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PALYNOLOGY OF PERMIAN-TRIASSIC BOUNDARY BEDS AT KAP STOSCH, EAST GREENLAND

BY

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WITH 3 FIGURES AND 3 PLATES

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Abstract

Palynological studies have been carried out on Permian and Early Triassic sediments from Kap Stosch, East Greenland. Pollen grains and spinose acritarchs were present in all samples and abundant in most; spores were uncommon in the Permian. Thirty-three taxa have been illustrated and briefly described and *Tympanicysta* gen. nov. (type: *T. stoschiana* sp. nov.) has been instituted to accommodate certain inaperturate vesicles of unknown affinities.

Permian assemblages, with abundant and diverse *Vittatina*, resemble those from Tatarian strata in northern European Russia. Two distinct plant microfossil associations occur in the Lower Triassic. One contains large numbers of *Protohaploxypinus*, *Striatoabieites*, *Ephedripites*, *Taeniaesporites* and *Cycadopites* and resembles Griesbachian assemblages described from Canada. It was found only in coarse arkosic sequences occurring south-east of Kap Stosch. Assemblages from the shale-carbonate succession exposed south-west of Kap Stosch are dominated by *Taeniaesporites* and lycopsid spores and are comparable to those from the Early Scythian of Pakistan, Malagasy and Western Australia. It is suggested that the arkosic succession is slightly older than the shale-carbonate sequence and should possibly be referred to a distinct formation.

No palynological evidence indicates extensive reworking of the fine clastic Permian lithotopes developed at Kap Stosch into sediments of the overlying Lower Triassic.

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INTRODUCTION AND ACKNOWLEDGEMENTS

This palynological study is based on samples of Permian and Triassic sediments collected in the area of Kap Stosch, East Greenland, by CURT TEICHERT and BERNHARD KUMMEL. In 1967 they were members of a field party, comprising Danish, American and Swiss geologists, that re-examined the controversial sequence at Kap Stosch and made extensive palaeontological collections. BIRKELUND (1968) described briefly the purpose of the expedition and several palaeontological and stratigraphical papers have been based on its collections and observations (e.g. FLÜGEL, 1973; BIRKELUND & PERCH-NIELSEN, 1976; BENDIX-ALMGREEN, 1976; SWEET, 1976).

TEICHERT & KUMMEL were primarily concerned with the nature of the Permian-Triassic boundary in coastal regions southwest and southeast of Kap Stosch and in the stratigraphical problems that it poses. Two questions, in particular, have been debated since the area was first geologically investigated by J. M. WORDIE & LAUGE KOCH about 50 years ago. One concerns the length of the depositional hiatus that separates basal Triassic strata from the underlying Permian and resolves into a debate on the chronostratigraphic implications of the ammonoid *Cyclolobus kullingi* (FREBOLD). The other relates to the significance of the so-called "mixed faunas", characterised by the presence of typically Permian brachiopods, crinoids, bryozoans and corals, in sediments that also contain *Glyptophiceras* (*Hypophiceras*) *triviale* SPATH and *Otoceras woodwardi boreale* SPATH, which are regarded by most workers as Lower Triassic indices.

TEICHERT & KUMMEL (1972, 1976) discussed these matters in comprehensive accounts that synthesised published information and their own field observations. They concluded that the Permian and Triassic boundary beds are separated by a non-depositional interval representing a substantial part of the Late Permian. They were reluctant to place a firm estimate on its length, but accepted the view of FURNISH (1972) that the presence of *Cyclolobus* indicated a post-Guadalupian age for the "*Martinia* limestone".

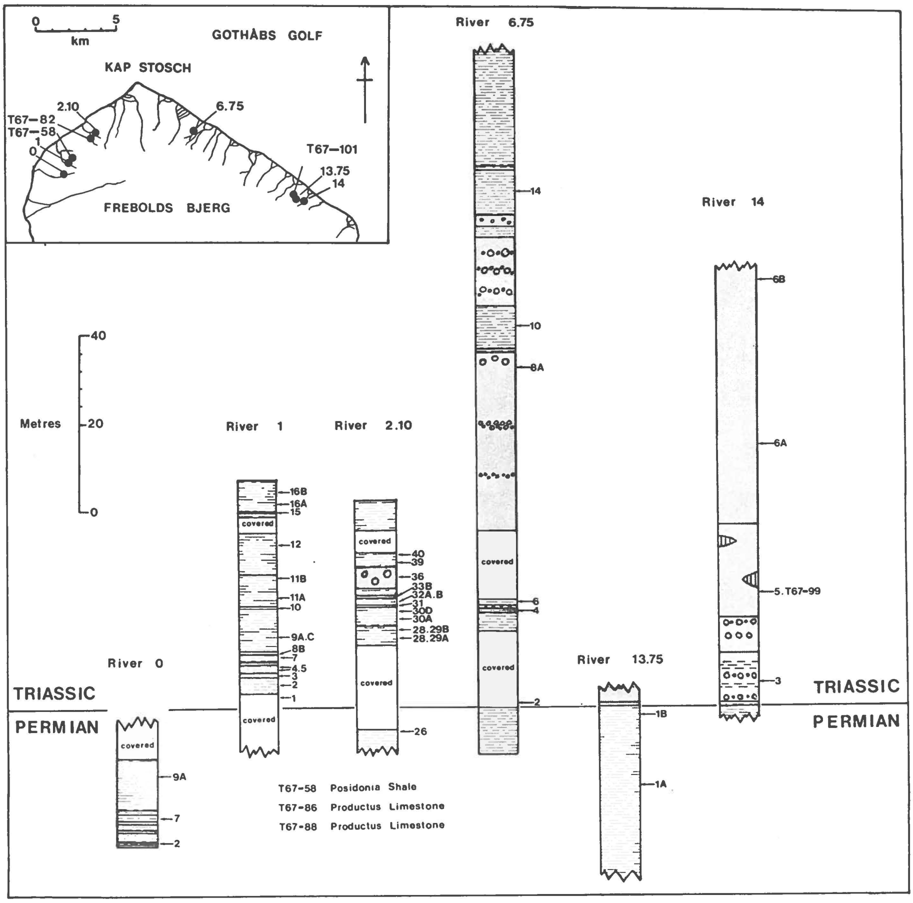

Fig. 1. Localities and relative stratigraphic positions of samples palynologically examined. Data based on TEICHERT & KUMMEL (1976).

In addition, they strongly supported the view that the "mixed faunas" are indeed composites, and that the Permian elements were reworked from *Martinia* shale and shalier portions of the *Productus* limestone.

Material for palynological study was available from six of the seven stratigraphic sections measured by TEICHERT & KUMMEL and described in their most detailed paper (TEICHERT & KUMMEL, 1976). Additional samples representing all the characteristic Permian lithotopes were obtained from localities intermediate between the principal sections. It was not possible to collect a closely spaced series of samples across the Permian-Triassic boundary at any single locality, because outcrops were disturbed by solifluction. Interpretations of palynological data have therefore been based on composite sections, in which the stratigraphic position of Permian samples cannot, in general, be accurately related. Because of this it was not possible to make any useful assessment of the significance of variations in composition among the Permian assemblages. However, they have sufficient common characteristics to justify regarding them as a single unit for the purpose of arguments advanced in this account.

In conclusion I wish to express my thanks to CURT TEICHERT and BERNHARD KUMMEL who suggested the investigation, supplied the samples and provided essential stratigraphic information. Dr. GEOFFREY WARRINGTON, Geological Institute, Leeds, assisted me by providing copies of several important Russian publications.

The paper was written during a six month stay at the Geologisk Institut, Århus Universitet. I am most grateful to the University for its hospitality, to LONE EKLUND who typed the manuscript, BITTEN LARSEN who helped with photomicrography and KAJ RAUNSGAARD PEDERSEN, whose considerable knowledge of Greenland geology and palaeobotany was always available to me. Preliminary laboratory studies were carried out in the Department of Geology, University of Western Australia and were financed partly by a grant from the Australian Research Grants Committee.

LOCALITIES OF SAMPLES EXAMINED

A total of 82 samples was processed for plant microfossils. Of these, 50 yielded sufficient useful palynological material for study, although in many of the productive samples spores and pollen grains were sparse and poorly preserved. Field numbers in the list below refer to the localities and stratigraphic units described by TEICHERT & KUMMEL (1976) and reference should be made to that work for full lithological and palaeontological information. Small samples of untreated sediment from the localities listed are stored in the collections of the Department of Geology, University of Western Australia and smear mounts of the processed residues are retained in the same repository. The principal sampling localities and relative stratigraphic positions of most of the samples listed are indicated in figure 1.

Locality 0: about 2.5–3 km from the mouth of River 0.

T67–73 (=0–2)	(*Martinia* shale)	grey shale	UWA 87694
0–2	(*Martinia* shale)	dark grey silty shale	UWA 62748
0–7	(*Martinia* shale)	dark grey shale	UWA 62749
0–9A	(*Martinia* shale)	grey silty shale	UWA 62749

Locality 1: north side of River 1.

1–1	pale grey limestone	UWA 62758
1–2	dark grey shale	UWA 62753
1–3	grey shale	UWA 62753
1–4	grey argillaceous sandstone	UWA 62754
1–5	grey shale	UWA 62754
1–7	grey shale	UWA 62754
1–8B	dark grey limestone	UWA 62755
1–9A	dark grey shale	UWA 62755
1–9C	grey shale	UWA 62755
1–10	grey sandstone	UWA 62756
1–11A	grey shale	UWA 62756
1–11B	dark grey shale	UWA 62756
1–12	pale grey shale	UWA 62757
1–15	pale grey siltstone	UWA 62757
1–16A	pale grey claystone	UWA 62757
1–16B	pale grey claystone	UWA 62757

River 1: upper section, loose on slope.

T67–86	(*Productus* limestone)	limestone with bryozoan fragments	UWA 87695
T67–88	(*Productus* limestone)	brown calcareous shale	UWA 87695

200 m NE of River 1: 200 m above sea-level UWA 87696

T67–58	(*Posidonia* shale)	brown shale	UWA 87697

River 2: unit 5 of Permian section.

T67–82	(*Posidonia* shale)	brown shale	UWA 87698

Locality 2.1: tributary entering northern bank of River 2.

201–26	(*Posidonia* shale)	dark grey shale	UWA 62763
201–28, 29A		dark grey shale	UWA 62762
201–28, 29B		dark grey shale	UWA 62762
201–30A		dark grey shale	UWA 62763
201–30D		dark grey shale	UWA 62764
201–31		grey limestone	UWA 62764
201–32		grey shale	UWA 62764

Locality 2.1: tributary entering northern bank of River 2.

201–32A	greenish-grey limestone	UWA 62765
201–32B	grey limestone	UWA 62765
201–33B	grey limestone	UWA 62766
201–36A	grey argillaceous sandstone	UWA 62767
201–39	grey silty shale	UWA 62767
201–40A	grey shale	UWA 62767

Locality 6.75: between Rivers 6 and 7.

750(675)–2	grey shale	UWA 62759
750(675)–4	greenish-grey shale	UWA 62759
750(675)–6	greenish argillaceous sandstone	UWA 62760
750(675)–8A	greenish-grey argillaceous sandstone	UWA 62760
750(675)–10	greenish-grey shale	UWA 62761
750(675)–14	greenish-grey shale	UWA 62761

Midway between Rivers 13 and 14.

T67–101	(*Martinia* limestone)	fossiliferous argillaceous limestone	UWA 87699

Locality 13.75: about 300 m N of River 14.

1375–1A	(*Posidonia* shale)	black shale	UWA 62750
1357–1B	(*Posidonia* shale)	black shale	UWA 62750

Locality 14: SW bank of River 14.

14–3	grey argillaceous sandstone	UWA 62752
14–5	grey argillaceous sandstone	UWA 62752
T67–99 (=14–5)	grey argillaceous sandstone	UWA 87700
14–6A	greenish-grey shale	UWA 62752
14–6B	greenish-grey shale	UWA 62752

SAMPLE PREPARATION AND PALYNOLOGICAL PROCEDURES

Carbonates were removed by allowing 4–5 g of crushed sediment to stand in warm dilute HCl until evolution of CO_2 had ceased. The disintegrated sedimentary material was then treated with cold HF (40%) for 48 hours and the residue subsequently oxidised for 3–5 minutes with conc. HNO_3. The alkali soluble organic fraction was then removed, using warm dilute (5%) NaOH. Heavy minerals, principally zircon and tourmaline, were common in some of the samples and could not be removed by chemical means. In these the organic and inorganic fractions were separated physically, using $ZnCl_2$ solution as a medium, after the alkali treatment was complete.

Most of the assemblages were poorly preserved, apparently mainly as a result of biological processes during early diagenesis. Many specimens showed the characteristic triangular pits associated with pyrite authigenesis (cf. pl. 2, fig. 15) and the sculpture of cryptogram spores was often partially or totally removed. Specimens from the Permian *Posidonia* shale were not generally corroded, but their surface features had a curiously blurred appearance, as though they had been slightly deformed plastically.

Spinose acritarchs were present in every assemblage, although they were not common in those from the *Posidonia* shale or in the Triassic samples from Locality 14. In general the acritarchs were considerably better preserved than the spores and pollen grains with which they were associated. Possibly they are less susceptible to biological attack, but their lesser degradation may simply reflect a different sedimentary history.

Assessment of the relative proportions of acritarchs in each of the microfossil assemblages were based on counts of about 150 specimens in which the only categories recorded were spinose acritarchs, spores and pollen grains. A second count of 150–200 specimens was then carried out in order to prepare estimates of the quantitative composition of the spore-pollen assemblage.

PLANT MICROFOSSIL ASSOCIATIONS

Three distinct plant microfossil assemblages were recovered from the samples from Kap Stosch. These have been designated Associations rather than Assemblages, because the latter term has been occasionally used to refer to composite biostratigraphic units, defined on palynological criteria. The *Vittatina*-Association was found in all the Permian samples examined but did not occur in any from the Triassic. It is therefore older than the other two, from which it is distinguished by qualitative and quantitative differences. Triassic assemblages were referred to either the *Protohaploxypinus*-Association or the *Taeniaesporites*-Association, which were distinguished principally on the basis of quantitative characteristics. Figure 3 illustrates diagrammatically the broad composition of the three Associations and figure 2 shows their known distribution in the succession at Kap Stosch. A more detailed discussion of the composition, distribution and significance of the three Associations is given in the paragraphs that follow.

Vittatina-Association

Composition

The *Vittatina*-Association occurred in 12 samples, all from the Permian sequence. Twenty-three species were recorded as components of the Association, and with the exception of *Pilasporites* sp. and *Inaperturopollenites nebulosus*, which may have originated from non-vascular plants, all were pollen grains. A few trilete spores were seen in the assemblages, but these were so rare and indistinctive that they could not usefully be referred to taxonomic categories. In most assemblages from the *Vittatina*-Association diversity was low and the only forms that were recorded from all twelve samples were *Pilasporites* sp., *Vittatina striata* JANSONIUS, *V. subsaccata* WILSON and *Alisporites* spp. The following species were found only in assemblages of the *Vittatina*-Association:

Inaperturopollenites nebulosus BALME
Vittatina minima JANSONIUS
Alisporites cf. *nuthallensis* CLARKE
cf. *Florinites luberae* SAMOILOVITCH
Falcisporites cf. *zapfei* POTONIÉ & KLAUS
Scutasporites cf. *unicus* KLAUS

Specimens of *Vittatina striata* JANSONIUS, *V. subsaccata* WILSON and *Lueckisporites virkkiae* POTONIÉ & KLAUS occurred extremely rarely in assemblages of the *Protohaploxypinus*-Association and may represent reworked Permian elements.

Quantitatively, the character that most readily distinguished the Permian assemblages was their high content of various species of *Vittatina*. Proportions of the genus fluctuated fairly markedly. The lowest percentage recorded was 7 % at locality 0–7 (*Martinia* shale) and the highest 37 % from T67–86 (*Productus* limestone) at River 1. In most of these assemblages, species of *Vittatina* (principally *V. striata*) composed about 20% of the total spore pollen suite.

Spinose acritarchs occurred in all assemblages belonging to the *Vittatina*-Association and were abundant in samples representing the *Martinia* shale and *Productus* limestone lithotopes. They were relatively uncommon in the three samples examined from the *Posidonia* shale facies, possibly because this lithotope represents sediments deposited in environments in which the normal marine circulation was physically restricted (MAYNC, 1962).

Distribution

The *Vittatina*-Association occurred in all the Permian samples that yielded plant microfossils. These included four samples from *Martinia* shale at Locality 0, which contained the *Neogondolella rosenkrantzi* conodont fauna (SWEET, 1976). The *Vittatina*-Association was also found in a single sample from Locality 2.10, where it occurred in *Posidonia* shale about 15 m below the lowest occurrence at that locality of the Triassic *Taeniaesporites*-Association. Poorly preserved examples of the *Vittatina*-Association were recovered from *Martinia* shale at Locality 13.75, also in conjunction with the *Neogondolella rosenkrantzi* fauna. Its other occurrences were in isolated samples collected at localities intermediate between TEICHERT & KUMMEL's measured sections. One of these, from the *Martinia* limestone (T67–101, mid-way between Rivers 13 and 14), yielded the best preserved and most diverse example of the Association.

Age and implications

The sharp palynological break at the Permian-Triassic boundary in east Greenland confirms the view of most recent authors that an unconformity separates the two systems. It also lends further support to TOZER's (1969) contention that no marine sequence transitional from Permian to Triassic is known anywhere in the world.

There is debate among palaeontologists concerning the age of the Permian sequence at Kap Stosch, but all appear to agree that it is "Upper" Permian in terms of the Russian standard scale. That is, it lies within the interval Ufimian (WATERHOUSE, 1972) to Tatarian (FURNISH & GLENISTER, 1970), if a partial correlation between the latter Stage and the Araksian is accepted.

Palynological arguments cannot at present conclusively resolve the controversy. The complexities of Late Palaeozoic phytogeography make it difficult to interpret Permian palynological data from remote areas in chronostratigraphic terms. In addition, there is little published information on the palynology of successions that can be correlated with assurance with the various marine Upper Permian Stages that have been proposed. Despite these basic difficulties certain important provisional conclusions are possible.

It is clear, for example, that the Kap Stosch assemblages have little in common with those from the European "Zechstein". These have now been intensively documented and VISSCHER (1973) has reviewed the published data and considered their stratigraphic implications. Some characteristic elements of "Zechstein" assemblages, such as *Lueckisporites virkkiae* POTONIÉ & KLAUS, *Limitisporites* sp., *Taeniaesporites noviaulensis* LESCHIK and *Striatoabieites richteri* (KLAUS) occurred as minor components of the Permian assemblages at Kap Stosch. Others, like *Nuskoisporites dulhuntyi* POTONIÉ & KLAUS and *Klausipollenites schaubergeri* (POTONIÉ & KLAUS), were not recorded. Conversely, *Vittatina striata* JANSONIUS, one of the most distinctive elements at Kap Stosch, has not been reported from "Zechstein" assemblages. The only published North American assemblage containing undoubted examples of *Vittatina striata* and *V. minima* JANSONIUS, came from the Belloy Formation, western Canada (JANSONIUS, 1962), which is thought to be Leonardian-Guadalupian. Assemblages from the Belloy Formation are not sufficiently diverse to allow useful comparisons to be made with Greenland, but they contain typical *Hamiapollenites*, a characteristic Early Permian and early Guadalupian genus from the United States midcontinent, which was not found at Kap Stosch.

The closest analogues to the assemblages of east Greenland occur in Upper Permian strata, in the northern regions of European Russia. These have been the subject of numerous comprehensive accounts. Papers by VARYUKHINA (1971) and MOLIN & KOLODA (1972), with many excellent photomicrographs, provide especially useful bases for palynological comparisons. These Late Permian assemblages, ranging from Ufimian to Tatarian, have an essential unity, in that they all contain an abundance of diverse species of *Vittatina* and taeniate disaccate pollen grains. However, the Tatarian is identifiable by its low content of cryptogram spores and *Cordaitina* pollen and by the presence in small numbers of *Lueckisporites virkkiae* and *Taeniaesporites noviaulensis*. In all these respects northern Russian Tatarian assemblages resemble the *Vittatina*-Association. There are other similarities of detail and additional common forms include *Florinites luberae* SAMOILOVITCH, *Pilasporites* sp., *Limitisporites* spp. and possibly *Scutasporites* cf. *unicus* KLAUS, which resembles the form illustrated by MOLIN & KOLODA as *Taeniaesporites ortisei* KLAUS.

Although the Tatarian sequence in northern European Russia

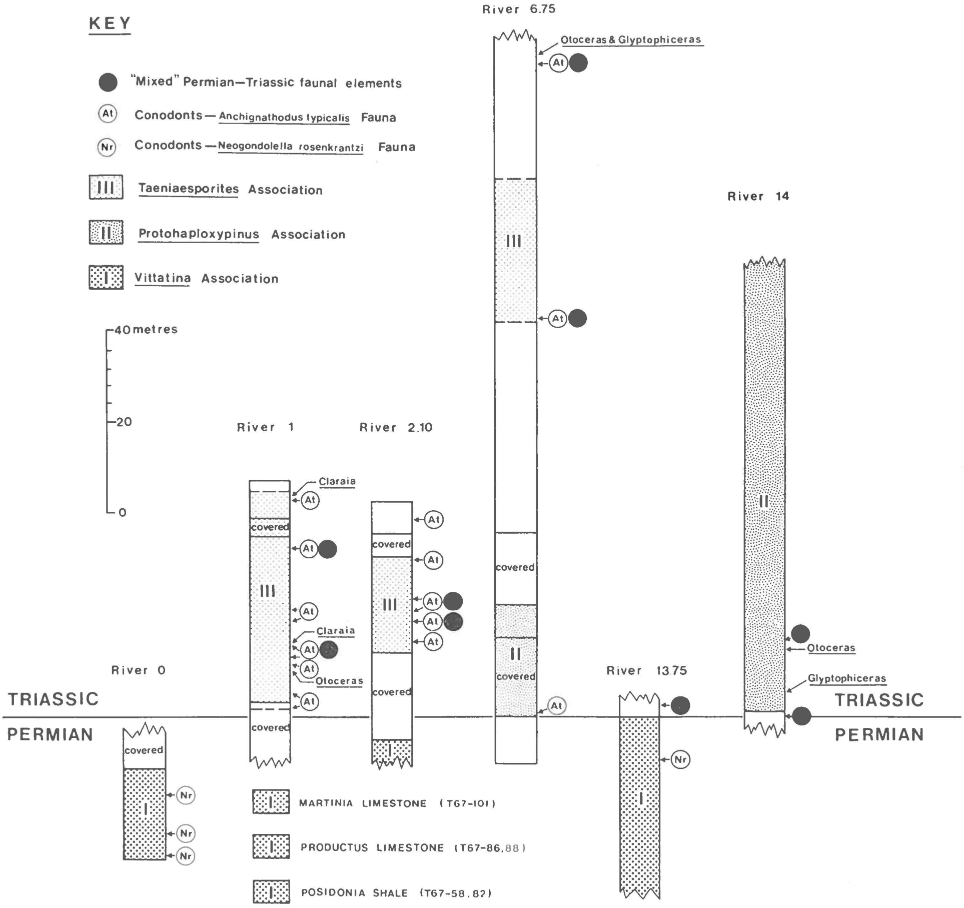

Fig. 2. Distributions of the three plant microfossil associations in the sections studied. Palaeontological controls summarised in the diagram are based on TEICHERT & KUMMEL (1976) and SWEET (1976).

represents the youngest Permian in the region it is separated from the overlying Triassic by a discordance. Because of this, its age in relation to Permian marine stages is somewhat uncertain, but it is unlikely to be as old as Guadalupian. Palynological evidence therefore supports the view that the youngest Permian sediments at Kap Stosch are Dzulfian (in the sense of FURNISH, 1972). It would, however, be dogmatic to say that it confirms it, while the patterns of Late Permian phytogeography in North America are still so poorly understood.

***Protohaploxypinus*-Association**

Composition

Twenty pollen and four spore species were recognised in the eight assemblages referred to the *Protohaploxypinus*-Association. The spore species identified were *Lundbladispora obsoleta* BALME, *Densoisporites playfordi* BALME, *Kraeuselisporites apiculatus* JANSONIUS and *Proprisporites pocockii* JANSONIUS. These are all trilete, cavate, forms and probably derived from lycopsids. The following 5 categories occurred in all assemblages belonging to the *Protohaploxypinus*-Association:

Cycadopites follicularis WILSON & WEBSTER
Ephedripites spp.
Protohaploxypinus samoilovitchii (JANSONIUS) —
  P. jacobii (JANSONIUS)
Striatoabieites richteri (KLAUS)
Taeniaesporites noviaulensis LESCHIK

These forms showed pronounced variations in their relative abundance from sample to sample. *Ephedripites* spp. composed 47 % of the total spore-pollen assemblage from Sample 14–6A, but was a minor component in those from 14–5, 6.75–4 and 6.75–6. *Striatoabieites richteri* was abundant in assemblages from localities 14–3 and 14–5 but less common in samples from the upper part of the section at locality 14 and in those from locality 6.75. Spinose acritarchs were present in all assemblages representing the *Protohaploxypinus*-Association but, in general, were less abundant than in either the *Taeniaesporites*- or *Vittatina*-Association. In samples from locality 14 acritarchs never accounted for more than 5 % of the total plant microfossil suite. They were more common in assemblages representing the *Protohaploxypinus*-Association at locality 6.75 and in Sample 6.75–2 made up nearly 40 % of the total count.

Distribution

The *Protohaploxypinus*-Association was found only in Triassic samples from localities 6.75 and 14, both in the coastal area south-east of Kap Stosch. At River 14 it is apparently present throughout the Triassic section sampled by TEICHERT & KUMMEL, a stratigraphic thickness of over 90 m. Here it occurs in strata that contain *Otoceras* and *Glyptophiceras* (*Hypophiceras*) *triviale* SPATH, as well as diverse, fragmentary, "Permian" invertebrates. In the succession at River 6.75 only the samples from the lower part (units 2, 4 and 6) contained the *Protohaploxypinus*-Association. These were associated with the *Anchigna-*

thodus typicalis conodont fauna (Sweet, 1976) but *Otoceras* and *Glyptophiceras* have not been found below unit 14, which yielded the *Taeniaesporites*-Association. The boundary between the Permian and Triassic is not exposed at locality 2.1 and hence no material was available for palynological study from about the basal 15 m of the Triassic succession. It is possible that the *Protohaploxypinus*-Association occurs in this unsampled interval, for assemblages from units 28, 29 and 30 at locality 2.1 contain high proportions of *Protohaploxypinus* and in this respect appear transitional between the *Protohaploxypinus*- and *Taeniaesporites*-Association. At River 1, however, the lowest Triassic assemblage (1–1) clearly belongs to the *Taeniaesporites*-Association and cannot be more than a few metres above the top of the Permian. Consequently it is unlikely that the *Protohaploxypinus*-Assciation occurs in strata at this locality.

Age and implications

To most stratigraphers the presence of *Otoceras woodwardi boreale* Spath, in strata that contain the *Protohaploxypinus*-Association, indicates indisputably an Early Triassic age. Nevertheless the association of *Striatoabieites richteri* (Klaus), *Taeniaesporites noviaulensis* Leschik and various species of *Protohaploxypinus* is, in Europe, more typical of "Zechstein" than of Early Triassic strata. In the Gondwana region, marine Early Scythian strata contain assemblages dominated by lycopsid spores and *Taeniaesporites* that are closely similar to the *Taeniaesporites*-Association of Kap Stosch. According to Visscher (1973) these Gondwana assemblages strikingly resemble those from European strata correlated with the Russian Vetlugian. Accepting that the *Protohaploxypinus*-Association is Early Scythian (or Lower Griesbachian in the Canadian scale) there seem three possible explanations to account for its composition, namely:

1. It has a high content of reworked Permian plant microfossils. This might be expected if the mechanism of transport by armoured mud-balls proposed by Teichert & Kummel (1976) is correct.

2. Strata containing the *Protohaploxypinus*-Association at Kap Stosch are Early Griesbachian and older than the marine Triassic deposits studied from the Salt Range (Balme, 1970), Madagascar (Goubin, 1965) and Western Australia (Balme, 1963; Dolby & Balme, 1976). The *Protohaploxypinus*-Association would thus be interpreted as representing a short-lived transitional flora that existed at the onset of the Early Triassic transgression.

3. It existed coevally with the *Taeniaesporites*-Association at Kap Stosch and its analogues elsewhere, and the compositional differences result from local and regional phytogeographic factors.

Dealing in turn with each of these possibilities:

1. *Vittatina* is extremely rare in the *Protohaploxypinus*-Association and nothing else suggests that it contains large numbers of reworked microfossils derived from Permian lithotopes developed at Kap Stosch. If a high proportion of reworked microfossils is present they must have originated from Permian sediments, younger than the *Martinia* shale and its equivalents, that were being rapidly eroded during the Early Triassic. This hypothesis seems unnecessarily complex and I believe that it is unlikely, for reasons that will be subsequently discussed. Palynological evidence does not therefore support the view that large quantities of unweathered fine clastic material from Permian sediments have been incorporated into the Lower Triassic. The conclusion has little direct bearing on the origin of the "mixed" faunas. Large invertebrate fragments and plant microfossils are sedimentary particles of quite different orders.

2. Two Early Triassic plant microfossil assemblages from Canada are especially relevant to a consideration of the significance of the *Protohaploxypinus*-Association. One came from the lower part of the Toad-Grayling Formation, penetrated by boreholes in the Peace River district, western Canada (Jansonius, 1962). The other, which was illustrated but not described by McGregor (1965), was from outcrops of the Bjorne Formation, northern Ellesmere Island. Griesbachian faunas have been reported from the Toad-Grayling Formation (Tozer, 1967), almost certainly from stratigraphic horizons higher than those studied by Jansonius, and *Otoceras* occurs in the Bjorne Formation (Tozer, 1967). Both the Canadian assemblages are therefore likely to be Early Griesbachian. They compare closely with the *Protohaploxypinus*-Association, especially those from the Toad-Grayling Formation, in which lycopsid spores, *Striatoabieites richteri* (Klaus), *Protohaploxypinus samoilovitchii* (Jansonius), *P. jacobii* (Jansonius) *Ephedripites* spp., *Taeniaesporites* spp. and *Cycadopites* spp. are all common. On the basis of comparisons with these Canadian assemblages the composition of the *Protohaploxypinus*-Association is therefore entirely consistent with an Early Griesbachian age. There is thus no need to invoke reworking to explain the presence of the large numbers of *Striatoabieites richteri* and *Protohaploxypinus* spp. in basal Triassic strata at some localities at Kap Stosch.

3. Stratigraphic relationships between the coarse clastic succession that forms the lower part of the Triassic south-east of Kap Stosch and the carbonate-shale sequence that immediately overlies the Permian in south-western coastal areas, cannot be resolved with certainty. Nevertheless, it seems unlikely from the palynological evidence that the two

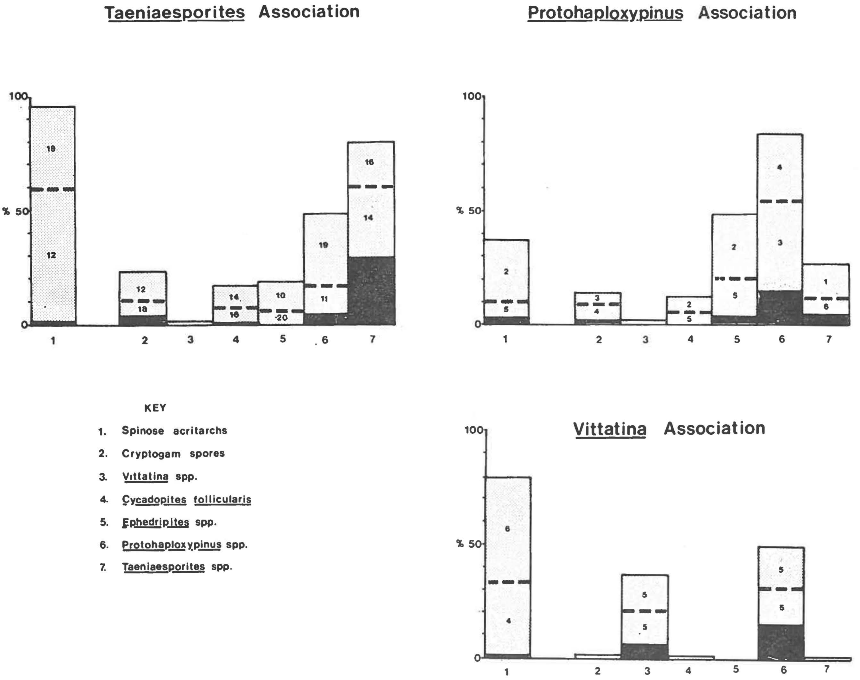

Fig. 3. Generalised composition of the three plant microfossil associations recognised. Proportions of spinose acritarchs have been calculated as a percentages of total plant microfossil assemblage. Relative proportions of the spore and pollen groups are shown as percentages of the assemblage, excluding spinose acritarchs. Lighter stippled areas in the histograms indicate the range of percentile values for each morphological group and heavy broken lines show arithmetic means of these values. Distribution of values about the arithmetic mean is indicated by numerals above and below the broken line. Thus in 30 assemblages representing the *Taeniaesporites*-Association 18 contained more than 60% acritarchs and 12 less.

lithologically distinct sequences represent coeval, lateral facies variants. The *Protohaploxypinus*-Association was found only in the south-eastern sections, where it occurred throughout the entire sampled interval of about 90 m at locality 14, and over about 20 m at the base of the Triassic at locality 6.75. Triassic samples from localities 1 and 2.1 in the south-west, and from the upper part of the sequence at locality 6.75, all contained the *Taeniaesporites*-Association. Sediments yielding the *Protohaploxypinus*- and *Taeniaesporites*-Associations were not intercalated in any of the sections studied, which suggests that the two distinct assemblages are not simply manifestations of reversible changes of local vegetational patterns. This inference is re-inforced by the regional occurrence of plant microfossil assemblages similar to the *Protohaploxypinus*-Association in basal Triassic strata from widely separated parts of mainland Canada and the Arctic islands.

These are persuasive reasons for regarding the *Protohaploxypinus*-Association as older than the *Taeniaesporites*-Association, which occurs at higher stratigraphic horizons at locality 6.75. However, the age difference cannot be great, and the *Protohaploxypinus*-Association represents a transitional, unstable, coastal flora that became established for a short time during the earliest Griesbachian. Hence the coarse arkosic and conglomeratic strata developed to the south-east presumably pinch out in a north-westerly direction and are over-stepped by younger Griesbachian, finer grained rocks of more marine aspect. These contain the *Taeniaesporites*-Association.

As Teichert & Kummel hinted (1976, p. 14), it may be desirable to refer the coarse clastic sequence to a distinct formation from the basal Triassic strata exposed to the south-west of Kap Stosch.

***Taeniaesporites*-Association**

Composition

The *Taeniaesporites*-Association was less diverse than the other two and only nineteen taxa were recorded from thirty assemblages. With the exception of *Densoisporites nejburgii* (Schulz) Balme and *Endosporites* spp., both of which were rare, all these nineteen forms also occurred in the *Protohaploxypinus*-Association. The constant quantitative characters that distinguished the *Taeniaesporites*-Association were its high content of *Taeniaesporites noviaulensis* Leschik and *T. pellucidus* (Goubin) Balme. These two species occurred abundantly in every sample and together were invariably the dominant elements of the plant microfossil suite (cf. figure 3). The other taxa that occurred in all examples of the *Taeniaesporites*-Association were:

Lundbladispore obsoleta Balme
Cycadopites follicularis Wilson & Webster
Ephedripites spp.
Klausipollenites staplinii Jansonius

Spinose acritarchs, principally small species of *Veryhachium*, *Baltisphaeridium* and *Micrhystridium*, were, as a rule, most abundant in assemblages representing the *Taeniaesporites*-Association. In almost all assemblages they made up more than 50% of the total plant microfossil suite and the only samples in which they were not common were 6.75–8A (1%) and 6.75–14 (2%). Cyst-like vesicles, referred to *Tympanicysta stoschiana* gen. et sp. nov., occurred more regularly in the *Taeniaesporites*-Association, especially in samples from locality 6.75. Assemblages from locality 1 contained large fragments of acid insoluble plant tissue that resembled cuticle in colour and gross appearance but lacked clearly defined cell outlines. These are the "laminar bodies" noted by Teichert & Kummel (1976) and appear to be algal fragments.

Distribution

The *Taeniaesporites*-Association occurred in 16 samples from locality 1, sampled over a stratigraphic interval of about 40 m, beginning a few metres above the obscured Permian-Triassic boundary. Elements of the *Anchignathodus typicalis* conodont fauna are distributed throughout the interval (Sweet, 1976) and the ammonoids *Otoceras* and *Glyptophiceras* (*Hypophiceras*) were found in unit 6, about 5 m above its base. *Claraia* has also been reported from units 9 and 16 at locality 1 (Teichert & Kummel, 1976).

All the assemblages examined from locality 2.10 have also been referred to the *Taeniaesporites*-Association although, as noted previously, those from units 28, 29 and 30 contained relatively high proportions of *Protohaploxypinus*. At locality 6.75 the *Taeniaesporites*-Association occurred over an interval ranging from the upper part of unit 8 to the middle of unit 14. Strata in which it is present are, at this locality, younger than those containing the *Protohaploxypinus*-Association which was found in units 2, 4 and 6. It is not possible to determine stratigraphic relationships of the *Protohaploxypinus*- and *Taeniaesporites*-Association at locality 6.75 accurately because their occurrences are separated by a stratigraphic interval about 40 m thick from which no material was studied palynologically.

Age and implications

Otoceras, *Glyptophiceras* (*Hypophiceras*) and the *Anchignathodus typicalis* conodont fauna occurred sporadically in the three sequences from which the *Taeniaesporites*-Association was recovered. *Claraia* is also associated with it at two horizons in the section at River 1, so that its Griesbachian age is clear from palaeontological evidence. This accords with the palynological results, perhaps remarkably, considering that the conclusion is principally based on comparisons with remote regions of Tethyan Gondwana. The oldest marine Triassic strata studied from Pakistan (Balme, 1970), Malagasy (Goubin, 1965) and Western Australia (Balme, 1963; Balme & Helby, 1973; Dolby & Balme, 1975) have all yielded plant microfossil assemblages of low diversity, dominated by spinose acritarchs, lycopsid spores and species of *Taeniaesporites*. There is no doubt that they were produced by plant communities of essentially similar structure to those represented in Greenland by the *Taeniaesporites*-Association. Balme & Helby (1973) discussed the evolutionary significance of these extraordinarily widespread Early Scythian assemblages and suggested that they represent spores and pollen grains of pioneer Triassic plant formations, established in coastal regions throughout the world, following collapse of mature Permian ecosystems. In east Greenland, stabilization of typically Triassic plant communities appears to have occurred during the Early Griesbachian rather than at the beginning of the Stage. The *Protohaploxypinus*-Assemblage, which characterises the earliest Griesbachian, may then represent a transitional flora, containing a substantial proportion of elements that elsewhere are more typical of the Permian.

Assemblages with transitional characters, comparable to those exhibited by the *Protohaploxypinus*-Association, have not been found in any of the marine Triassic sequences examined from the Gondwana region. This may indicate that the oldest marine Triassic rocks that have yet been palynologically studied from Pakistan, Malagasy and Western Australia, are younger than Early Griesbachian. On the other hand, their absence may simply relate to patterns of phytogeography during earliest Triassic time. These are questions that cannot be decided until further data have become available.

SYSTEMATIC DESCRIPTIONS AND COMMENTS

Introductory notes

It was possible to refer all the commonly occurring spores and pollen grains in the Kap Stosch assemblages to existing taxa. Forms that appear to be undescribed were too rare to serve as bases for clearly circumscribed new species and the quality of preservation of most assemblages was unsatisfactory for taxonomic innovation. The systematic comments that follow are therefore principally explanatory and intended to clarify the nomenclatural concepts that have been adopted. The only new taxon introduced is *Tympanicysta stoschiana* gen. et sp. nov. This embraces a group of organic-walled microfossils of uncertain relationships and is defined on the basis of characters that do not require well-preserved material for their determination.

Estimates of frequency given under the heading "Distribution" were based on counts of between 100 and 200 specimens using permanent smear mounts. Most of the counts were very imprecise because the assemblages were so poorly preserved. Frequencies are indicated in the following way.

S (sporadic) — not recorded in some assemblages
VR (very rare) — not appearing in counts but observed during examination of additional slides
R (rare) — < 1 % of assemblage
C (common) — 1 %–9 % of assemblage
A (abundant) — 10 %–40 % of assemblage
D (dominant) — > 40 % of assemblage

Microfossils incertae sedis

Genus: *Pilasporites* Balme & Hennelly, 1956
Pilasporites sp.
(pl. 2, fig. 1)

Description. — Alete, simple, outline circular or sub-circular, distorted by compressional folds in most specimens. Wall about 1 µm thick, smooth and without visible structure.

Dimensions (20 specimens): diameter 36–52 µm (mean 45 µm).

Discussion. — Some of these morphologically indistinctive forms may be non-motile algal cysts, others probably represent the stripped intexine of saccate pollen grains or of species of *Vittatina.* Similar bodies have been frequently recorded from the Upper Permian and Lower Triassic of the U.S.S.R. and have usually been assigned by Russian palynologists to *Azonaletes*, a genus attributed to Luber and Val'ts.

Distribution: *Vittatina*-Association, VR–C; *Protohaploxypinus*-Association, S–R.

Genus: *Inaperturopollenites* Thomson & Pflug, 1953
Inaperturopollenites nebulosus Balme, 1970
(pl. 1, figs. 1, 2)

Despite the implication of the generic name there is no necessary suggestion that these thin-walled, inaperturate bodies are the spores or pollen grains of vascular plants. They possess a scabrate sculpture and most specimens are ruptured. The species was described from the Upper Permian (Chhidruan) of Pakistan (Balme, 1970) and the specimens from Greenland conform with the original diagnosis, except that they are generally a little larger. Twenty measured specimens from Sample T67–101 ranged in diameter from 75–110 µm, compared to a range 71–82 µm in the type material from the Chhidru Formation in the Salt Range.

Distribution: *Vittatina*-Association, S–C.

Genus: *Tympanicysta* Balme gen. nov.

Diagnosis. — Cyst-like microfossils occurring as isolated individuals or linked into short linear chains. Individual vesicles hollow or containing small masses of amorphous material, which in some specimens simulate the shrunken shape of the enclosing vesicle. Vesicles originally subcylindrical, ovoid, fusiform or clavate; wall inaperturate, about 2 µm thick, without sculpture or obvious internal structure. A rim-like thickening of the wall, surrounding a shallow depression, is developed at both extremities in most specimens, but in some it occurs only at one. When they occur in chains the vesicles are joined along the crests of adjacent terminal rims. The length of the major axis of individual vesicles varies between about 50 µm and 250 µm and the ratio of length to maximum diameter is variable. Some specimens are long and slender, others short and stout.

Type species: *Tympanicysta stoschiana* BALME sp. nov., Lower Triassic, Greenland.

Comparisons. — *Foveofusa* LELE & CHANDRA from the Lower Permian of India (LELE & CHANDRA, 1972) is the only closely similar genus described previously. In *Foveofusa*, however, the wall is perforate and often bears fine striations. In addition LELE & CHANDRA did not report the occurrence of linked chains in any of the descriptions of their seven species of *Foveofusa*, none of which possesses the rim-like terminal thickenings that characterise *Tympanicystia.*

HOROWITZ (1972) described and illustrated a fusiform body from the Upper Permian of Israel which he referred to the species *Desmochitina elongata* HOROWITZ, 1972, a taxon that appears to be invalid as it lacks a designated type. From the single illustration provided, *Desmochitina elongata* closely resembles some of the vesicles referred here to *Tympanicysta* and in his description HOROWITZ mentions its occurrence in short chains. The only distinguishing feature may be the presence of terminal openings in *D. elongata.*

Discussion. — There is little doubt that *Tympanicysta* represents a mechanism for encystment, but its biological affinities are quite uncertain. If it derives from the plant kingdom it may represent a stage in a fungal or algal cycle, but there seems an equal possibility that it is of animal origin.

Tympanicysta is widespread in Late Permian and Early Triassic strata. It occurs commonly in the Sadlerochit Formation, northern Alaska and in Zechstein sediments from Conisborough, Yorkshire, England (BALME, unpublished data). Small numbers are also present in the Lower Triassic of Pakistan and Dr. R. J. HELBY (personal communication) has recorded the genus from strata of the same age in the Bonaparte Gulf Basin, Western Australia. JANSONIUS & HILLS (1977) in their comments on the genus *Foveofusa* noted the common occurrence of vesicles, which from their description undoubtedly belong to *Tympanicysta*, in the Permian of Canada and Europe.

Tympanicysta stoschiana Balme sp. nov.

(pl. 1, figs 3–7)

As the genus is at present monotypic the generic circumscription also serves as a description of the type species, *Tympanicysta stoschiana*.

Dimensions (20 measured individual vesicles): length 72–180 µm, maximum breadth 36–96 µm.

Holotype: Pl. 1, fig. 7, UWA 87701, locality 6.75–14 (field no. 750–14), Lower Triassic, Kap Stosch, Greenland. Specimen consisting of two linked vesicles with sub-quadrilateral outlines, following compression.

Dimensions of the larger vesicle are 105 × 62 µm and of the smaller 75 × 58 µm.

Distribution: *Protohaploxypinus*-Association, S–VR, *Taeniaesporites*-Association, S–C.

Trilete spores

Genus: *Lundbladispora* Balme, 1963

Lundbladispora obsoleta Balme, 1970

(pl. 2, figs 22–23)

Cavate, rimulate, trilete spores, with a finely spongeous exoexine and principally distal spinose sculpture, occurred in almost all assemblages from the Lower Triassic sequence. Tetrads were common in some samples. Size and form of the sculptural elements varied markedly from specimen to specimen, but well-preserved specimens usually processes consisting of a mammilloid base surmounted by a finer spine. The finely textured exoexine seems especially susceptible to preservational damage and specimens assigned to the species show an apparent wide range of sculpture.

Lundbladispora obsoleta belongs to the group of sculptured trilete spores of lycopsid aspect that is commonly represented in Early Triassic strata in many parts of the world. It includes *Lundbladispora willmottii* Balme from Western Australia, *Aculeisporites variabilis* Jansonius from western Canada and the European species *Kraeuselisporites ullrichi* Reinhardt and Schmitz.

Distribution: *Protohaploxypinus*-Association, S–A; *Taeniaesporites*-Association, VR–A.

Genus: *Kraeuselisporites* Leschik, 1955

Kraeuselisporites apiculatus Jansonius, 1962

(pl. 2, fig. 25)

Trilete spores with a thin equatorial zona and spinose distal sculpture were minor components of some of the Lower Triassic assemblages. They have been referred to *Kraeuselisporites apiculatus* JANSONIUS, but could with equal reason have been assigned to a number of other validly named taxa that encompass forms of essentially similar morphology.

Distribution: *Protohaploxypinus*-Association, S–R; *Taeniaesporites*-Association, S–R.

Genus: *Densoisporites* WEYLAND & KRIEGER, 1953
Densoisporites playfordi (BALME) DETTMANN, 1963
(pl. 2, fig. 24)

Specimens assigned to *Densoisporites playfordi* include forms with a finely granulate exoexine that do not strictly conform with the diagnosis of the species. However, they have the same gross morphology as *D. playfordi* and are considered to be preservational variants of this widely distributed Early Triassic species. *Densoisporites playfordi* is also almost certainly lycopsid in origin and dispersed microspores of the heterosporous strobilis *Selaginellites polaris* LUNDBLAD would be assigned to the species. The type material of *Selaginellites polaris* came from Lower Triassic strata exposed at Steensby Bjerg, Hold-with-Hope, about 50 km SSE of Kap Stosch (LUNDBLAD, 1948).

Distribution: *Protohaploxypinus*-Association, S–C; *Taeniaesporites*-Association, S–R.

Densoisporites nejburgii (SCHULZ) BALME, 1970
(pl. 2, figs 19, 20)

Densoisporites nejburgii is a category that includes the dispersed spores of the Early Triassic lycopod *Pleuromeia rossica* NEUBERG. Spores of this type are common in Lower Triassic sediments of central Europe and northern European Russia (SCHULZ, 1964; ORLOWSKA-ZWOLINSKA, 1977; TSCHALYSHEV & VARYUKHINA, 1962). They have also been reported from the Lower Triassic of Pakistan and the form described and illustrated by JANSONIUS (1962) as *Lycospora* sp. T may also represent *D. nejburgii*.

Distribution: *Taeniaesporites*-Association, S–R.

Genus: *Endosporites* WILSON & COE, 1940
Endosporites sp.
(pl. 2, fig. 18)

A few specimens were encountered which resembled *Densoisporites playfordi* in general morphology except that their exoexine was relatively thin with a fine rather regular intragranulate structure. They are referable to the genus *Endosporites* which is also at least partly lycopsid.

Distribution: *Taeniaesporites*-Association, S–R.

Genus: *Proprisporites* Neves, 1958
Proprisporites pocockii Jansonius, 1962
(pl. 2, fig. 21)

Proprisporites pocockii is a distinctive trilete cavate species with a thin, finely plicate exoexine which closely envelopes a darker, more rigid intexine. In compressed specimens the exoexine projects at the equator and simulates a narrow, hyaline, zona. The species was originally described from the lower part of the Toad-Grayling Formation of western Canada (Jansonius, 1962). This is the first record from outside Canada.

Distribution: *Protohaploxypinus*-Association, S–R; *Taeniaesporites*-Association, S–VR.

Non-saccate pollen grains

Genus: *Cycadopites* Wodehouse ex Wilson & Webster, 1946
Cycadopites follicularis Wilson & Webster, 1946
(pl. 2, figs 2–3)

Monosulcate pollen grains, with a thin exine that lacks observable, clearly defined structure under high power oil immersion objectives, were common in most of the Triassic assemblages from Kap Stosch, although their relative abundance fluctuated markedly from sample to sample. Pollen grains with this simple generalised morphology occur in several distinct gymnosperm groups and they have a wide stratigraphic distribution. They are nevertheless especially common in Lower Triassic sediments in widely separated regions (cf. Jansonius, 1962; Balme, 1970; Visscher, 1973).

Distribution: *Vittatina*-Association, S–VR; *Protohaploxypinus*-Association VR–A; *Taeniaesporites*-Association, VR–A.

Genus: *Ephedripites* Bolkhovitina ex Potonié, 1958
Ephedripites sp.
(pl. 2, fig. 4)

Monosulcoid pollen referred to *Ephedripites* sp. and possessing numerous longitudinal ribs separated by narrow grooves, was recorded from all the Lower Triassic assemblages and, as a rarity, in two from the Permian. Like those of *Cycadopites follicularis*, the proportions of *Ephedripites* sp. varied sharply from sample to sample, but the species was especially abundant in assemblages from the Triassic section at River 14. In that from Sample 14–6A, for example, it made up 47% of the total spore-pollen assemblage.

The similarity of *Ephedripites* sp. to the pollen of certain living species of *Ephedra* and *Welwitschia* is striking, especially to those that compose *Ephedra* Group D of Steeves & Barghoorn (1959). However, there is no other evidence linking Palaeozoic and Mesozoic pollen of this type with the Gnetales and some (Ash, 1972) that indicates it may have been produced by other extinct gymnosperm groups.

Most of the specimens assigned here to *Ephedripites* sp. resemble *Ephedripites corrugatus* Wilson from the Guadalupian of Oklahoma, which is in turn difficult to distinguish from the Canadian Lower Triassic species *Gnetaceaepollenites steevesi* Jansonius. Some display the cavate exine that characterises *Gnetaceaepollenites scottii* Jansonius; a few possess narrower and more numerous ribs and resemble *Gnetaceaepollenites multistriatus* Jansonius.

Distribution: *Vittatina*-Association, S–VR, *Protohaploxypinus*-Association R–D, *Taeniaesporites*-Association, VR–A.

Unassigned monosulcate pollen grains

(pl. 2, figs 5–6)

Small monosulcate pollen grains with structured and, in some specimens, finely sculptured exines, occurred in several assemblages. Well-preserved specimens were not sufficiently common to provide the basis of a satisfactory taxon, but the pollen type is recorded because of its unusual morphology. The specimen illustrated in pl. 2, fig. 5 possesses a finely columellate, relatively thick, tectate exine of a type not encountered in living gymnosperms. Structurally it resembles that of the Gondwanan Permian genus *Praecolpatites* Bharadwaj & Srivastava, although that form is polysulcate and much larger.

Distribution: *Protohaploxypinus*-Association, S–R, *Taeniaesporites*-Association, S–R.

Genus: *Vittatina* Luber ex Wilson, 1962

Transversely elongate, monosulcate pollen grains, with sets of subparallel, predominantly proximal, transverse ribs were characteristic of all the Permian assemblages. They were particularly common in samples from the *Posidonia* shale facies. Although they clearly belong to the genus *Vittatina* they displayed a wide spectrum of gradual morphological variation and were difficult to classify satisfactorily at a lower taxonomic level. These difficulties were accentuated by the poor preservation of much of the material. Most of the specimens whose detailed morphology was adequately determinable are referable to four existing species, *Vittatina striata* Jansonius, *V. costabilis* Wilson, *V. subsaccata* Wilson and *V. minima* Jansonius. There were, however, many specimens that did not clearly conform precisely to any of these taxa and which were recorded in counts as *Vittatina* spp.

Vittatina striata LUBER ex JANSONIUS, 1962
(pl. 3, figs 11–12)

The principal distinguishing feature of *Vittatina striata* was taken to be the continuation of looped proximal ribs on to the lateral margins of the distal surface. Thus, in specimens preserved as polar compressions the sulcus appears to be bordered laterally by two sets of ribs at right angles. Pollen grains of this type are abundant at many Permian localities in the European U.S.S.R. and especially from post-Artinskian strata. The record by JANSONIUS is one of the few from any other part of the northern hemisphere, but this may solely reflect the sparcity of published information on the palynology of the North American Late Permian.

Distribution: *Vittatina*-Association, C–A; *Protohaploxypinus*-Association, S–VR.

V. costabilis WILSON, 1962
(pl. 3, fig. 6)

Specimens of *Vittatina* with a median distal strip of thickened exine, running at right angles to the proximal ribs, were observed occasionally in Permian assemblages. In most, the distal strip was weakly developed and none showed the additional bands of distal thickening that WILSON reported in his original description. However, they conform with the re-interpretation of the species provided by TSCHUDY & KOSANKE (1966).

Distribution: *Vittatina*-Association, S–C.

Vittatina subsaccata SAMOILOVITCH ex WILSON, 1962
(pl. 2, fig. 7)

Specimens assigned here to *Vittatina subsaccata* possessed transverse ribs that are almost entirely confined to the proximal side and not looped on the distal face as they are in *Vittatina striata.* The ribs in some specimens become discontinuous towards their extremities and form low verrucae at the lateral margins of the proximal surface and bordering the distal sulcus. Partial separation of the exoexine and intexine was observed in a few specimens, but the condition was not common in material from Kap Stosch.

Distribution: *Vittatina*-Association, VR–C, *Protohaploxypinus*-Association, S–VR.

Vittatina minima JANSONIUS, 1962
(pl. 2, fig. 10)

Vittatina minima is a small species with about six proximal ribs and a strip of slightly thickened exine bordering each lateral margin of the distal sulcus. JANSONIUS described it from the Permian Belloy Formation of western Canada and it was subsequently recorded from the Artinskian Sabine Bay Formation, Melville Island, Canadian Arctic by Barss (1967).

Distribution: *Vittatina*-Association, S–C.

Non-taeniate saccate pollen

Genus: *Cordaitina* Samoilovitch, 1953
cf. *Cordaitina* spp.
(pl. 3, fig. 18)

Radially and bilaterally symmetrical pollen grains with a single equatorially detached saccus were recorded as extremely rare components of both Permian and Triassic sediments. None of the few specimens observed possessed the limboid saccus that characterises the typical *Nuskoisporites dulhuntyi* Potonié & Klaus and they have been compared with the broader genus *Cordaitina*.

Distribution: *Vittatina*-Association, S–VR; *Protohaploxypinus*-Association, S–R.

Genus: *Florinites* Schopf, Wilson & Bentall, 1944
cf. *Florinites luberae* Samoilovitch, 1953

Bilaterally symmetrical monosaccate pollen grains, with a clearly defined sub-circular corpus, occurred fairly commonly in some Permian samples. They agree in their broad characters with some of the forms assigned by Russian workers to *Florinites luberae*, a category that is common and widely distributed in the Permian of the northern European U.S.S.R. (cf. Varyukhina, 1971; Molin, 1975).

Distribution: *Vittatina*-Association, S–R.

Genus: *Alisporites* Daugherty, 1941
Alisporites spp.

Disaccate non-taeniate pollen grains that could not be justifiably referred to an existing less non-committal taxon have been assigned to *Alisporites* (s.l.). Pollen of this type was abundant, but poorly preserved, in samples from the Permian section. It occurred less commonly in the Triassic.

Distribution: *Vittatina*-Association, R–A; *Protohaploxypinus*-Association, S–C; *Taeniaesporites*-Association, S–R.

Alisporites sp. cf. *A. nuthallensis* Clarke, 1965
(pl. 3, figs 1–2)

Description. — Disaccate, haploxylonoid or slightly diploxylonoid pollen grain. Corpus circular or sub-circular in polar view, cappa about 1 µm thick, finely and closely columellate so that the surface appears punctate. Sacci semicircular in polar view, height equal to, slightly greater or slightly less that of the corpus, strongly inflated with a pronounced distal inclination, sub-saccale folds may or may not be present adjacent to the distal bases of the sacci. Cappula thin, relatively narrow, faintly structured, displaying an elongated ragged rupture in most specimens.

Dimensions (20 specimens measured from Sample T67–101): Total width 54–73 µm (mean 61 µm), height of corpus 31–51 µm (mean 39 µm).

Distribution: *Vittatina*-Association, S–C.

Discussion. — The persistent occurrence of a ragged distal rupture in the cappula of *Alisporites* sp. may indicate the presence of a differentiated distal sulcus rather than a leptoma and hence serve to distinguish the Greenland specimens from *Alisporites nuthallensis*, which was first described from the Zechstein of England. Otherwise there seem no significant differences between the two forms.

Genus: *Klausipollenites* Jansonius, 1962

Klausipollenites staplinii Jansonius, 1962

(pl. 2, fig. 13)

Klausipollenites staplinii is the only non-taeniate disaccate pollen grain that occurs commonly in Lower Triassic sediments at Kap Stosch. Specimens studied in detail conform precisely with the description given by Jansonius and the range of variation is similar to that illustrated from the type material from the western Canadian Lower Triassic.

Distribution: *Vittatina*-Association, S–C; *Protohaploxypinus*-Association, S–R; *Taeniaesporites*-Association, VR–A.

Genus: *Vitreisporites* Leschik, 1955

Vitreisporites pallidus (Reissinger) Nilsson, 1958

Small disaccate pollen grains identical with those produced by *Caytonia* were rare and sporadically occurring components of both Permian and Triassic assemblages.

Genus: *Limitisporites* Leschik, 1956

Limitisporites sp.

(pl. 3, figs 3–4)

The transverse tetrad mark that characterises the typically Zechstein genus *Limitisporites* cannot usually be seen in poorly preserved material and the genus may be somewhat more common in the Permian of Kap Stosch than the counts suggest.

Distribution: *Vittatina*-Association, S–R; *Protohaploxypinus*-Association, S–R.

Genus: *Falcisporites* Leschik, 1955
Falcisporites sp. cf. *F. zapfei* (Potonié & Klaus) Leschik, 1956
(pl. 2, fig. 17)

Haploxylonoid pollen with a defined distal sulcus were minor components of some Permian assemblages. None of the specimens seen was well enough preserved to determine the detailed structure of the cappa, which is the principal criterion that has been used to differentiate *Falcisporites zapfei* from other members of the genus. The Greenland specimens possess the rather rigid, distally inclined sacci that characterise the European Zechstein species and are of similar size, with a total width of about 100 µm.

Distribution: *Vittatina*-Association, S–R.

Taeniate saccate pollen

Genus: *Protohaploxypinus* Samoilovitch, 1953

Satisfactory discrimination between sub-generic categories of *Protohaploxypinus* is difficult even when dealing with well-preserved material. In the Kap Stosch assemblages it was often impossible and in estimates of quantitative composition most haploxylonoid forms with numerous closely spaced taeniae were counted as *Protohaploxypinus* spp. Estimates of the relative abundance of identifiable species are therefore undoubtedly lower than their true proportions.

Protohaploxypinus samoilovitchii (Jansonius) Hart, 1964
(pl. 3, figs 16–17) and *Protohaploxypinus jacobii* (Jansonius)
Hart, 1964 (pl. 3, fig. 15)

Protohaploxypinus samoilovitchii differs from *P. jacobii* principally in the form of its taeniae which are continuous across the full width of the cappa. The distinction is a rather arbitrary one, but has been maintained by most workers who have dealt with the group.

Distribution: *Vittatina*-Association, S–C; *Protohaploxypinus*-Association, S–A; *Taeniaesporites*-Association, S–R.

Protohaploxypinus chaloneri Clarke, 1965
(pl. 3, fig. 12)

Except that their mean size is a little larger (total width 65 µm against 57 µm) the specimens from Kap Stosch referred to *Protohaploxypinus chaloneri* conform precisely with Clarke's (1965) description of specimens from the Zechstein of England. Similar pollen grains have been frequently illustrated from the Russian Permian and assigned to various taxa of uncertain status. Forms referred to *Pemphygaletes latissimus* Luber by some Russian workers (e.g. Zauer, 1965; Varyu-

KHINA, 1971) may also be accommodated in *Protohaploxypinus chaloneri*.

Distribution: *Vittatina*-Association, S–A; *Protohaploxypinus*-Association, S–R.

Genus: *Striatoabieites* SEDOVA, 1965
Striatoabieites richteri (KLAUS) HART, 1965
(pl. 3, figs 19–20)

The name *Striatoabieites richteri* has been used here for large, slightly diploxylonoid pollen grains with between about 15–20 relatively narrow proximal taeniae and a finely structured cappa. A prominent transverse monolete or geniculate tetrad scar was present in many specimens. The subsidiary clefts or fine plications that are present in the taeniae of KLAUS's type material, and which he regarded as an essential character of the species, were visible in some of the specimens from Kap Stosch, but in most the taeniae appeared to be undissected. The criterion is a delicate one and in poorly preserved material difficult to apply, so that the concept of *Striatoabieites richteri* adopted here is a broad one. It incorporates specimens that could equally well have been assigned to *Strotersporites jansonii* KLAUS, *Strotersporites wilsonii* KLAUS, *Striatoabieites brickii* SEDOVA and perhaps to other validly published taxa.

Distribution: *Vittatina*-Association, S–R; *Protohaploxypinus*-Association, R–A; *Taeniaesporites*-Association, S–R.

Genus: *Lueckisporites* POTONIÉ & KLAUS, 1954
Lueckisporites virkkiae POTONIÉ & KLAUS, 1954
(pl. 3, figs 7–9)

Specimens of *Lueckisporites virkkiae* resembling Variants A and C of CLARKE (1965) were observed in several Permian assemblages and extremely rarely in the Triassic. They were never abundant and only made up more than 1 % of the assemblage at a single locality (0–9A). Most were poorly preserved.

Distribution: *Vittatina*-Association, S–C; *Protohaploxypinus*-Association, S–VR.

Genus: *Scutasporites* KLAUS, 1963
Scutasporites sp. cf. *S. unicus* KLAUS, 1963
(pl. 3, fig. 5)

Description. — Disaccate, haploxylonoid pollen grain. Corpus sub-circular or transversely elongated oval; cappa finely columellate, structure gradually modified towards the proximal sacci bases so that it merges into that of the sacci. Exoexine of the cappa thickened in a relatively broad transverse band to form a single polar taenia with a width about onethird that of the diameter of the corpus. Sacci hemispherical in polar view; cappula broad with sub-parallel lateral margins.

Dimensions (8 measured specimens from Sample T67–101): total breadth 57–66 µm.

Distribution: *Vittatina*-Association, S–R.

Discussion. — *Scutasporites* was rare and only identified in one sample, but the record is an interesting one as the genus was previously known only from the Upper Permian Grödner Sandstone and *Bellerophon* Beds of the Austrian Southern Alps (KLAUS, 1963). The specimens from Kap Stosch agree with KLAUS's description except that none clearly showed a monolete tetrad scar. However, this would be difficult to discern in poorly preserved material.

Genus: *Taeniaesporites* LESCHIK, 1955

Disaccate pollen grains with about 4 taeniae that are separated by relatively broad proximal clefts, are referred here to *Taeniaesporites* rather than *Lunatisporites* LESCHIK, which is regarded by some workers as a senior subjective synonym (e.g. SCHEURING, 1970). The emendations of *Lunatisporites* proposed by BHARADWAJ (1962) and SCHEURING (1970) are both deficient, in that it is uncertain whether the type species (*Lunatisporites acutus* LESCHIK) possesses the morphological characters that these authors ascribe to the genus (see also MORBEY, 1975). *Taeniaesporites*, by contrast, is a well-established name, with a clearly illustrated type, that has been used in a consistent sense by workers in many parts of the world. These are clear reasons for retaining it.

Taeniaesporites noviaulensis LESCHIK, 1956
(pl. 3, figs 10–11)

Specimens referred here to *Taeniaesporites noviaulensis* are haploxylonoid or slightly diploxylonoid with a relatively thick intexine so that the corpus is markedly darker than the sacci. The cappa is dissected into four primary taeniae separated by broad clefts; in some specimens the primary taeniae are further dissected by a few narrow secondary clefts; a short monolete scar is visible within the polar cleft in most well-preserved specimens. Dark, longitudinal, distal sub-saccale folds parallel the margins of the cappula.

Many of the specimens treated for quantitative purposes as *T. noviaulensis* were not well-preserved and did not exhibit all the definitive characters of the species. They could, with equal justification, have been assigned to various other existing taxa, including *Taeniaesporites novimundi* JANSONIUS and *Taeniaesporites hexagonalis* JANSONIUS.

Distribution: *Vittatina*-Association, S–R; *Protohaploxypinus*-Association VR–C; *Taeniaesporites*-Association, A (all samples).

Taeniaesporites pellucidus (GOUBIN) BALME, 1970
(pl. 3, figs 13–14)

Taeniaesporites pellucidus possesses a thin hyaline intexine so that corpus and sacci are not clearly differentiated, as they are in *T. noviaulensis.* Distal sub-saccale folds are present in some specimens, but do not appear as pronounced heavily darkened bands and no monolete tetrad scar was observed on any specimen of *T. pellucidus* that was examined closely.

Distribution: *Protohaploxypinus*-Association, S–R; *Taeniaesporites*-Association, C–A.

Taeniaesporites transversundatus JANSONIUS, 1962
(pl. 3, fig. 6)

Forms from Kap Stosch that possess the broad characters of *Taeniaesporites transversundatus* showed fairly wide variation as to detail. All were slightly diploxylonoid, but in some the sacci were larger than the corpus, in others smaller. The size range was also considerable and ranged from 52–86 µm (total width) in 12 specimens measured from Sample 750 (675)–10. They all possessed a relatively thick exoexine and a small number of taeniae which in most specimens were contracted towards their lateral extremities. In addition the taeniae were characterised by fine cross-plications which cause their margins to appear finely undulating.

Distribution: *Protohaploxypinus*-Association, S–C; *Taeniaesporites*-Association, S–C.

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Færdig fra trykkeriet 11. jan. 1980.

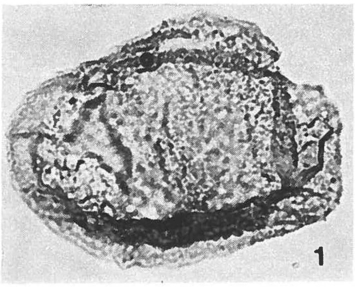
PLATES

All magnifications x 500. Photomicrographs are of specimens either mounted singly or in smear mounts. Slide numbers refer to the catalogue of the Department of Geology, University of Western Australia. Slides with numbers marked with an asterisk (*) are single grain mounts.

Plate 1

1. *Inaperturopollenites nebulosus* BALME, Sample 0–9A, UWA 87702.
2. *Inaperturopollenites nebulosus* BALME, Sample T67–101, UWA 87703.

3–7. *Tympanicysta stoschiana* BALME, 3, subcylindrial form, Sample 750 (675)–14, UWA 87704. 4, clavate body with fine amorphous organic material simulating the external form within the central cavity, Sample 750 (675)–4, UWA 87704. 5, sub-fusiform form, Sample 750 (675)–14, UWA 87705. 6, sub-fusiform form with amorphous organic material within the central cavity, Sample 750 (675)–14, UWA 87705. 7, holotype, two linked sub-cylindrical forms, Sample 750 (675)–14, UWA 87705.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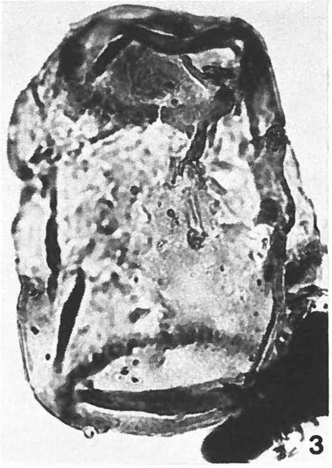
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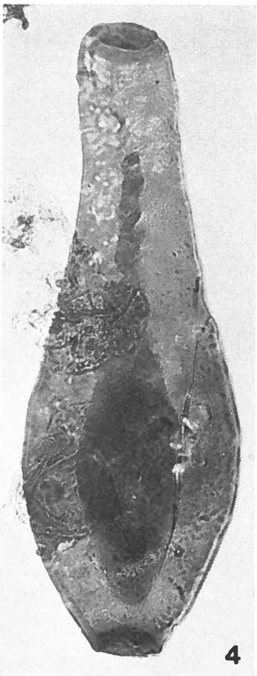
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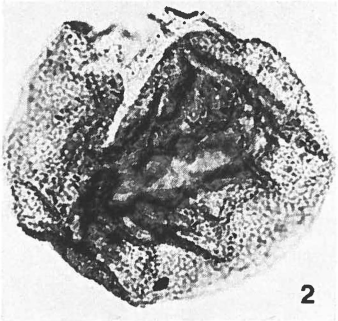
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Plate 2

1. *Pilasporites* sp., Sample T67–88, UWA 87706.
2. *Cycadopites follicularis* WILSON & WEBSTER, Sample 750 (675)–10, *UWA 87707.
3. *Cycadopites follicularis* WILSON & WEBSTER, Sample 14–6B, *UWA 87708.
4. *Ephedripites* sp., Sample 750 (675)–10, *UWA 87709.
5. Unassigned monosulcate pollen grain with columellate, tectate exine, Sample 201–36A, UWA 87710.
6. Unassigned monosulcate pollen grain with a relatively broad rectangular sulcus and structured, finely tuberculate exine, Sample 201–39, UWA 87711.
7. *Vittatina subsaccata* SAMOILOVITCH ex WILSON, Sample T67–58, UWA 87712.
8. *Vittatina* sp., Sample T67–58, UWA 87712.
9. *Vittatina costabilis* WILSON, Sample T67–88, UWA 87706.
10. *Vittatina minima* JANSONIUS, Sample T67–101, UWA 87703.
11. *Vittatina striata* LUBER ex JANSONIUS, proximal face uppermost, Sample T67–82, UWA 87713.
12. *Vittatina* sp., cf. *V. striata* LUBER ex JANSONIUS, Sample T67–58, UWA 87712.
13. *Klausipollenites staplinii* JANSONIUS, Sample 14–6B, *UWA 87714.

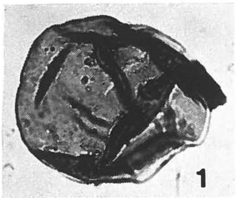
14.-16. Cf. *Florinites luberae* SAMOILOVITCH, 14 and 16 from Sample 0–9A, UWA 87702; 15 from sample T67–101, UWA 87703, specimen showing pyritic corrosion pits on the corpus.

17. *Falcisporites zapfei* POTONIÉ & KLAUS, Sample 1–7, UWA 87715.
18. *Endosporites* sp., Sample 750 (675)–14, UWA 87701.
19. *Densoisporites nejburgii* (SCHULZ) BALME, Sample 201–39, UWA 87711.
20. *Densoisporites nejburgii* (SCHULZ) BALME, sub-lateral view, proximal face uppermost, Sample 201–39, UWA 87711.
21. *Proprisporites pocockii* JANSONIUS, Sample 201–39, *UWA 87716.

22, 23. *Lundbladisporites obsoleta* BALME, Sample 201–39, UWA 87711.

24. *Densoisporites playfordi* (BALME) DETTMANN, Sample 14–6B, UWA 87717.
25. *Kraeuselisporites apiculatus* JANSONIUS, Sample 201–39, UWA 87711.

Plate 2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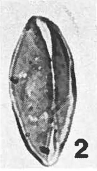
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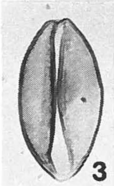
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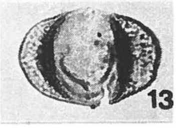
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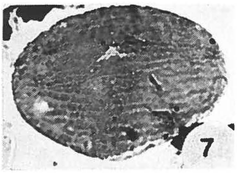
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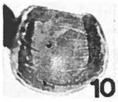
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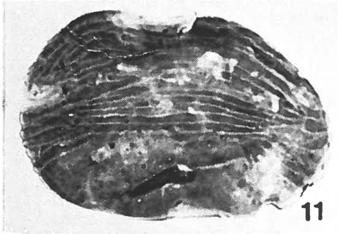
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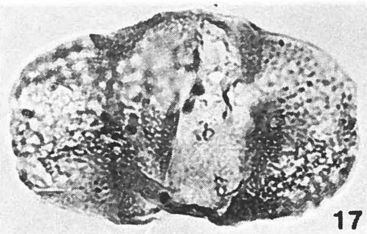
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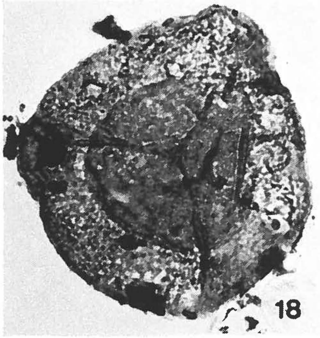
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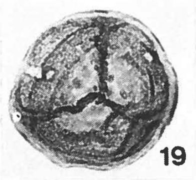
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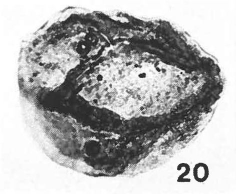
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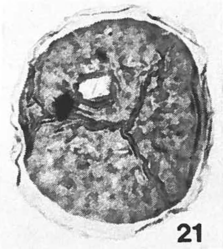
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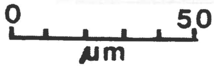

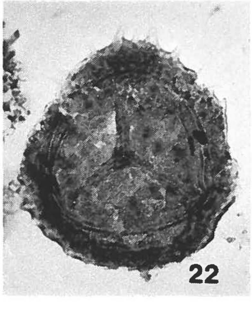
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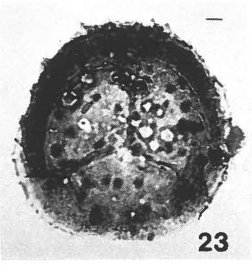
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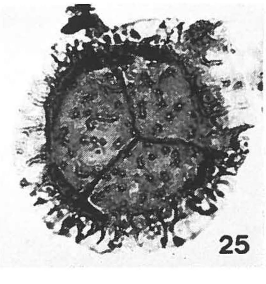
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Plate 3

1, 2. *Alisporites* sp. cf. *A. nuthallensis* CLARKE, Sample T67–101, UWA 87703.

3, 4. *Limitisporites* sp., Sample T67–101, UWA 87703.

5. *Scutasporites* sp. cf. *S. unicus* KLAUS, T67–101, UWA 87703.

6. *Taeniaesporites transversundatus* JANSONIUS, Sample 750 (675)–10, *UWA 87718.

7. *Lueckisporites* sp. cf. *L. virkkiae* POTONIÉ & KLAUS, Sample 0–9A, UWA 87702.

8. *Lueckisporites virkkiae* POTONIÉ & KLAUS, Variant A of CLARKE (1965), Sample 0–9A, UWA 87702.

9. *Lueckisporites virkkiae* POTONIÉ & KLAUS, Variant C of CLARKE (1965), Sample T67–101, UWA 87703.

10, 11. *Taeniaesporites noviaulensis* LESCHIK, Sample 14–6B, UWA 87717.

12. *Protohaploxypinus chaloneri* CLARKE, Sample T67–101, UWA 87703.

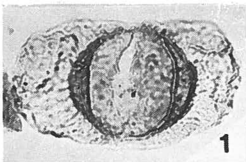
13, 14. *Taeniaesporites pellucidus* (GOUBIN) BALME, Sample 14–6B, UWA 87717.

15. *Protohaploxypinus jacobii* (JANSONIUS) HART, Sample 750 (675)–10, UWA 87719.

16, 17. *Protohaploxypinus samoilovitchii* (JANSONIUS) HART, Sample 14–6B, UWA 87717.

18. Cf. *Cordaitina* sp., Sample T67–58, UWA 87712.

20, 19. *Striatoabieites richteri* (KLAUS) HART, Sample 201–39, 19, *UWA 87720; 20, *UWA 87721.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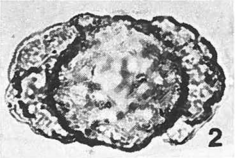
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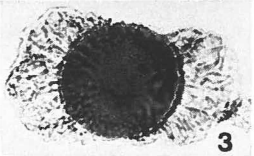
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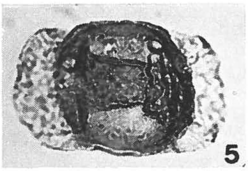
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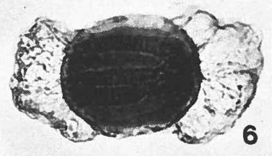
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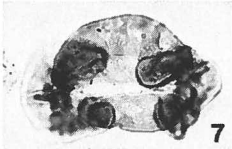
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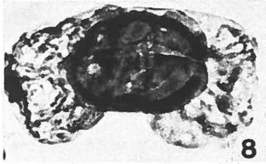
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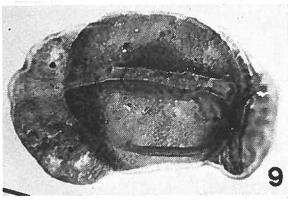
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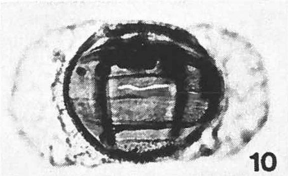
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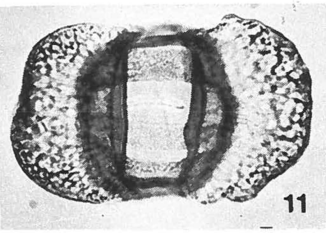
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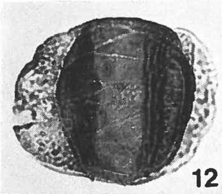
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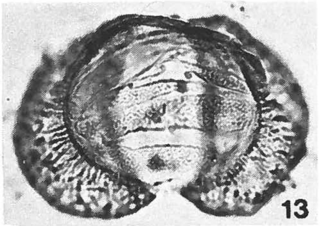
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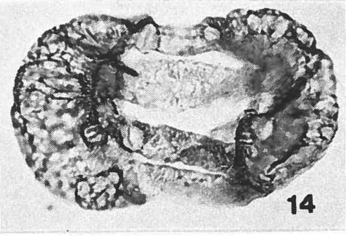
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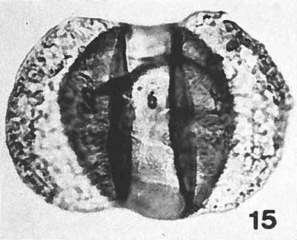
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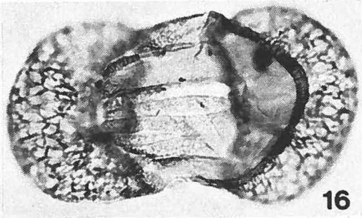
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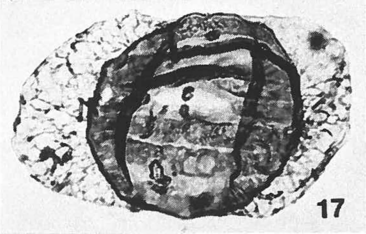
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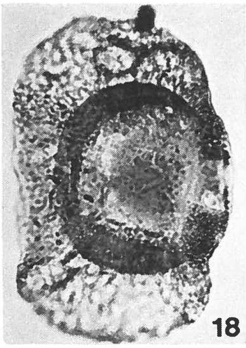
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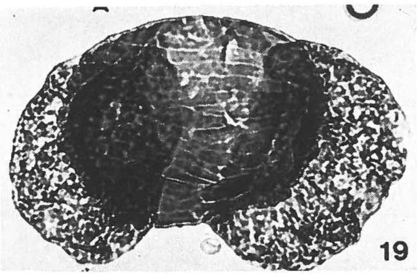
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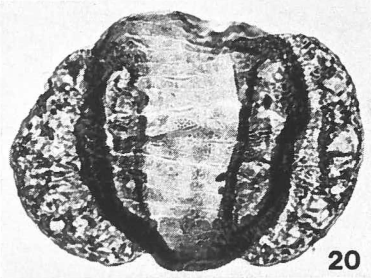
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