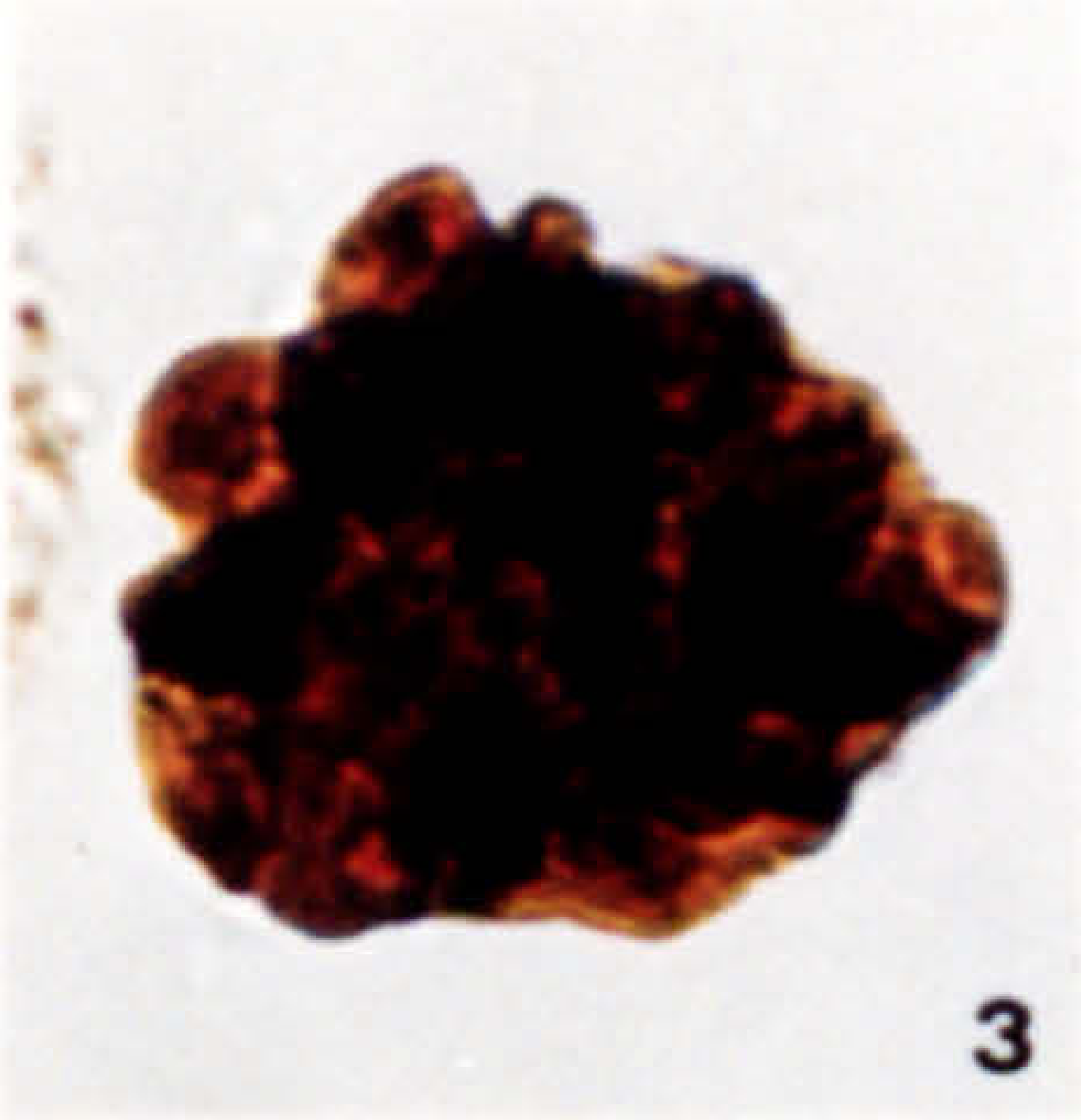
PLATE 9.

1. *Reticulatisporites reticulatus*. 44/22-1, 11685', 1, L40.
2. *Reticulatisporites polygonalis*. 44/22-4, 12095', 2, U50.2.
3. *Secarisporites remotus*. 44/22-3, 11558', 1, B47.
4. *Stenozonotriletes perforatus*. 44/22-1, 11685', 1, S45.4.
5. *Archaeozonotriletes variabilis*. 44/22-1, 12032', 2, O60.
6. *Secarisporites* cf. *remotus*. 44/22-1, 11527', 1, P51.4.
7. *Secarisporites remotus*. 44/22-4, 12300', 2, O33.
8. *Stenozonotriletes lycosporoides*. 44/22-1, 11610', 1, D46.
9. *Kraeuselisporites crassus*. Holotype, partial equatorial focus. 44/22-3, 11558', 1, T60.1.
10. *Kraeuselisporites crassus*. Same specimen as above, distal focus.
11. *Kraeuselisporites crassus*. 44/22-3, 11558', 1, O43.1.
12. *Kraeuselisporites pseudoornatus*. 44/22-4, 12155', 1, L44.
13. *Fragilipollenites radiatus*. 44/22-3, 11975', 2, K63.
14. *Kraeuselisporites pseudoornatus*. Holotype. 44/22-4, 12155', 2, T56.1.
15. *Kraeuselisporites echinatus*. 44/22-3, 11867', 1, U49.4.
16. *Kraeuselisporites ornatus*. 44/22-4, 12155', 1, H57.

PLATE 9

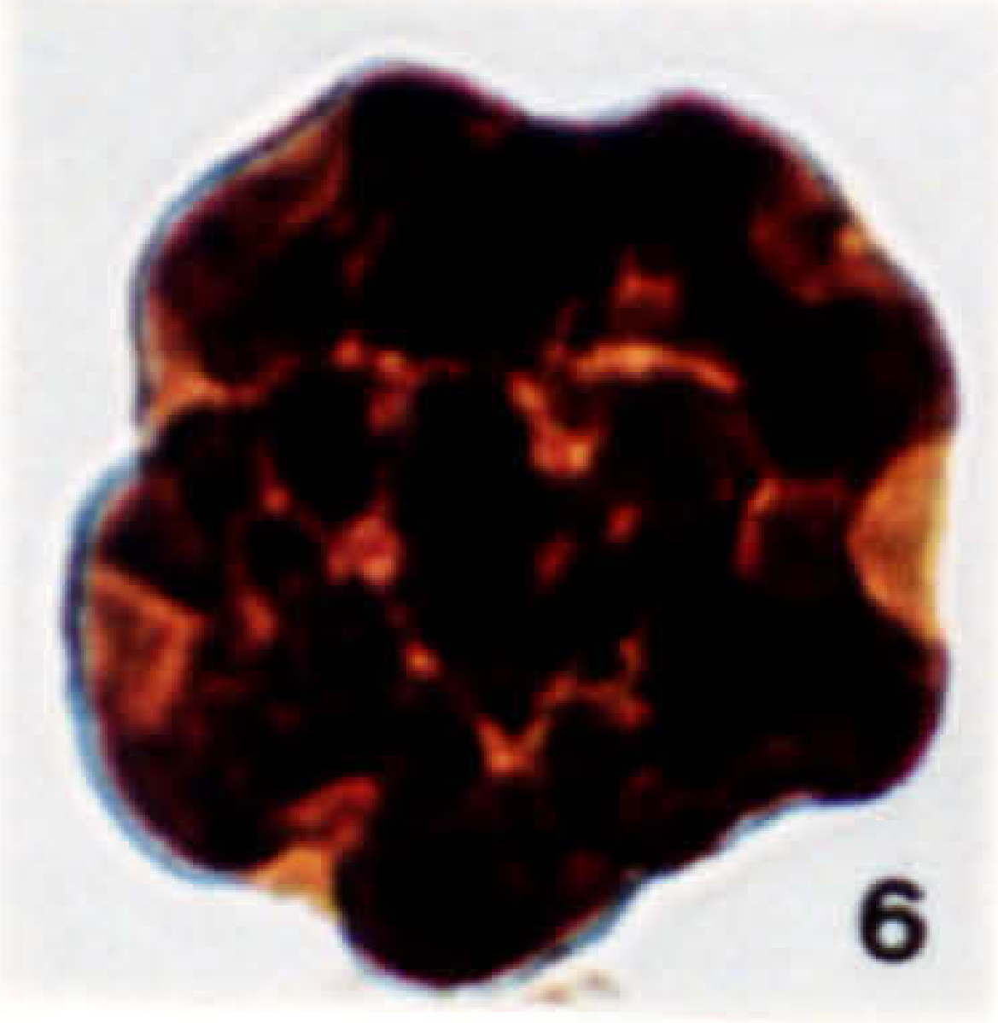

1


2


3


4


5

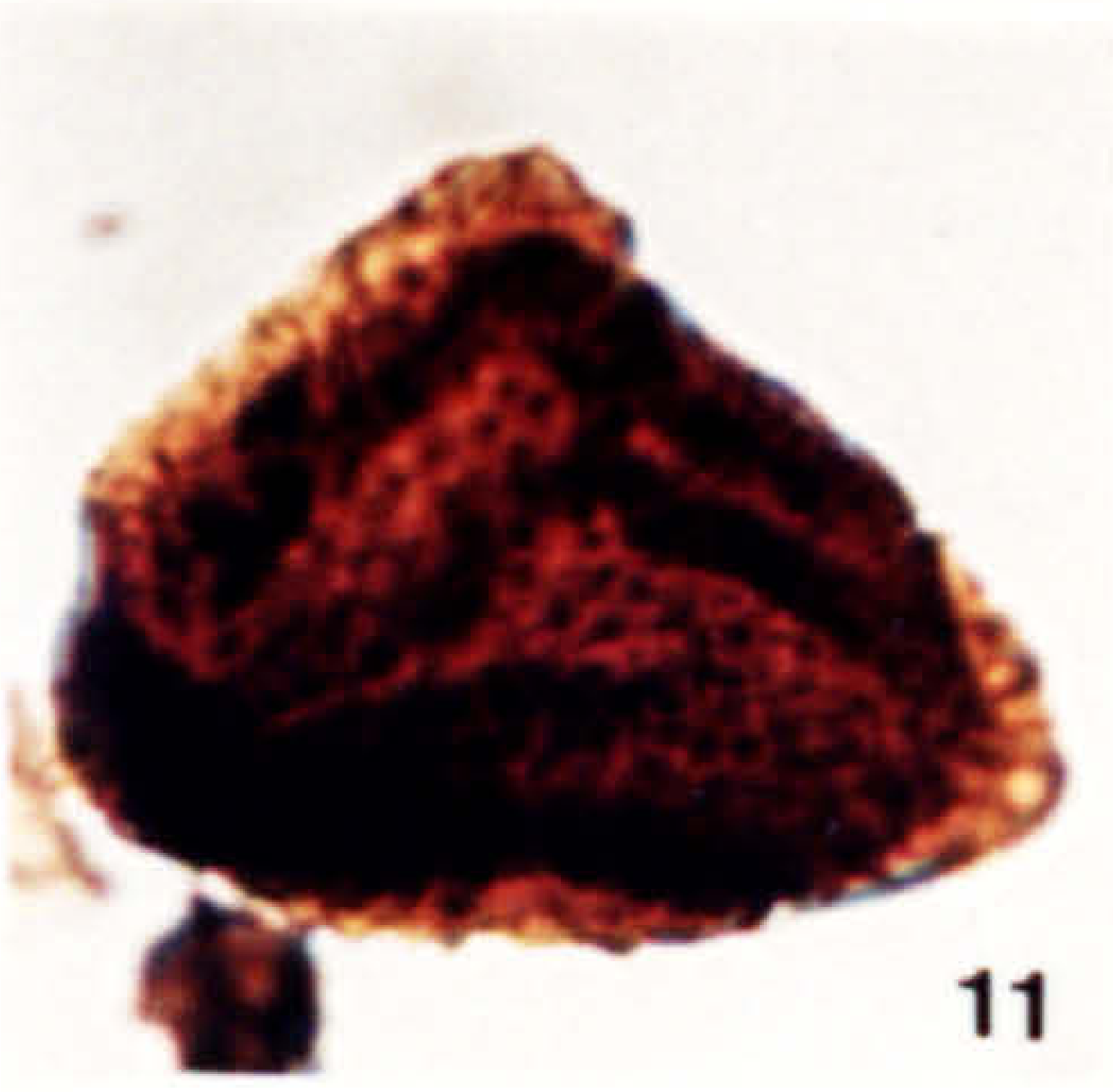

6

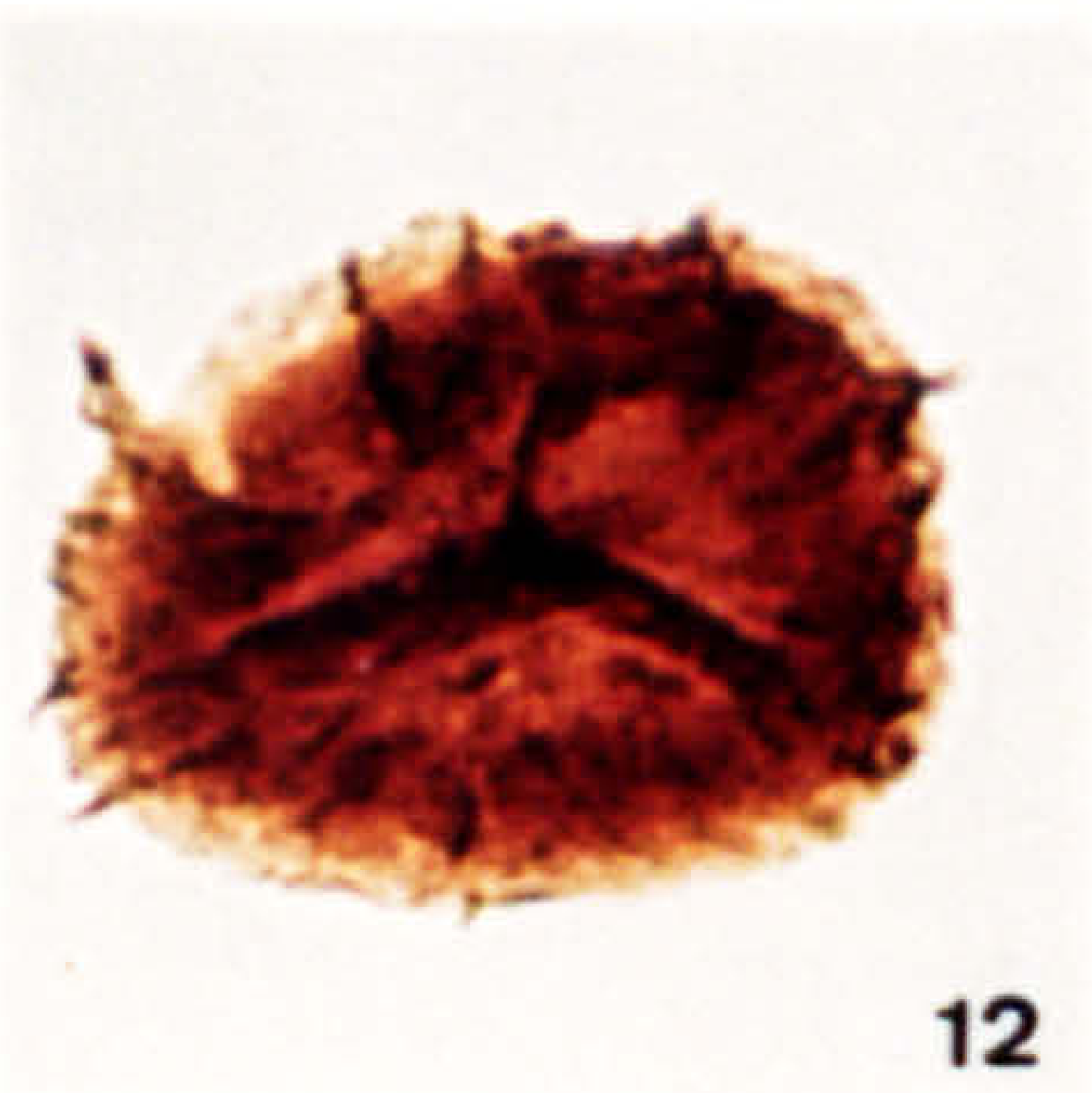

7

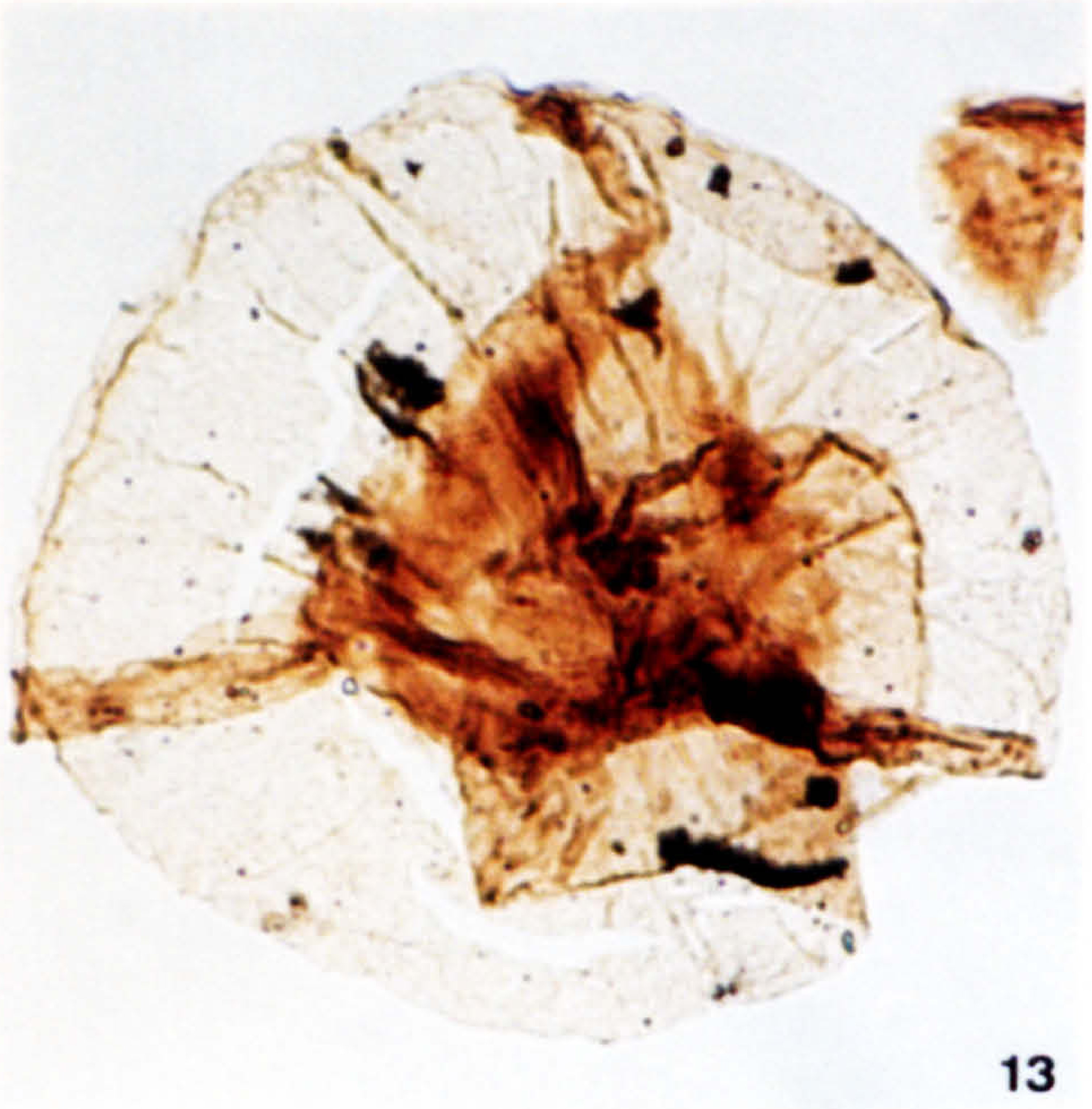

8

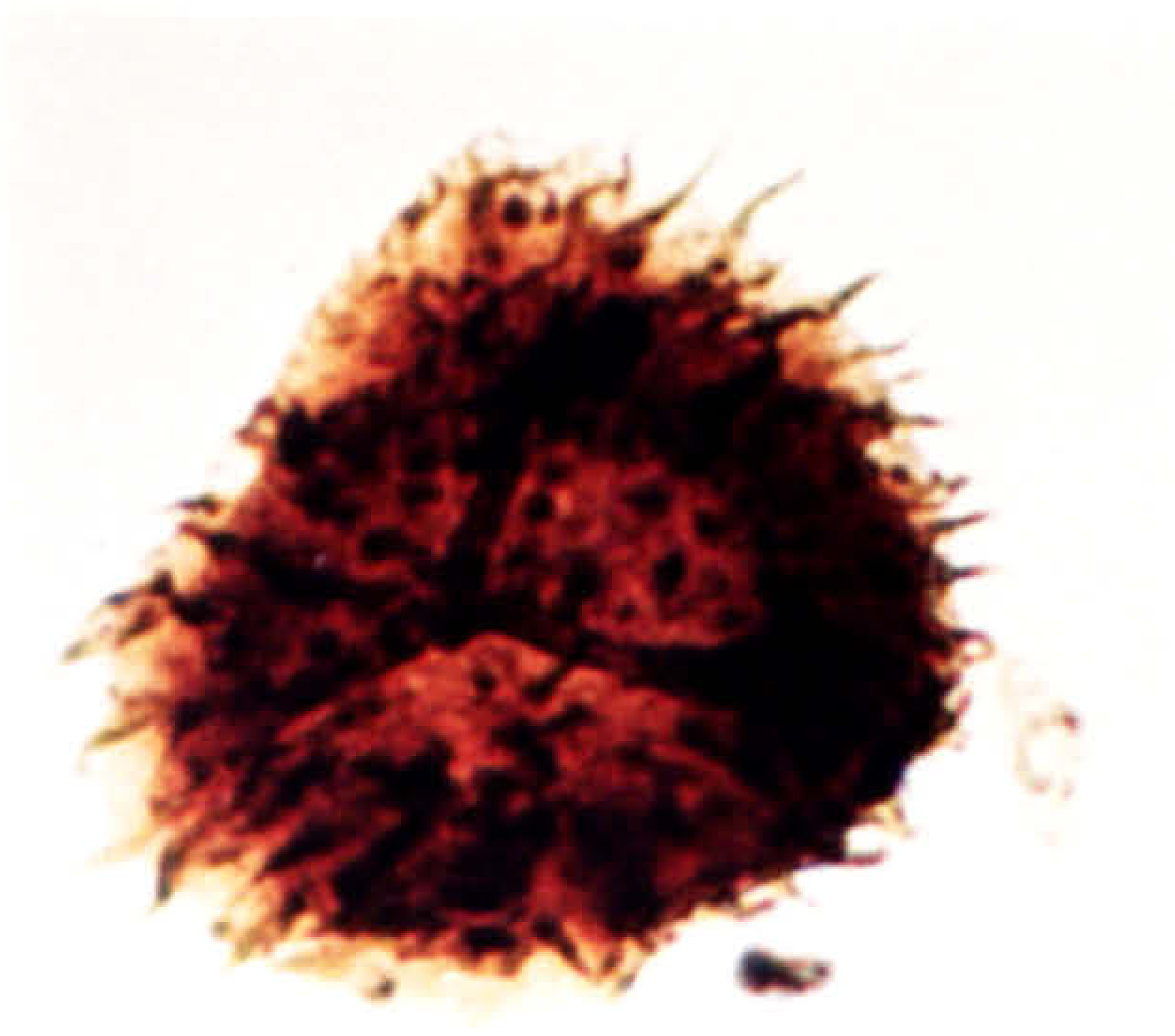

9


10


11


12


13


14

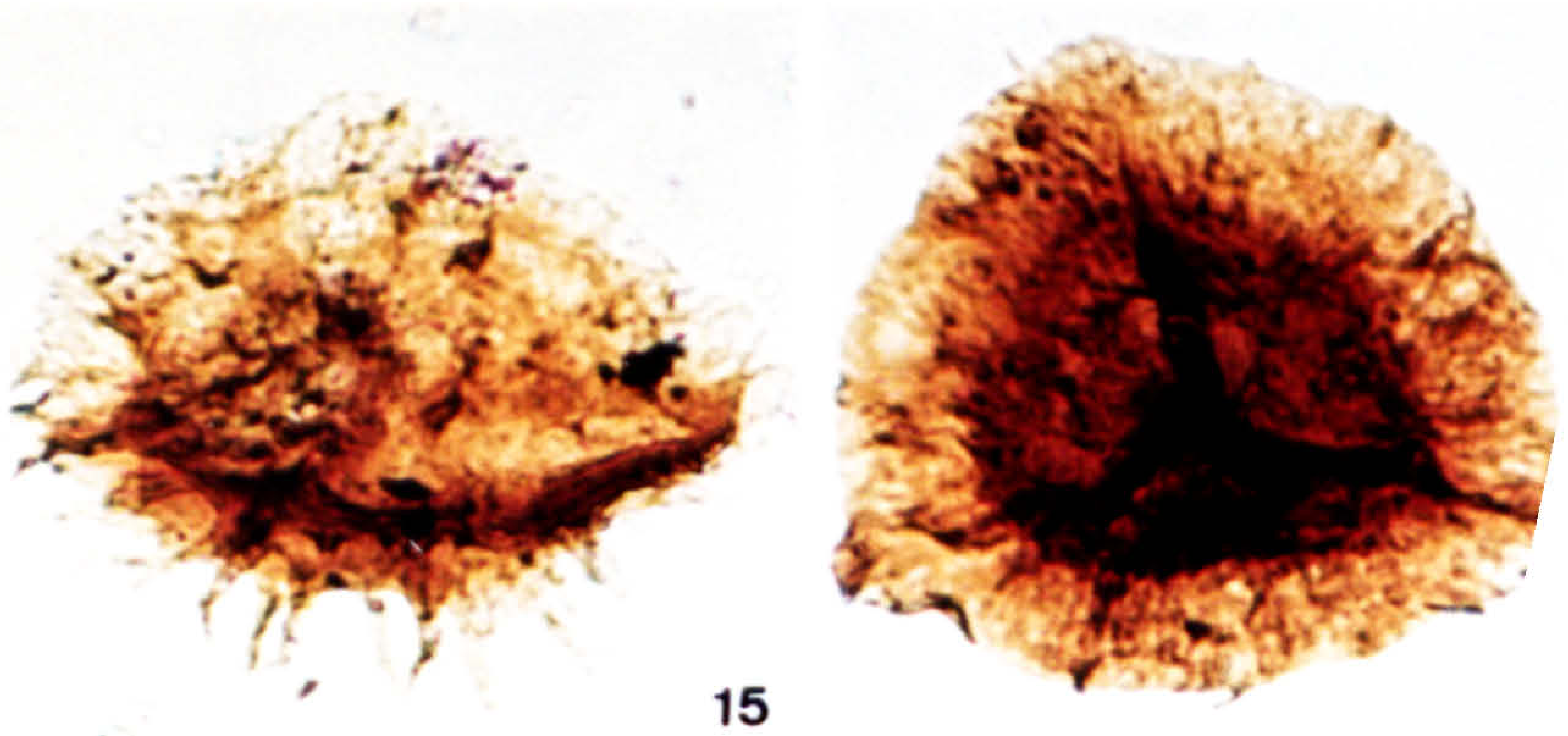
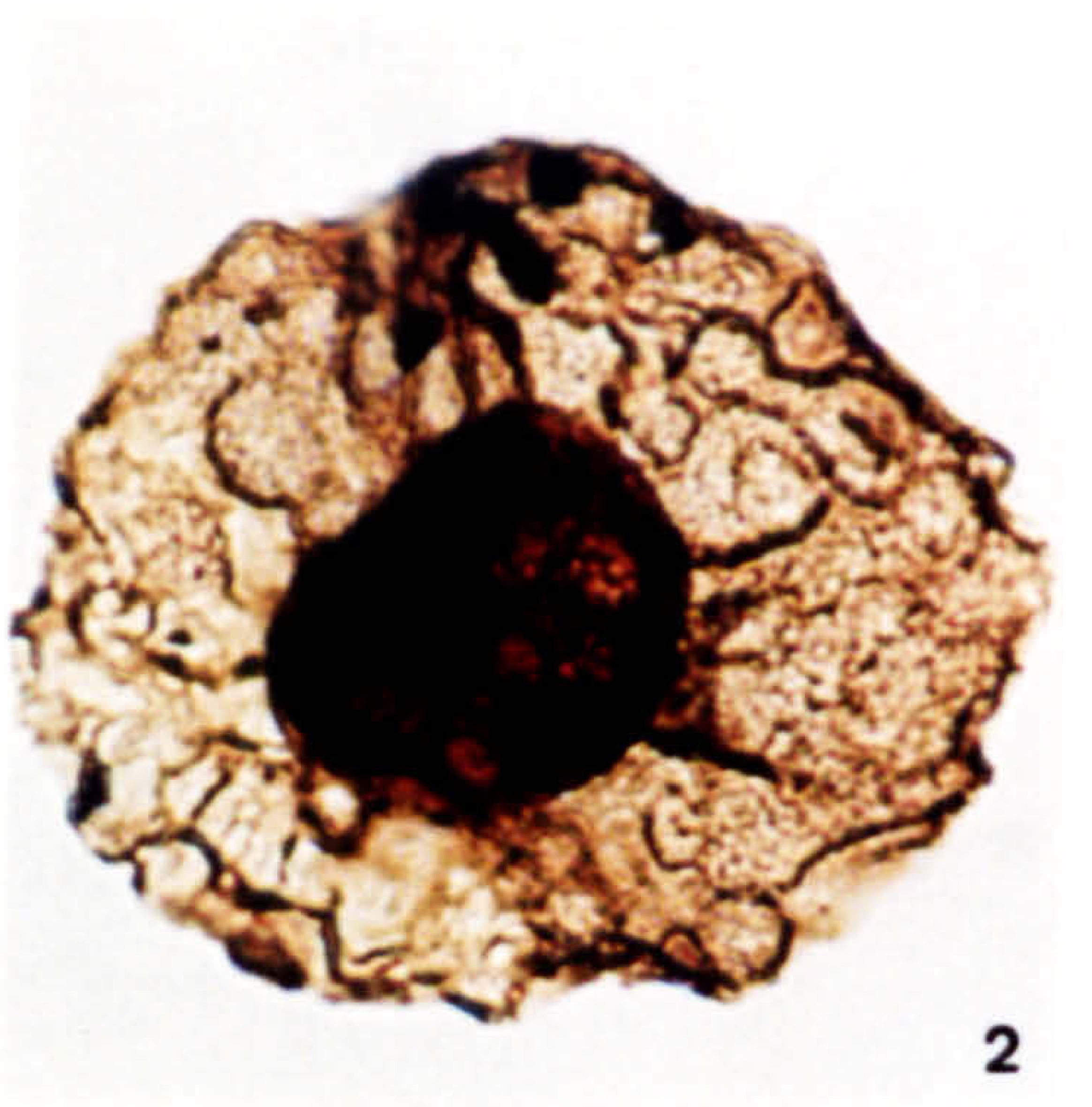

15

PLATE 10.

1. *Auroraspora? pseudogranulata.* 44/22-3, 11872', 1, W67.
2. *Auroraspora? pseudogranulata.* 44/22-3, 11872', 1, P43.
3. *Auroraspora velata.* 44/22-3, 11872', 2, L38.
4. *Auroraspora velata.* 44/22-3, 11522', 2, S50. 3.
5. *Auroraspora pickerillensis.* Holotype. 44/22-1, 11878', 1, N52.2.
6. *Auroraspora pickerillensis.* 44/22-1, 11878', 1, K36.
7. *Auroraspora solisortus.* 44/22-1, 12242', 2, B37.4.
8. *Endosporites pygmaeus.* Holotype. 44/22-1, 11414.9', 1, K43.3.
9. *Endosporites globiformis.* 44/22-1, 11389', 2, E53.2.
10. *Endosporites zonalis.* 44/22-1, 11880', 2, J54.
11. *Endosporites conarus.* 44/22-1, 12045', 1, F40.
12. *Endosporites conarus.* 44/22-1, 12019', 2, H51.1.
13. *Grumosisporites papillosus.* 44/22-4, 12258.8', 2, C45.2.
14. *Grumosisporites varioreticulatus.* 44/22-3, 11695', 1, P45.4.
15. *Grandispora spinosa.* 44/22-1, 12031', 2, S57.4.

PLATE 10


1


2


3


4


5


6


7

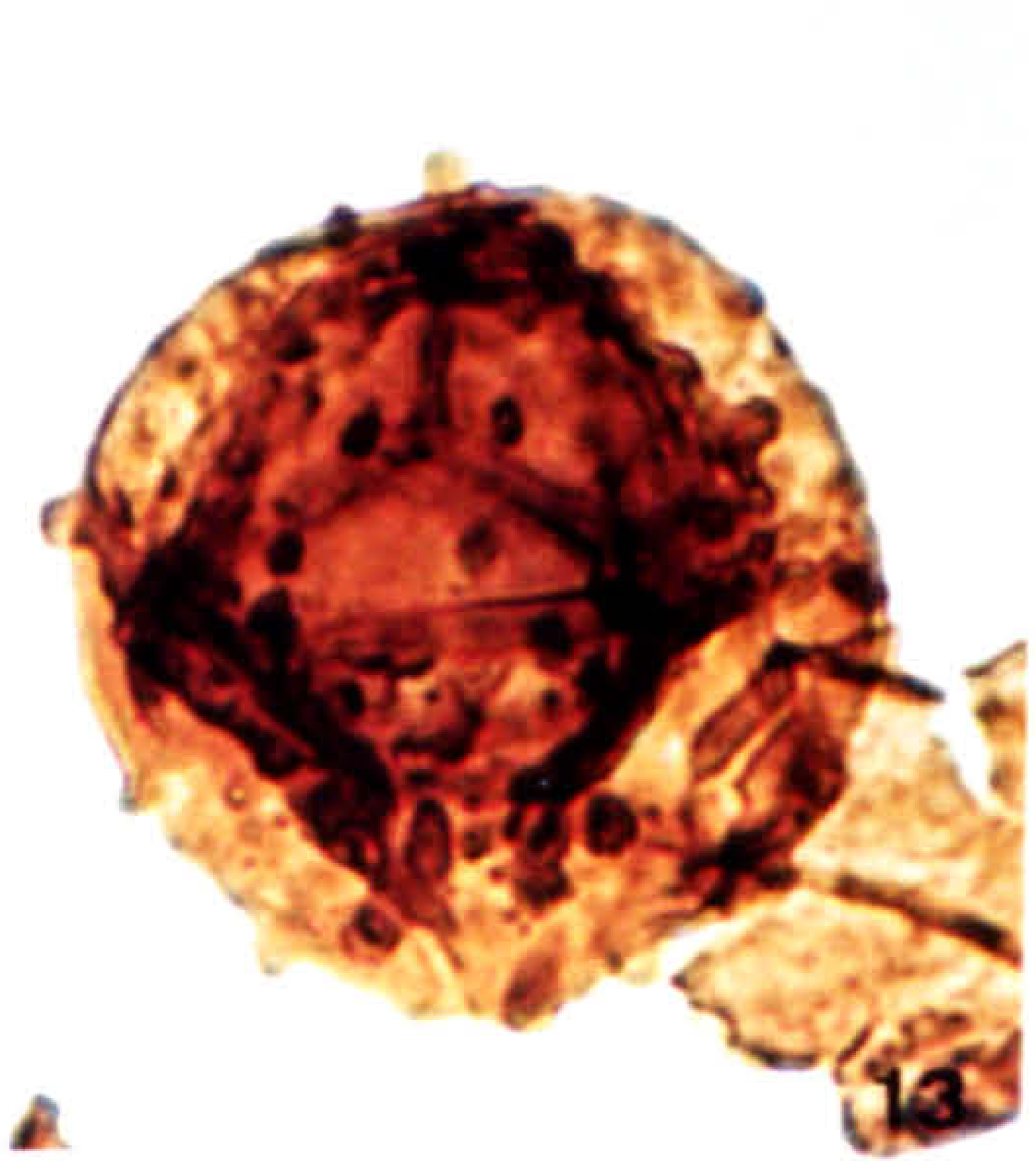

8

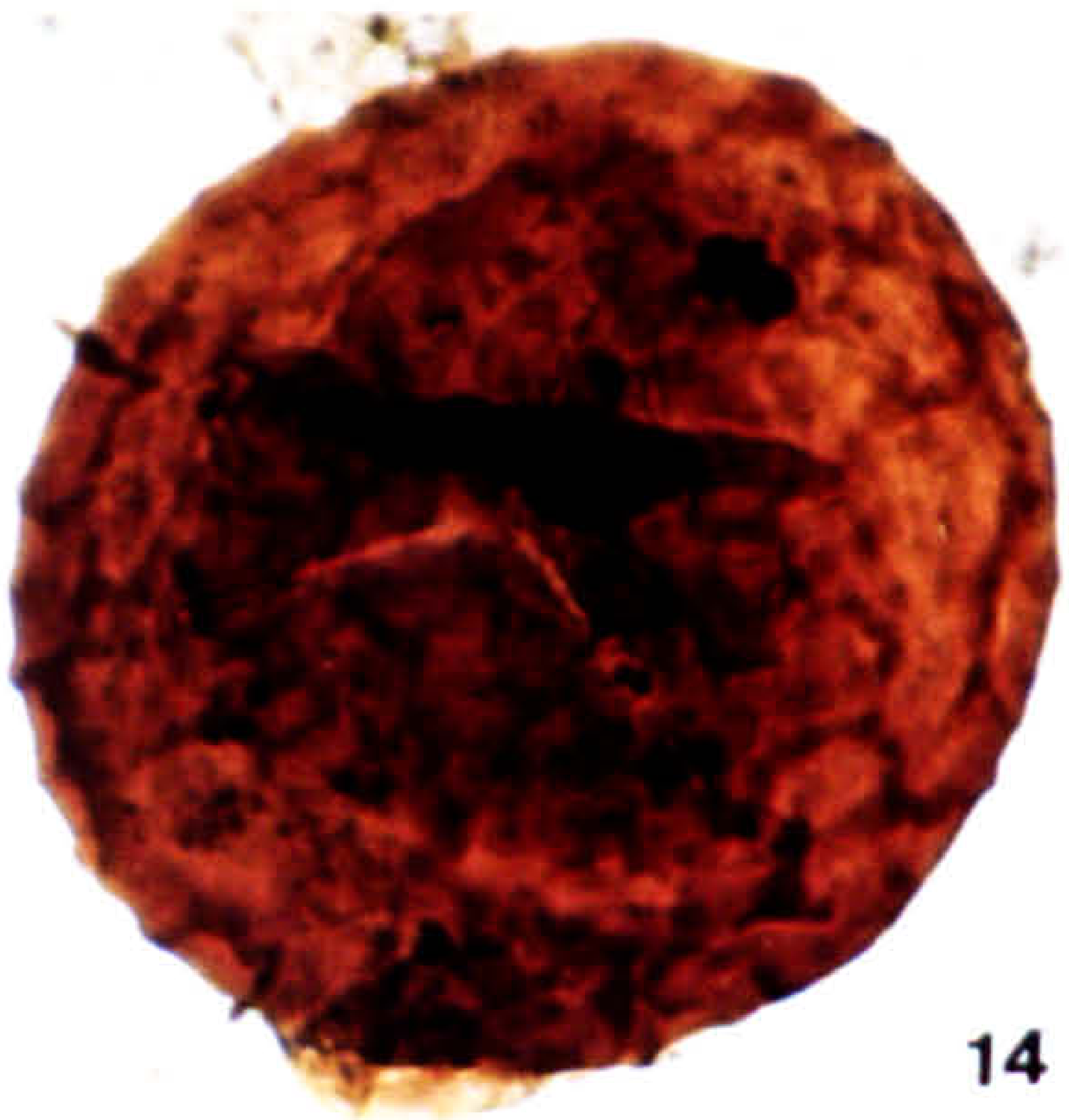

9


10


11


12


13

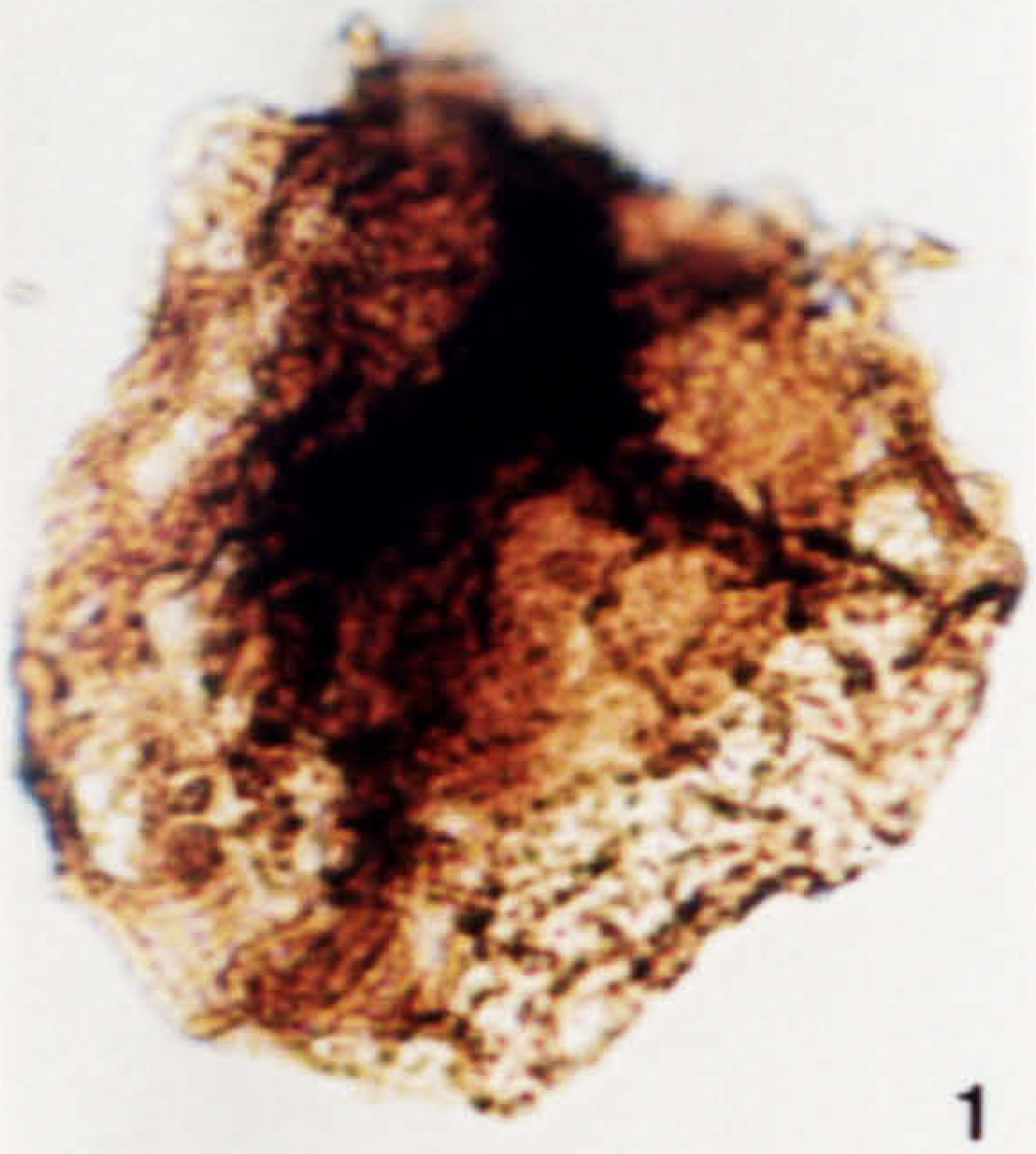

14

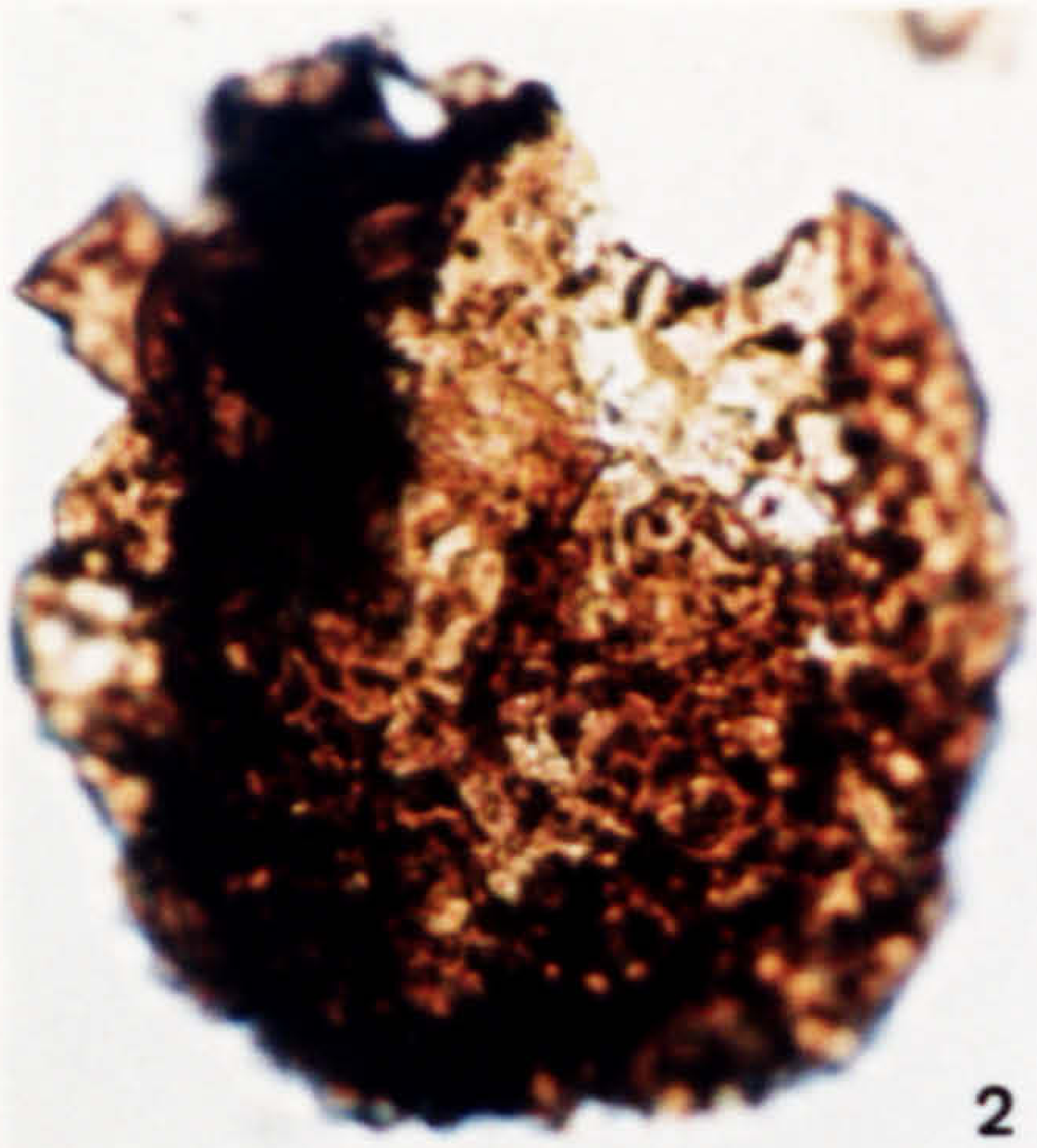

15

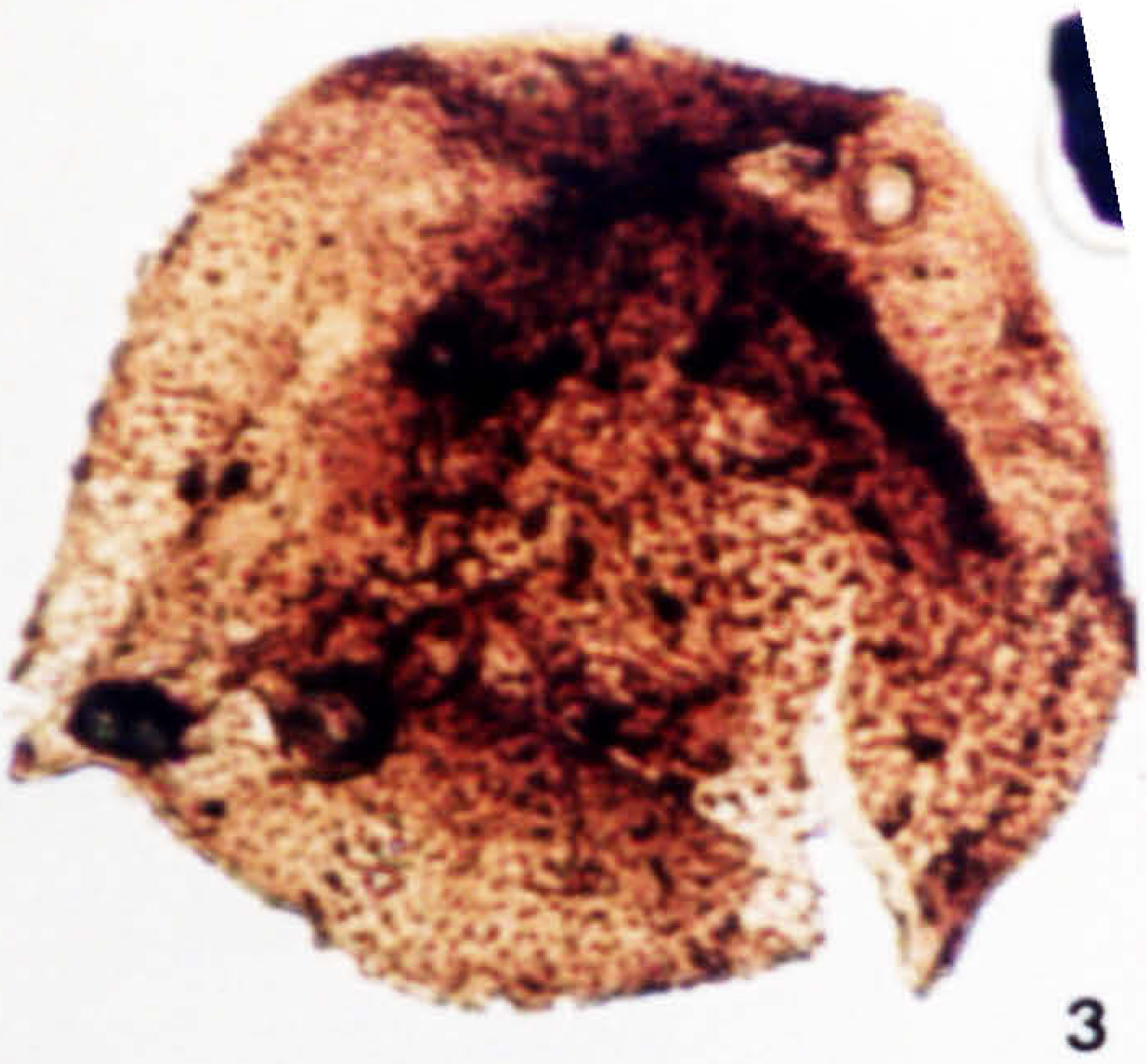
PLATE 11.

1. *Rugospora corporata.* 44/22-1, 11873', 1, G45.1.
2. *Rugospora corporata.* 44/22-1, 12030', 2, B53.4.
3. *Spelaeotriletes arenaceus**. 43/15b-3a. 13843', 1, W65.
4. *Spelaeotriletes oppletus.* Holotype. 44/22-3, 11872', 5, J55.
5. *Spelaeotriletes* cf. *oppletus.* Proximal and equatorial focus. 44/22-4, 12262', 5, J52.2.
6. Same specimen as above. Distal focus.
7. *Spelaeotriletes* cf. *pretiosus.* 44/22-4, 12261.6', 2, F43.3.
8. *Spelaeotriletes bulboides.* Holotype. 44/22-1, 11878', 1, H48.1.
9. *Spelaeotriletes bulboides.* 44/22-1, 11928', 2, E55.2.
10. *Spelaeotriletes* cf. *pretiosus.* 44/22-1, 12040', 1, O52.3.
11. *Discernisporites micromanifestus.* 44/22-1, 12060', 1, K53.
12. *Discernisporites micromanifestus.* 44/22-4, 12258.8', 2, F51.4.
13. *Discernisporites* cf. *irregularis.* 44/22-1, 12060', 1, G38.1.
14. *Discernisporites* cf. *irregularis.* 44/22-1, 11785', 1, M39.3.
15. *Discernisporites* cf. *irregularis.* 44/22-1, 12060', 2, K44.3.
16. *Discernisporites* cf. *irregularis.* 44/22-4, 12262', 5, J52.4.

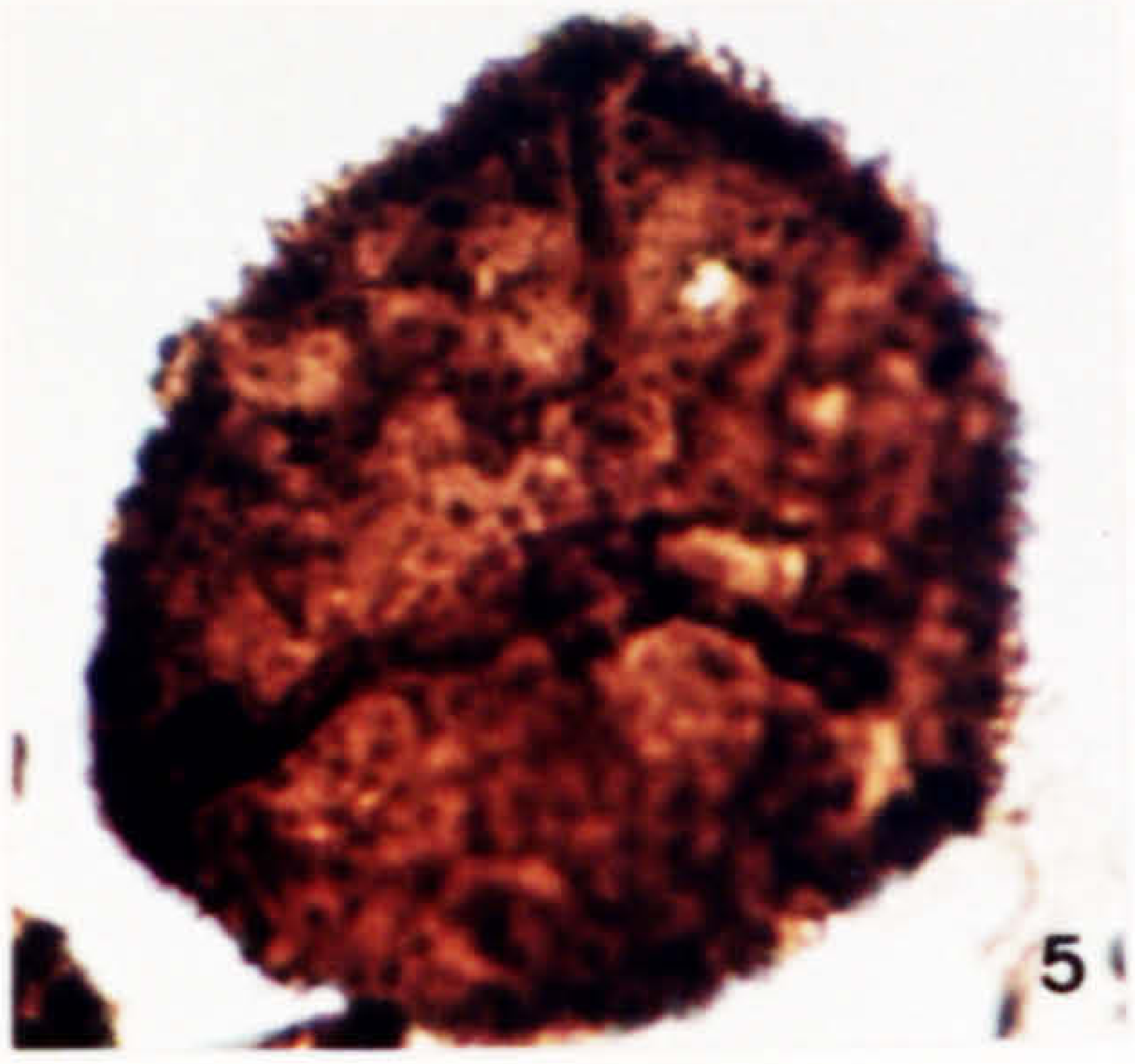
PLATE 11

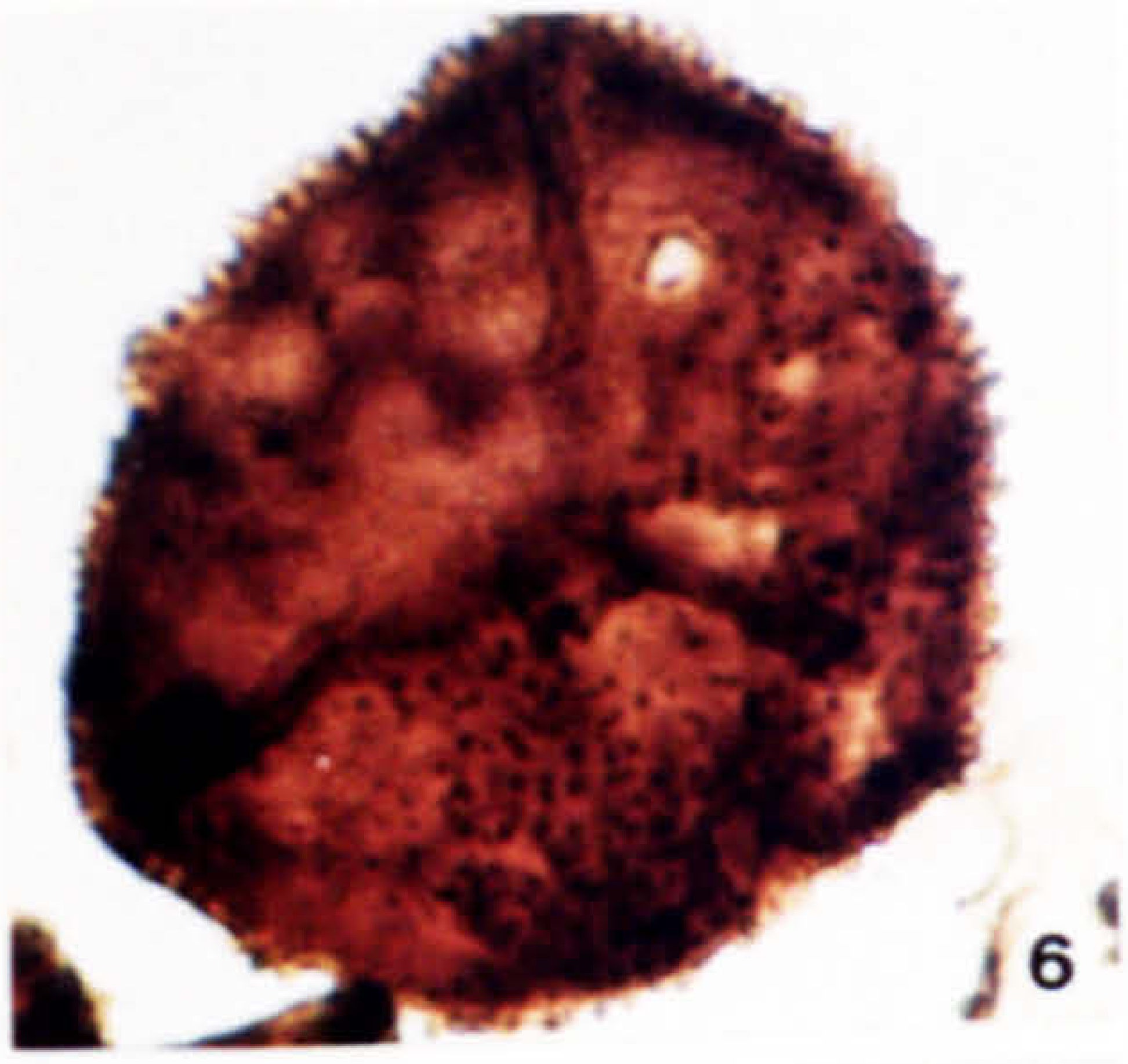

1

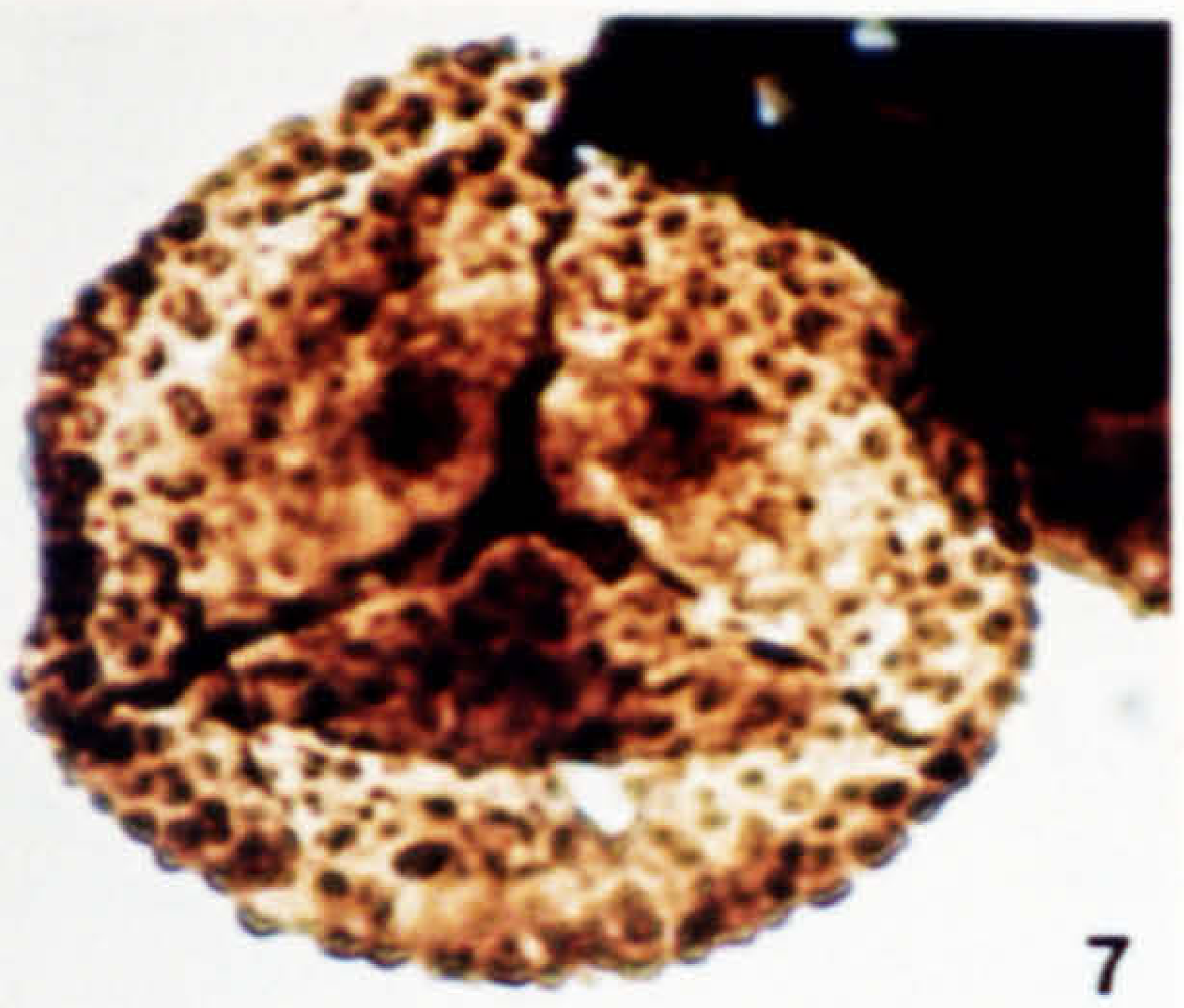

2


3

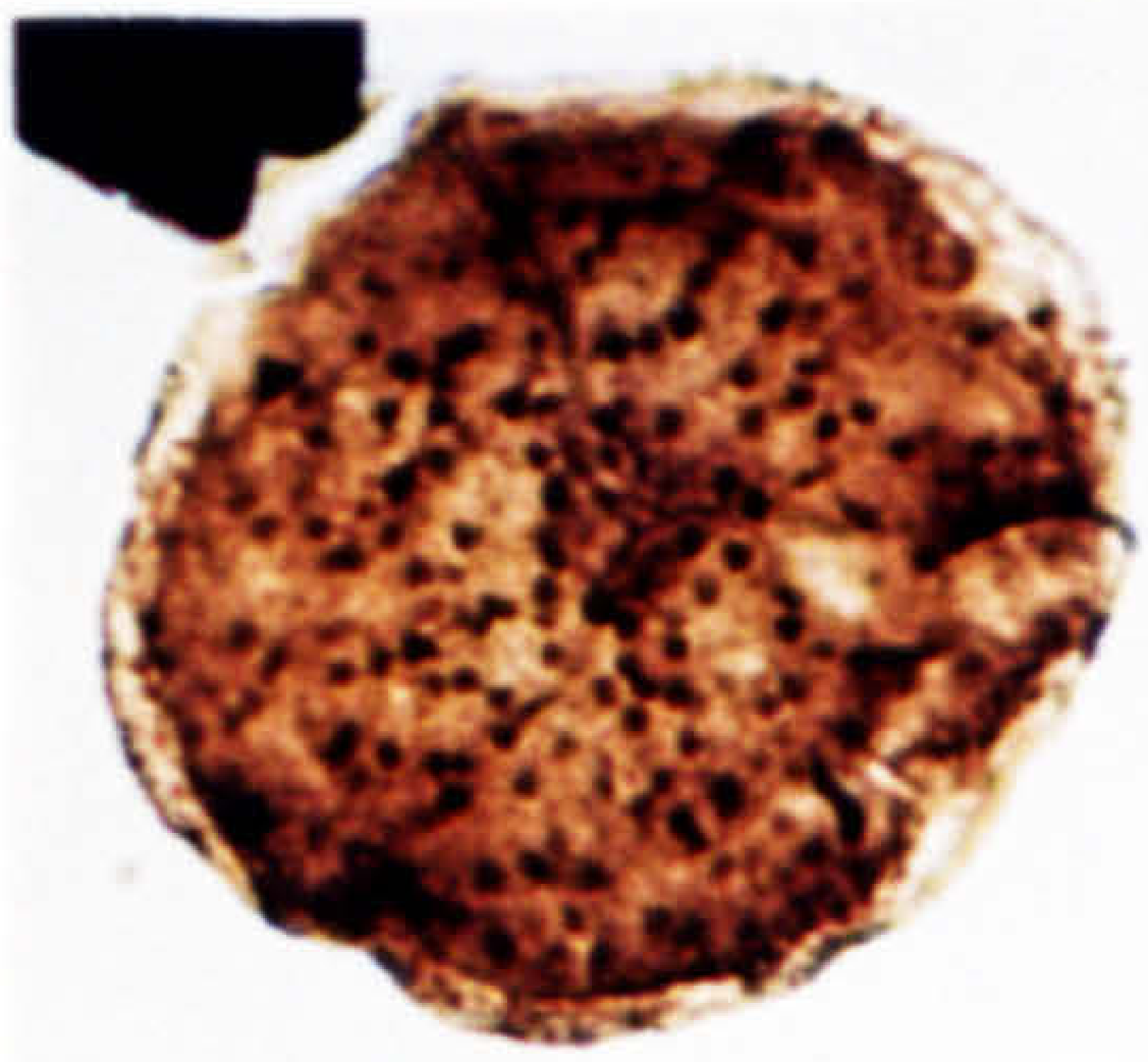

4

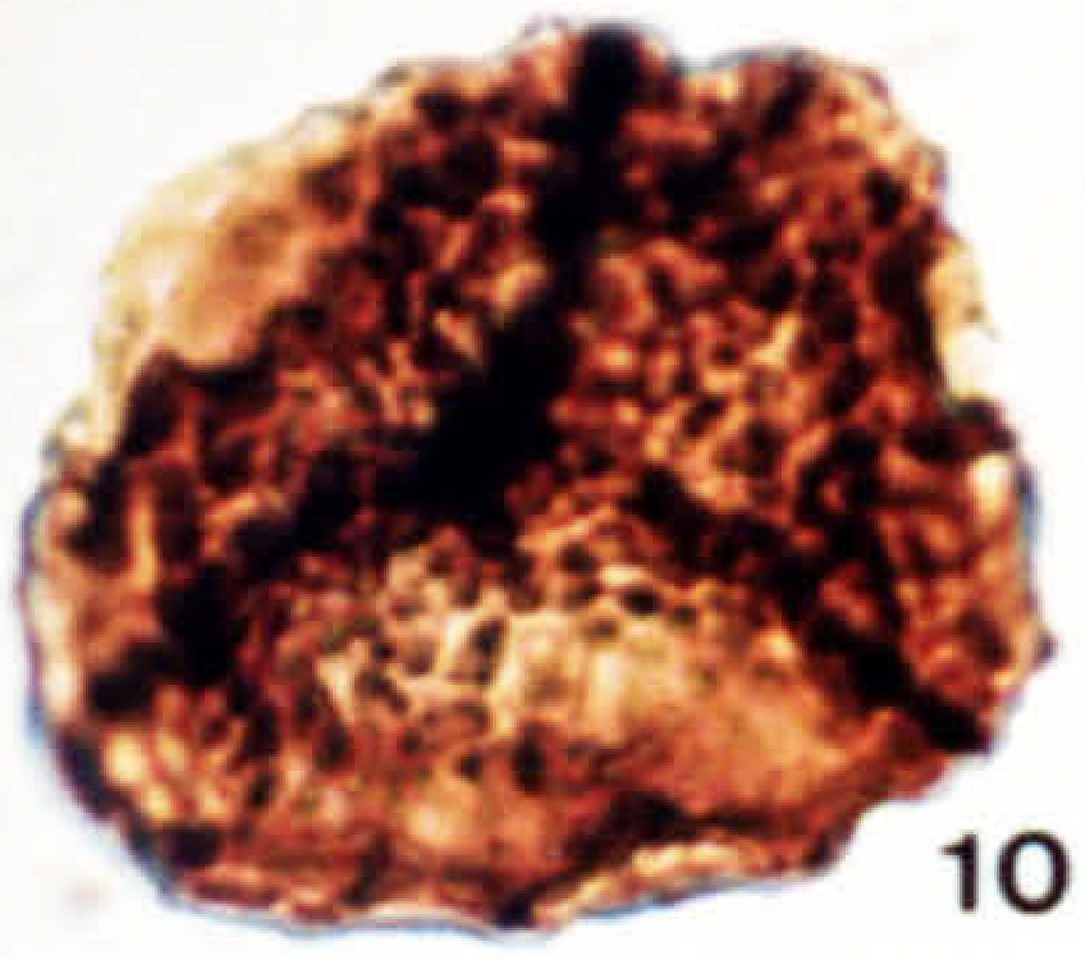

5

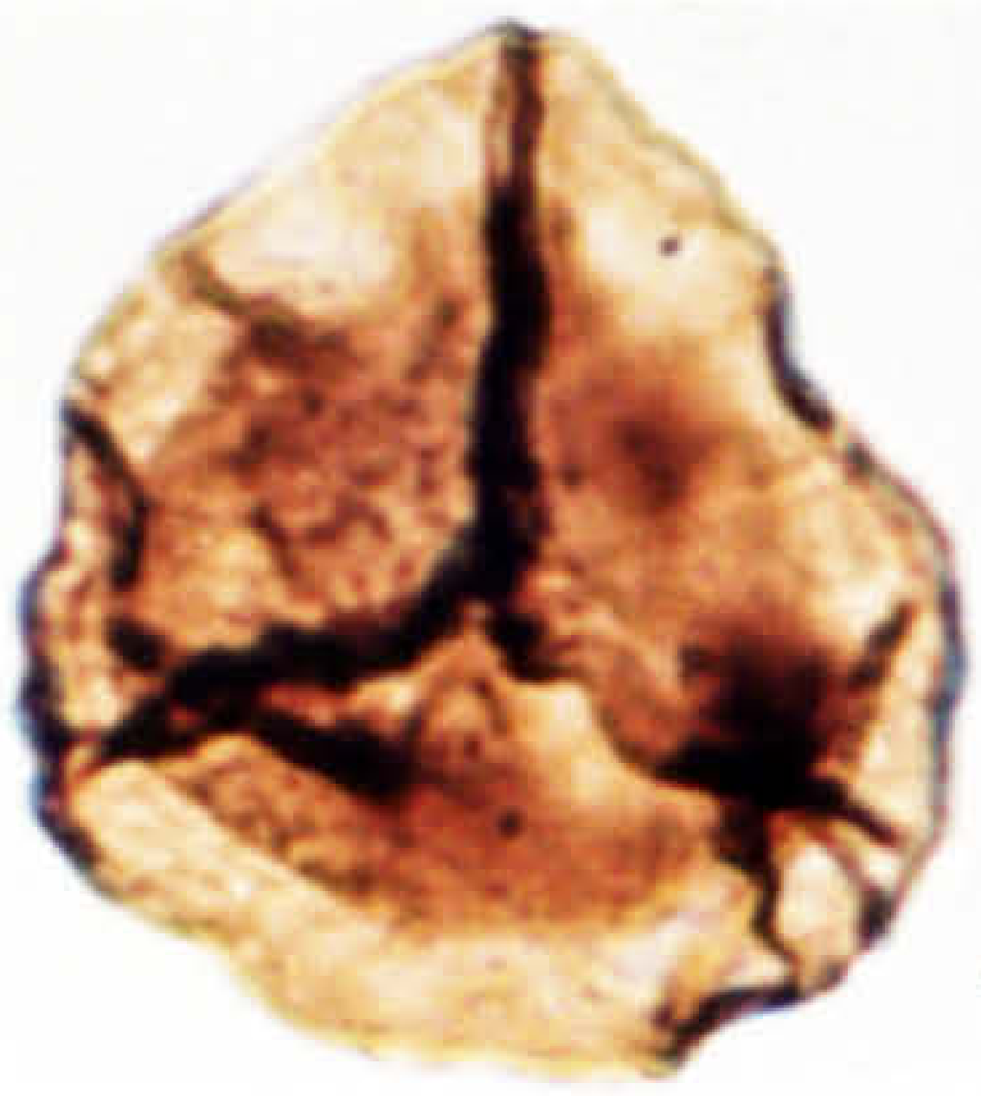

6

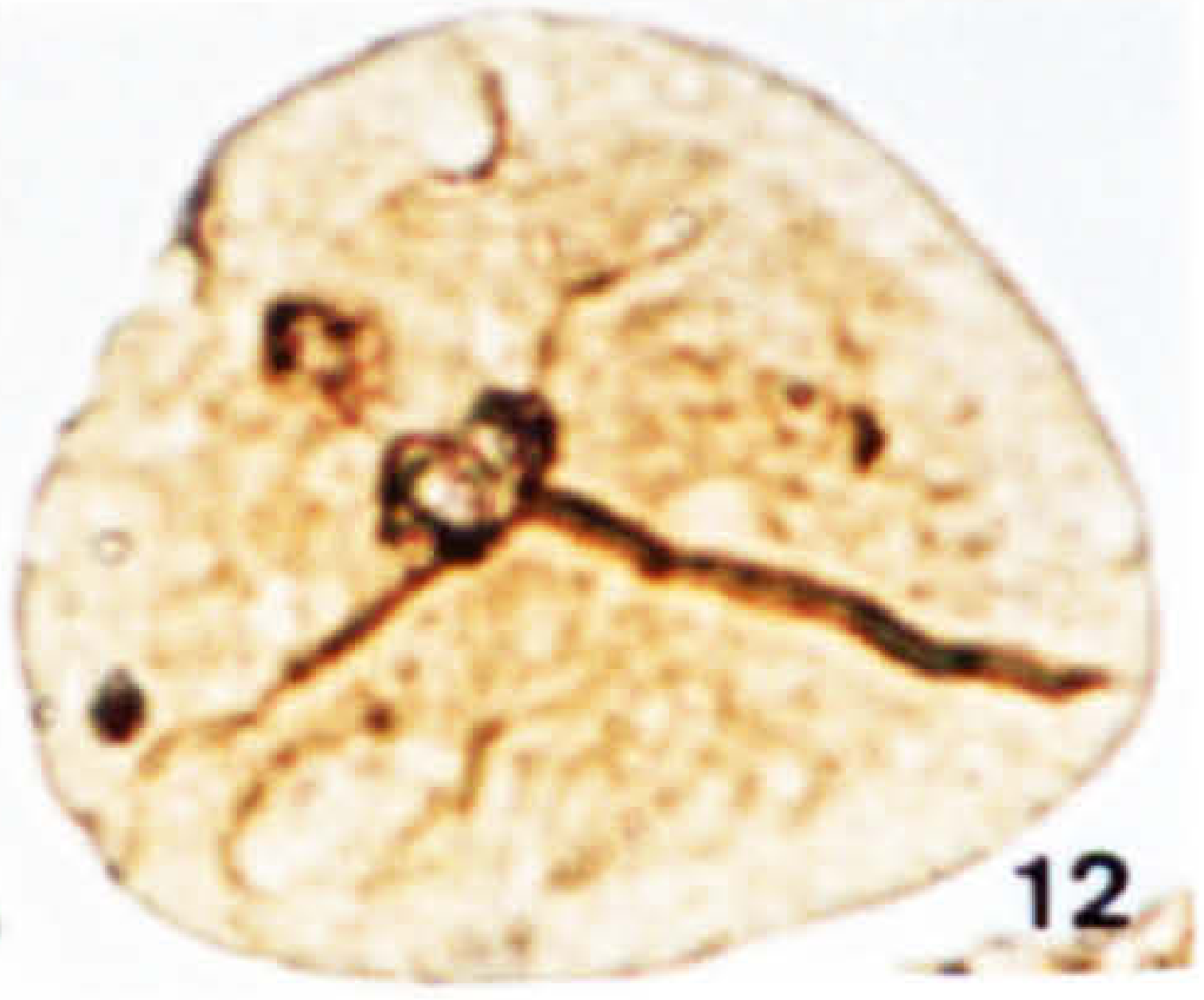

7

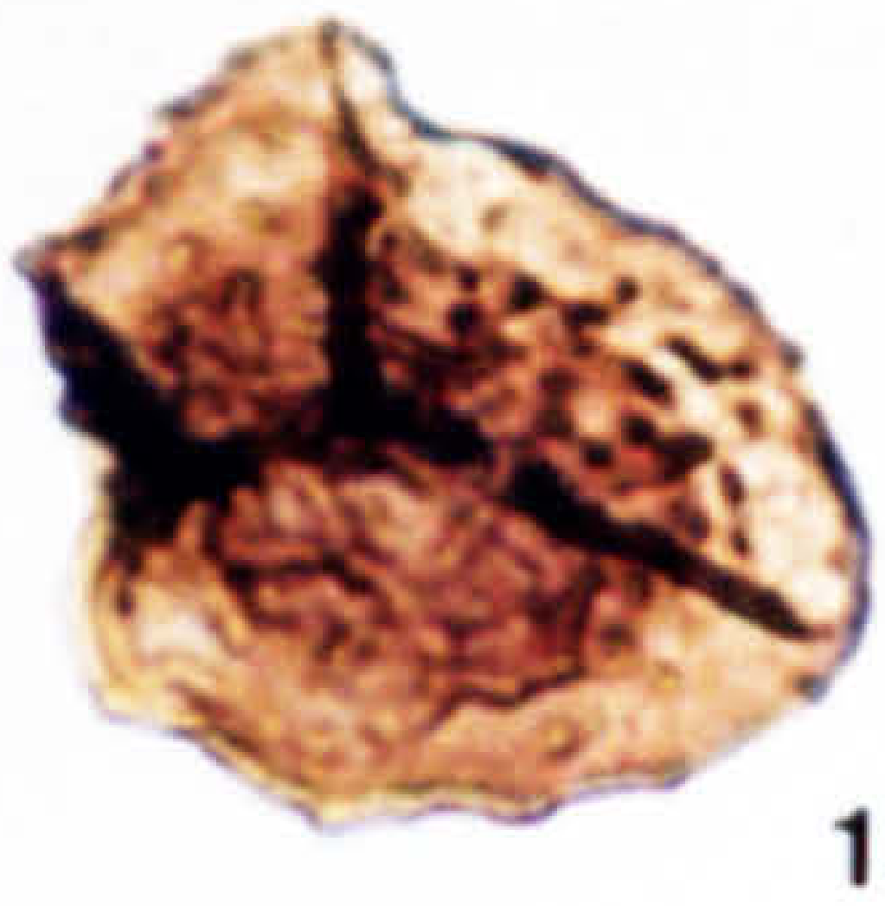

8

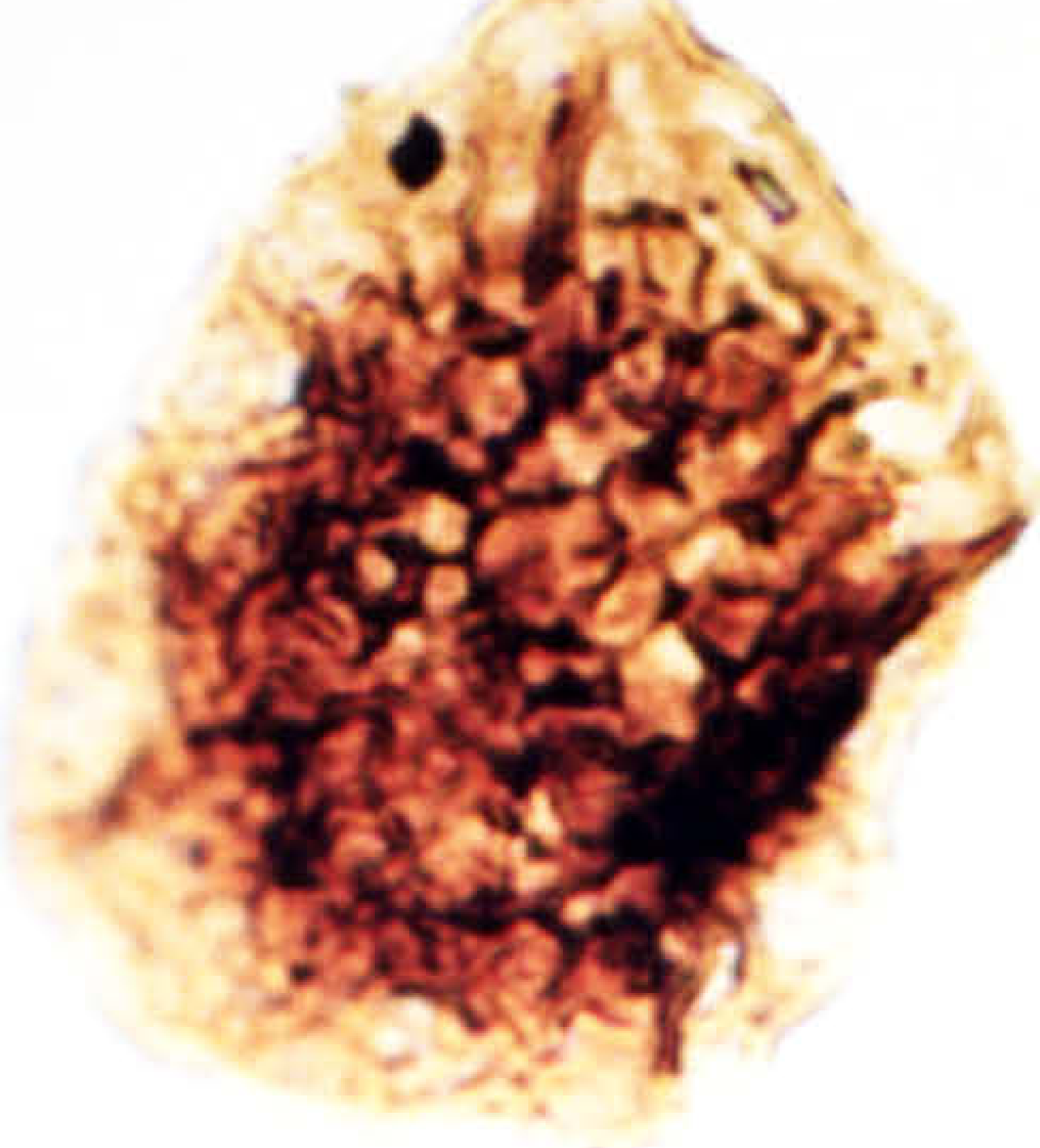

9

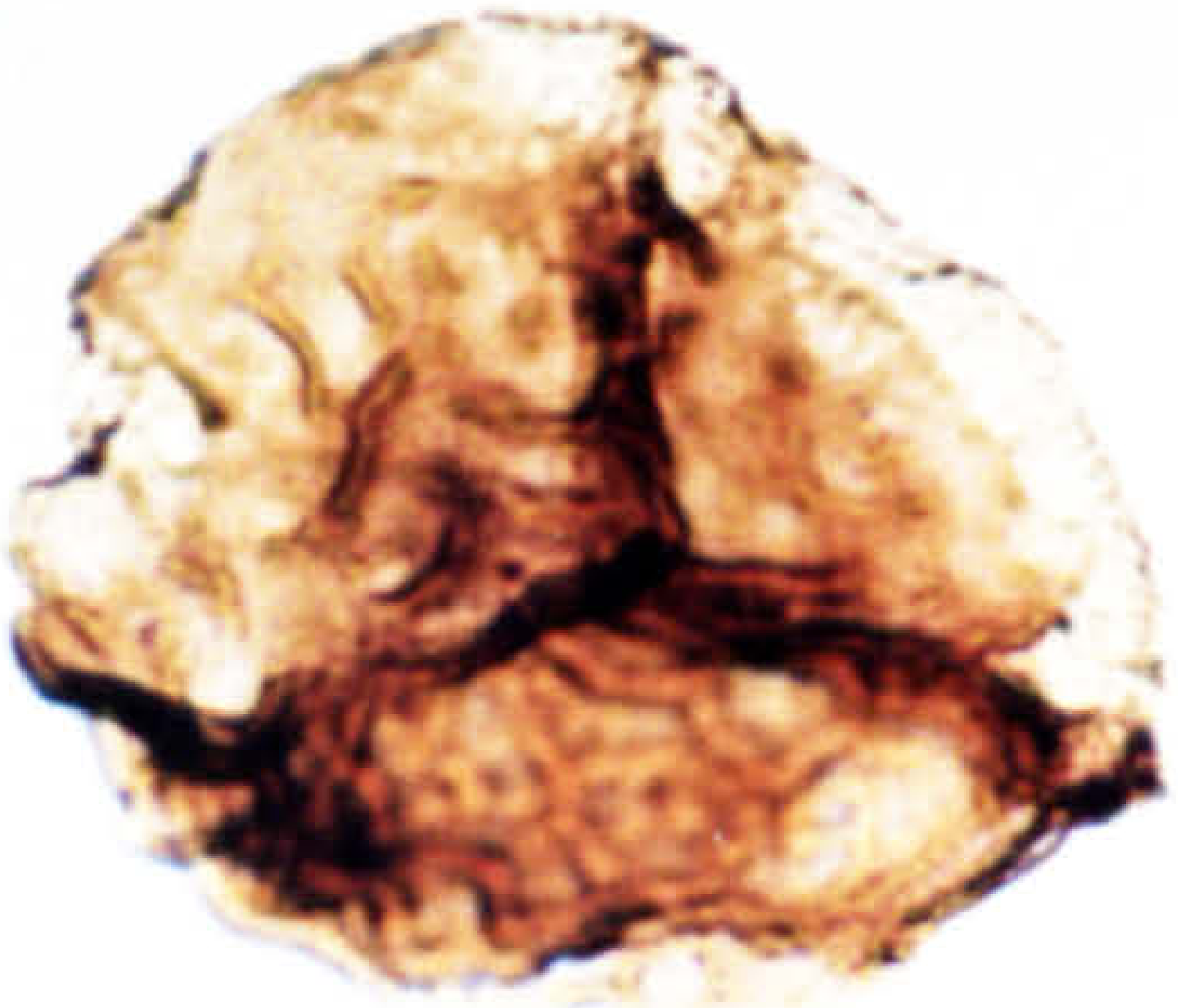

10


11


12


13


14


15

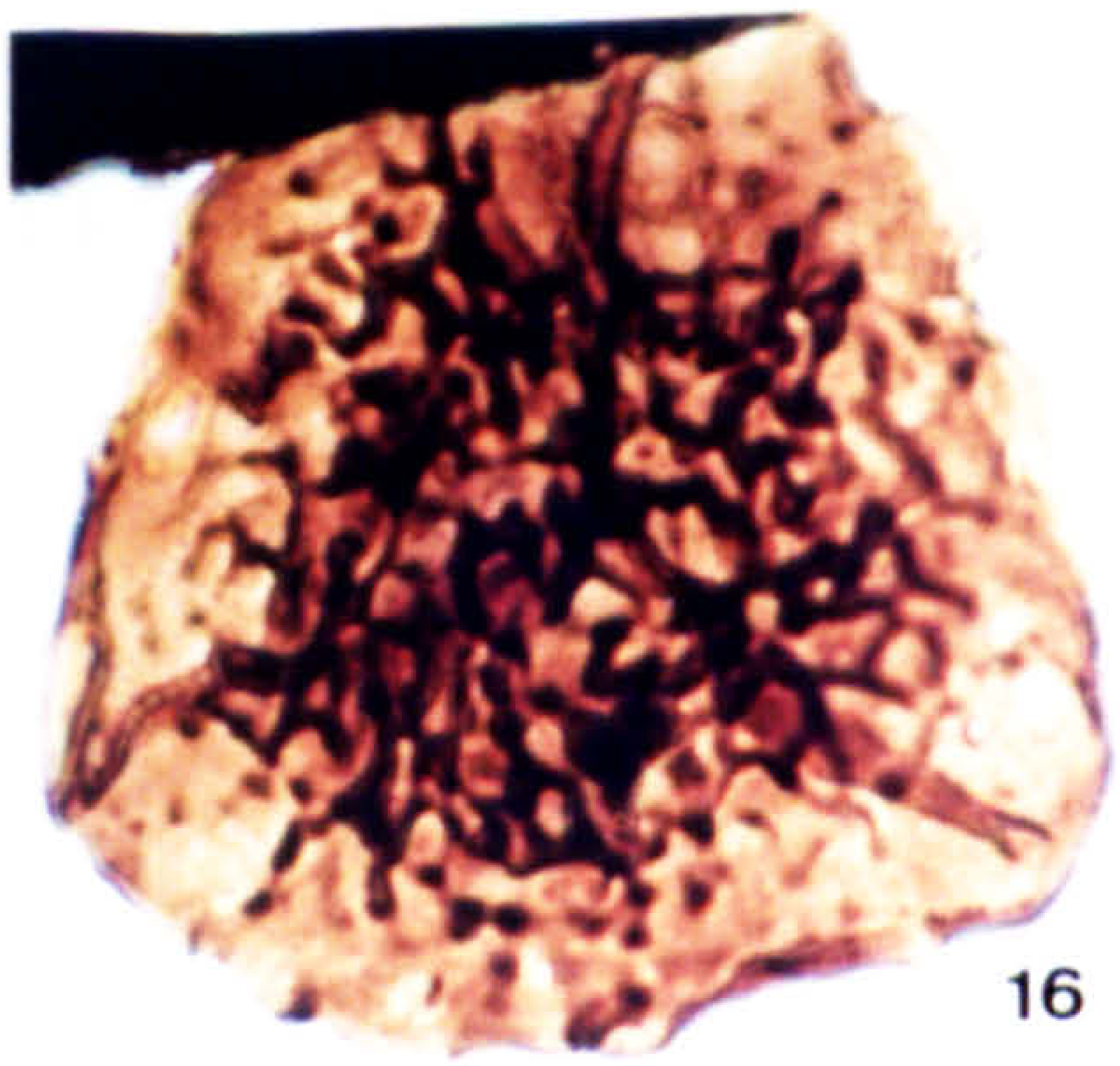
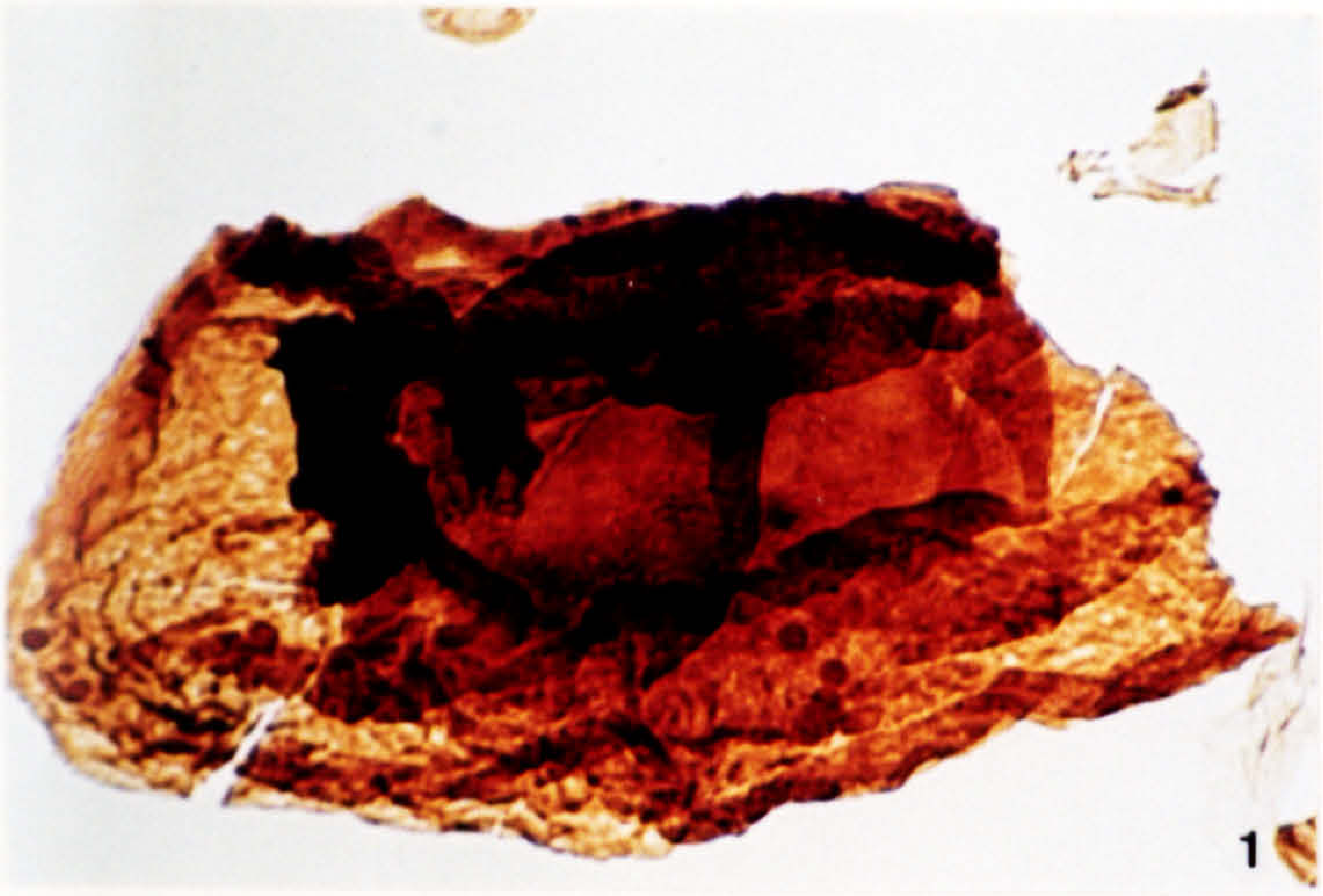
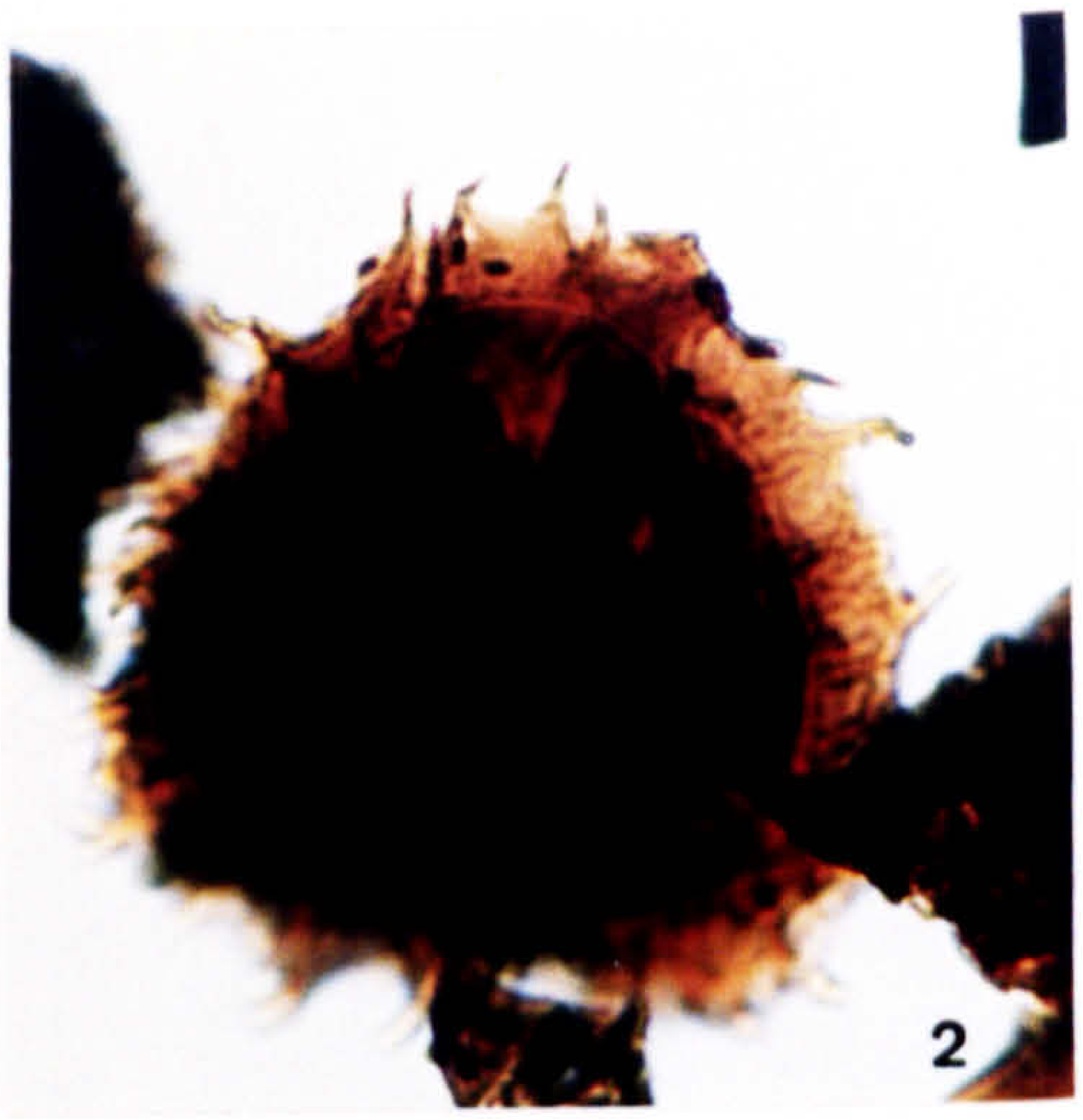

16

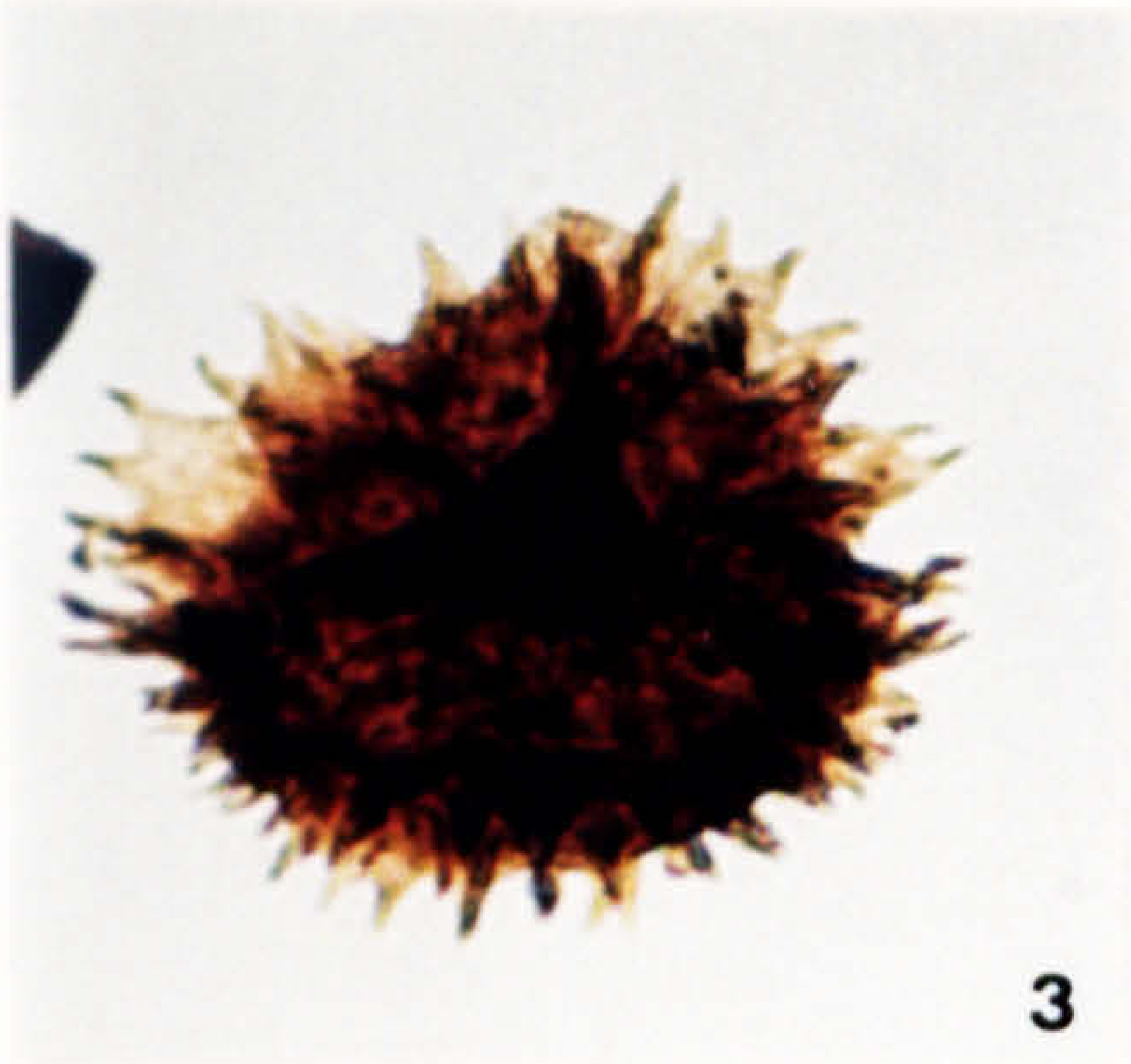
PLATE 12.

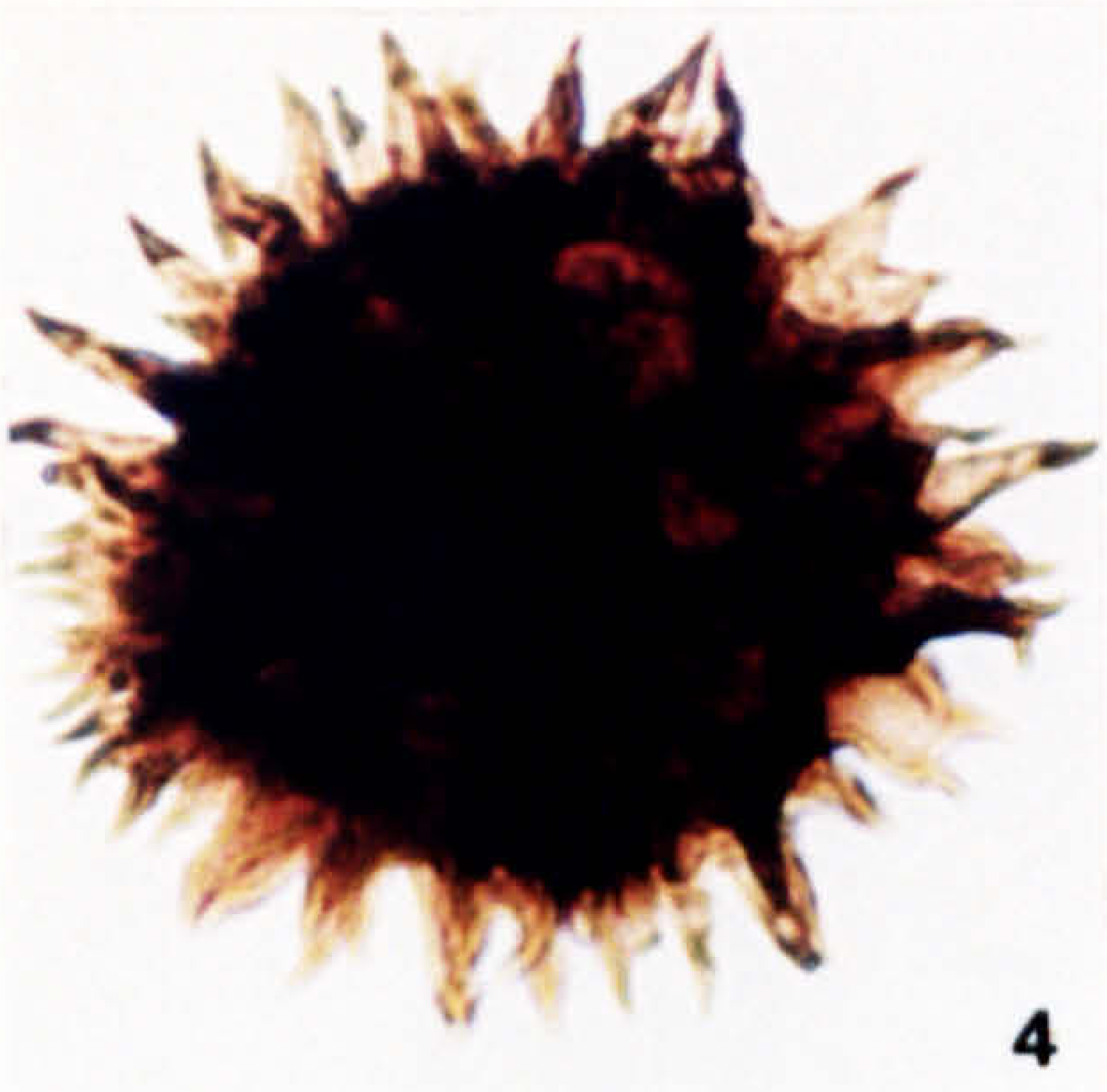
1. *Spencerisporites radiatus*. Broken specimen, magnification x250. 44/22-4, 12430', 1, L42.4.
2. *Spinozonotriletes uncatus*. 44/22-1, 12024', 2, K42.
3. *Spinozonotriletes* cf. *uncatus*. 44/22-4, 12104', 2, C57.
4. *Ibrahimispores microhorridus*. 44/22-4, 12262', 5, H48.
5. *Ibrahimispores brevispinosus*. 44/22-1, 12064', 1, F64.4.
6. *Cirratriradites rarus*. 44/22-1, 12032', 1, O59.3.
7. *Cirratriradites saturni*. 44/22-3, 11570', 1, H39.
8. *Crassispora kosankei*. 44/22-1, 11422', 1, O42.
9. *Hymenozonotriletes explanatus*. Questionably assigned specimen. 44/22-3, 11458', 1, S50.
10. *Densosporites duriti*. 44/22-1, 11880', 1, L41.
11. *Densosporites sphaerotriangularis*. 44/22-4, 12080', 2, E54.
12. *Densosporites crassigranifer*. Two specimens. 44/22-1, 11818', 1, S39.
13. *Densosporites anulatus*. 44/22-1, 11424', 1, E50.3.
14. *Densosporites pseudoannulatus*. 44/22-1, 11758', 1, T40.
15. *Densosporites tenuis*. 44/22-4, 12010', 1, C46.
16. *Densosporites gracilis*. 44/22-4, 11880', 1, P63.3.
17. *Densosporites crassigranifer*. 44/22-3, 11570', 1, T49.

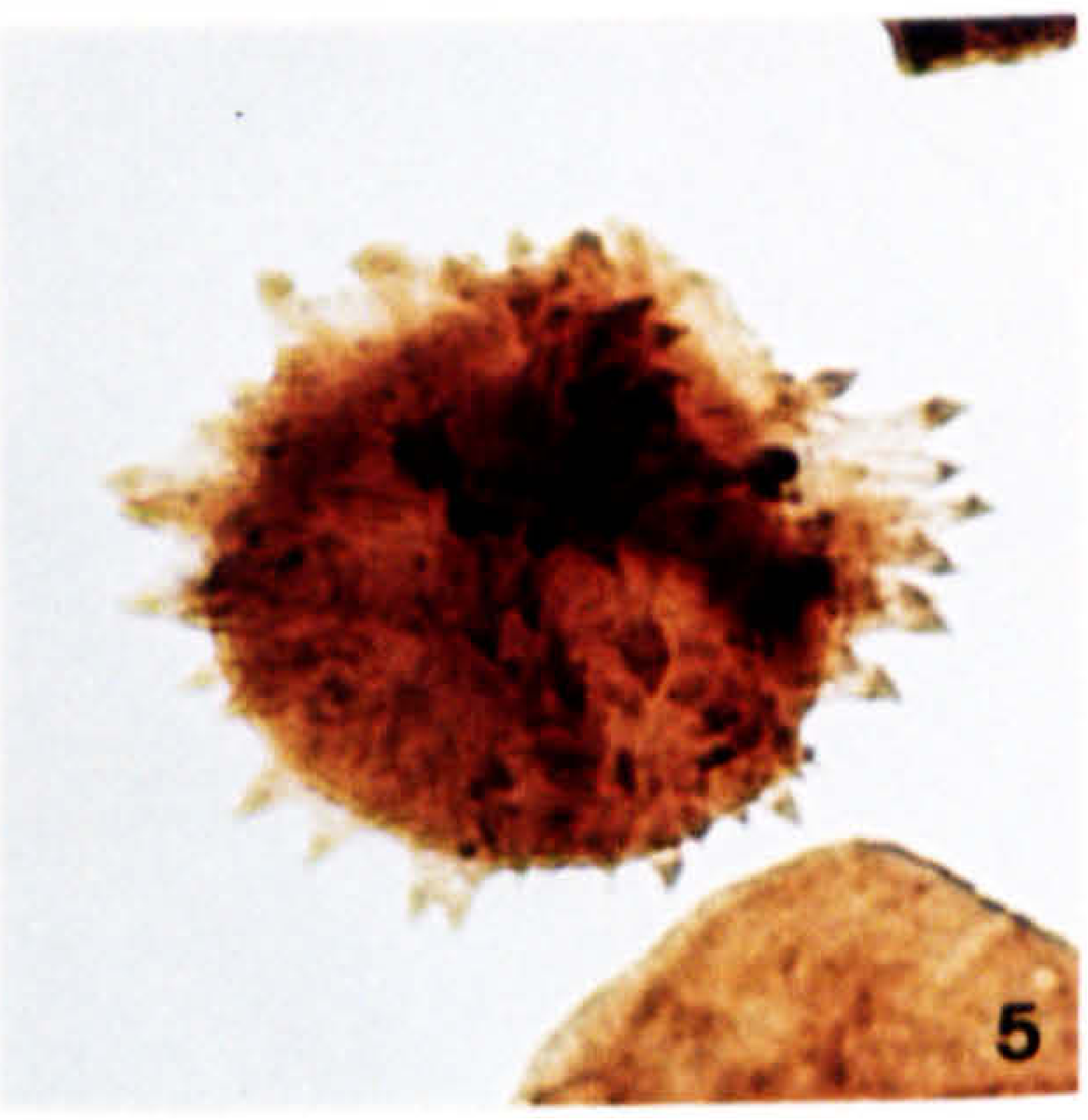
PLATE 12

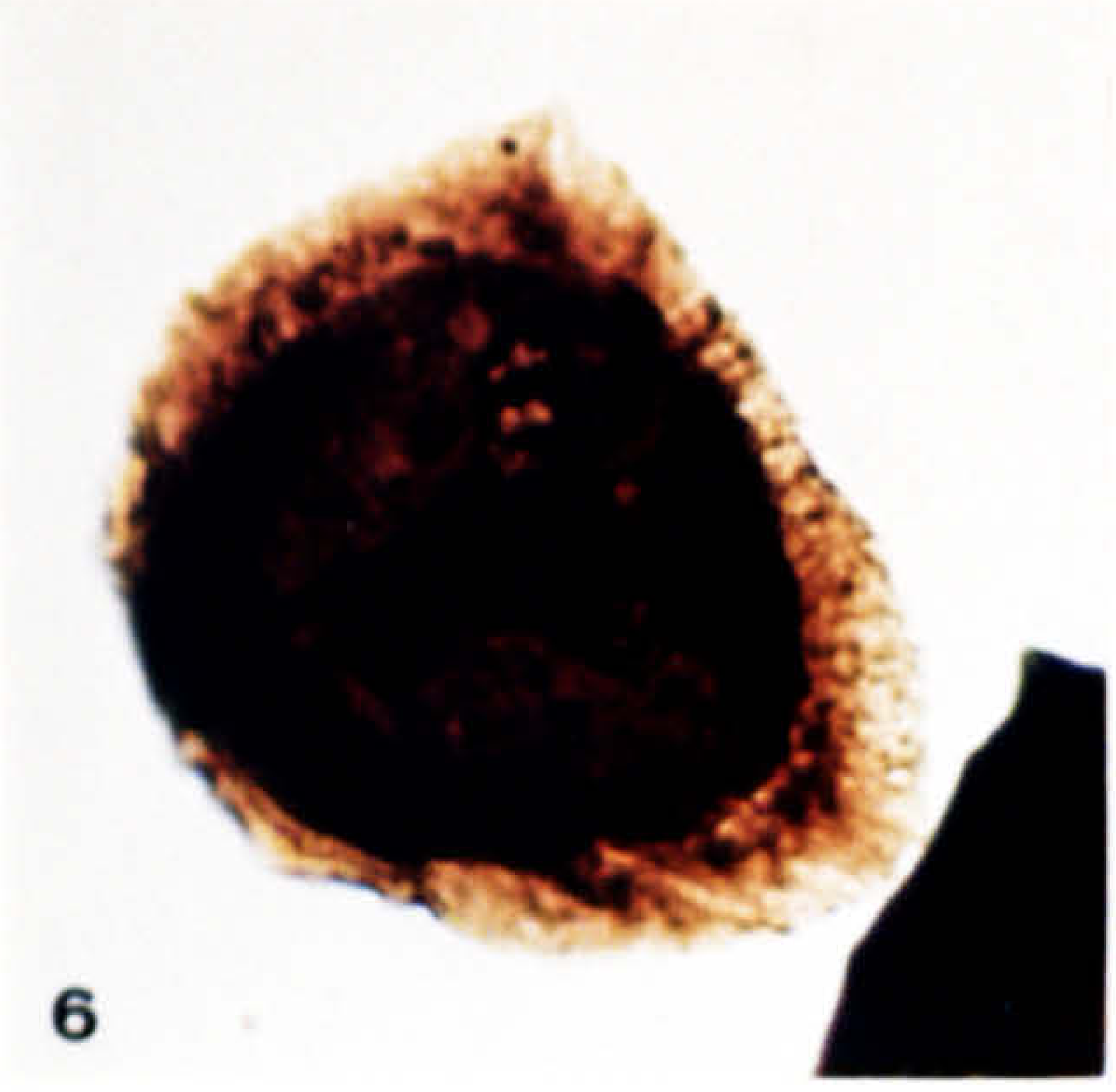

1


2


3

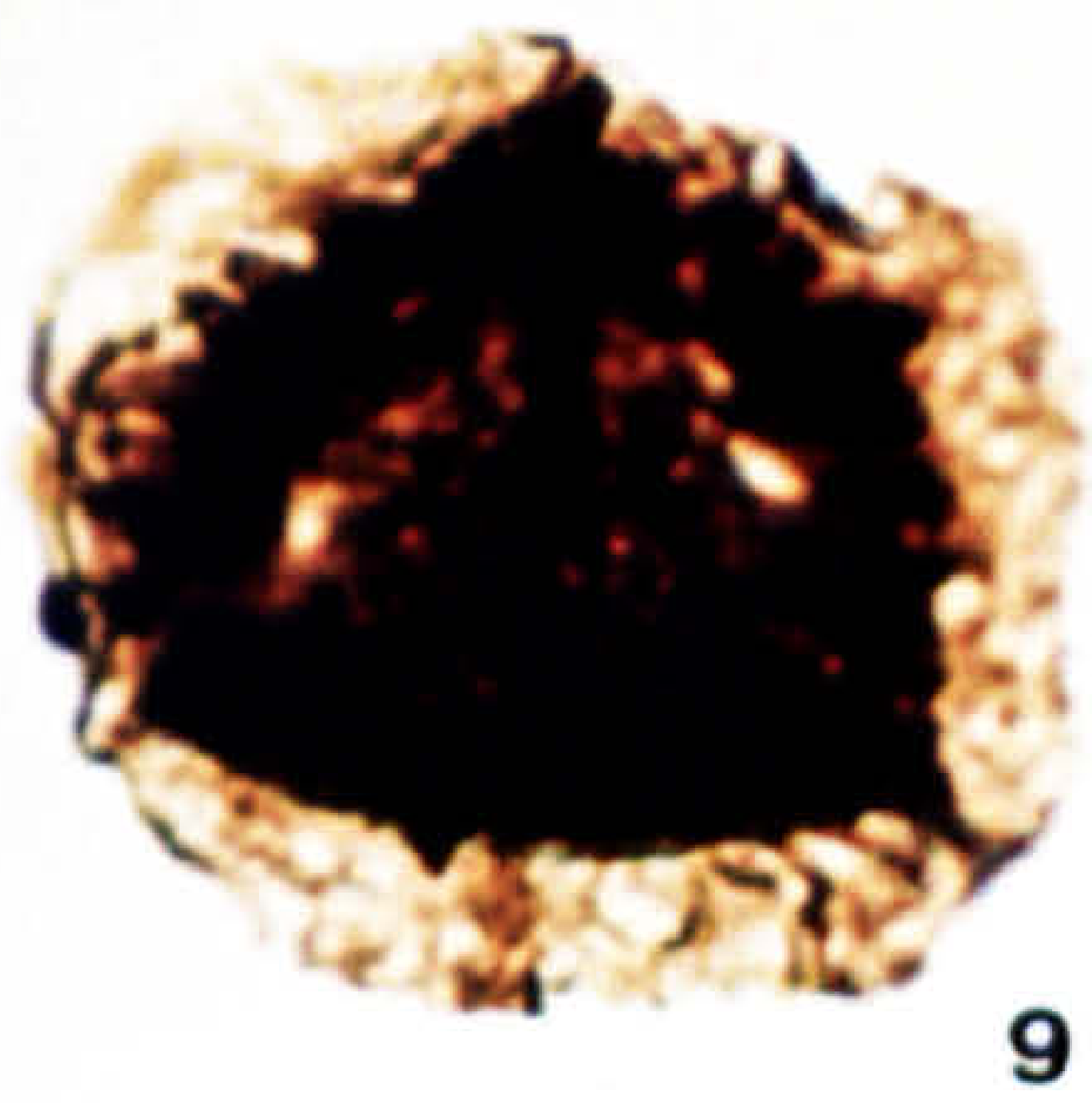

4

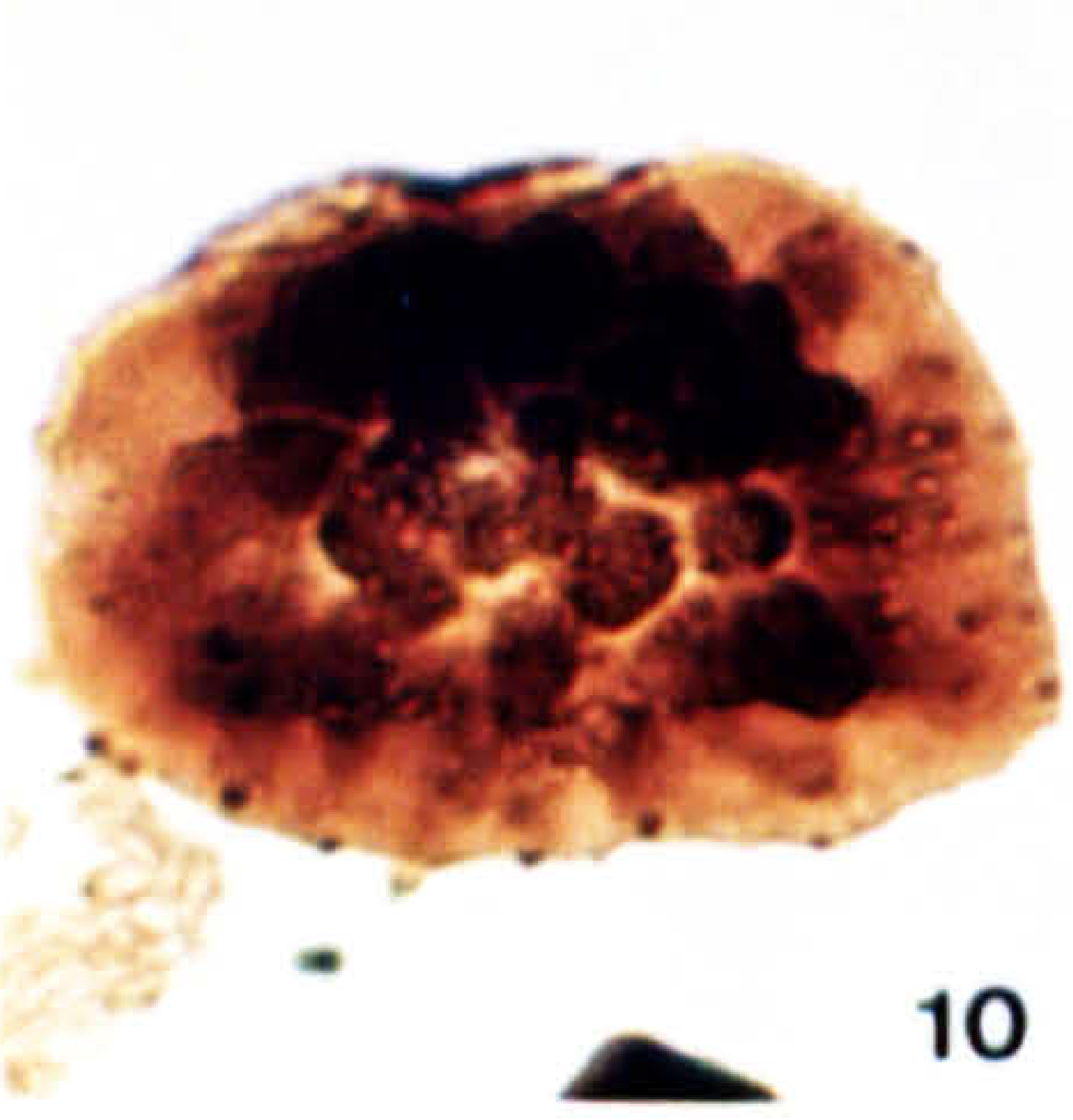

5


6

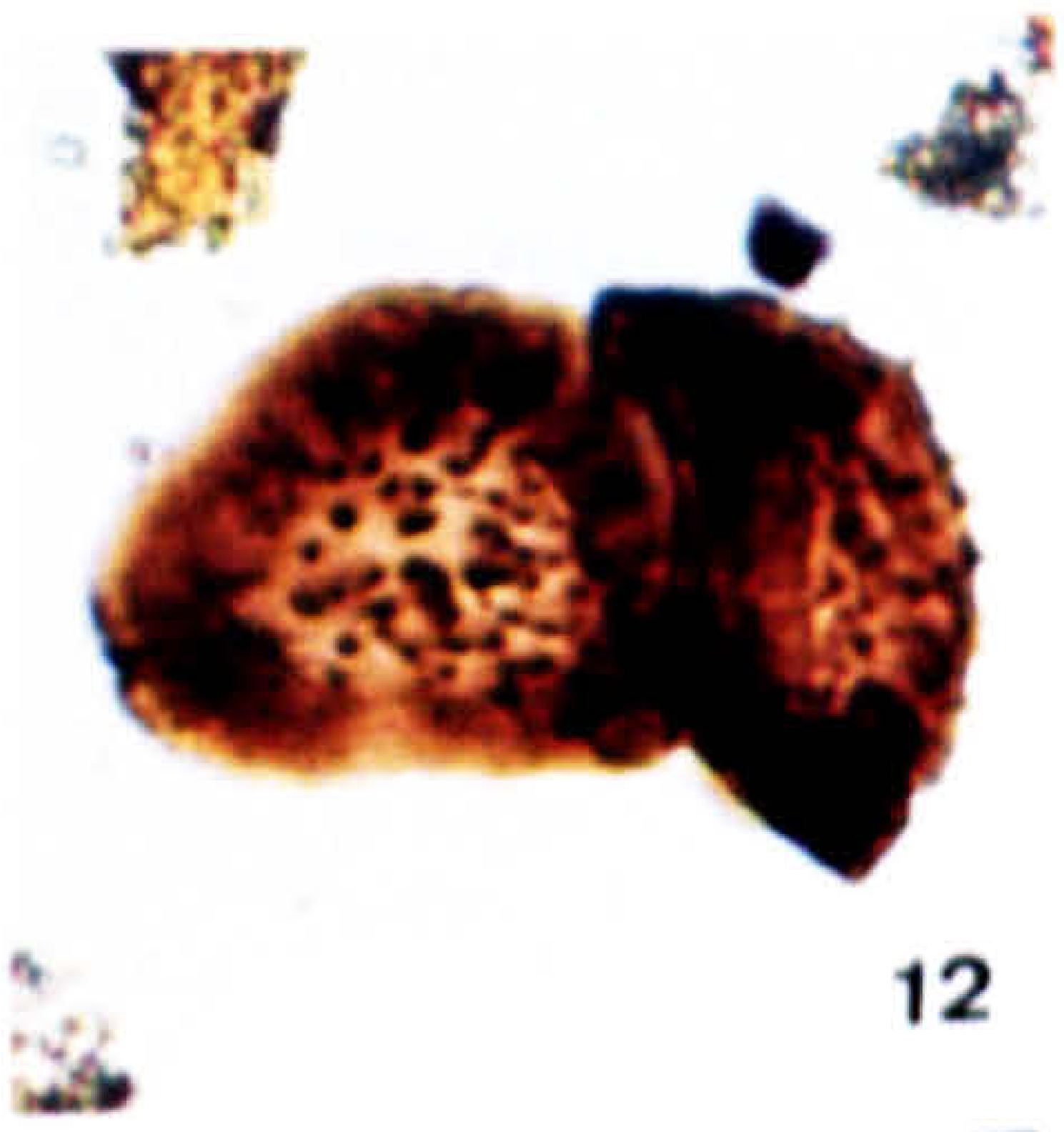

7


8


9

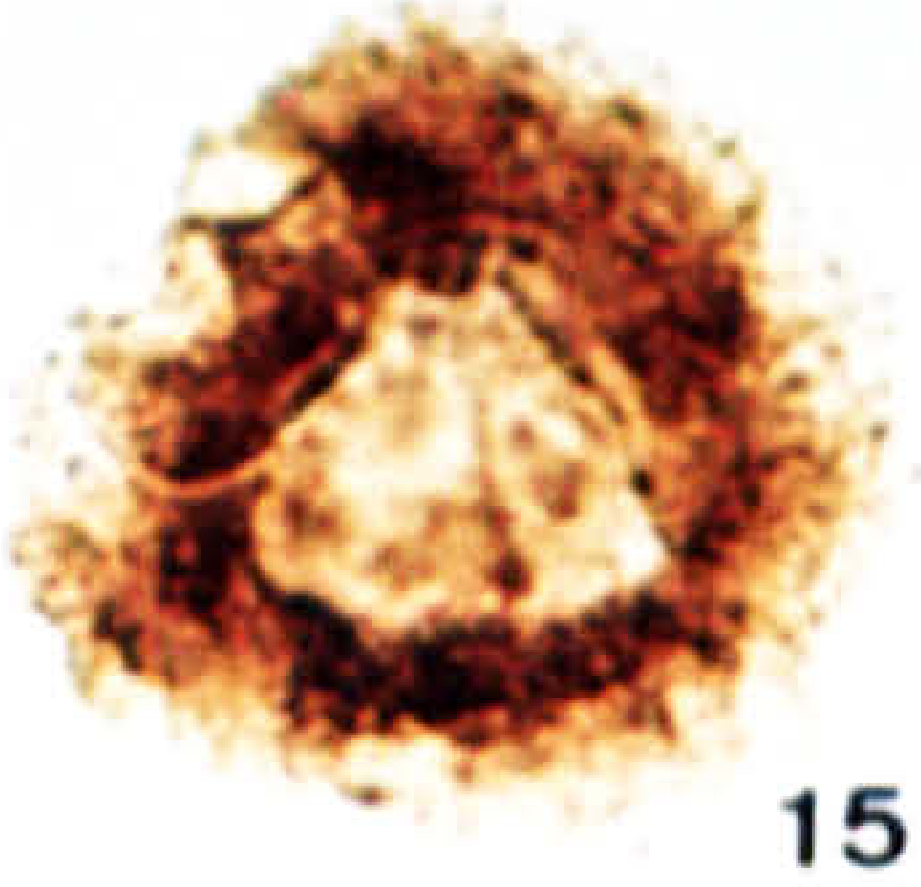

10


11


12


13


14


15


16

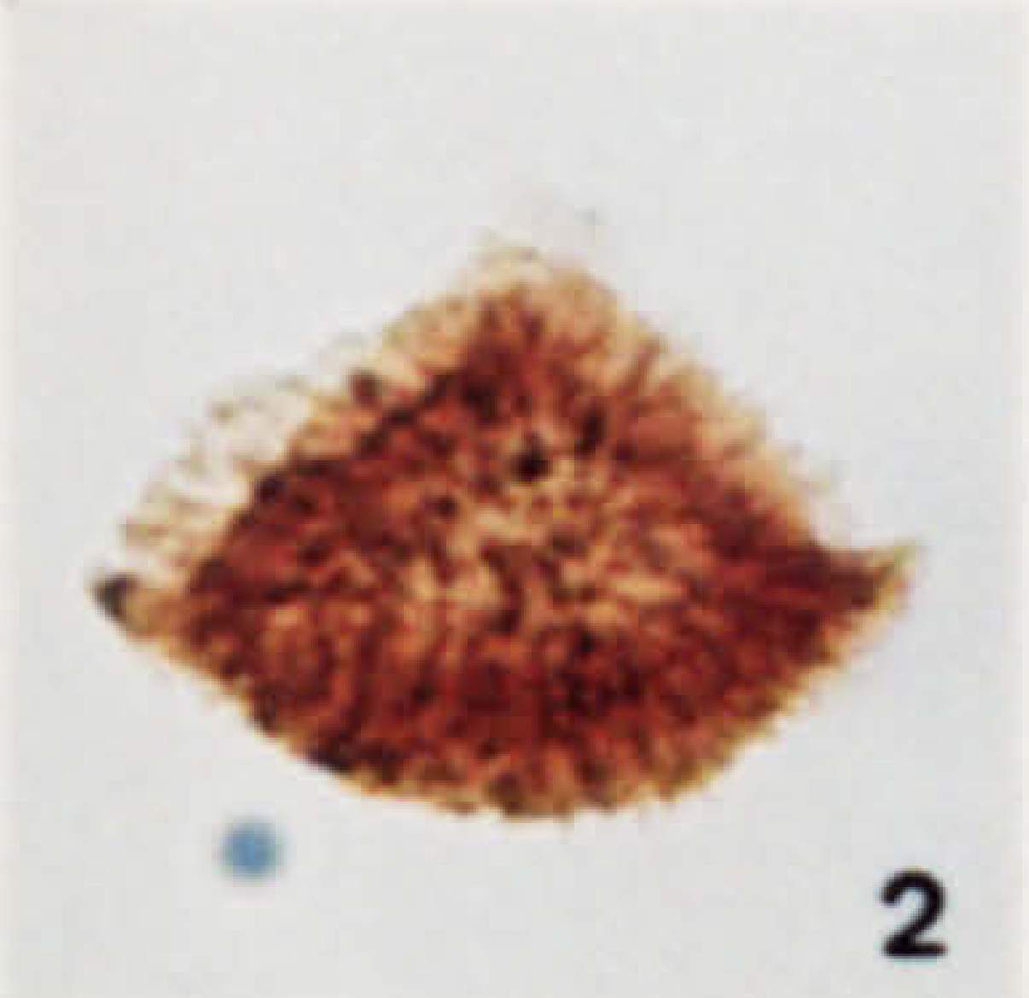

17

PLATE 13.

1. *Densosporites spinosus*. 44/22-4, 12102', 1, P47.1.
2. *Densosporites spinosus*. 44/22-4, 12430', 2, L45.1.
3. *Cingulizonates bialatus**. 43/15b-3a, 13580', 1, H63.3.
4. *Cingulizonates loricatus*. 44/22-1, 11620', 1, C45.2.
5. *Lycospora noctuina*. 44/22-1, 11393', 1, N50.2.
6. *Lycospora orbicula*. 44/22-1, 11425', 1, J41.2.
7. *Lycospora pusilla*. 44/22-1, 11422', 1, O65.
8. *Lycospora rotunda*. 44/22-1, 11393', 1, C50.2.
9. *Cristatisporites connexus*. 44/22-1, 11880', 1, K44.3.
10. *Cristatisporites splendidus*. 44/22-1, 11880', 1, H61.4.
11. *Radiizonates aligerens*. 44/22-3, 12120', 1, K53.
12. *Radiizonates difformis*. 44/22-4, 12460', 2, T50.2.
13. *Cristatisporites indignabundis*. 44/22-1, 11880', 1, L44.
14. *Cristatisporites splendidus*. 44/22-1, 11414.9', 2, U44.2.
15. *Radiizonates tenuis*. 44/22-4, 12095', 2, B37.
16. *Radiizonates striatus*. 44/22-3, 12030', 2, G47.3.
17. *Radiizonates* aff. *straitus*. 44/22-1, 12758', 1, L52.1.
18. *Radiizonates faunus*. 44/22-1, 11758', 1, D47.
19. *Simozonotriletes intortus*. 44/22-1, 11453', 2, L62.
20. *Vallatisporites vallatus*. 44/22-3, 11986.5', 2, O47.1.
21. *Diaphanospora parvigracila*. 44/22-1, 11422', 1, E41.
22. *Hymenospora murdochensis*. Holotype. 44/22-1, 12064', 1, V58.
23. *Hymenospora murdochensis*. 44/22-1, 12064', 1, M68.
24. *Hymenospora murdochensis*. 44/22-1, 12064', 1, U67.1.
25. *Hymenospora* cf. *caperata*. 44/22-1, 12045', 1, K48.
26. *Colatisporites decorus*. 44/22-3, 12016', 1, O50.
27. *Schulzospora campyloptera*. 44/22-1, 11878', 2, F52.1.
28. *Schulzospora rara*. 44/22-1, 12064', 1, U54.
29. *Schulzospora rara*. 44/22-1, 12064', 2, M65.3.

PLATE 13


1


2


3

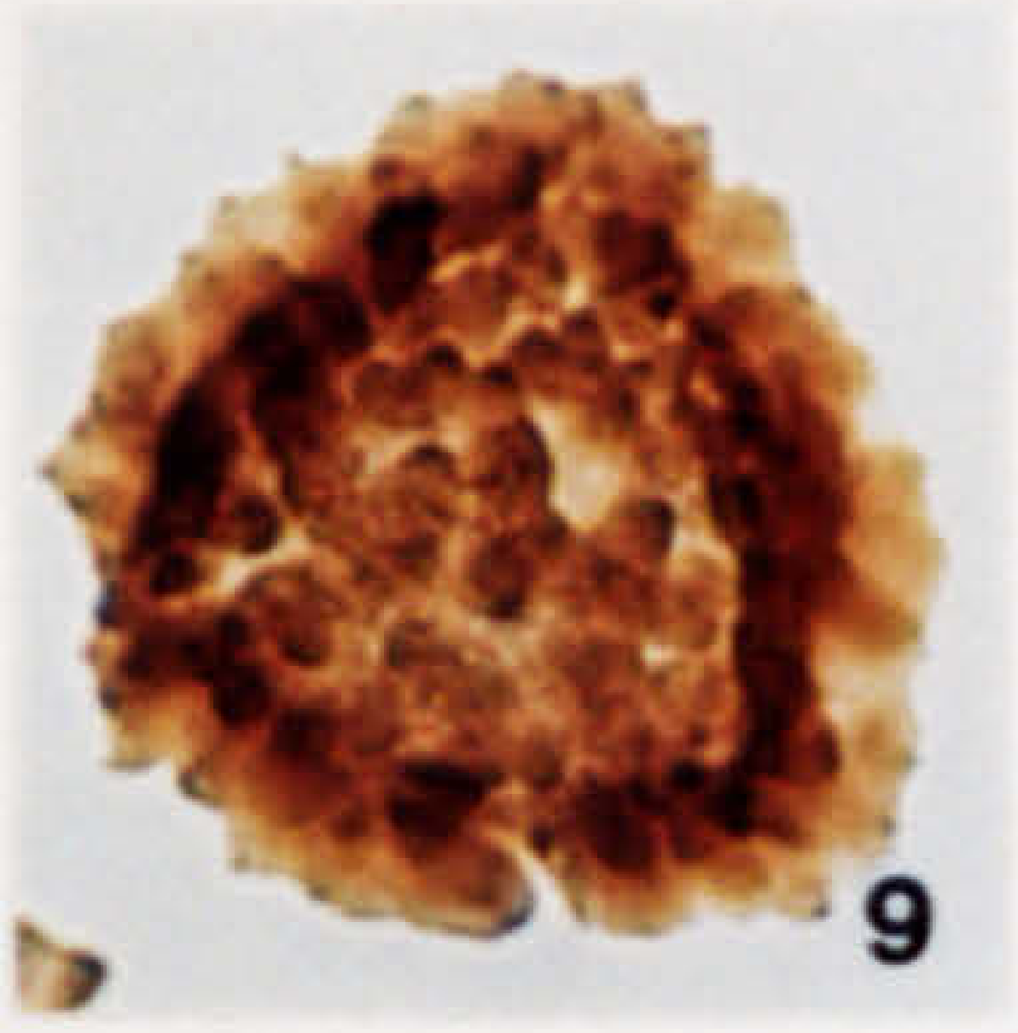

4

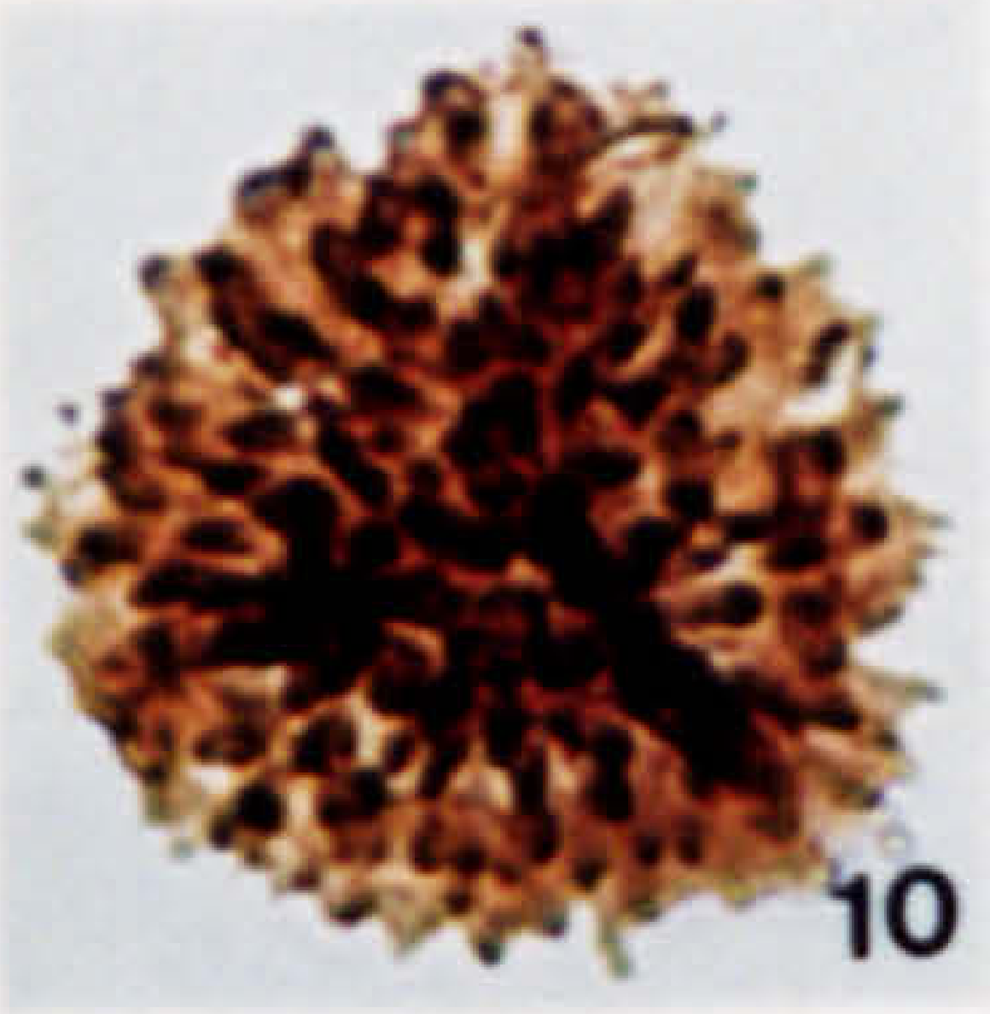

5

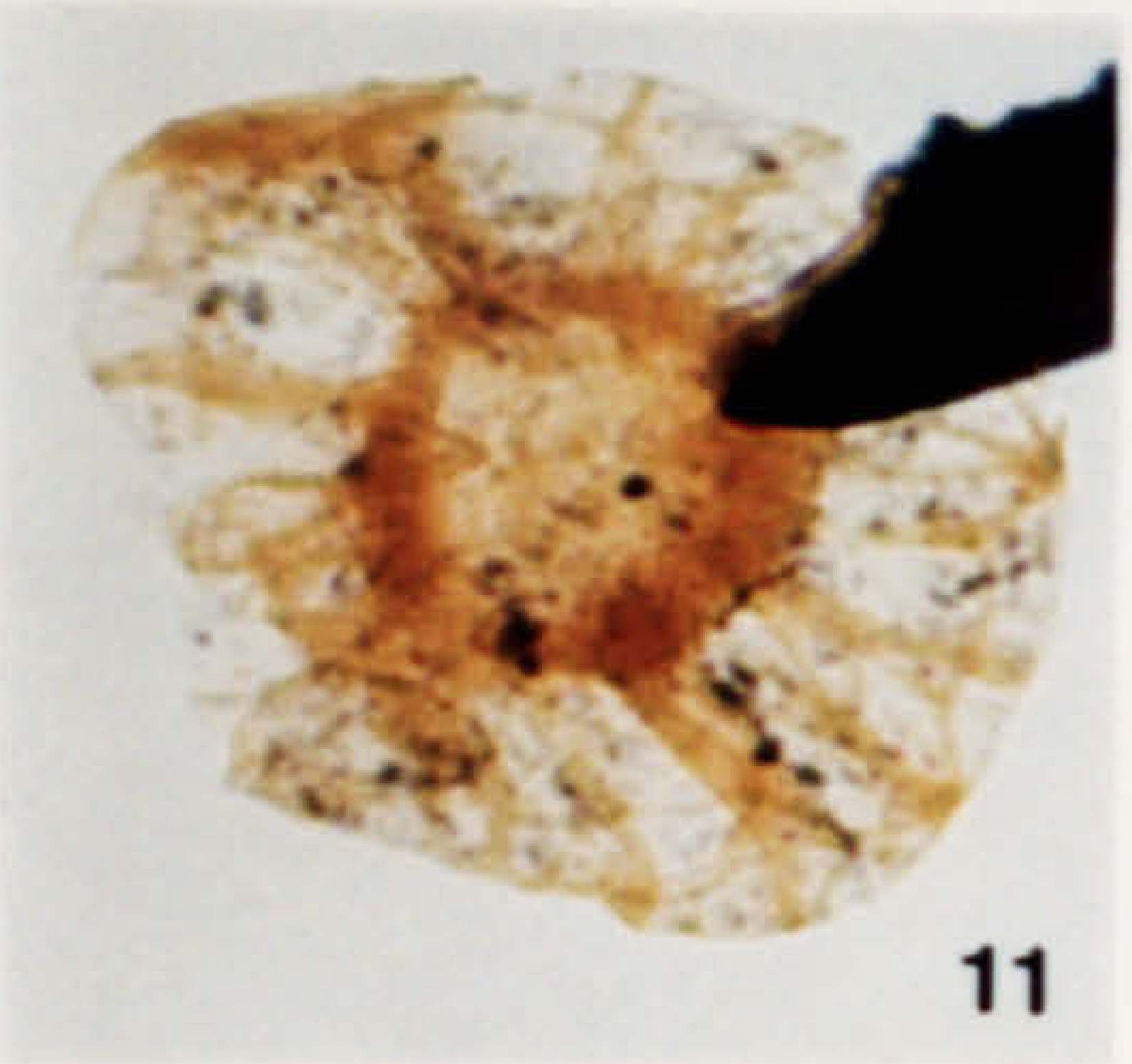

6

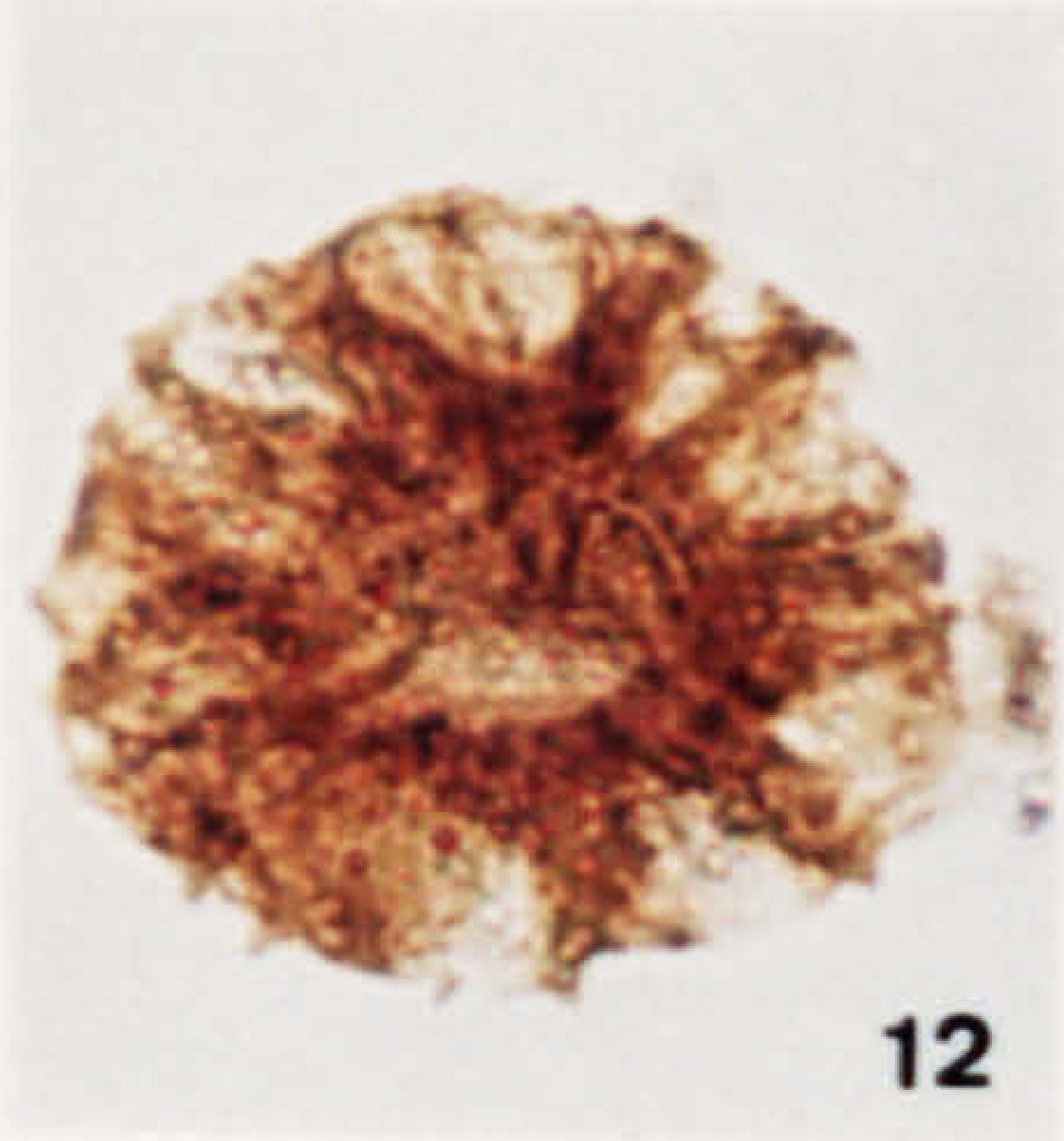

7

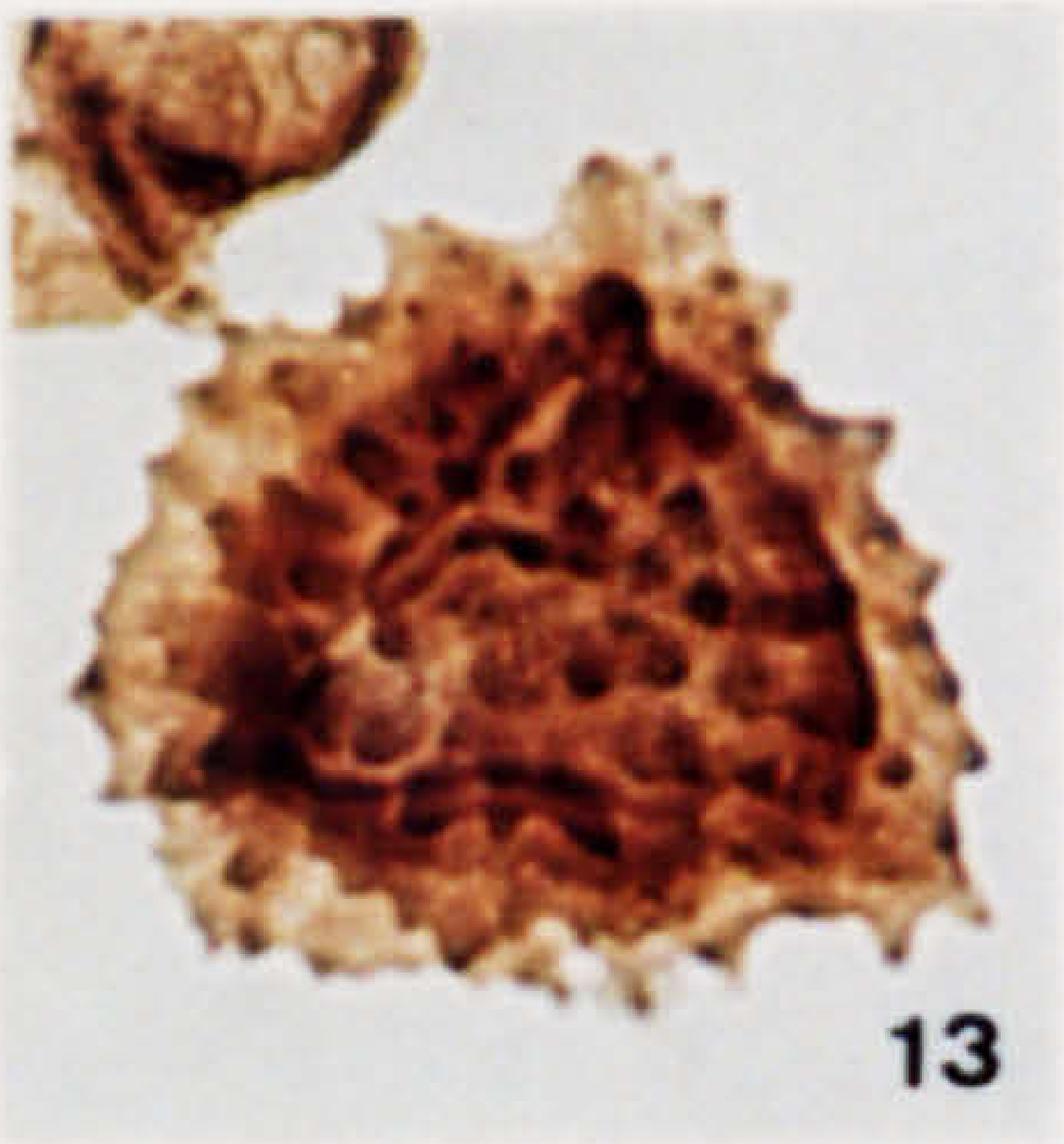

8

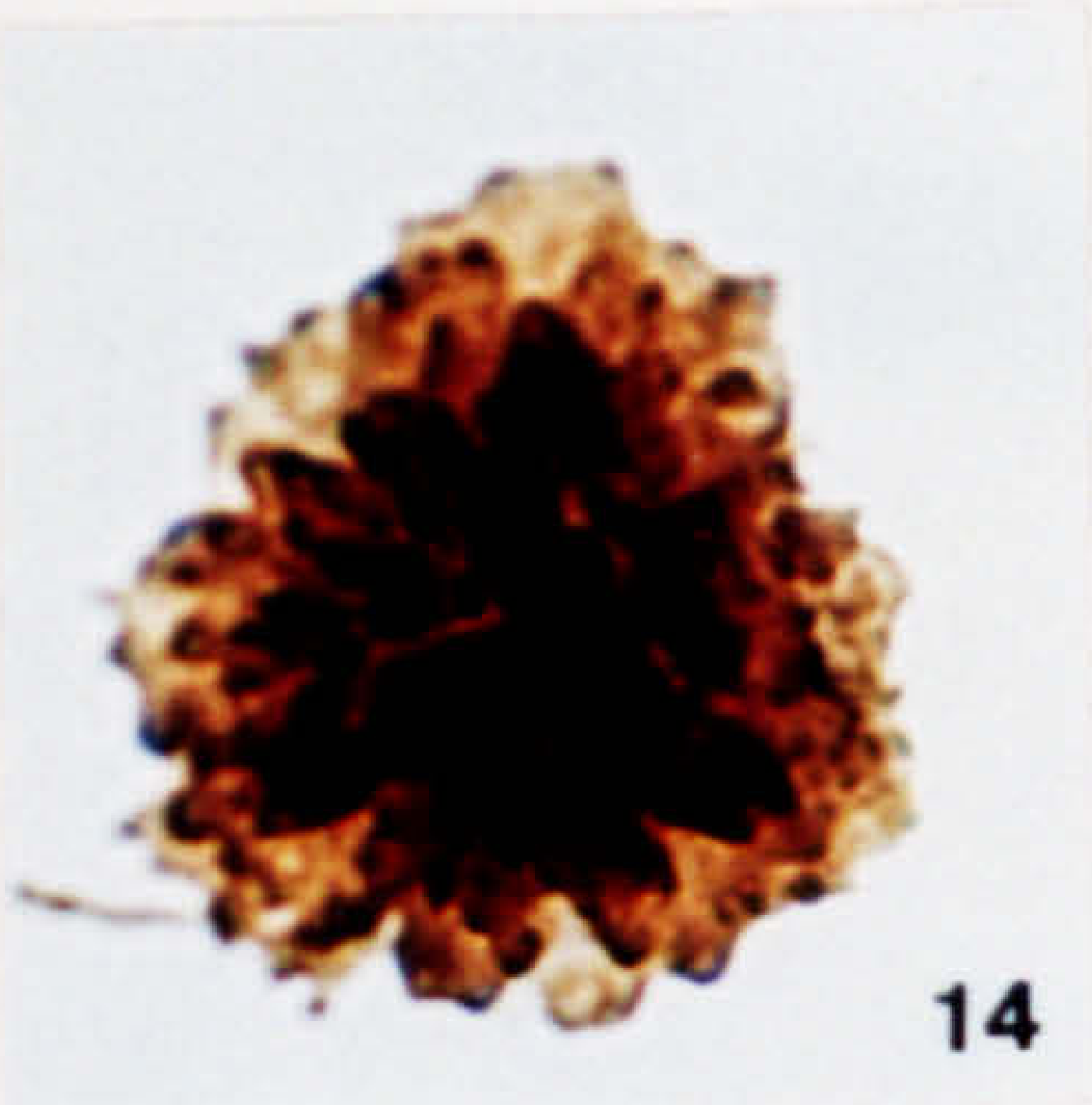

9

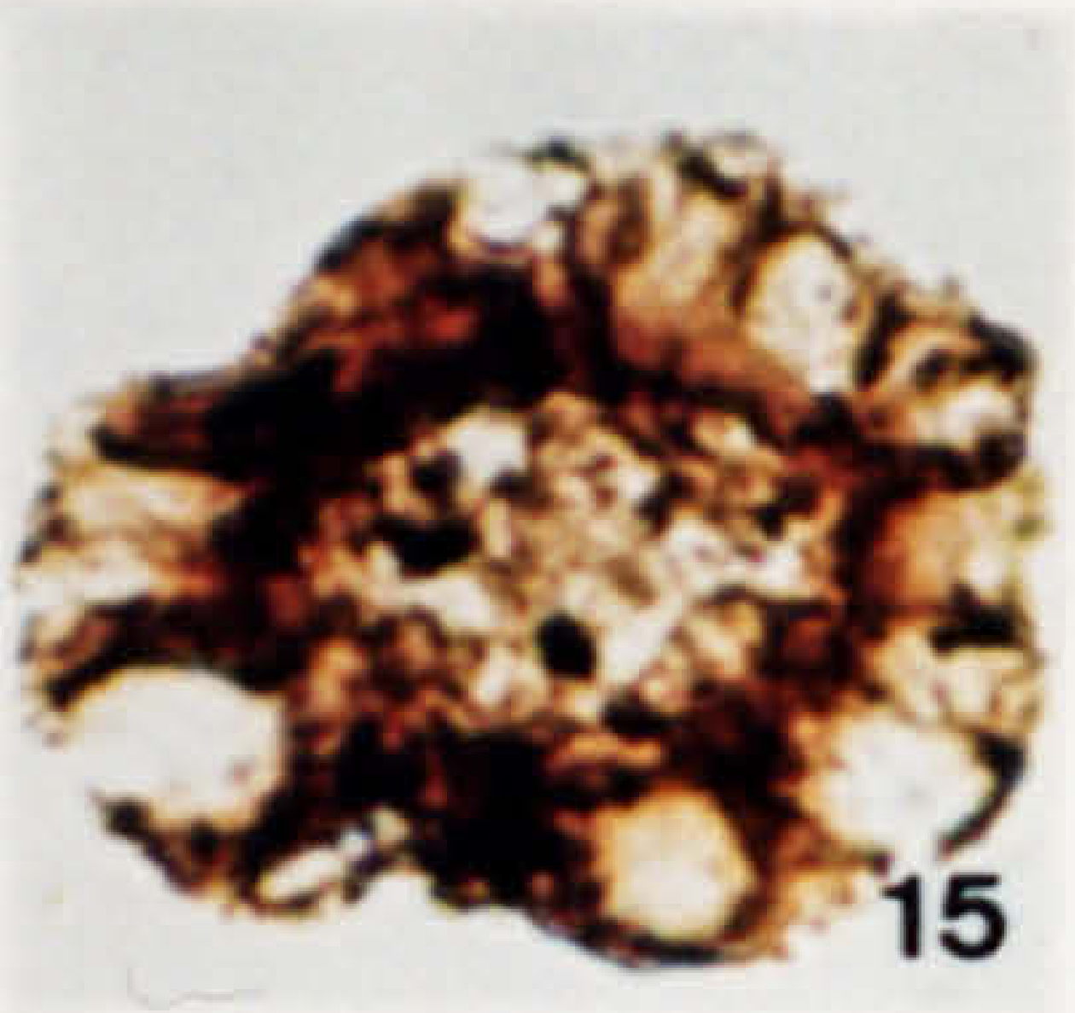

10


11


12


13


14


15


16


17

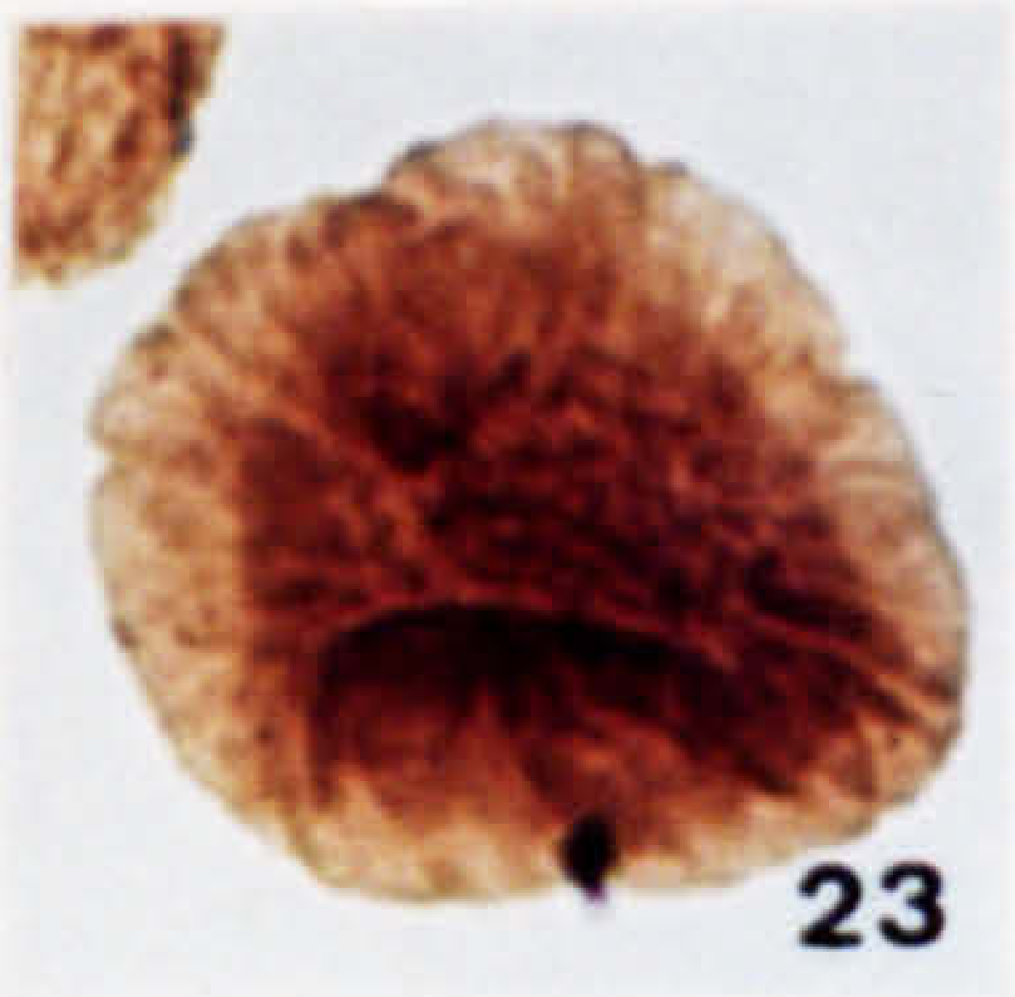

18


19

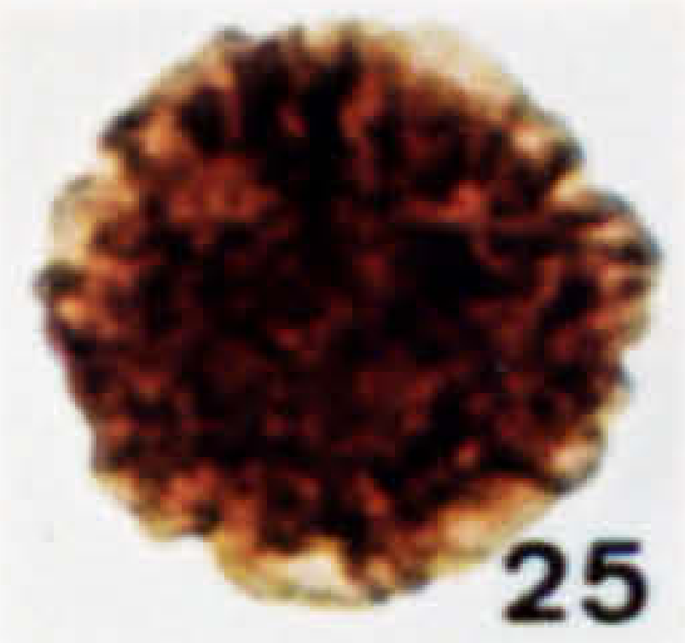

20


21

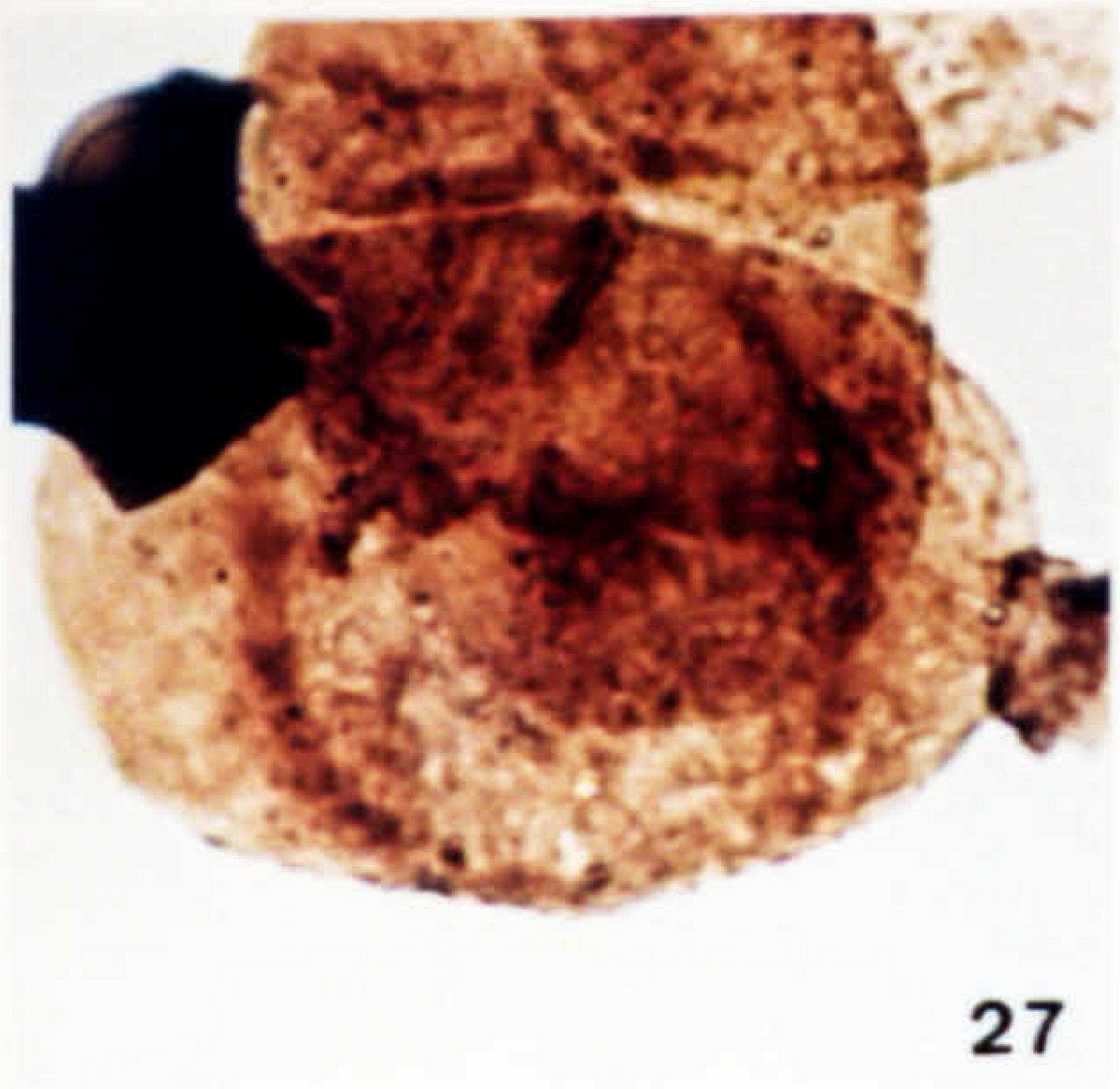

22

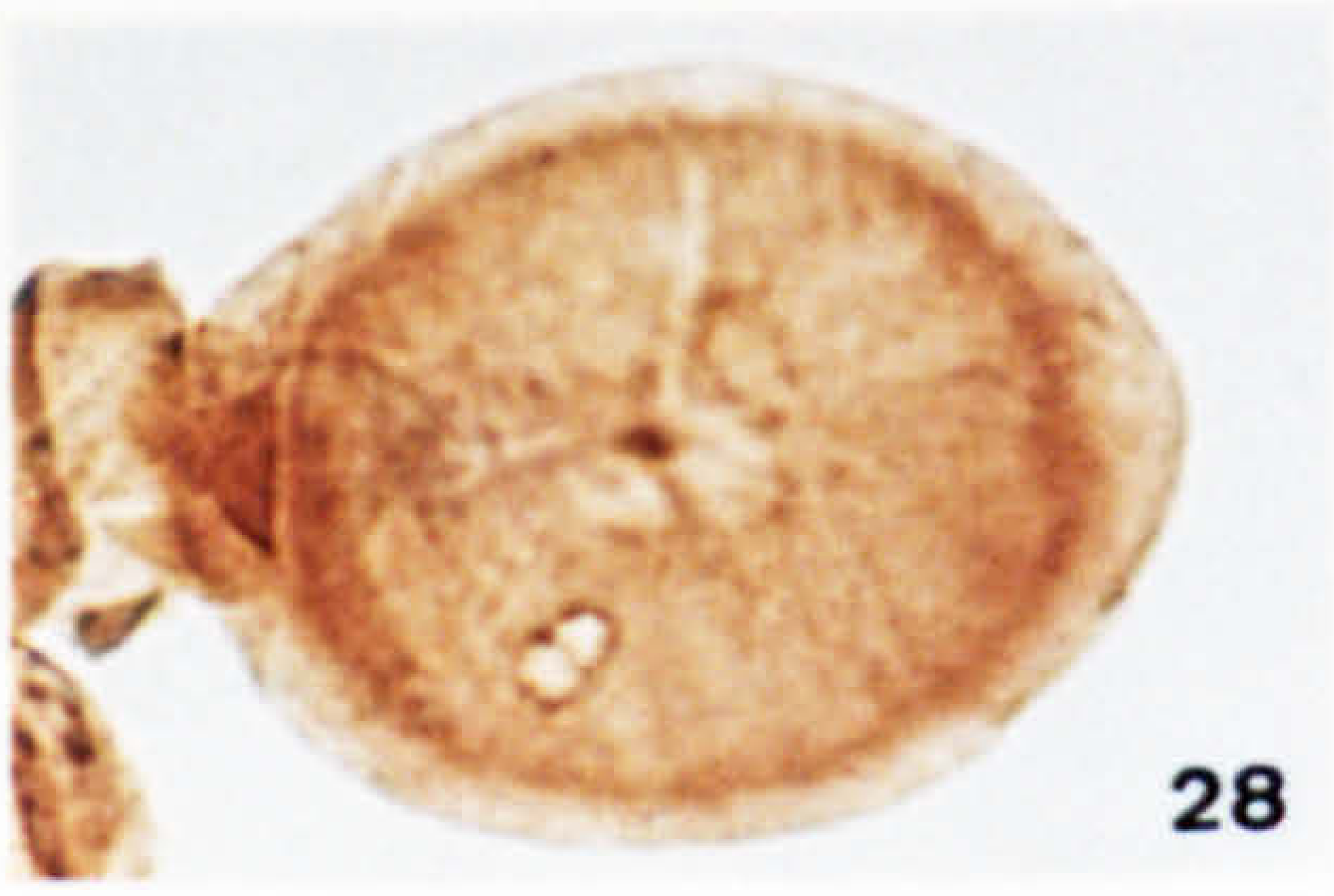

23


24


25


26


27


28

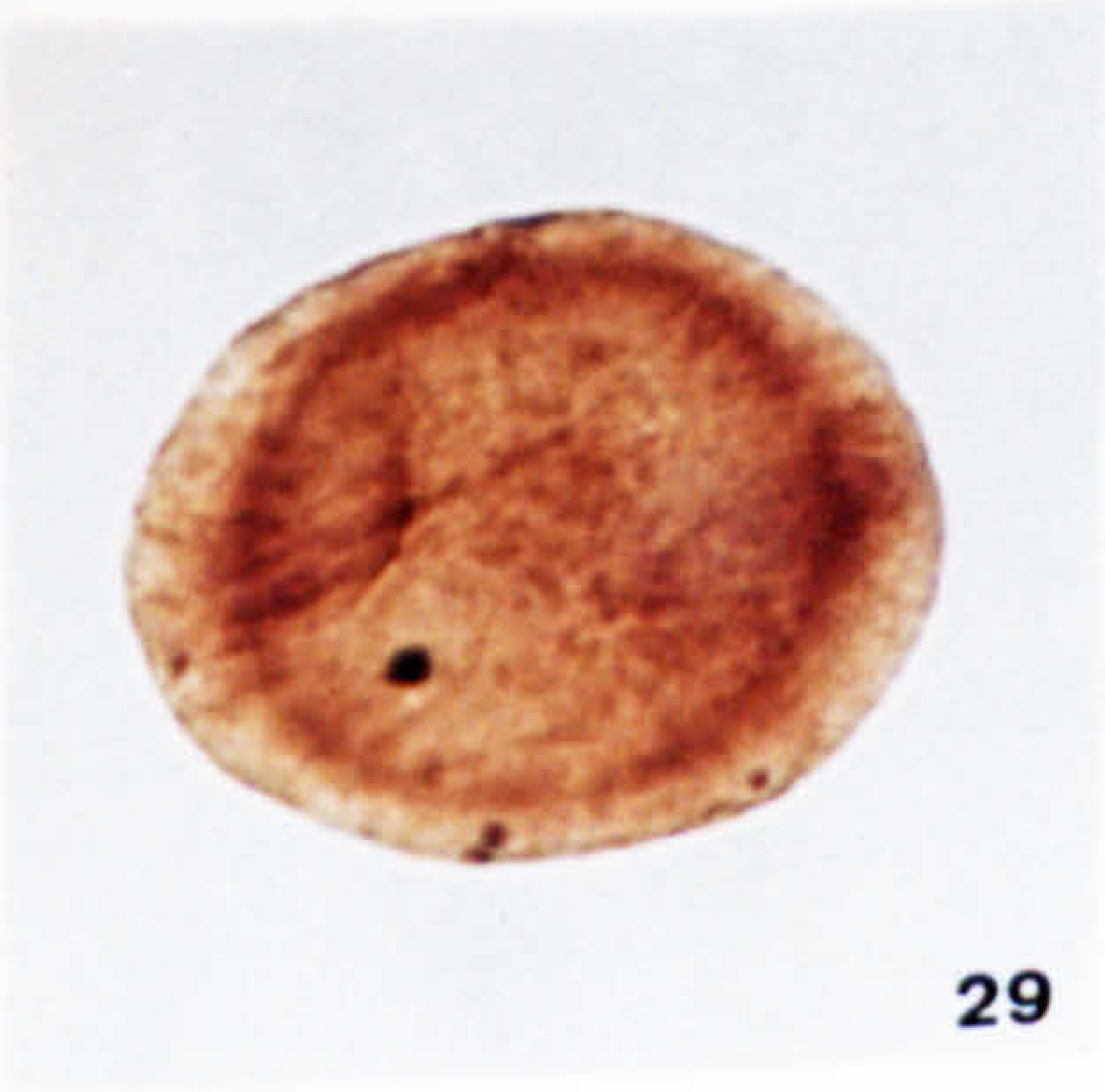
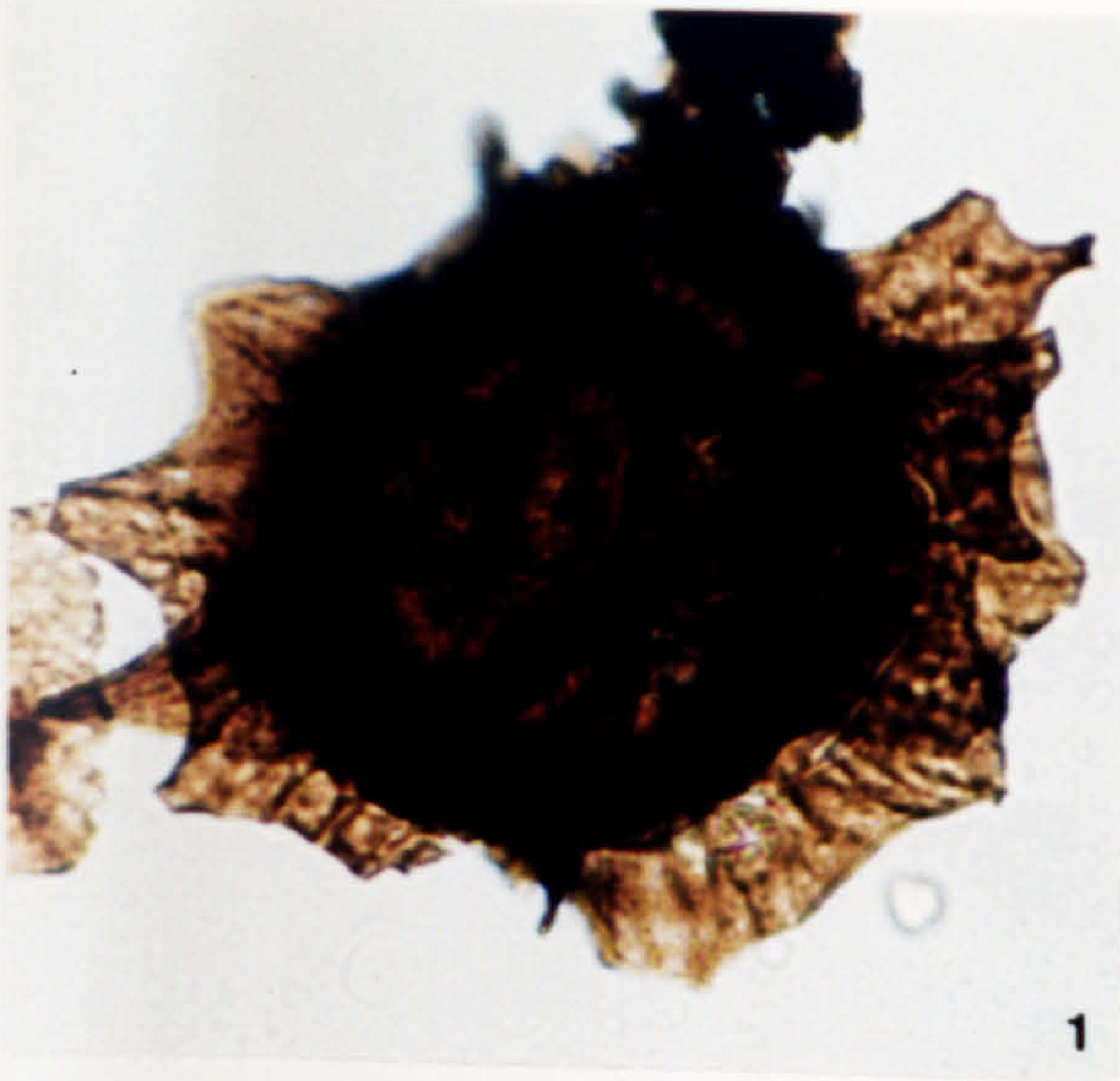
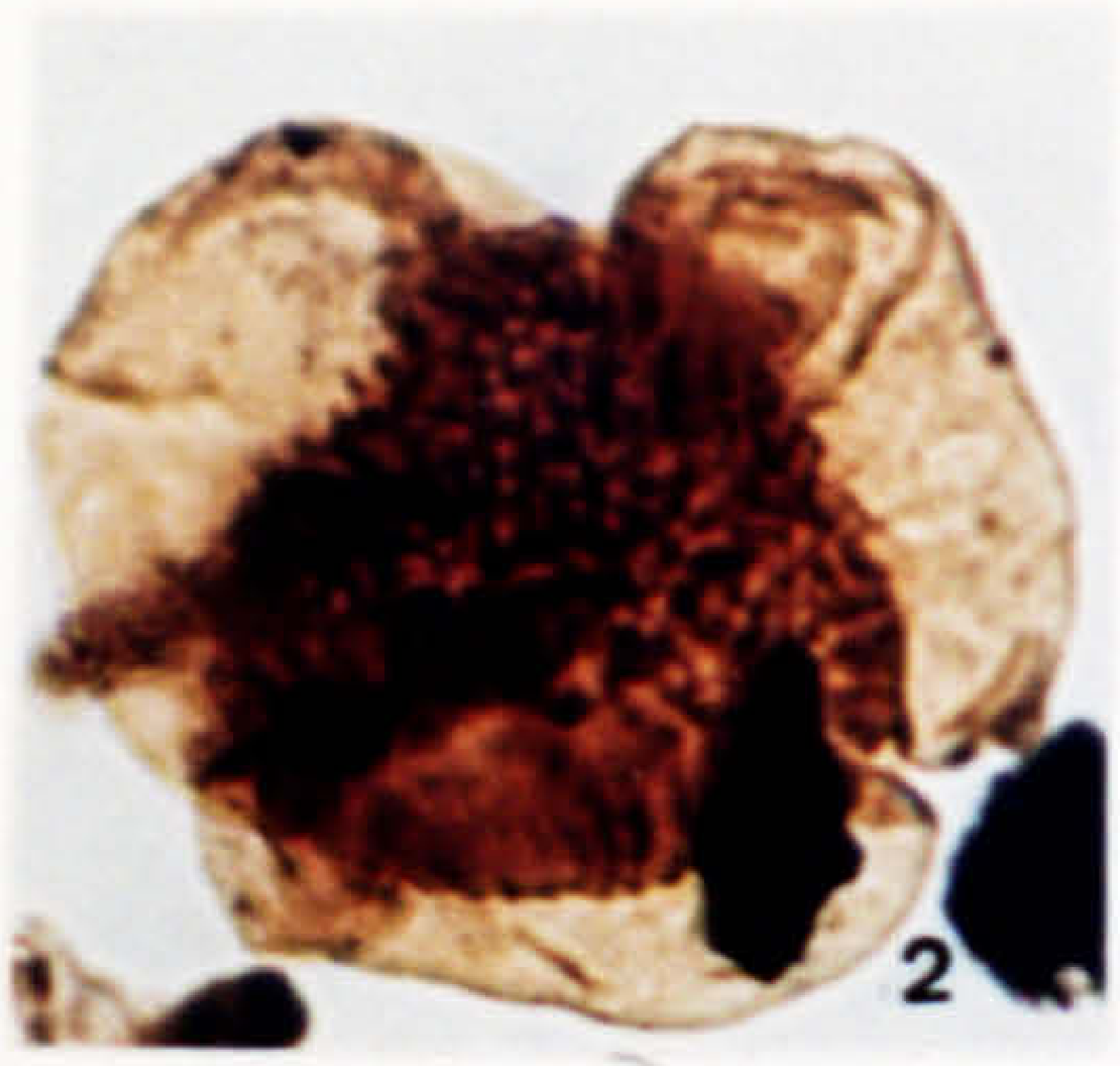

29

PLATE 14.

1. *Pteroretis primum.* 44/22-1, 12090', 1, E37.3.
2. *Alatisporites pustulatus.* 44/22-1, 11880', 1, V37.2.
3. *Alatisporites hoffmeisterii.* 44/22-4, 12102', 2, M30.3.
4. *Alatisporites nudus.* 48/11b-4, 9680', 1, R48.4.
5. *Elaterites anfractus.* 44/22-1, 12090', 2, Q40.
6. *Elaterites anfractus.* 44/22-1, 11414.9', 2, H32.3.
7. *Elaterites anfractus.* 44/22-1, 12090', 2, U37.3.
8. *Elaterites anfractus.* Holotype. 44/22-1, 12090', 1, D40.1.
9. *Laevigatosporites densus.* 44/22-1, 11422', 1, N56.2.
10. *Laevigatosporites densus.* 44/22-4, 11880', 1, K55.
11. *Laevigatosporites vulgaris.* 44/22-4, 12104', 2, S47.
12. *Laevigatosporites desmoinesensis.* 44/22-1, 11393', 1, T57.3.
13. *Laevigatosporites minimus.* 44/22-1, 11683', 1, O52.3.
14. *Latosporites globosus.* 44/22-1, 11685', 1, T66.1.
15. *Punctatosporites minutus.* 44/22-1, 11506', 1, X55.
16. *Fabasporites pallidus.* 44/22-3, 11458', 1, D51.
17. *Dictyomonolites swadei.* 44/22-1, 11414.9', 2, R5.
18. *Dictyomonolites swadei.* 44/22-1, 11752', 1, D35.
20. *Columinisporites ovalis.* 44/22-1, 11375.5', 2, R37.
21. *Columinisporites ovalis.* 44/22-4, 12104', 2, K31.1.
22. *Thymospora* sp.*. Form intermediate between *T. obscura* and *T. pseudothiessenii.* 44/21-3, 4060m., 1, D34.
23. *Torispora securis**. 44/21-3, 4153m., 1, E38.

PLATE 14


1

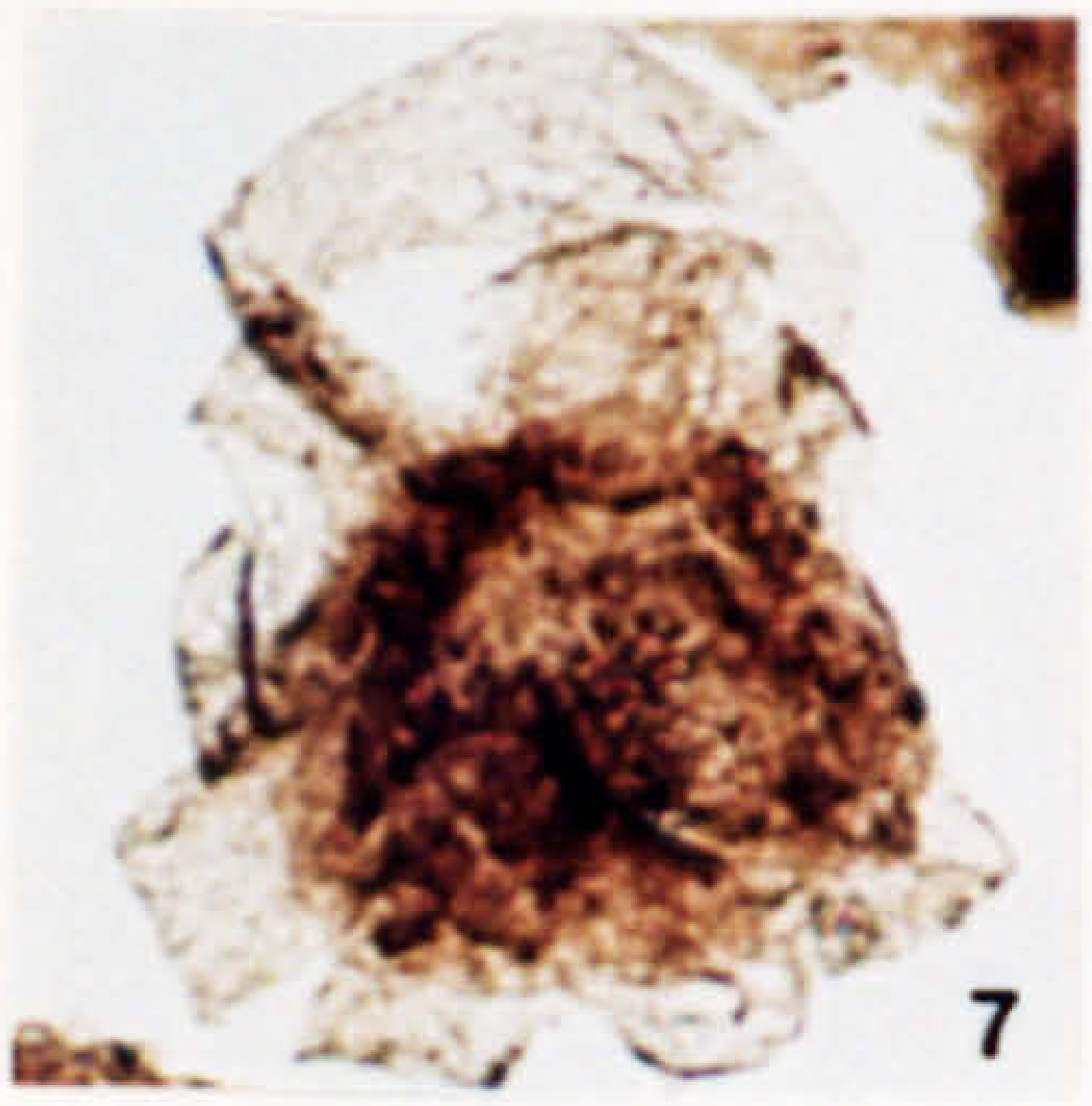

2


3


4


5


6


7


8


9


10


11


12


13


14


15


16


17


18


20


21


22


23

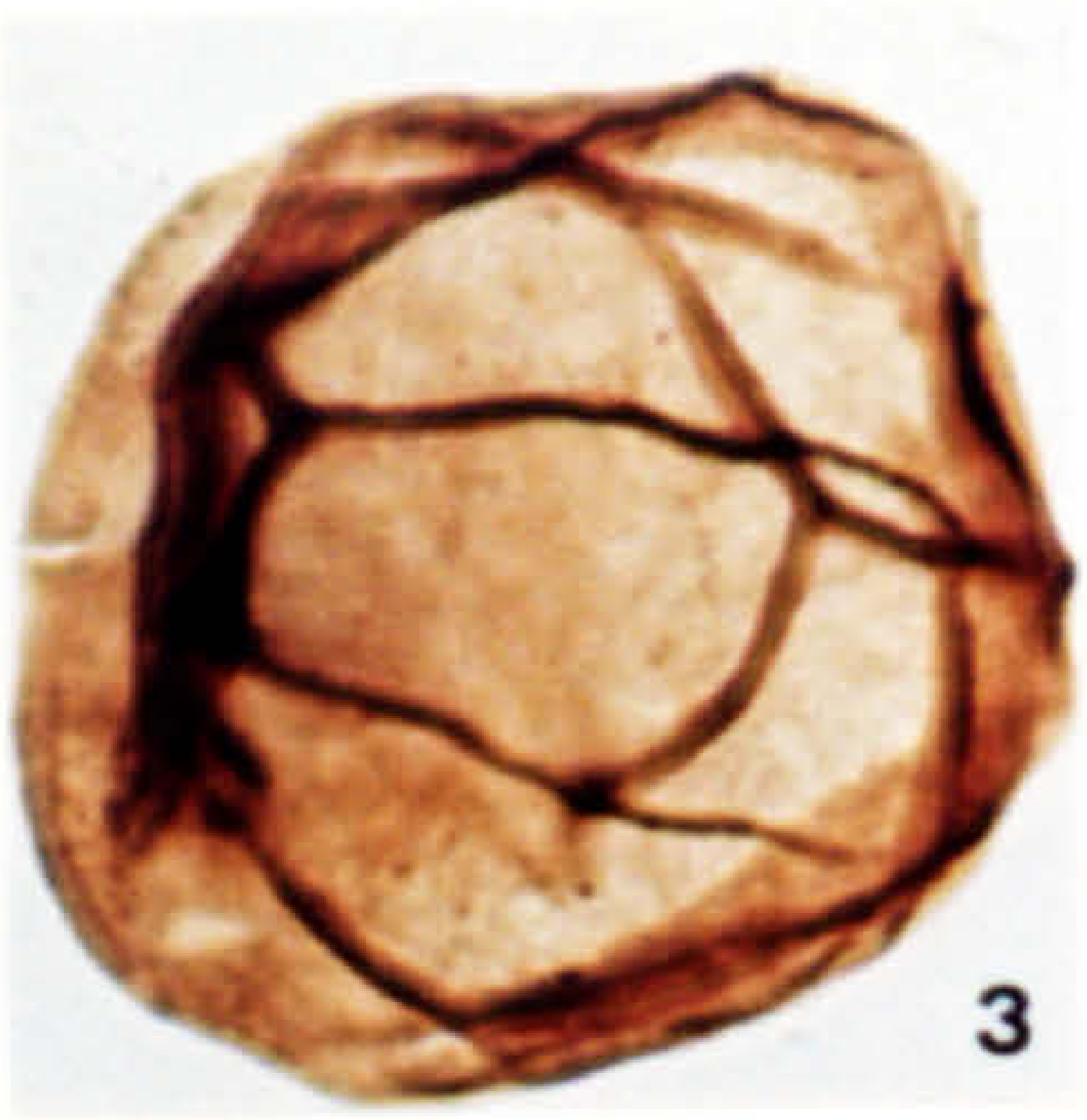
PLATE 15.

1. *Vestispora costata*. 44/22-1, 11878', 2, V56.4.
2. *Vestispora? dubia*. Holotype. 44/22-1, 11878', 1, L49.4.
3. *Vestispora? dubia*. 44/22-1, 11878', 1, Q34.
4. *Vestispora fenestrata**. 44/21-3, 4168m., 1, L41.
5. *Vestispora magna**. 44/21-4, 3888m., 1, U58.1.
6. *Vestispora magna**. 44/21-4, 4228m., 1, D45.
7. *Vestispora pseudoreticulata*. 44/22-1, 11422', 1, B48.
8. *Vestispora* cf. *magna**. 44/21-4, 3888m., 1, U63.
9. *Vestispora* cf. *magna**. 44/21-4, 3888m., 1, H49.3
10. *Vestispora tortuosa*. 44/22-1, 11752', 1, J64.
11. *Costatascyclus crenatus*. 44/22-1, 12064', 2, R58.4.
12. *Tinnulisporites microsaccus*. 44/22-4, 12104', 2, L37.3.
13. *Guthoerlisporites* cf. *magnificus*. 44/22-3, 11872', 6, K53.

PLATE 15

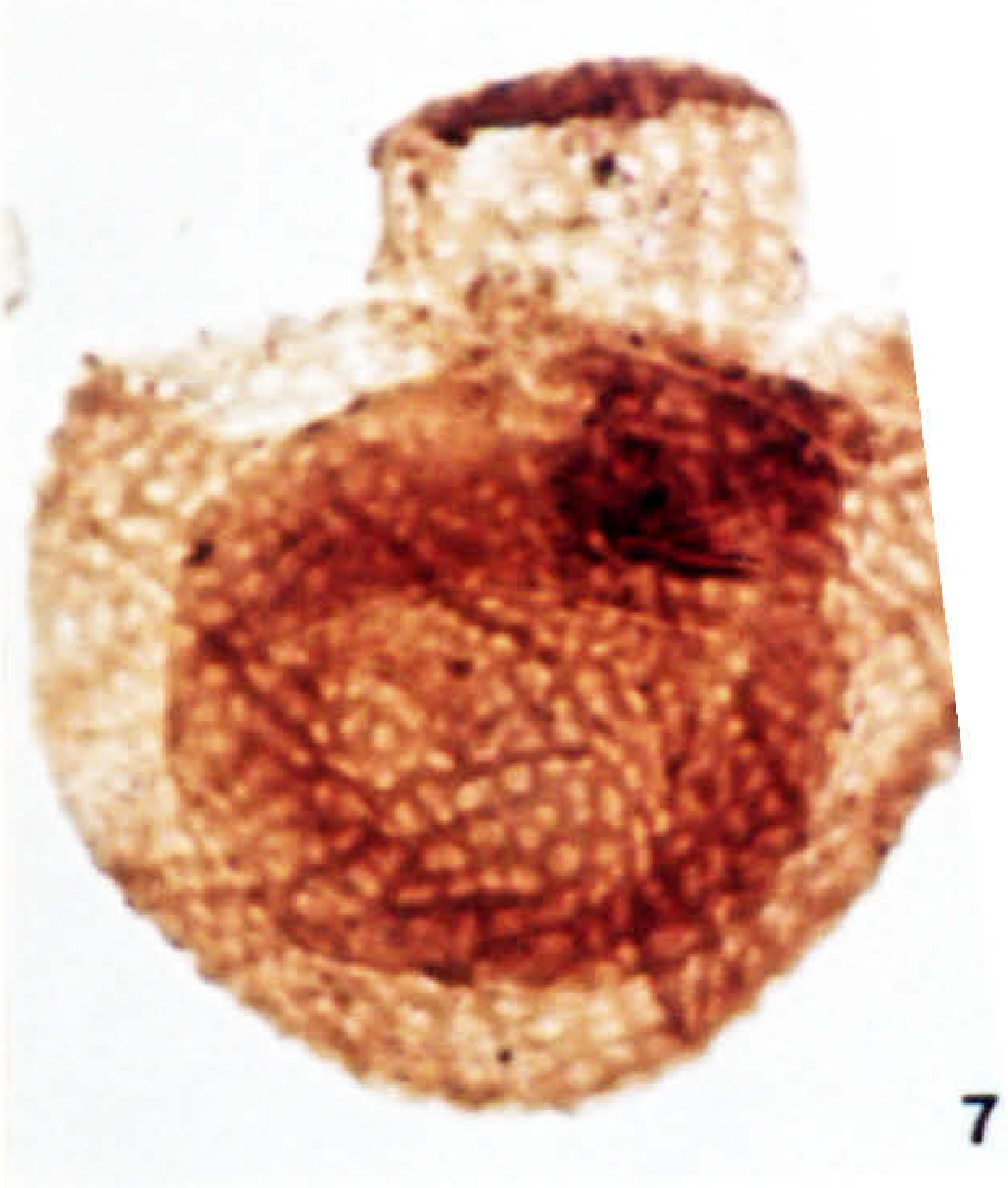

1


2

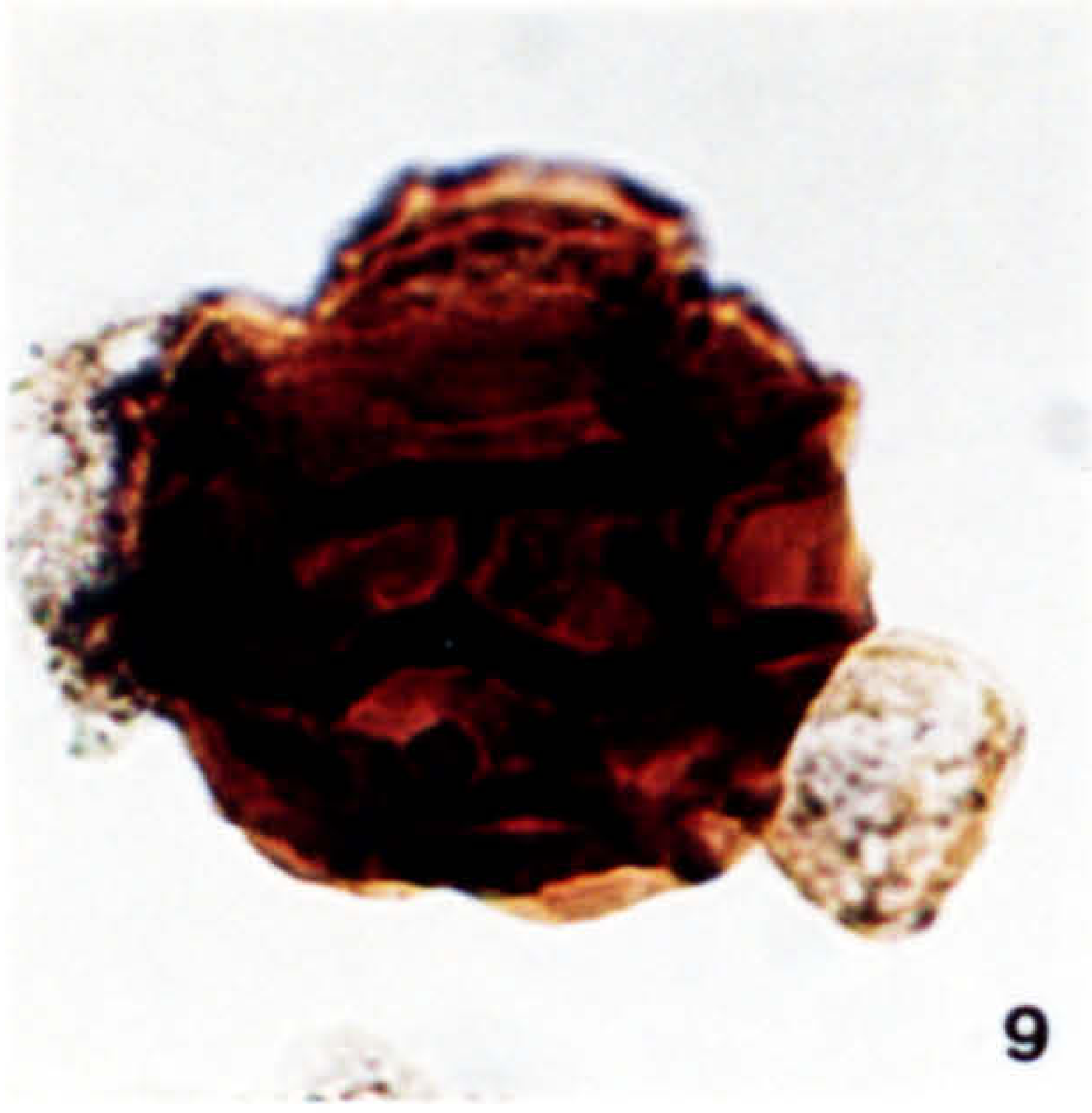

3

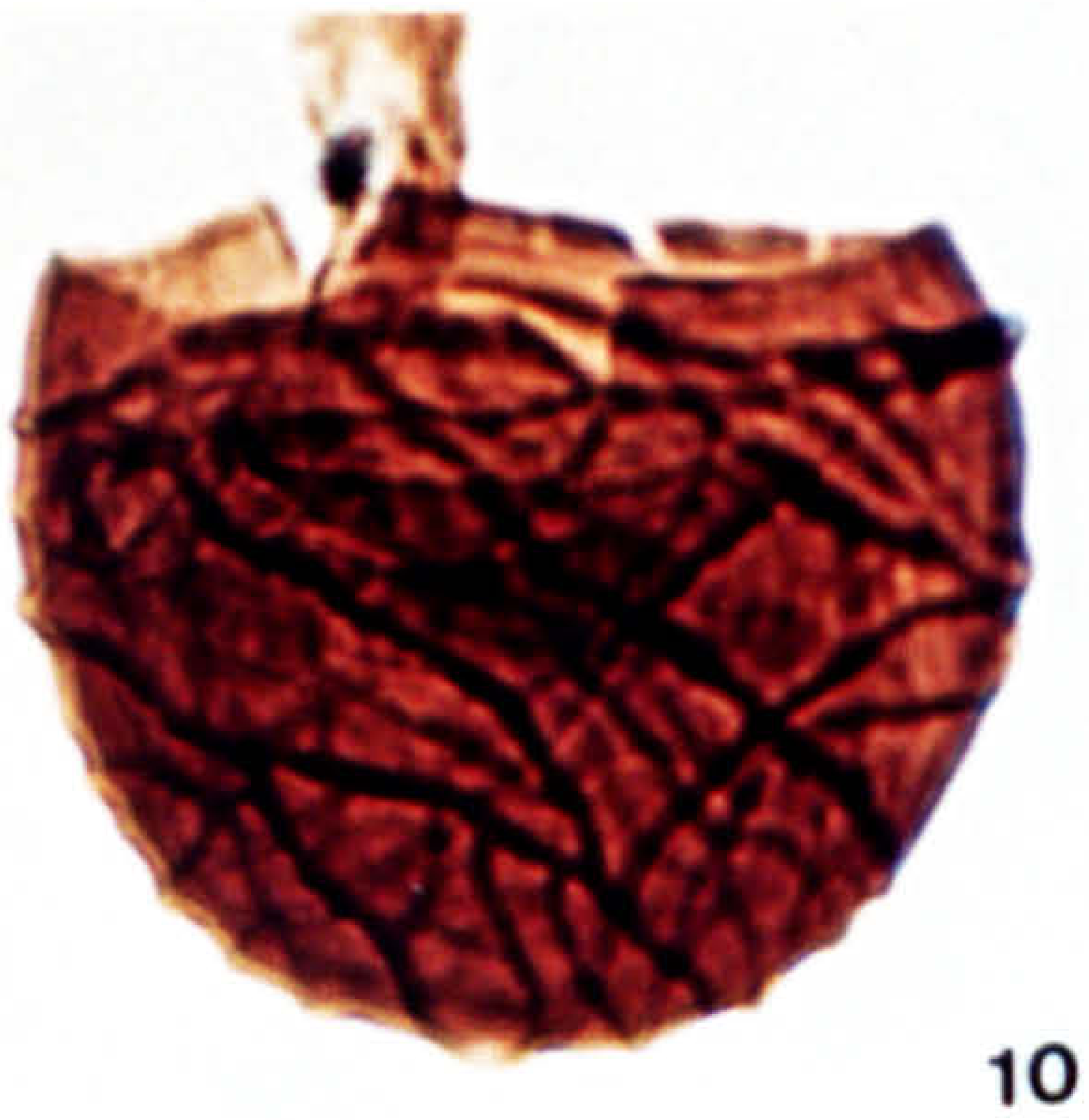

5


6


7


8


9


10


11

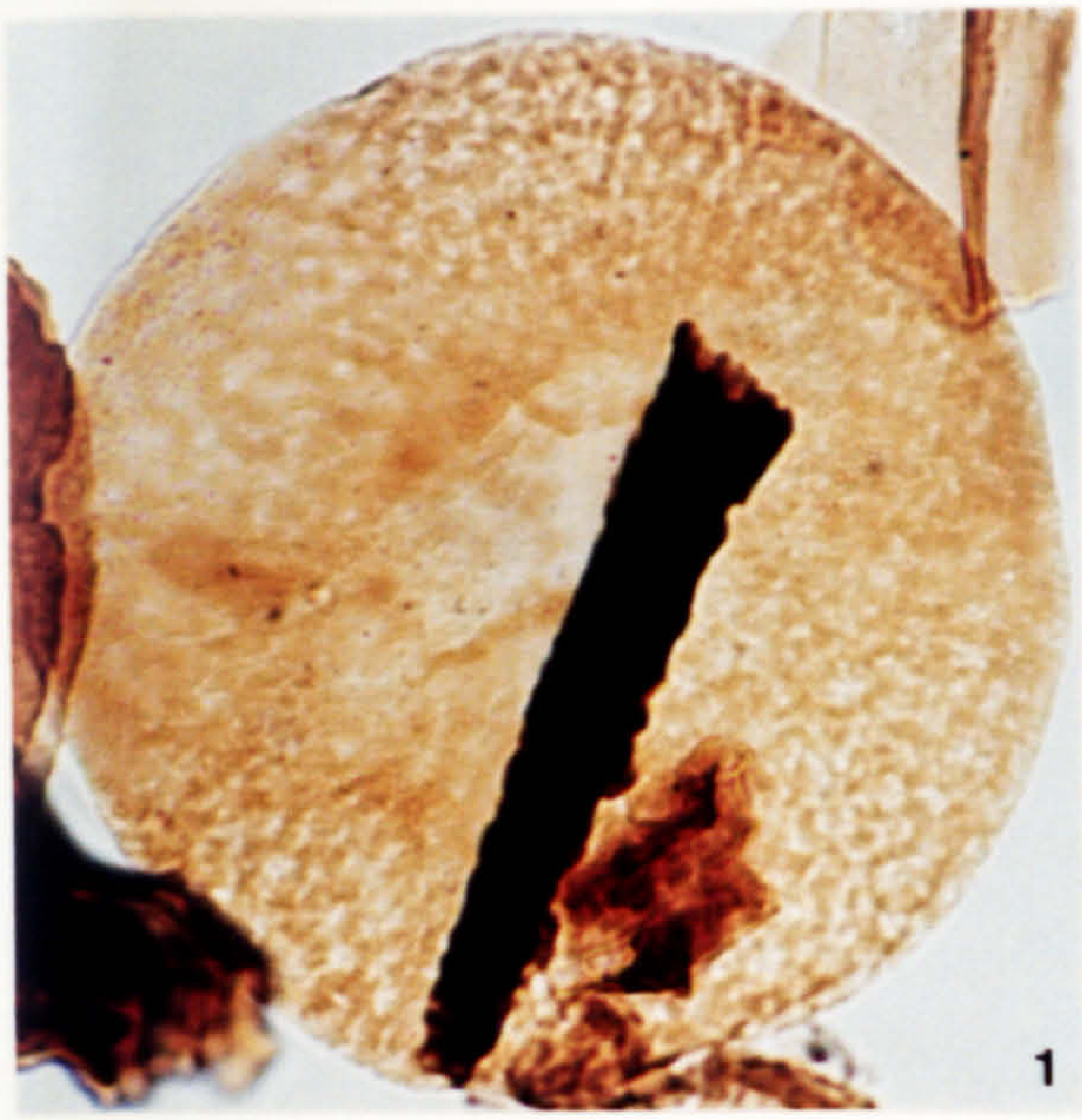

12


13

PLATE 16.

1. *Wilsonites kosankei.* 44/22-4, 12380', 1, U56.4.
2. *Wilsonites vesicatus.* 44/22-4, 12104', 2, N42.3.
3. *Wilsonites ephemerus.* 44/22-1, 11414.9', 2, L43.4.
4. *Wilsonites circularis.* 44/22-4, 12104', 2, G34.4.
5. *Peppersites ellipticus.* 44/22-1, 11433', 1, M60.4.
6. *Quasillinites diversiformis.* 44/22-1, 12242', 2, J31.4.
7. *Wilsonites delicatus.* 44/22-3, 11716', 2, D54.2.
8. *Florinites pumicosus.* 44/22-3, 11872', 5, J41.
9. *Potonieisporites microsaccus.* 44/22-1, 11752', 1, N34.1.
10. *Potonieisporites elegans.* 44/22-4, 12262', 1, L58.2.
11. *Florinites florini.* 44/22-1, 11506', 1, M57.
12. *Florinites mediapudens.* 44/22-1, 11424.9', 21, S39.2.
13. *Florinites minutus.* 44/22-1, 11506', 1, P37.1.
14. *Florinites visendus.* 44/22-3, 11872', 5, F48.

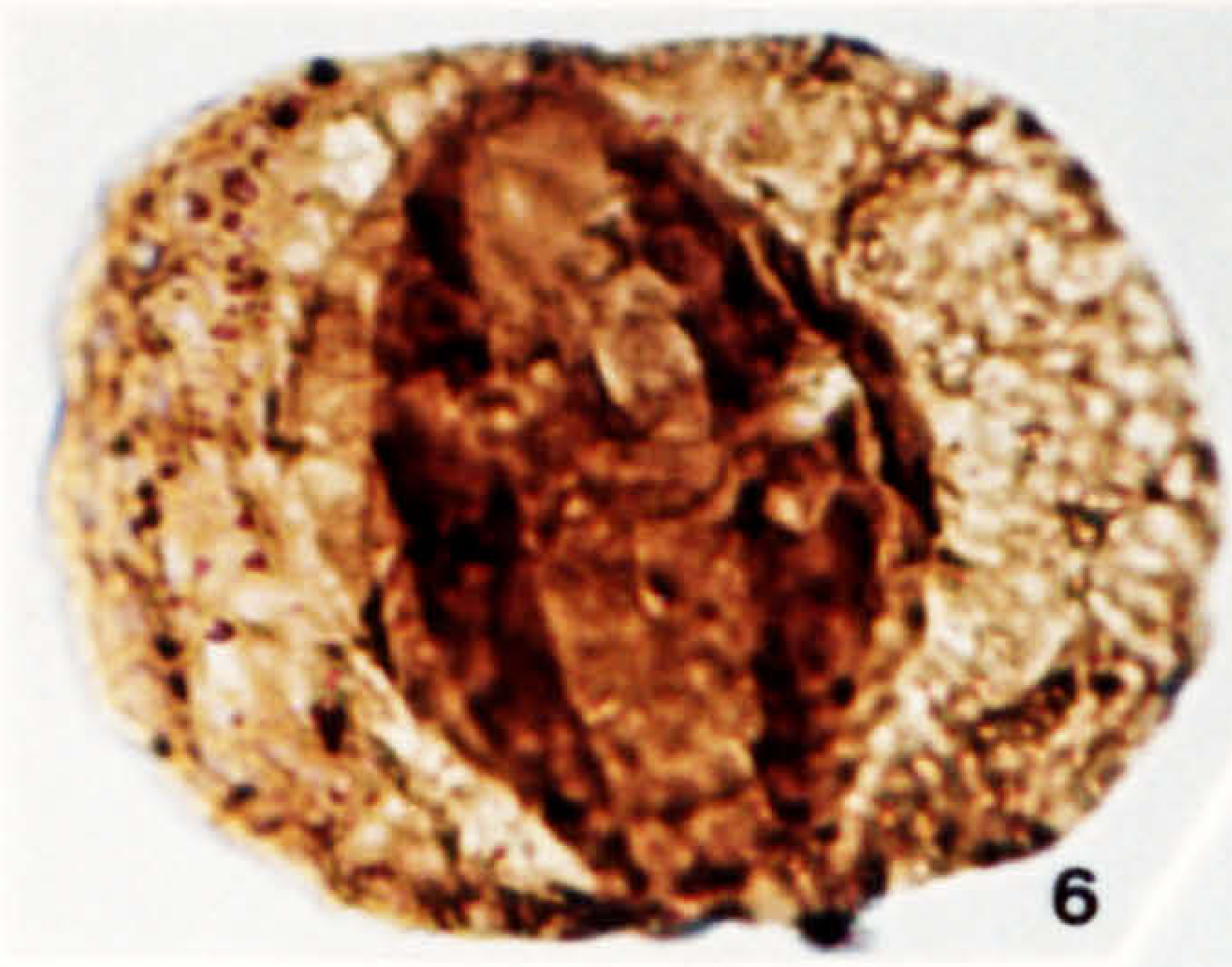
PLATE 16


1


2


4

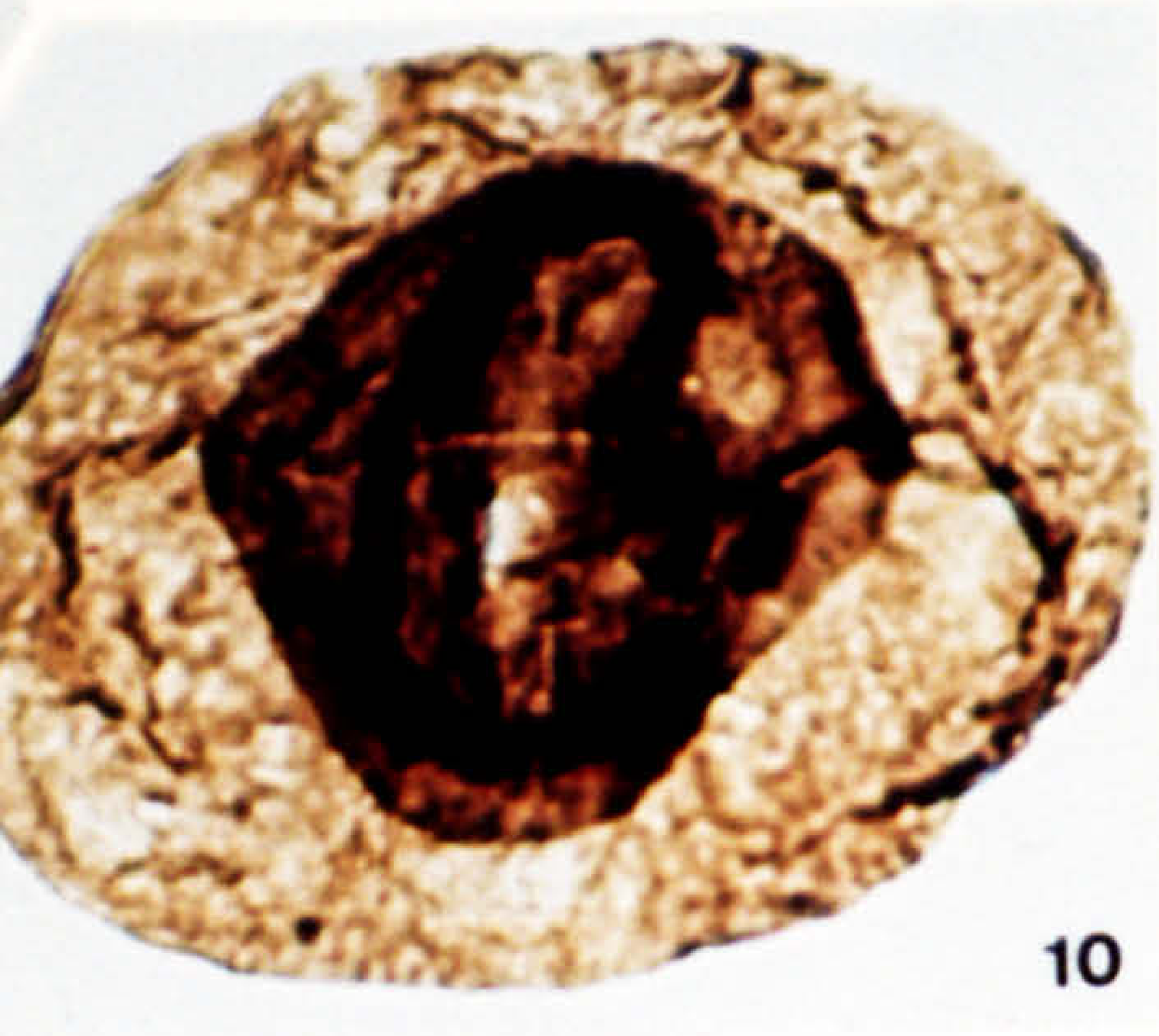

5


6


7


8


9


10


11


12


13

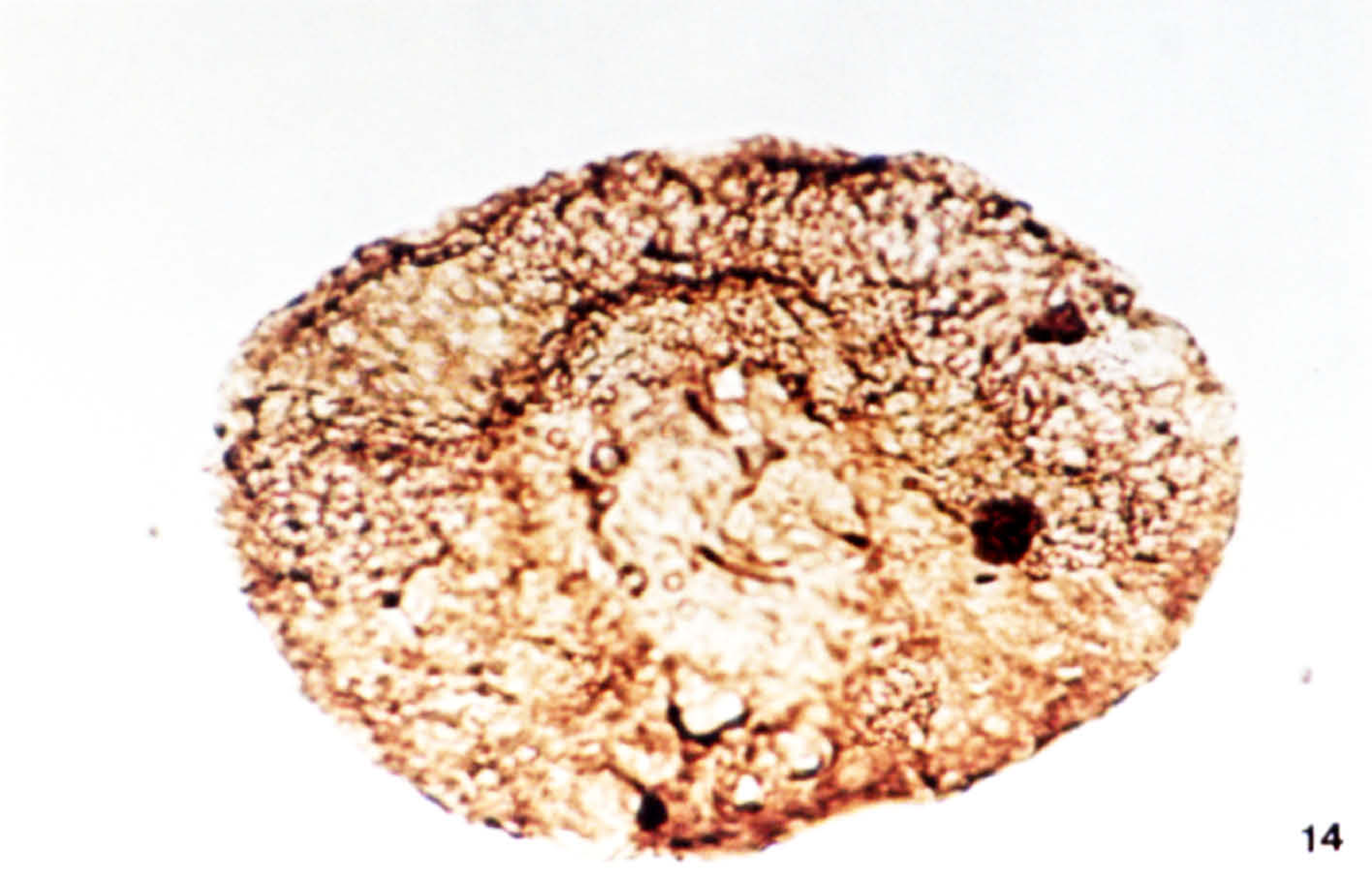

14

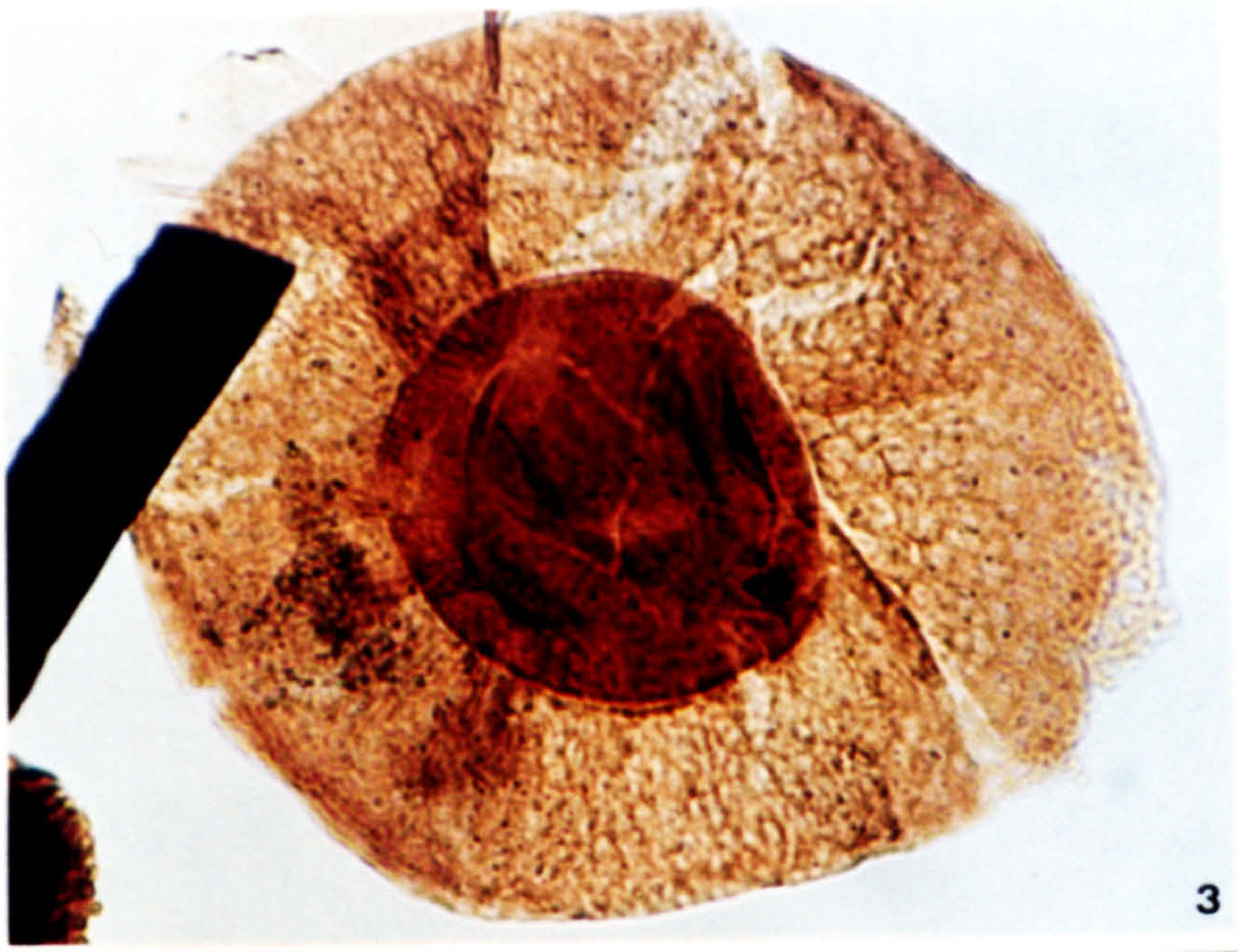
PLATE 17.

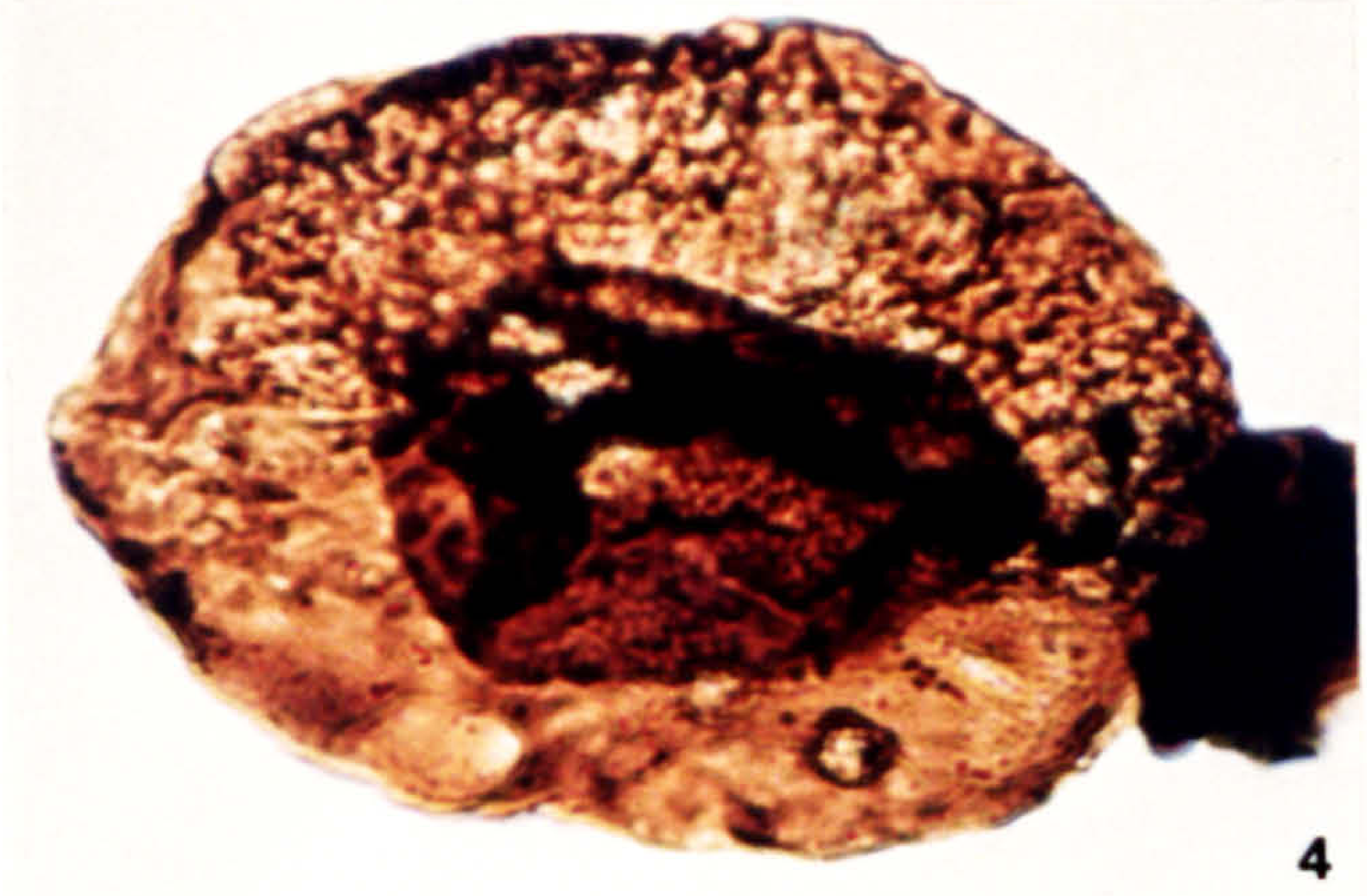
1. *Florinites triletus.* 44/22-4, 12104', 2, S45.
2. *Florinites junior.* 44/22-3, 11920', 1, F62.1.
3. *Florinites similis.* 44/22-1, 11685', 1, P42.4.
4. *Florinites volans.* 44/22-3, 11872', 5, R44.2.
5. *Paleospora fragila.* Folded specimen. 44/22-4, 12102', 2, K37.
6. *Parasporites macanensis.* 44/22-3, 11872', 6, L39.
7. *Illinites unicus.* 44/22-3, 11886', 1, Q57.3.
8. *Illinites unicus.* 44/22-3, 12013', 1, U44.
9. Gen. et. sp. indet. Striate monosacccate. 44/22-4, 12257', 2, P61.1.
10. *Pityosporites westphalensis.* 44/22-1, 11752', 2, G55.
11. *Parasporites* cf. *macanensis.* 44/22-1, 11425', 2, F55.2.
12. *Pityosporites in aequus.* Holotype. 44/22-1, 11752', 1, J65.
13. *Pityosporites in aequus.* 44/22-1, 11422', 1, Q49.3.
14. *Pityosporites inaequus.* 44/22-1, 11752', 2, P39.1.

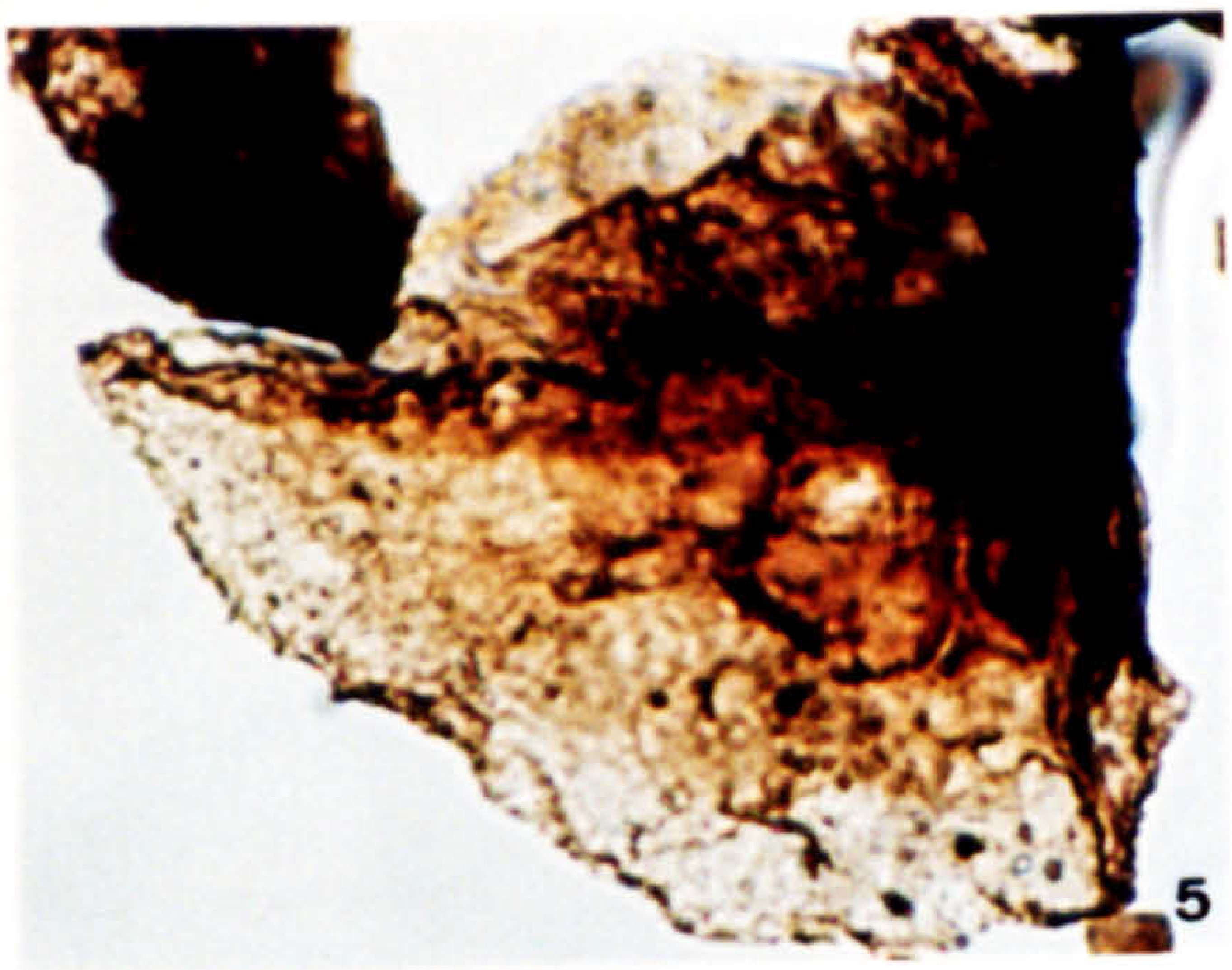
PLATE 17

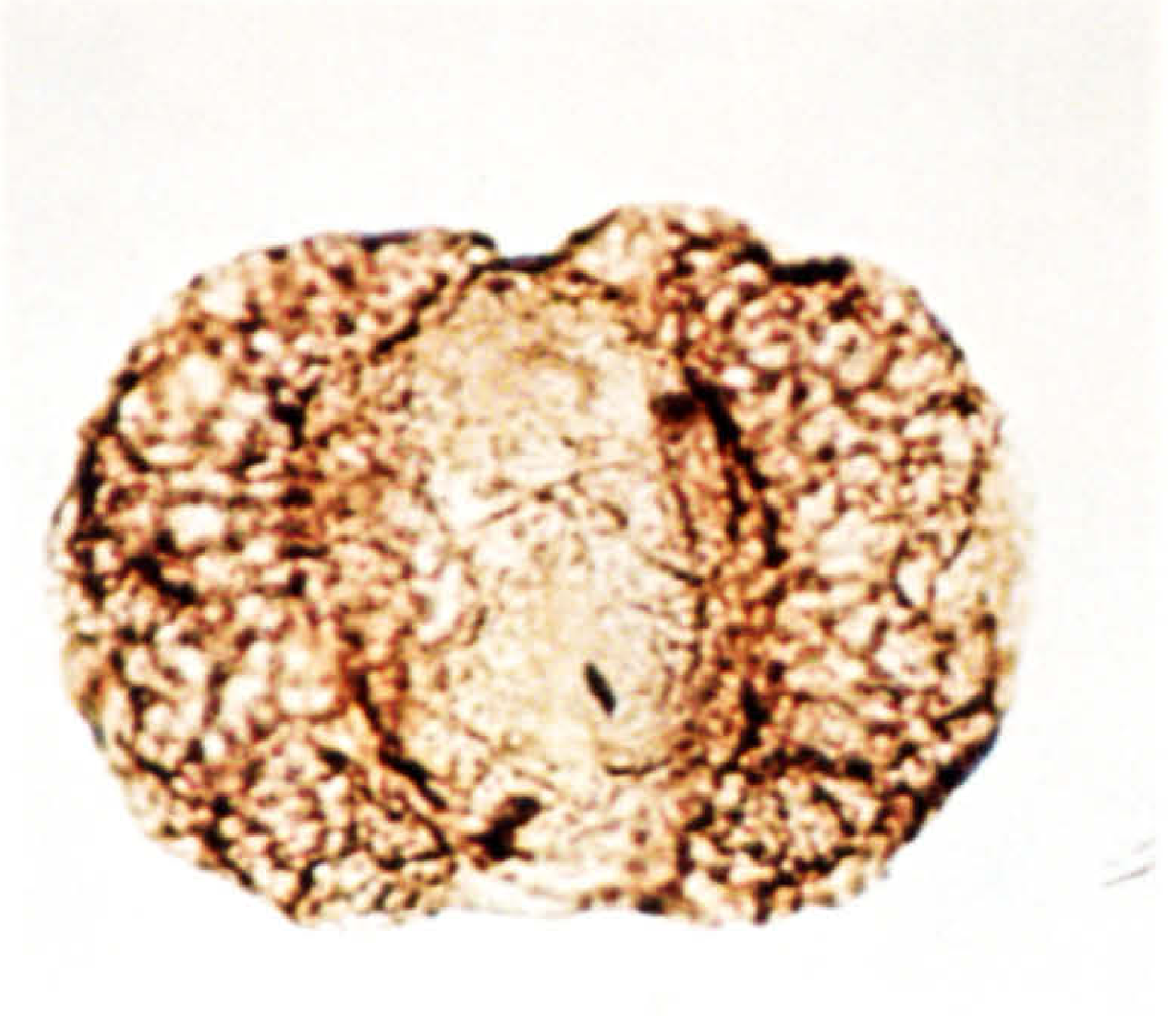

1


2


3

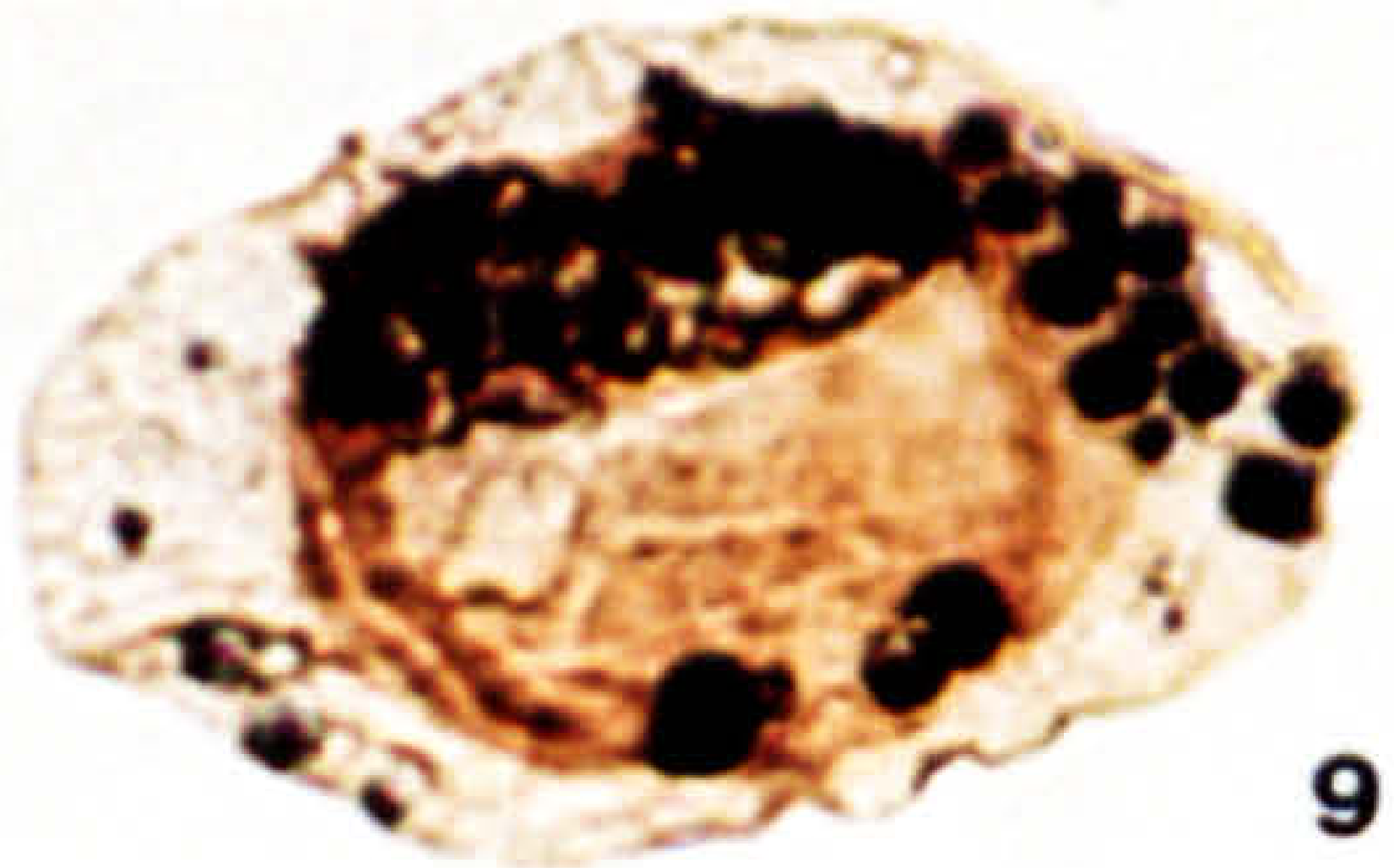

4

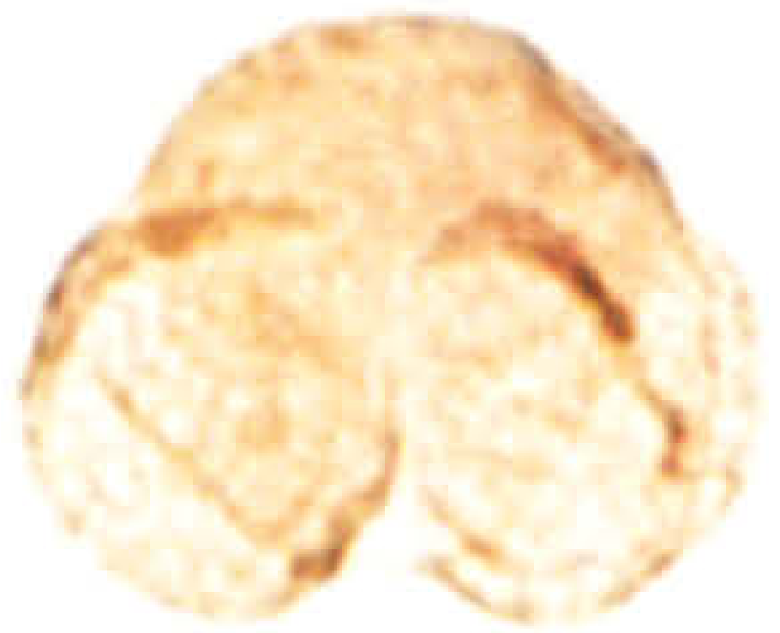

5


6

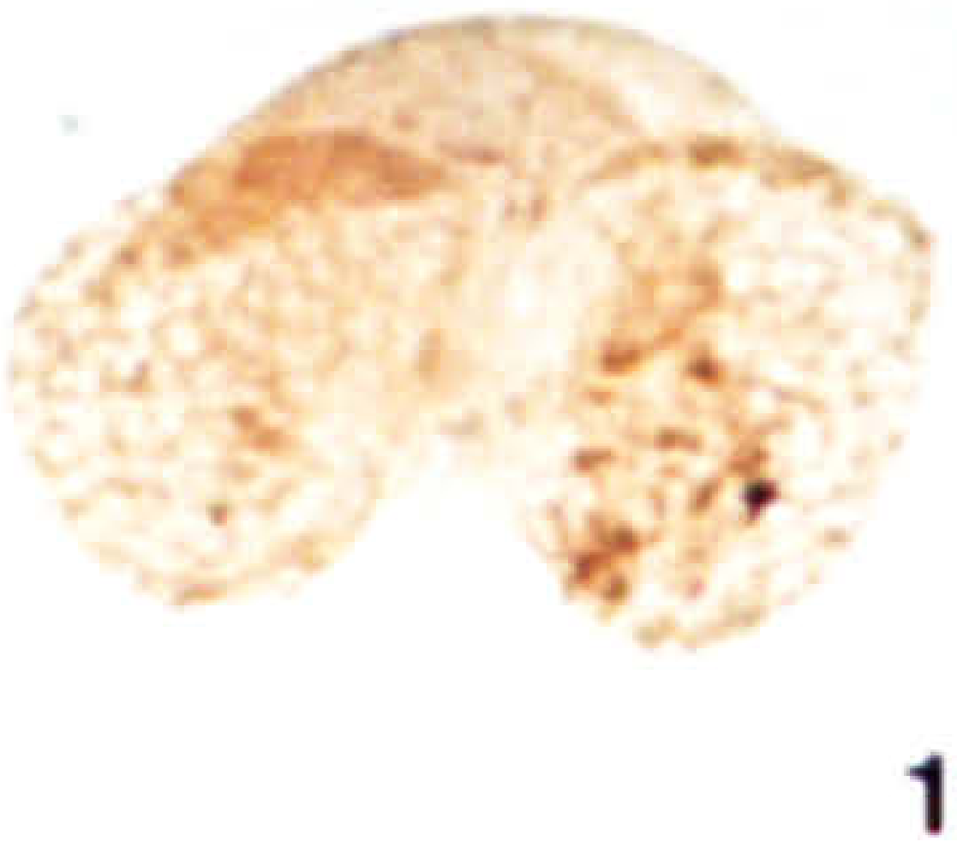

7

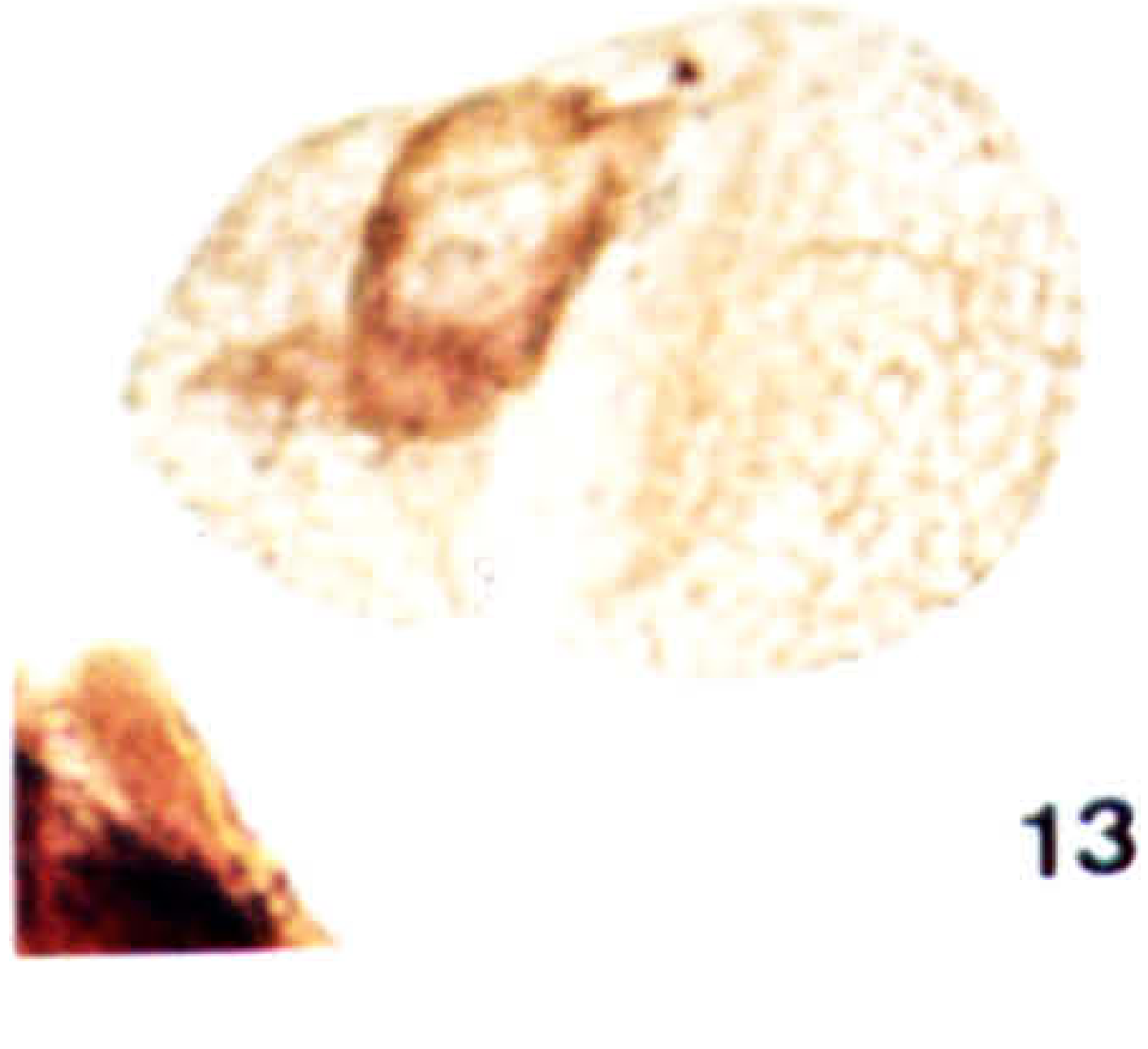

8


9


10


11


12


13


14

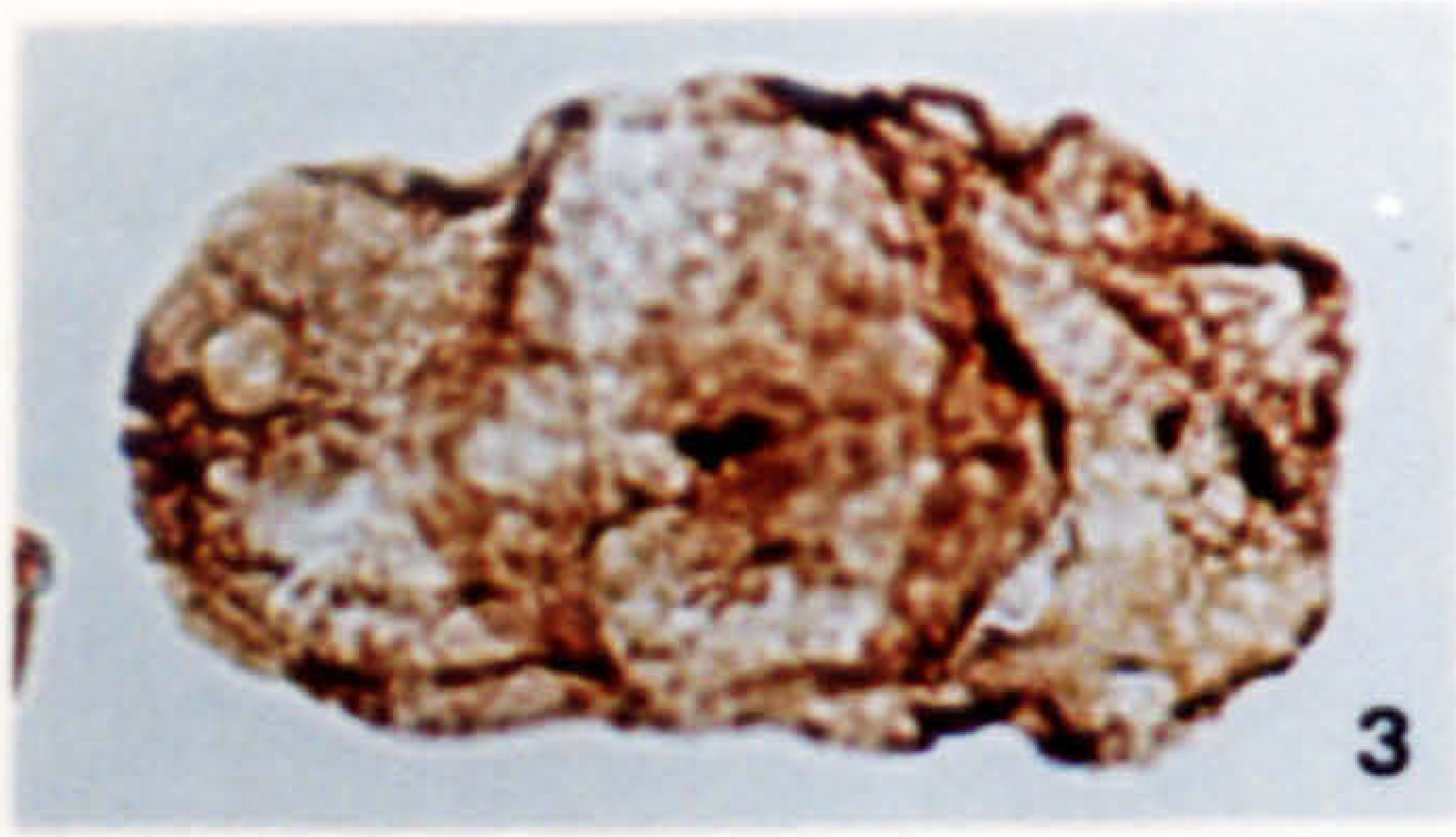
PLATE 18.

1. *Limitisporites* cf. *rectus*. 44/22-1, 11425', 1, K68.4.
2. *Limitisporites* cf. *rectus*. 44/22-4, 12262', 2, Q52.4.
3. *Limitisporites* cf. *rectus*. 44/22-1, 12060', 2', L36.
4. *Limitisporites* cf. *latus*. 44/22-1, 11527', 2, O67.3.
5. *Protohaploxypinus masonii*. Holotype. Focus on tenae. 44/22-1, 12045', 1, L46.
6. *Platysaccus saarensis*. 44/22-1, 11928', 1, M29.3.
7. *Protohaploxypinus masonii*. Holotype (as figure 5). Focus on sacci.
8. *Cycadopites* sp. A. 44/22-4, 12257', 5, H55.
9. *Cycadopites* sp. A. 44/22-3, 11522', 2, E63.2.
10. *Protohaploxypinus masonii*. 44/22-4, 12262', 1, V45.
11. *Zonalosporites ellipsoides*. 44/22-3, 12120', 1, S62.
12. *Protohaploxypinus* cf. *amplus*. 44/22-1, 12060', 2, U33.3.
13. *Protohaploxypinus* cf. *amplus*. 44/22-4, 12262', 1, G51.

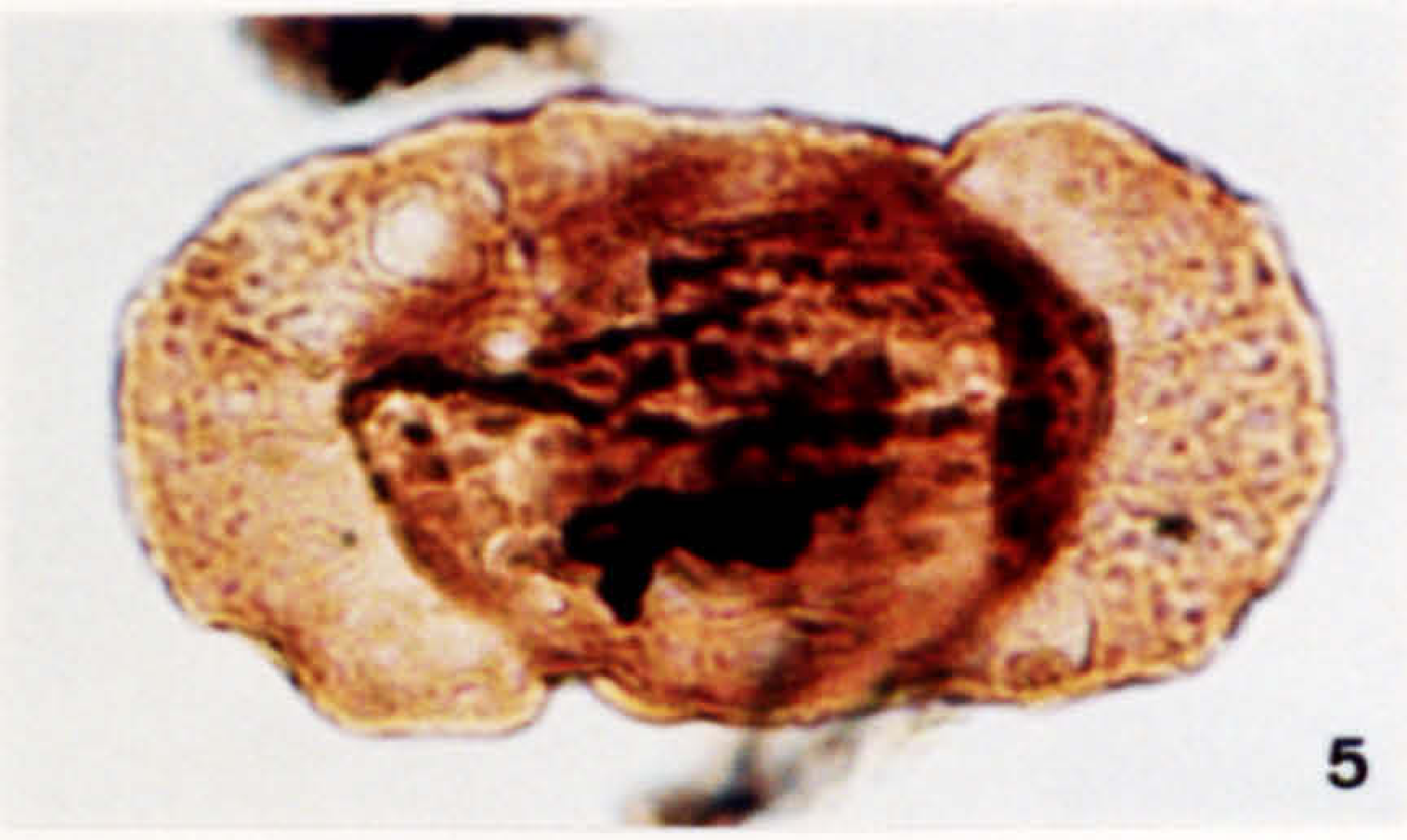
PLATE 18


1

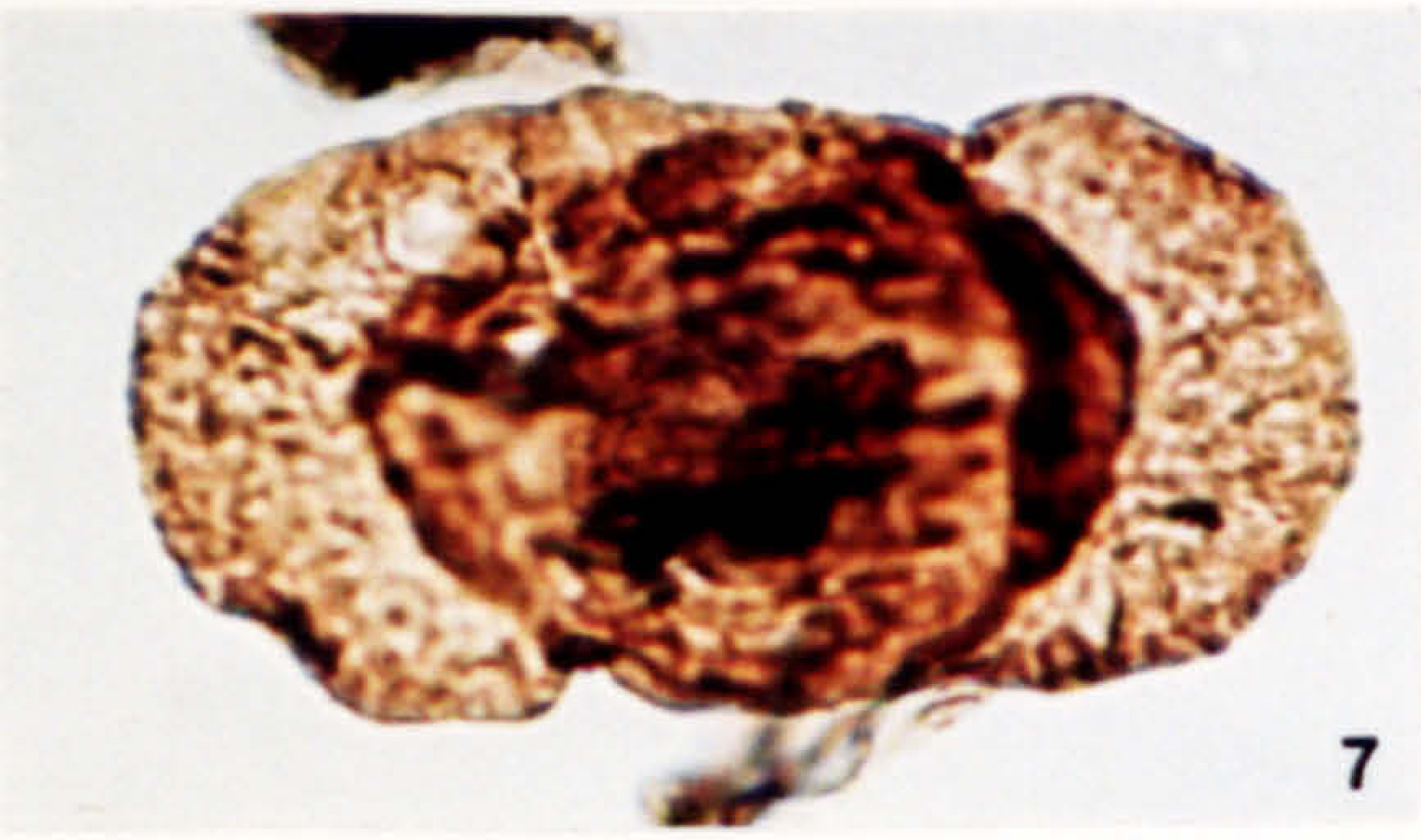

2


3


4


5

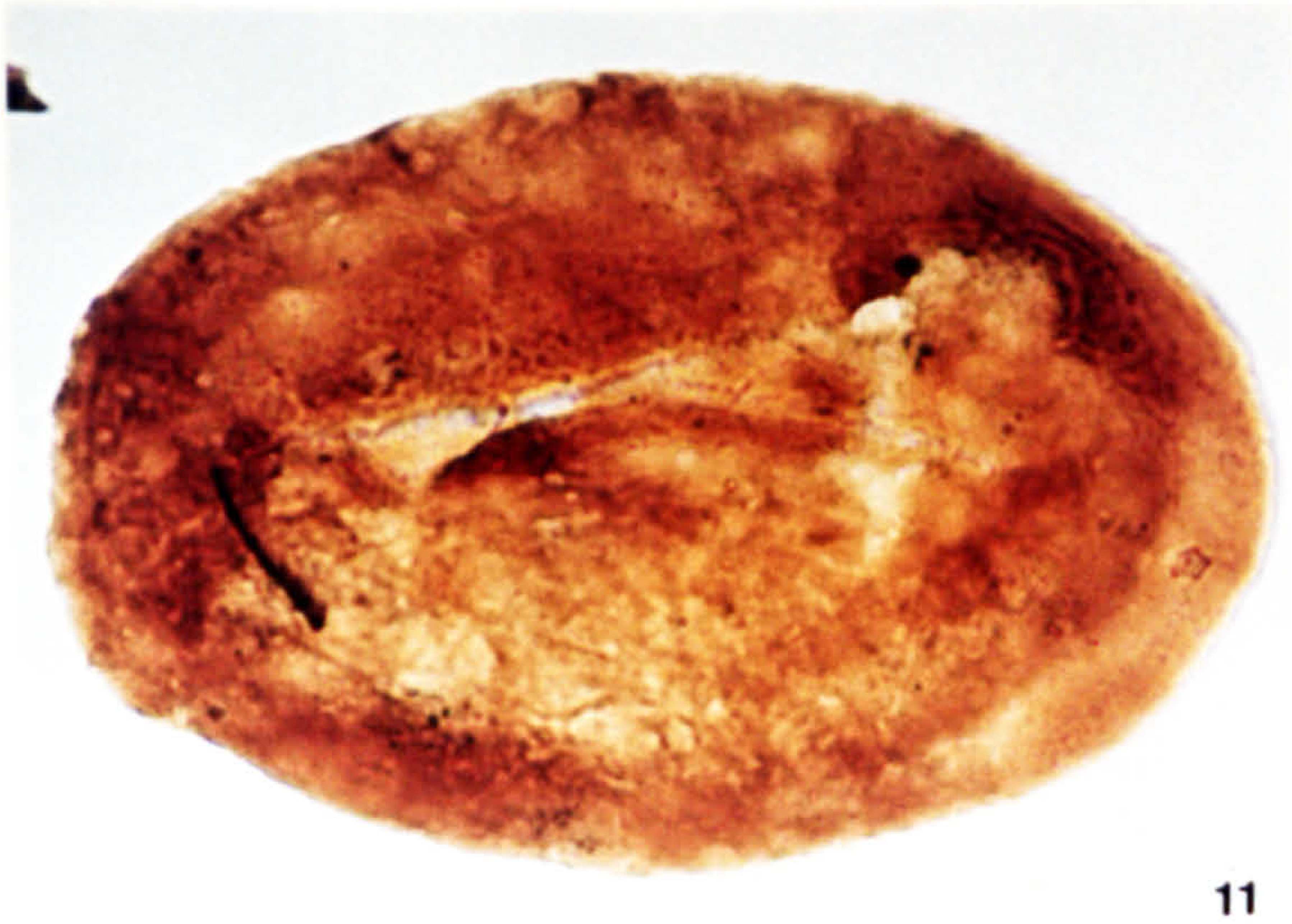

6


7


8


9


10


11


12

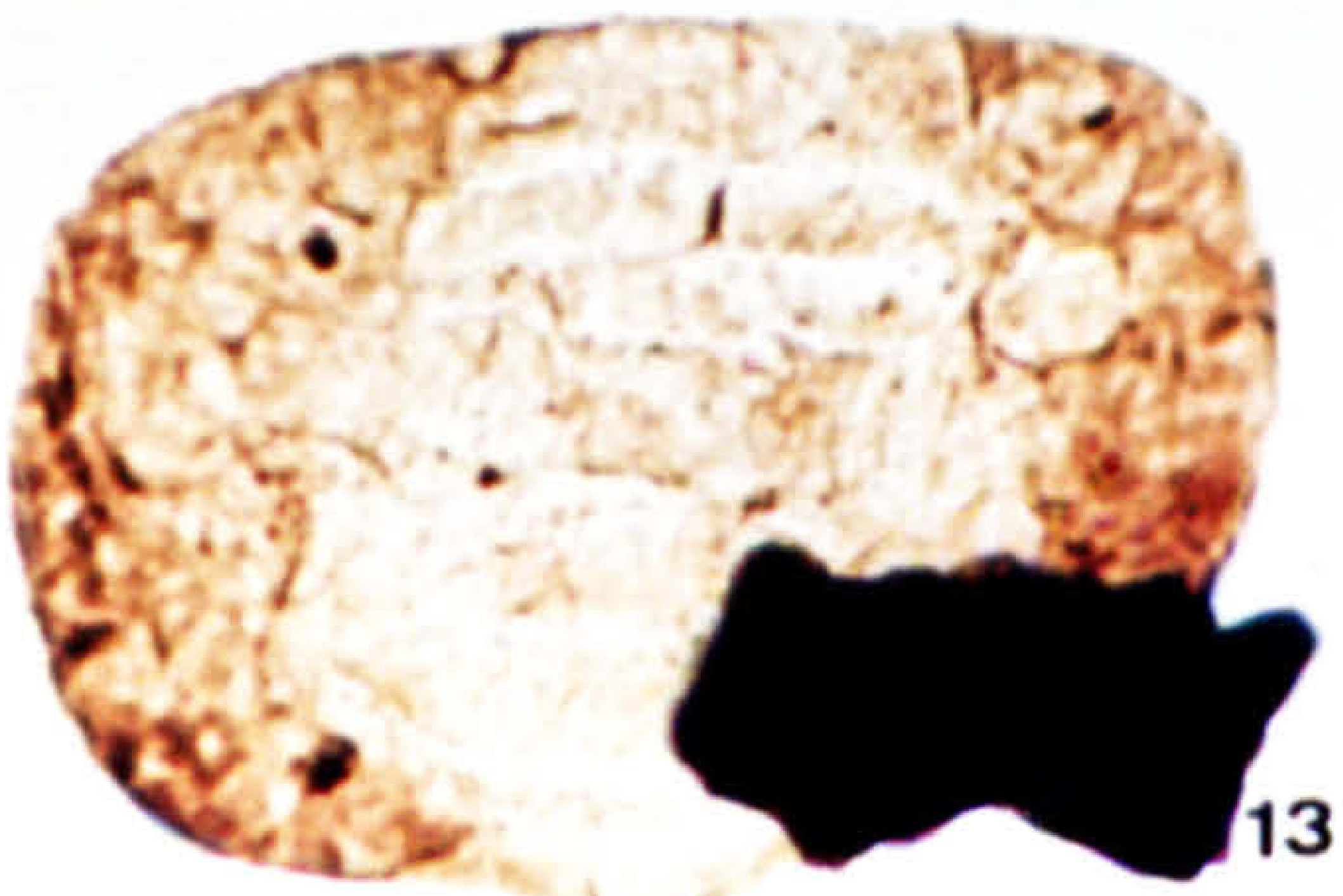

13

PLATE 19.

1. *Biannulatisphaerites simplex*. 44/22-3, 12013', 1, M40.
2. *Chomotriletes vedugensis*. 44/22-1, 12055', 1, F43.3.
3. *Leiosphaeridium* sp. 44/22-3, 11726', 2, G45.
4. *Buedingiisphaeridium* cf. *pyramidale*. 44/22-1, 12032', 2, L63.3.
5. *Micrhystridium* sp. 44/22-3, 11468', 1, M49.4.
6. *Micrhystridium* sp. 44/22-1, 11763', 1, M56.
7. *Baltisphaeridium* sp. 44/22-3, 11458', 2, S61.1.
8. *Baltisphaeridium* sp. 44/22-1, 11763', 1, H54.
9. *Multiplicisphaeridium* sp. 44/22-1, 11763', 2, D31.4.
10. *Timofeevia acrimonia*. 44/22-1, 11527', 1, R66.2.
11. *Polygonium gracile*. 44/22-1, 11878', 2, L37.
12. *Polygonium gracile*. 44/22-1, 11683', 1, K37.
13. *Cymatiosphaera* sp. 44/22-1, 12032', 2, C58.
14. *Veryhachium wenlockianum*. 44/22-1, 11763', 2, U43.1.
15. *Acanthodiacrodium ignoratum*. 44/22-4, 11850', 2, W36.4.
16. *Acanthodiacrodium unigeminum*. 44/22-1, 12040', 1, O42.
17. *Acanthodiacrodium spinum*. 44/22-1, 12055', 2, S55.
18. *Dasydiacrodium annosum*. 44/22-1, 12050', 2, R42.3.
19. *Priscogalea cortinula*. 44/22-1, 11818', 1, X39.
20. *Priscogalea fimbria*. 44/22-1, 12024', 2, L55.
21. *Cymatiogalea cristata*. 44/22-1, 11763', 1, S50.
22. *Cymatiogalea cuvillierii*. 44/22-1, 11683', 2, H28.1.
23. *Cymatiogalea multarea*. 44/22-1, 11873', 1, F33.1.
24. *Stelliferidium simplex*. 44/22-1, 11873', 1, F43.1.
25. *Stelliferidium simplex*. 44/22-1, 12004', 1, O40.
26. *Lophosphaeridium* sp. 44/22-1, 11873', 1, J27.
27. *Cymbosphaeridium bikidium*. 44/22-3, 11468', 1, K46.
28. *Stelliferidium* sp. Fragment. 44/22-4, 12104', 2, P55.3.
29. *Veryhachium* sp. 44/22-1, 11818', 2, E28.2.
30. *Cymbosphaeridium bikidium*. 44/22-3, 11468', 1, G48.3.
31. *Diexallophasis* sp. 44/22-3, 11480', 2, N63.4.

PLATE 19


1


2

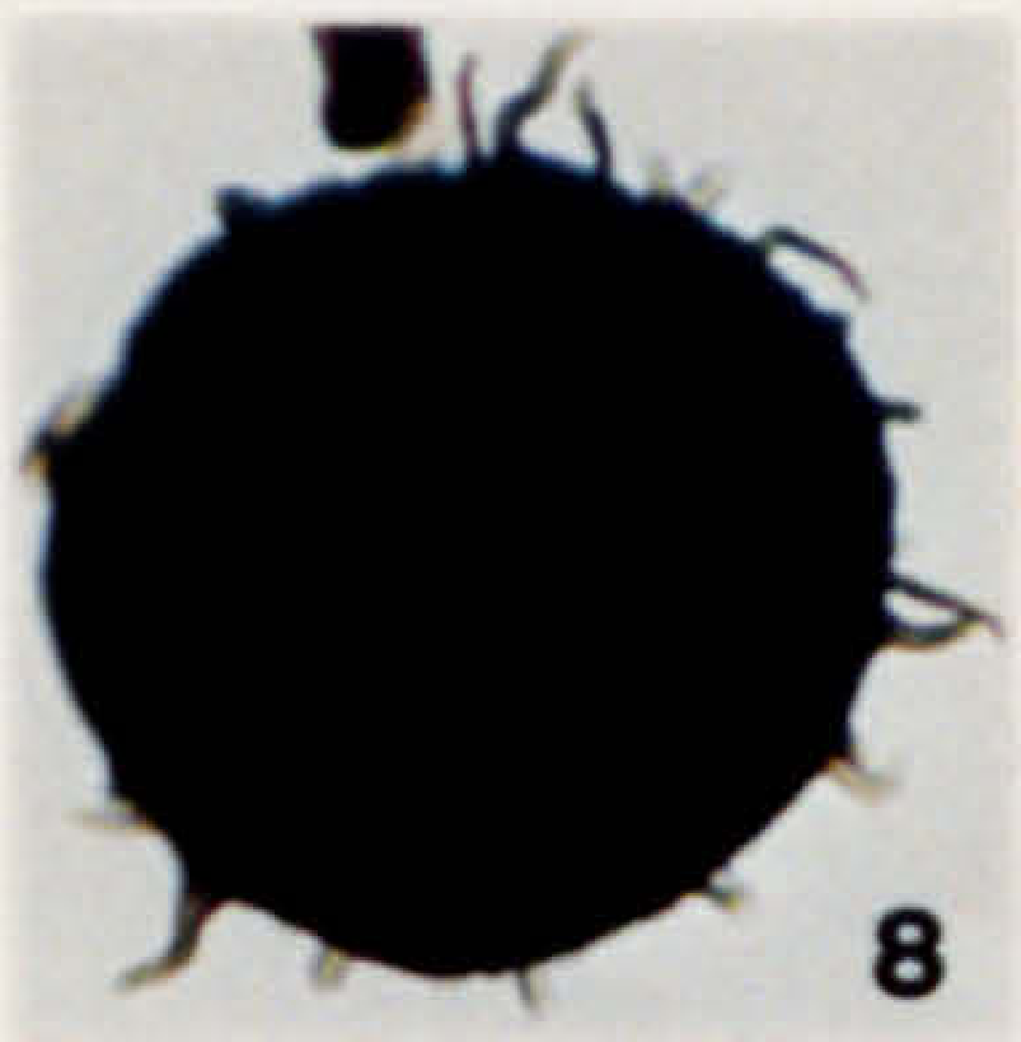

3


4

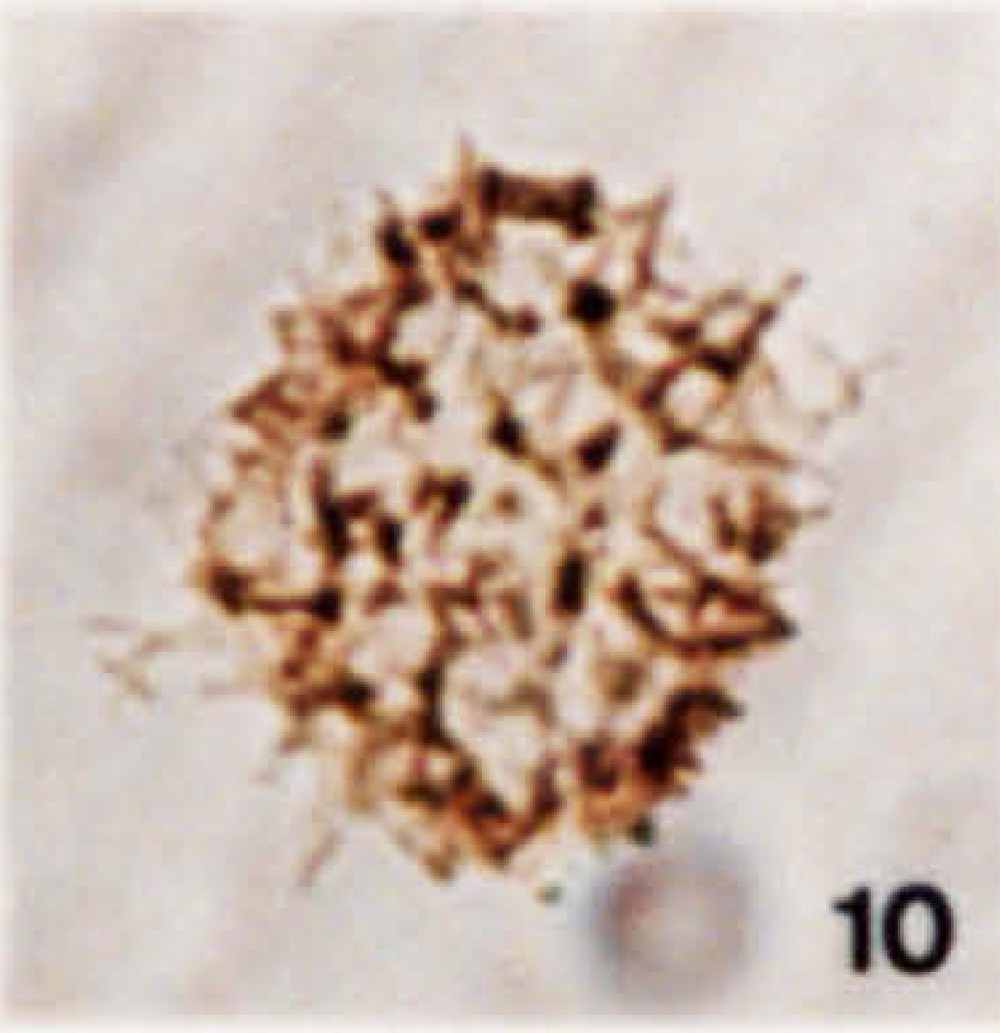

5


6


7


8


9


10


11


12

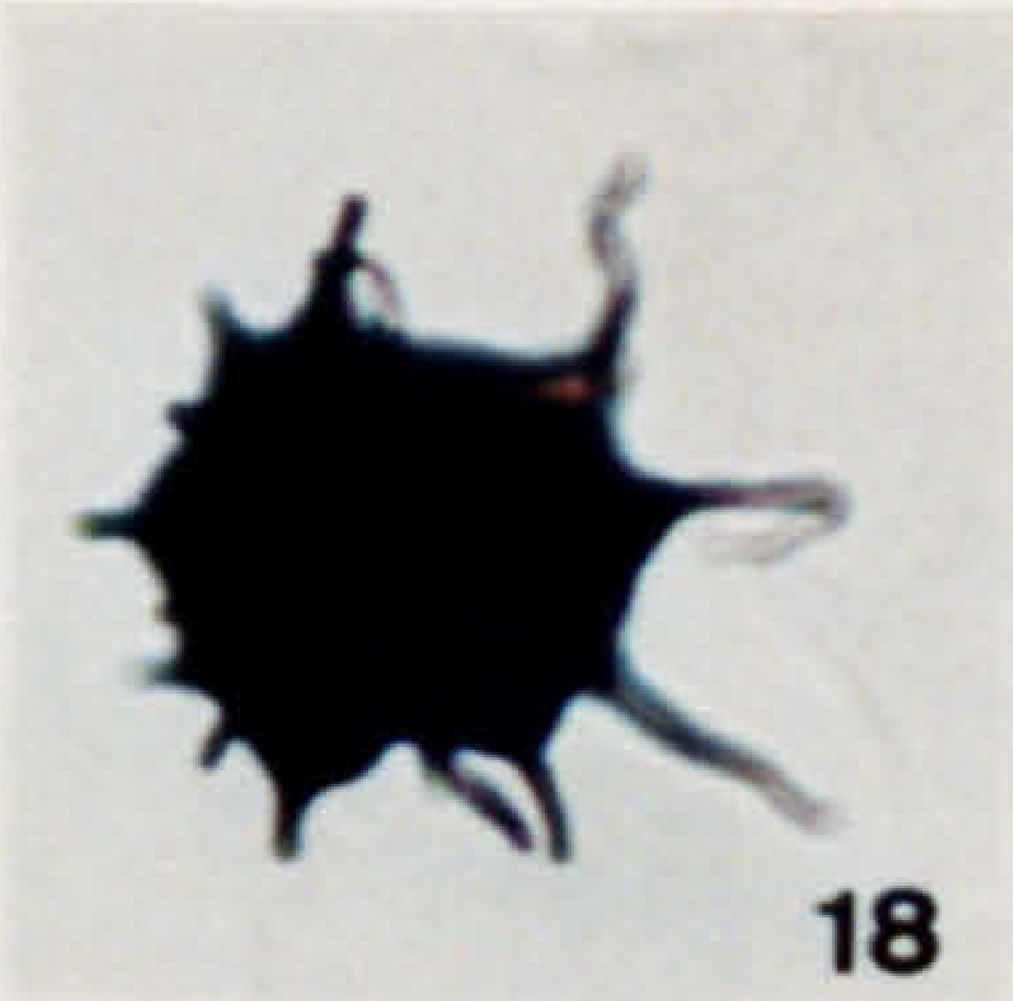

13


14

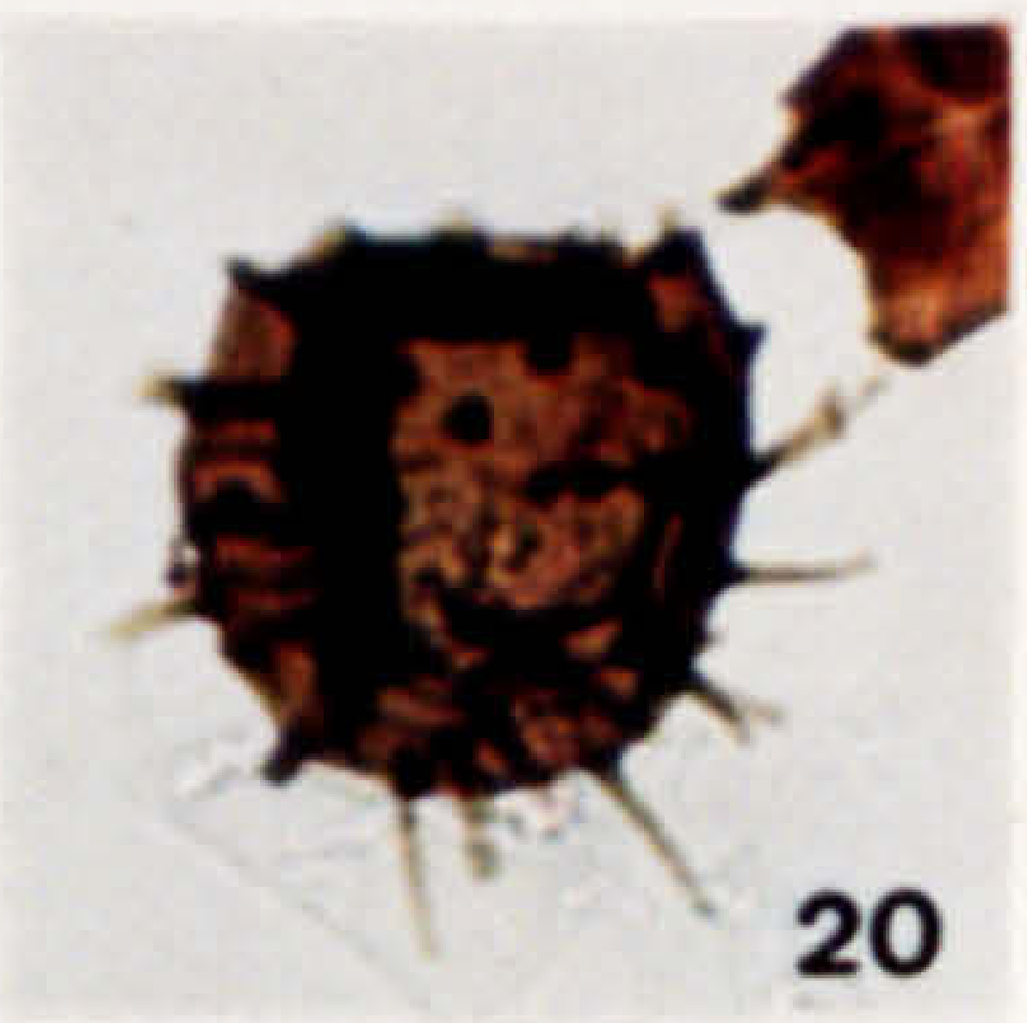

15

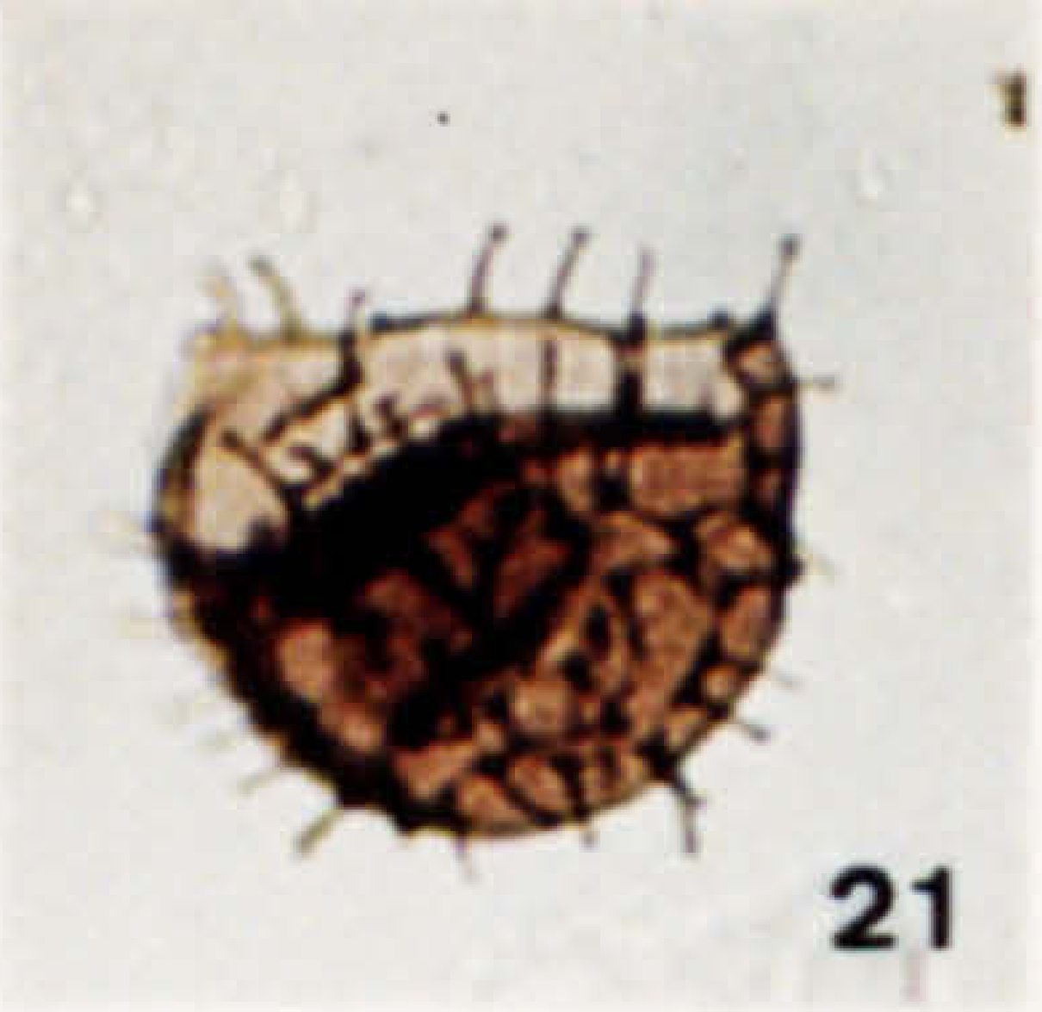

16


17


18


19


20


21


22

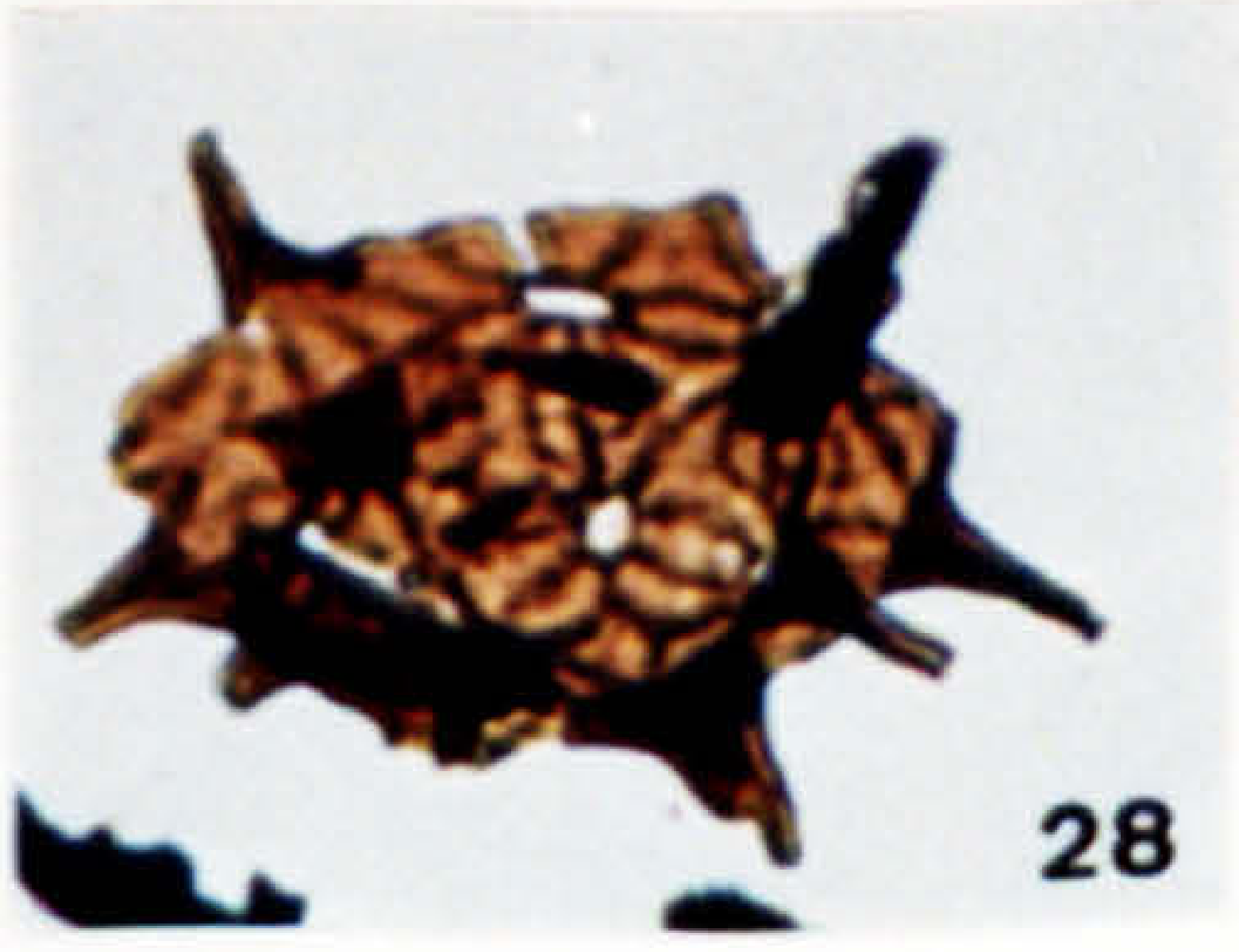

23

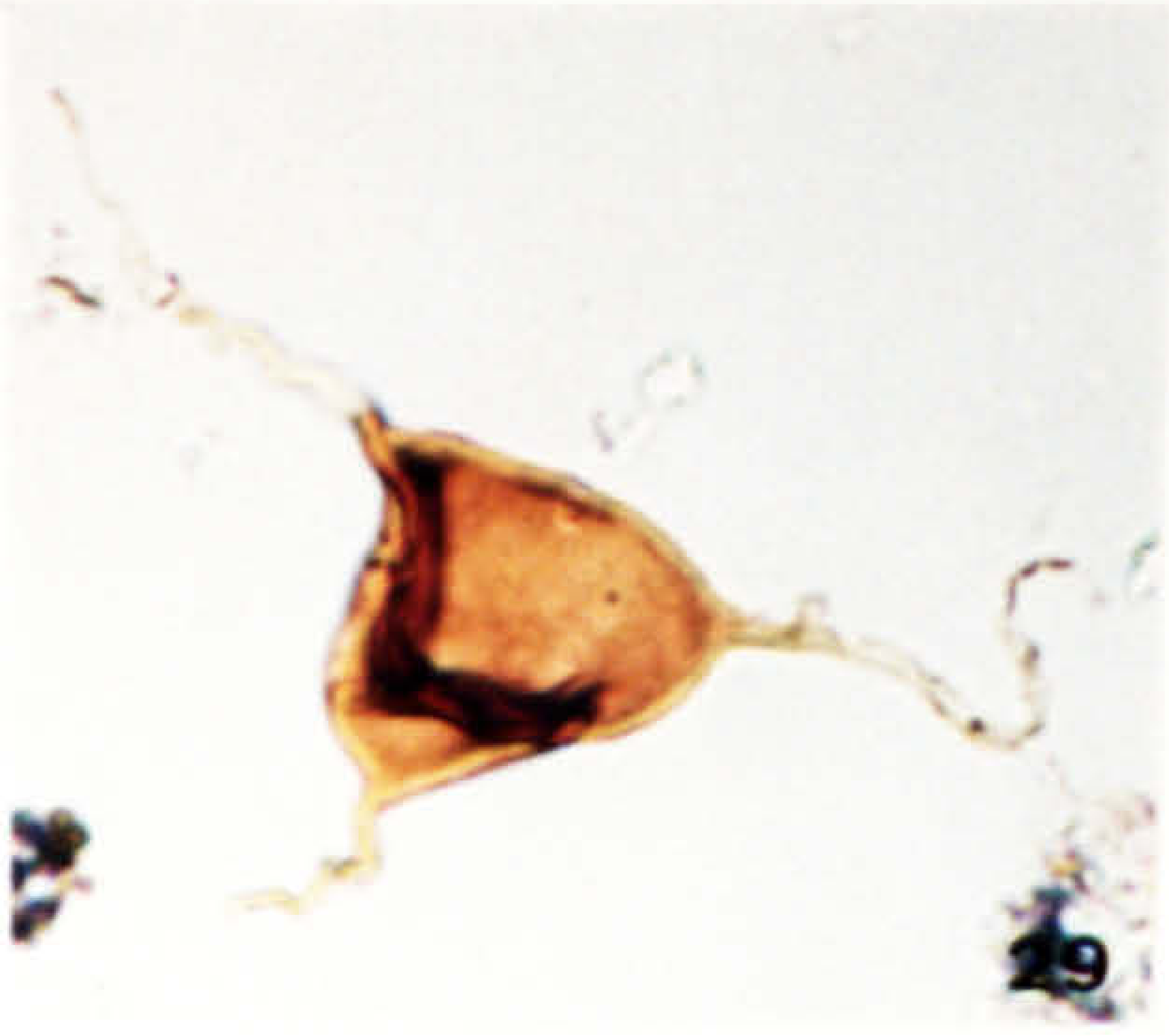

24


25


26


27


28


29


30


31

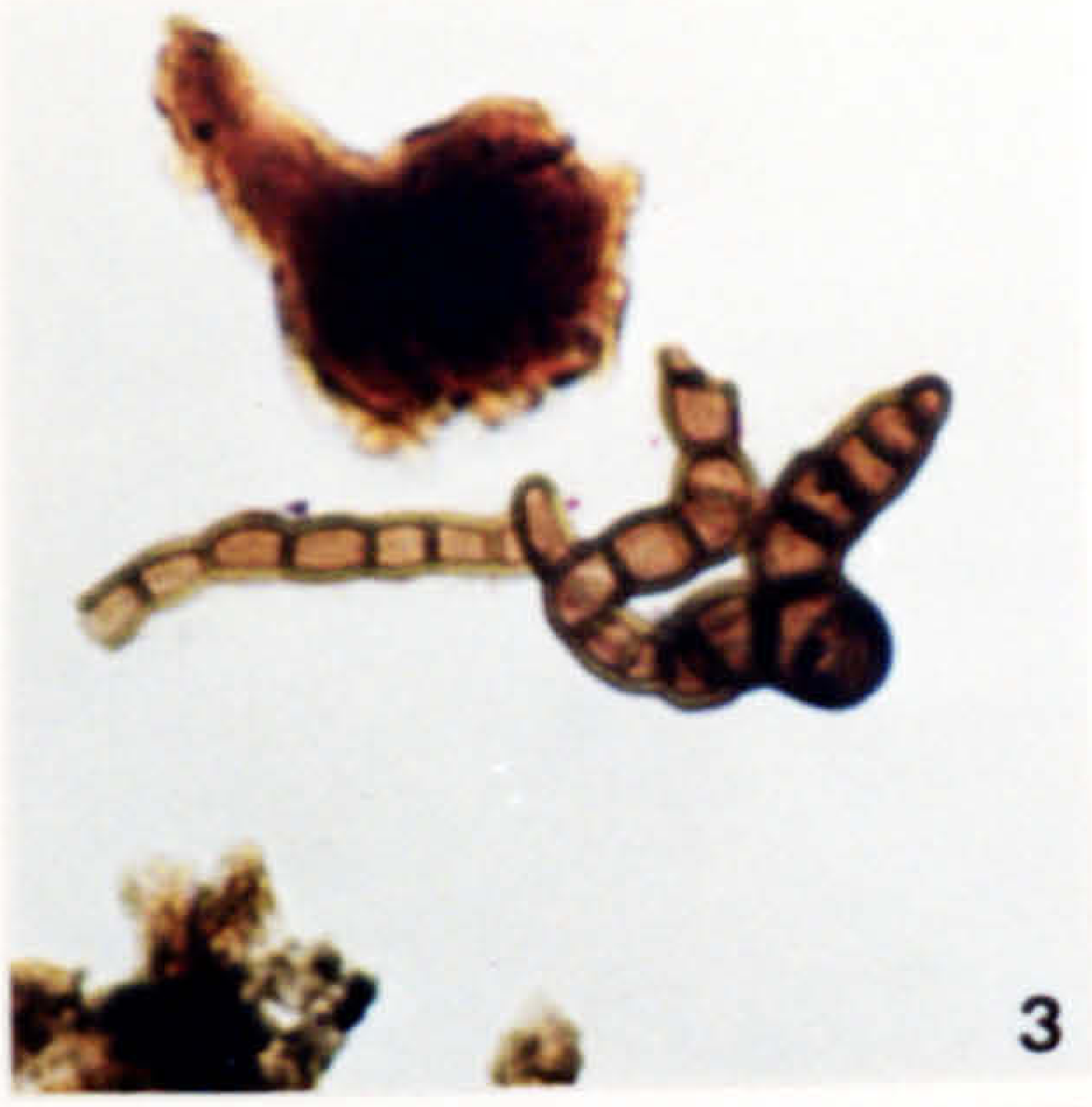
PLATE 20.

1. Scolecodont element. 44/22-1, 12019', 2, O55.1.
2. Scolecodont element. 44/22-1, 12019', 2, E63.1.
3. Fungi and *Botryococcus braunii*. 44/22-4, 12010', 1, B46.4..
4. *Spirifer pennystonensis*. 44/22-1, 12031'.
5. *Lingula mytilloides*. 44/22-1, 12019'.
6. Crinoid ossicle. 44/22-1, 12031'.
7. *Anthracosia ovum*. 44/22-1, 11878'.

PLATE 20


1


2


3


4


5


6


7