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Miospore systematics and stratigraphic correlation of Devonian-Carboniferous Boundary deposits in the European part of the USSR and western Europe

VIOLETA I. AVCHIMOVITCH, TAMARA V. BYVSCHEVA,
KENNETH HIGGS, MAURICE STREEL & VALENTINA T. UMNOVA

ABSTRACT

The authors have reached agreement on the specific identification of 65 taxa of late Devonian - early Carboniferous miospores from the Pripyat Depression of Byelorussia. Of these 62 are illustrated and 26 are discussed and compared with other taxa. 1 new species, **Stenozonotriletes meyenii**, is erected and 10 new combinations are proposed.

In an attempt to improve stratigraphic correlations between the European part of the USSR and western Europe, several biozonal schemes ranging from the late Famennian to early Tournaisian are compared and correlated.

INTRODUCTION

In January 1987 a working meeting between Soviet and western European palynologists took place at the USSR Academy of Sciences in Moscow. This meeting formed part of an ongoing study of the international Devonian-Carboniferous boundary project. The participants at this meeting are listed above. The proceedings were organized and coordinated by K. V. SIMAKOV who is thanked here for his invaluable help.

The aims of the joint project were to study the sequence of spore assemblages occurring in the boundary deposits of selected areas in the European part of the USSR and western Europe; to identify and resolve any taxonomic problems, and finally to correlate the respective zonation schemes of the various east - west regions. This joint paper presents the results and findings of the meeting.

Samples from the Soviet Union came mainly from Devonian-Carboniferous boundary beds of the Pripyat Depression of Byelorussia (Turov 123, Shestovichi 10 Boreholes, see fig. 1, and 505 Borehole). Also additional samples were studied from the eastern and central Russian Platform and from the Berchogur section in the Mugodzhar Mountains in the Urals. A number of samples from western Europe included material from Hook Head in southern Ireland and from the Ardenne-Rhine region of Belgium and Germany. However, most attention was given to the analysis of the Russian samples.

It was felt that the primary objective of the meeting was to reach agreement on the specific identification and nomenclature of the spores. This fundamental task was considered necessary before any meaningful zonal or stratigraphical correlations could be attempted. Consequently this area of the study occupied most of the working time of the meeting. Not all of the recorded taxa were dealt with and in some cases a few problems still need to be resolved, however, a consensus opinion was reached for the majority of the stratigraphically important taxa. The following section summarizes the findings of this taxonomic study.

SYSTEMATIC NOTES

The following list of taxa are only illustrated on plates 1 to 5. Occurrences of these taxa are given in the legend of the plates.

Ancyrospora ? capillata DOLBY & NEVES, 1970 (pl. 5, fig. 19).
Apiculiretusispora verrucosa (CARO-MONIEZ) STREEL, 1977 (pl. 1, fig. 9).
Auroraspora asperella (KEDO) VAN DER ZWAN, 1980 (pl. 4, fig. 15).
Camptotriletes paprothii HIGGS & STREEL, 1984 (pl. 1, fig. 8).
Convolutispora ampla HOFFMEISTER, STAPLIN & MALLOY, 1955 (pl. 2, fig. 9, 12).
C. cf. cerebra BUTTERWORTH & WILLIAMS, 1958 (pl. 2, fig. 8).
C. lactucosa HIGGS, CLAYTON & KEEGAN, in press (pl. 4, fig. 13).

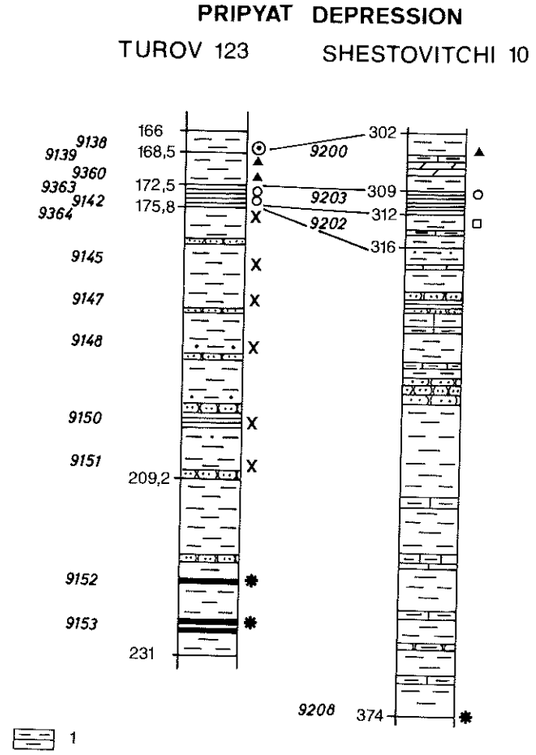


Fig. 1. Sampling in two boreholes from Byelorussia.
1: mudstone; 2: silty mudstone; 3: shale; 4: highly indurated shale; 5: sandstone; 6: marlstone; 7: limestone; 8: argillaceous limestone.
9. **T. malevkensis** (M)
10. **V. pusillites - T. malevkensis** (PM)
11. **V. pusillites - R. lepidophyta - H. explanatus** (PLE)
12. **R. lepidophyta - H. explanatus** (LE_2)
13. **R. lepidophyta - H. explanatus** (LE_1)
14. **R. lepidophyta - K. literatus** (LL)

C. major (KEDO) TURNAU, 1978 (pl. 2, fig.18).
C. mellita HOFFMEISTER, STAPLIN & MALLOY, 1955 (pl. 2, fig. 13).
C. usitata PLAYFORD, 1963 (pl. 2, fig. 16, 17).
Corbulispora cancellata (WALTZ) BHARADWAJ & VENKATACHALA,1962 (pl. 2, fig. 11).
Cymbosporites magnificus (Mc GREGOR) Mc GREGOR & CAMFIELD, 1982 (pl. 5, fig. 4).
Cymbosporites sp. (pl. 5, fig. 3).
Cyrtospora cristifera (LUBER) VAN DER ZWAN, 1980 (pl. 2, fig. 14, 15).
Diaphanospora rugosa (NAUMOVA) BYVSCHEVA, 1985 (pl. 4, fig. 11).
D. submirabilis (KEDO) BYVSCHEVA, 1985 (pl. 4, fig. 12).
Dictyotriletes scrobiculatus KEDO, 1971 (pl. 2, fig. 7).
Endoculeospora gradzinskii TURNAU, 1975 (pl. 4, fig. 6).
Grandispora echinata HACQUEBARD, 1957 (pl. 4, fig. 18).
G. senticosa (ISCHENKO) BYVSCHEVA, 1985 (pl. 4, fig. 19).
Hymenozonotriletes explanatus KEDO, 1957 (pl. 5, fig. 18).
? **Knoxisporites** sp. (pl. 3, fig. 11).
Kraeuselisporites hibernicus HIGGS, 1975 (pl. 5, fig. 17).
Kraeuselisporites sp. (pl. 5, fig. 15).
Lophozonotriletes excisus NAUMOVA, 1953 (pl. 2, fig. 1, 2).
Punctatisporites glaber (NAUMOVA) PLAYFORD, 1962 (pl. 1, fig. 3).
P. irrasus HACQUEBARD, 1957 (pl. 1, fig. 1).
P. solidus HACQUEBARD, 1957 (pl. 1, fig. 2).
Pustulatisporites dolbii HIGGS, CLAYTON & KEEGAN, in press (pl. 1, fig. 14).
Raistrickia corynoges SULLIVAN, 1968 (pl. 1, fig. 15).
R. minor (KEDO) DOLBY & NEVES, 1970 (pl. 1, fig. 13).
R. ramiformis (KEDO) AVCHIMOVITCH & HIGGS comb. nov. (pl. 1, fig. 16).
R. variabilis DOLBY & NEVES, 1970 (pl. 1, fig. 12).
Retispora lepidophyta (KEDO) PLAYFORD, 1976 (pl. 4, fig. 5).
Retusotriletes digressus PLAYFORD, 1976 (pl. 1, fig. 7).
R. incohatus SULLIVAN, 1964 (pl. 1, fig. 5, 6).
R. witneyanus (CHALONER) STREEL, 1967 (p. 1, fig. 4).
? **Secarisporites** sp. (pl. 2, fig. 10).
Spelaeotriletes crustatus HIGGS, 1975 (pl. 4, fig. 10).
Stenozonotriletes conformis NAUMOVA, 1953 (pl. 3, fig. 4).
Tholisporites esenensis BYVSCHEVA, 1976 (pl. 4, fig. 9).

? **Tumulispora** sp. (pl. 3, fig. 5, 6).
Vallatisporites vallatus HACQUEBARD, 1957 (pl. 5, fig. 9).

Besides the former list of undescribed taxa, taxonomic conclusions of the authors are presented below as mainly informal notes. Emphasis is given to three important groups of spores, here called the **Vallatisporites**, **Tumulispora** and **Diducites** complexes which characteristically dominate many of the boundary bed assemblages. Also additional systematic notes are given for a number of stratigraphically important taxa which has resulted in several new combinations. One new species is erected which is named in honour of the late Soviet palaeobotanist Dr. Sergei MEYEN.

Because the participants did not have time to discuss an acceptable suprageneric nomenclature, the taxa are listed below in alphabetic order of genera.

Auroraspora evanida (KEDO) AVCHIMOVITCH comb. nov.
pl. 4, fig. 14

1957 **Hymenozonotriletes evanidus** (KEDO), p. 22, pl. 2, fig. 13

Remarks: This species is distinguished from other representatives of the genus by its prominent broad labra. **Diducites commutatus** (NAUMOVA) AVCHIMOVITCH comb. nov. is similar but differs in possessing small radial folds and thin outer exoexine.

Bascaudaspora mischkinensis (BYVSCHEVA) BYVSCHEVA comb. nov.
pl. 5, fig. 5 - 6

1971 **Archaeozonotriletes mischkinensis** BYVSCHEVA, p. 100, pl. 1, fig. 16 - 18
1985 **Chelinospora mischkinensis** (BYVSCHEVA) BYVSCHEVA, p. 128 - 129, pl. 24, fig. 12

Remarks: This species is characterized by a cristate/rugulate ornament which may be sinuous, irregular or variably reticulate. Spore diameter: 25 - 50 µm.

There are two closely related species which are very similar in morphology:

Bascaudaspora collicula (PLAYFORD) HIGGS et al. (in press) possesses a similar ornament of dominantly cristate elements and appears to differ only by its larger size (49 - 88 µm; average 63 - 76 µm).

Bascaudaspora submarginata (PLAYFORD) HIGGS et al. (in press) differs from the former two species by possessing dominantly rugulate / reticulate ornament and by its one layered exine. However, UTTING (1987) has recently found that specimens of **B. submarginata** from the Windsor Group of eastern Canada are indeed two-layered. It is therefore possible that these three species may be synonymous.

Cymbosporites menendezii (MENENDEZ & AZCUY) HIGGS comb. nov.
pl. 5, fig. 1 - 2

1972 **Ancistrospora verrucosa** MENENDEZ & AZCUY, p. 162, pl. 1, fig. 1 - 6, pl. 3, fig. 3 - 5
1978 **Cristatisporites menendezii** (MENENDEZ & AZCUY) PLAYFORD, p. 137, pl. 10, fig. 3 - 6

Remarks: This species is characterized by well spaced, large mammoid verrucae which are mainly discrete, rarely coalescent. The intexine is evident to barely perceptible. The nature of the patina is considered to be more appropriate to the genus **Cymbosporites**, the new specific epithet proposed by PLAYFORD (1978) is retained to avoid homonymy with **Cymbosporites verrucosus** RICHARDSON & LISTER, 1969. **Cymbosporites acutus** (KEDO) BYVSCHEVA, 1985, differs from **C. menendezii** by its smaller and predominately spinose/galeate elements.

Cymbosporites minutus (KEDO) AVCHIMOVITCH & STREEL comb. nov.
pl. 5, fig. 7

1963 **Archaeozonotriletes minutus** KEDO, pl. 7, fig. 165 - 166
1970? **Archaeozonotriletes acutus** KEDO; DOLBY & NEVES, p. 638, pl. 2, fig. 5 - 6
1980 **Asperispora acuta** KEDO; VAN DER ZWAN, p. 226 - 228, pl. 13, fig. 1, 4, non fig. 2, 3, 5

Remarks: This species is distinguished by its small size, thickened exine and ornament of small wide based spinae, which are closely spaced and often fused equatorially.

Diducites complex

The genus **Diducites** VAN VEEN, 1981, is characterized by spores exhibiting a two layered exoexine, in which the outer exoexinal layer is narrow, light coloured and presumably thin. The exine possesses a wide range of folds, wrinkles and rugulae. VAN VEEN (1981) described this complex as the **Diducites mucronatus** morphon, it comprised four species, three of which are Russian. These species were examined during the present study and the following conclusions

were reached.

Diducites poljessicus (KEDO) VAN VEEN, 1981
pl. 4, fig. 3

1957 **Hymenozonotriletes poljessicus** KEDO, p. 25, pl. 3, fig. 6 - 8
1974 **Auroraspora poljessica** (KEDO) STREEL in BECKER et al., pl. 20, fig. 8 - 14
1981 **Diducites poljessicus** (KEDO) VAN VEEN, p. 271 - 273, pl. 4, fig. 1 - 4, 6

Remarks: D. poljessicus is distinguished by a strongly folded intexine with large and chaotic folds and rugulae developed. The exoexine is usually unfolded or it may have minor wrinkles and rugulae.

Diducites mucronatus (KEDO) VAN VEEN, 1981
pl. 4, fig. 1

1974 **Hymenozonotriletes mucronatus** KEDO, p. 40, pl. 10, fig. 11 - 15
1981 **Diducites mucronatus** (KEDO) VAN VEEN, p. 275, pl. 3, fig. 8; pl. 4, fig. 5-7; pl. 5, fig. 1 - 6

Remarks: This species lacks the exinal folding seen in other representatives of the genus. Also the intexine is symmetrically positioned. VAN VEEN (1981) considered **Diducites** (**Hymenozonotriletes**) **commutatus** (NAUMOVA) AVCHIMOVITCH comb. nov. to be a junior synonym of **D. mucronatus**. However, this proposal is rejected by the Soviet palynologists; they recognize **D. commutatus** as an independent species which is characterized by small and sparse radial folds which do not extend to the distal apical region (pl. 4, fig. 4).

Diducites versabilis (KEDO) VAN VEEN, 1981
pl. 4, fig. 2

1957 **Hymenozonotriletes versabilis** KEDO, p. 25, pl. 3, fig. 4
1974 **Rugospora versabilis** (KEDO) STREEL in BECKER et al., pl. 21, fig. 3 - 5
1975 **Auroraspora versabilis** (KEDO) TURNAU, p. 561, pl. 5, fig. 7
1981 **Diducites versabilis** (KEDO) VAN VEEN, p. 268, pl. 2, fig. 5 - 6; pl. 3, fig. 1 - 6, 9

Remarks: This species is characterized by abundant radial folds and rugulae which affect all of the distal exine and produce an undulate equatorial outline.

Endoculeospora setacea (KEDO) AVCHIMOVITCH & HIGGS, comb. nov.
pl. 4, fig. 7 - 8

1971 **Retusotriletes setaceus** KEDO, p. 172 - 173, pl. 11, fig. 1 - 6

Remarks: This species possesses a large folded intexine and a dense ornament of small pilose/baculate elements. Folds with a proximal dark area are rare. **Endoculeospora gradzinskii** TURNAU, 1978, possesses a smaller more well defined intexine. **Apiculiretusispora verrucosa** (CARO-MONIEZ) STREEL, 1977, posses ses a similar ornament but lacks an intexinal layer.

Grandispora facilis (KEDO) AVCHIMOVITCH comb. nov. (not figured)

1957 **Hymenozonotriletes facilis** KEDO, p. 24, pl. 3, fig. 2
1971 **Grandispora notensis** PLAYFORD, p. 48, pl. 16, fig. 15 - 17

Remarks: This distinctive species is recognized by its distal ornament of dense but evenly spaced coni and spinae. The Russian authors consider the Australian species **G. notensis** as a junior synonym.

Knoxisporites literatus (WALTZ) PLAYFORD, 1963
pl. 3, fig. 2 - 3

1938 **Zonotriletes literatus** WALTZ in LUBER & WALTZ, p. 18, pl. 2, fig. 21; pl. A, fig. 11
1956 **Euryzonotriletes literatus** (WALTZ) ISCHENKO, p. 52 - 53, pl. 9, fig. 108
1956 **Anulatisporites literatus** (WALTZ) R. POTONIÉ & KREMP, p. 111
1957 **Cincturasporites literatus** (WALTZ) HACQUEBARD & BARSS, p. 23 - 24, pl. 3, fig. 2 - 5
1962 **Labiadensites literatus** (WALTZ; HACQUEBARD & BARSS) BHARDWAJ & VENKATACHALA, p. 38, pl. 8, fig. 128 - 130
1963 **Knoxisporites literatus** (WALTZ) PLAYFORD, p. 634, pl. 90, fig. 7, 8
1963 **Archaeozonotriletes literatus** (WALTZ) KEDO, p. 75 - 76, pl. 8, fig. 188 - 190

Remarks: K. literatus is distinguished by possessing the following features: A variably thickened cingulum, broad labra and an ornament of low smooth and irregularly disposed muri. A number of other Famennian-Tournaisian species of **Knoxisporites** are very similar to **K. literatus** but differ in the follwing ways: **K. hederatus** (WALTZ) PLAYFORD, 1963, possesses a wider evenly thickened cingulum and no labra. **K. dedaleus** (NAUMOVA) MOREAU-BENOIT, 1980, possesses a narrow evenly thickened cingulum and a granulate exine.

K. pristinus SULLIVAN, 1968, possesses poorly defined muri.

Knoxisporites incrassatus (KEDO) HIGGS comb. nov.
pl. 3, fig. 1

1974 **Archaeozonotriletes incrassatus** KEDO, p. 62 - 63, pl. 14, fig. 8.

Remarks: This species is characterized by its large size (135 - 150 µm), thick cingulum (25 µm) and irregular distal muri.

Retispora macroreticulata (KEDO) BYVSCHEVA, 1985 (not figured)

Remarks: A detailed synonymy for this species has been given in BYVSCHEVA (1985). The present study has confirmed that **Retispora cassicula** (HIGGS) HIGGS & RUSSELL, 1981, is a junior synonym of **R. macroreticulata**. One of the authors (AVCHIMOVITCH) prefers to recognize this species as a variety of **R. lepidophyta**, i. e. **R. lepidophyta** (KEDO) PLAYFORD var. **macroreticulata** KEDO.

Rugospora radiata (JUSCHKO) BYVSCHEVA, 1985
pl. 4, fig. 16 - 17

1960 **Camptotriletes radiatus** JUSCHKO, p.128, pl. 2, fig. 26
1974 **Trachytriletes radiatus** (JUSCHKO) KEDO, p. 7, pl. 1, fig. 1
1985 **Rugospora radiata** (JUSCHKO) BYVSCHEVA, p. 148 - 149, pl. 30, fig. 6 - 8

Remarks: This species is distinguished by a distal ornament of dense rugulae which are characteristically radially arranged. It would appear that this species has regularly been misidentified by western palynologists. In 1967, NEVES & DOLBY referred to it as **Hymenozonotriletes famennensis** KEDO. In more recent years STREEL in BECKER et al. (1974) and subsequent authors have called it **Rugospora flexuosa** (JUSCHKO) STREEL. However, BYVSCHEVA (1985) has noted that specimens with radially aligned rugulae should be assigned to **Rugospora radiata** and those with chaotic and irregular rugulae are more typical of **R. flexuosa** (JUSCHKO) BYVSCHEVA. This latter species tends to be more circular in shape and possesses simple suturae.

Stenozonotriletes meyenii STREEL, HIGGS & AVCHIMOVITCH, sp. nov.
pl. 3, fig. 7

Holotype: pl. 3, fig. 7, diameter 115 µm.

Type locality: sample 9363, depth 173,8; Lower Kalinov (KL1) horizon, Turov Borehole 123, Byelorussia.

Diagnosis: Trilete acamerate cingulate miospores. Amb convexly triangular. Suturae distinct, straight, length to the inner margin of cingulum. Suturae bordered by broad labra 8 - 12 µm in overall width, normally uniform but in some cases slightly wavy. Exine laevigate to finely infragranulate. Cingulum distinct and not uniform in thickness, 10 - 15 µm in width.

Comparison: Stenozonotriletes sp. B PLAYFORD, 1976, is similar in size and structure to **S. meyenii** but has not labra associated with the suturae.

Tumulispora complex

Several taxa displaying a simple cingulate structure and distal verrucate ornament have been widely recorded in Devonian-Carboniferous boundary strata. Most of these taxa were originally assigned to the Russian genus **Lophozonotriletes.** However, doubts concerning the cingulate nature of the type species of this genus led some palynologists to transfer these taxa to the genus **Tumulispora** STAPLIN & JANSONIUS, 1964. The present study has confirmed that **Lophozonotriletes** is indeed a non-cingulate genus and that the Russian palynologists now prefer to use **Tumulispora** for the following cingulate/verrucate taxa.

Tumulispora rarituberculata (LUBER) POTONIÉ, 1966
pl. 3, fig. 12 - 13

1941 **Zonotriletes rarituberculatus** LUBER, p. 10, pl. 1, fig. 5; pl. 5, fig. 76
1956 **Euryzonotriletes rarituberculatus** (LUBER) ISCHENKO var. **triangulatus** (ISCHENKO), p. 51, pl. 8, fig. 104
1957 **Lophozonotriletes rarituberculatus** (LUBER) KEDO, p. 33, pl. 4, fig. 24 - 25, non fig. 23
1961 **Lophozonotriletes triangulatus** HUGHES & PLAYFORD, p. 35, pl. 3, fig. 3 - 7
1966 **Tumulispora rarituberculata** (LUBER) POTONIÉ, p. 85, pl. 7., fig. 82

Remarks: This distinctive species has a long and much debated history (see PLAYFORD, 1976, BYVSCHEVA, 1985). It id distinguished by its large (5 - 15 µm) well spaced verrucae. The overall size of the spore diameter ranges from 50 - 70 µm.

Tumulispora malevkensis (KEDO) TURNAU, 1978
pl. 3, fig. 8 - 9

1963 **Lophozonotriletes malevkensis** KEDO, p. 87, pl. 10, fig. 240-241, non fig. 242
1978 **Tumulispora malevkensis** (KEDO) TURNAU, p. 9, pl. 3, fig. 8

Remarks: BYVSCHEVA (1985) gives a detailed synonymy of this species. It differs from **T. rarituberculata** by its smaller size, which is less than 50 µm (30 - 40 µm average) and by its correspondingly smaller verrucae (2 - 5 µm).

Tumulispora varia (KEDO) BYVSCHEVA, comb. nov.
pl. 3, fig. 15

1963 **Euryzonotriletes varius** KEDO, p. 57, pl. 5, fig. 104
1964 **Tumulispora ordinaria** STAPLIN & JANSONIUS, p. 110, pl. 20, fig. 20, 24, text-fig. 2-o
1974 **Lophozonotriletes monotorosus** KEDO, p. 69, pl. 16, fig. 1

Remarks: This species differs from most representatives of the genus by the possession of one solitary verrucus at the centre of the distal surface.

Tumulispora variverrucata (PLAYFORD) STAPLIN & JANSONIUS, 1964
pl. 3, fig. 10, 14

1963 **Lophozonotriletes variverrucatus** PLAYFORD, p. 640, pl. 91, fig. 6 - 7, text-fig. 10 c
1964 **Tumulispora variverrucata** (PLAYFORD) STAPLIN & JANSONIUS, p. 110, pl. 20, fig. 9 - 13, 18, 19

Remarks: T. variverrucata is distinguished by its granular exine and more particularly the presence of abundant verrucae. The verrucae are variable in size (2 - 10 µm) and are characteristically distributed around the inner margin of the cingulum, where they are usually fused to form a compact ring. **Archaeozonotriletes malevkensis** KEDO, 1963, is very similar to **T. variverrucata** and it may prove synonymous; it appears to differ only by the presence of fine spines on the exine.

Umbonatisporites abstrusus (PLAYFORD) CLAYTON, 1971
pl. 1, fig. 10 - 11

1963 **Raistrickia abstrusus** PLAYFORD, p. 24, pl. 6, fig. 1 - 3
1963 **Acanthotriletes rarisetosus** KEDO, p. 40, pl. 2, fig. 43
1971 **Umbonatisporites abstrusus** (PLAYFORD) CLAYTON, p. 591

Remarks: This species possesses an ornament of small and slender baculate type elements which may have simple, rounded or expanded terminations, the tips of which usually possess a small spine. The suturae are simple and short, usually less than half the spore radius. **Umbonatisporites distinctus** CLAYTON, 1971, differs from **U. abstrusus** by possessing longer spear-like processes which bear prominent spinose tips (see CLAYTON, 1971: fig. 3). The specimen figured in the present paper as **U.** cf. **distinctus** (pl. 1, fig. 17) appears to be transitional in morphology between the two species.

Umbonatisporites (Acanthotriletes) regidesetosus (KEDO) BYVSCHEVA & STREEL, comb. nov.
(not figured)

The diagnosis of this species was emended by BYVSCHEVA (1985) and it is characterized by forms with more uniform ornaments of pilose-like elements which are more densely distributed than in the former two species.

Vallatisporites pusillites s.l. complex

The work of the joint study has clearified the understanding of the stratigraphically important taxon **Vallatisporites pusillites.** Over the years there has been considerable discussion in the palynological literature about the morphological concept of this species and its relationship with other related species such as **V. vallatus, V. verrucosus** and **V. hystricosus.** These discussions which are summarized in PLAYFORD (1976) and STREEL & TRAVERSE (1978) have focused mainly on nature and size of the ornamentation. However, they have always been inconclusive due to the uncertainty surrounding the precise concept of the Russian taxon **V. pusillites.** This uncertainty has now been removed following the joint study of the authors. Clarification of the characteristic features of each species of this complex is given below.

Vallatisporites pusillites (KEDO) DOLBY & NEVES emend. BYVSCHEVA, 1985
pl. 5, fig. 10 - 13, 16

1957 **Hymenozonotriletes pusillites** KEDO, pl. 22, fig. 1 (holotype)
1963 **Hymenozonotriletes pusillites** KEDO; KEDO, p. 66, pl. 6, fig. 138 - 140, 142, non fig. 141
1970 **Vallatisporites pusillites** (KEDO) DOLBY & NEVES, p. 639, pl. 2, fig. 3 - 4, non fig. 1 - 2
1985 **Vallatisporites pusillites** (KEDO) DOLBY & NEVES emend. BYVSCHEVA, p. 135 - 136, pl. 27, fig. 1 - 3

Remarks: The present Russian concept of this species embraces only forms with small and somewhat sparsely distributed spines. The spines range from 1 - 3 µm in height but are normally 1 - 2 µm. The holotype is a small spinose form. This precise circumscription of **V. pusillites** constrasts with the much broader concept described by DOLBY & NEVES (1970) and KEDO & GOLUBCOV (1971). These authors and many subsequent western palynologists have included coarsely ornamented specimens (spines greater than 3 µm) within **V. pusillites.** In the light of the present work it is now clear that these larger ornamented forms should be assigned to **V. hystricosus.**

Vallatisporites vallatus HACQUEBARD (1957) differs from **V. pusillites** in that it possesses a dense ornament of coni and subordinate grana and spinae up to 2 µm in height.

Vallatisporites hystricosus (WINSLOW) BYVSCHEVA, 1985
pl. 5, fig. 14

1962 **Cirratriradites hystricosus** WINSLOW, p. 40 - 41, pl. 18, fig. 5
1962 **Cirratriradites** sp. A WINSLOW, p. 41, pl. 18, fig. 1 - 2
1963 **Hymenozonotriletes pusillites** KEDO; KEDO, pl. 6, fig. 141, non fig. 138 - 140, 142
1970 **Vallatisporites pusillites** (KEDO) DOLBY & NEVES, pl. 2, fig. 1 - 2, non fig. 3 - 4
1985 **Vallatisporites hystricosus** (WINSLOW) BYVSCHEVA, p. 136

Remarks: This species accomodates forms which possess spinae and galeae, 3 - 16 µm in height.

Vallatisporites verrucosus HACQUEBARD, 1957
pl. 5, fig. 8

1957 **Vallatisporites verrucosus** HACQUEBARD, p. 313, pl. 2, fig. 13

Remarks: The species is represented by forms with dominantly verrucate ornament, occasionally some verrucae are fused to form short rugulae and some may possess small spinose tips.

Verrucosisporites nitidus (NAUMOVA) PLAYFORD, 1964
pl. 2, fig. 5 - 6

1953 **Lophotriletes grumosus** NAUMOVA, p. 57, pl. 7, fig. 14 - 15
1956 **Lophotriletes** aff. **grumosus** NAUMOVA in ISCHENKO, p. 40, pl. 6, fig. 74
1964 **Verrucosisporites nitidus** PLAYFORD nom. nov., p. 13 - 14, pl. 3, fig. 3 - 6
1964 **Verrucosisporites grumosus** (NAUMOVA) SULLIVAN, p. 1252 - 1253, pl. 1, fig. 9 - 15

Remarks: This species is characterized by an ornament of dense verrucae which is so closely spaced that a negative microreticulatum is often developed. The verrucae have a large size range but their size is usually constant on each individual specimen. Spore diameter: 30 - 72 µm.

Verrucosisporites mesogrumosus (KEDO) BYVSCHEVA, 1985
pl. 2, fig. 3 - 4

1963 **Lophotriletes mesogrumosus** KEDO, p. 51, pl. 4, fig. 82
1985 **Verrucosisporites mesogrumosus** (KEDO) BYVSCHEVA, p. 90, pl. 17, fig. 27

Remarks: This species is differentiated from **Verrucosisporites nitidus** by possessing an ornament of more widely spaced verrucae, which are usually more irregular in shape and variable in size on each specimen. Also the exine wall is more prominently defined. Spore diameter: 50 - 86 µm.

ZONAL CORRELATION

Detailed spore zonation schemes for the Devonian-Carboniferous boundary strata of the USSR and western Europe have been published in recent years, e. g. AVCHIMOVITCH (1986 a, b) for the Pripyat Depression in Byelorussia, BYVSCHEVA (1985) for eastern and central Russian Platform, HIGGS & STREEL (1984) for western Germany and HIGGS, CLAYTON & KEEGAN (in press) for southern Ireland. A joint paper by BYVSCHEVA, HIGGS & STREEL (1984) made some preliminary correlations of the respective spore zones between the Russian Platform and the Rhenish Slate Mountains of Germany. This study indicated the value and potential in such east-west collaborative work. The present study has provided even more detailed analysis and correlation of the Devonian-Carboniferous spore assemblages and zones between the various regions. These correlations are shown on fig. 2 and are discussed below in ascending order.

(1) Lty (Retispora lepidophyta - typica) zone described from the central and eastern parts of the USSR European territory is correlated with the **LF (Retispora lepidophy-**

ta - **Grandispora facilis**) zone of the Byelorussia territory. In western Europe this part of the sequence is correlated with the **LV** (**Retispora lepidophyta - Apiculiretusispora verrucosa**) zone. The authors have agreed that it is necessary to verify the supposition of the stratigraphic break (which corresponds to the lower portion of **LF** zone in Byelorussia) at the base of **LV** zone in the Franco-Belgian basin (see STREEL, 1986, p. 77). After AVCHIMOVITCH (1986 a) and AVCHIMOVITCH & DEMIDENKO (1985) this break within the full **LF** zone may fall upon the **Clymenia/Wocklumeria** genozone boundary. The relationship between the **LV** and **LF** zones in terms of their microfloral composition still remains a subject for discussion until a more detailed comparative palynological study of the corresponding deposits in Byelorussia and Franco-Belgian basin is undertaken.

(2) **Ltn** (**Retispora lepidophyta - tenera**) zone in the central and eastern parts of the Russian Platform corresponds to two zones in Byelorussia; these are the **LL** zone (**R. lepidophyta - Knoxisporites literatus**) and the **LMb** zone (**R. lepidophyta - Tholisporites mirabilis**) which occur within the Stvizh beds and lower portion of the Borov beds. The **LL** zone yields the first **K. literatus.**

Besides the index-species **Grandispora** (al. **Hymenozonotriletes**) **valida** (NAZARENKO et al., 1971) BYVSCHEVA & AVCHIMOVITCH comb. nov. is a characteristic element of **LMb** zone. In the central part of the Russian Platform, the **Ltn** zone includes the upper portion of the Ozersky horizon (= **LL**) and the Khovan horizon (= **LMb**). Also the correlation between the bases of **LL** zones in the western Europe and Byelorussia is not fully established since it is quite possible that the lower part of the **LL** zone in western Europe is absent or has not yet been recognized (see STREEL, 1986, p. 77).

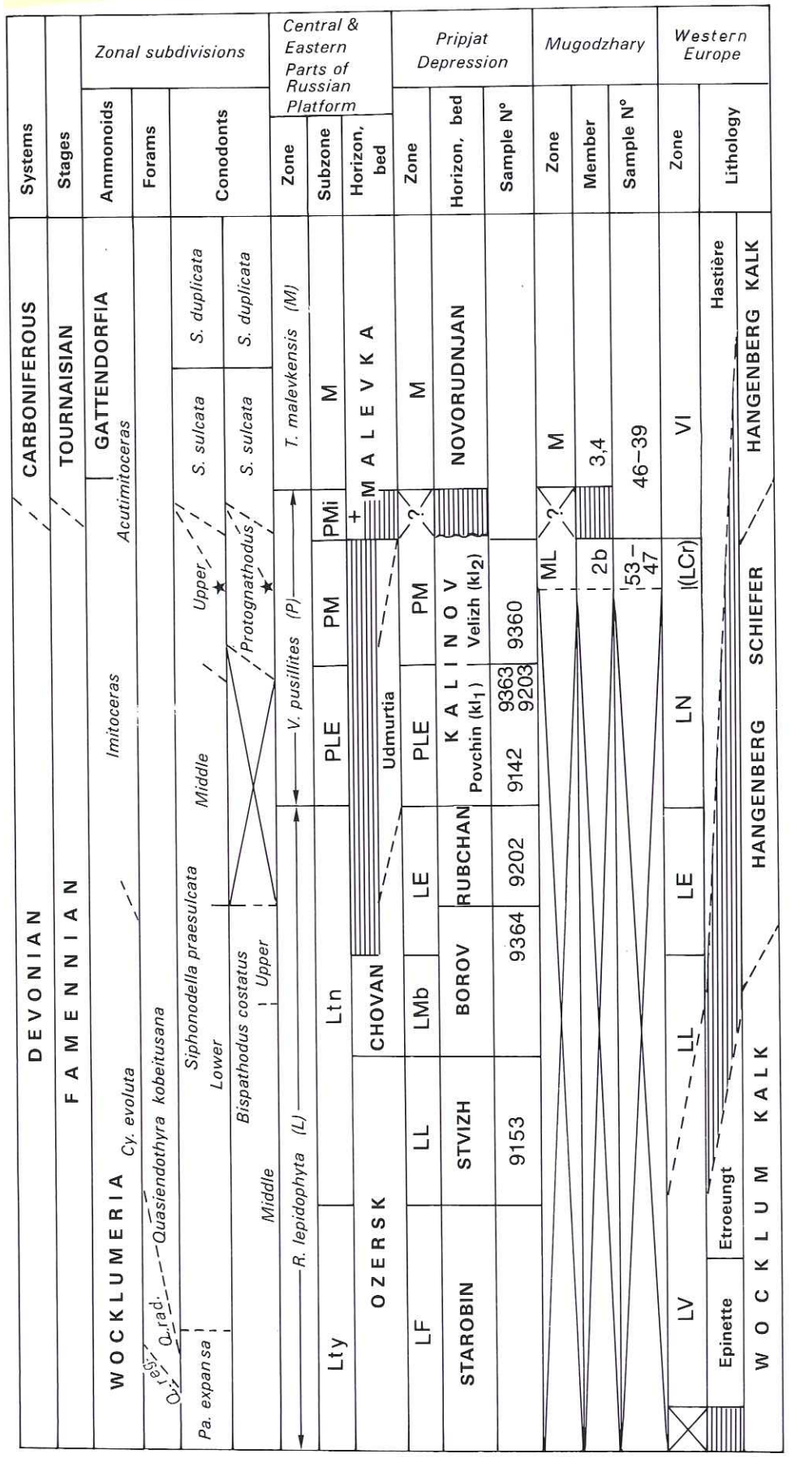
(3) The deposits of **LE** zone (**Retispora lepidophyta - Hymenozonotriletes explanatus**) are absent in the central region of the Russian Platform. In Byelorussia **Cymbosporites minutus** is a characteristic species of the **LE** zone and consequently AVCHIMOVITCH (1986 b) defined this part of the sequence as the **LMi** zone. (**Retispora lepidophyta - Cymbosporites minutus**). However, now that assemblages of the **LMi** zone in Byelorussia and the **LE** zone in western Europe are considered identical, the former definition of this zone (**LE**) is used.

In Byelorussia territory two spore assemblages are recognized within **LE** zone. The lower assemblage (the upper portion of the Borov beds) yields solitary **Hymenozonotriletes explanatus** while the upper one (Rubchan beds) yields the first **Vallatisporites hystricosus** and **V. pusillites** and is dominated by **Cymbosporites minutus.** In western Europe assemblages of the **LE** zone yield a large amount of **Vallatisporites hystricosus**, however, **Cymbosporites minutus** is less commonly represented.

(4.1.) The **P.** zone (**Vallatisporites pusillites**) in the USSR European territory is subdivided into three subzones. These are the **PLE** (**Vallatisporites pusillites - Retispora lepidophyta - Hymenozonotriletes explanatus**) subzone, the **PM** (**Vallatisporites pusillites - Tumulispora malevkensis**) subzone and the **PMi** (**Vallatisporites pusillites - Bascaudaspora mischkinensis**) subzone. In Byelorussia the P zone assemblages correlate with the **LN** (**Retispora lepidophyta - Verrucosisporites nitidus**) zone of western Europe. The **LN** zone is defined by the first occurrence of **Verrucosisporites nitidus** and a characteristic feature is the gradual disappearance of **Retispora lepidophyta.** In western Europe the boundary between **LN/VI** zones (**Vallatisporites verrucosus - Retusotriletes incohatus**) is regarded as almost corresponding to the Devonian-Carboniferous boundary (since **Retispora lepidophyta** dies out at the top of the **LN** zone). In the Russian Platform the abundance of **Retispora lepidophyta** specimens gradually diminishes upwards through the **P** zone until its complete disappearance at the top of this zone. In connection with this, in the central regions of the Russian Platform the **PMi** subzone has been established. It differs from the **PM** subzone in Byelorussia by the complete absence of **Retispora lepidophyta.** In the centre of the Russian Platform the **PMi** subzone within the Kupavin beds (Malevka horizon) is correlated with the lower portion of **VI** zone of western Europe on the basis of the absence of **Retispora lepidophyta.** It is quite possible, that in Byelorussia the **PMi** subzone should include the uppermost portion of the Upper Kalinov (Velizh) beds, which also must be correlated with the lower portion of **VI** zone in western Europe.

(4.2.) In the Berchogur section (Mugodzhar Mountains, see BARSKOV et al., 1984) members 2 b (Gumerov horizon) contain the spore assemblage of the **ML** (**Tumulispora ma-**

Fig. 2. Comparison between miospore and faunal zonations in the european part of the USSR and western Europe near the Devonian-Carboniferous boundary.



levkensis - Retispora lepidophyta) zone and members 3 and 4 (Kalapov horizon) of the Dzhanganin suite contain the spore assemblage of the **M** zone (**Tumulispora malevkensis**). Member 2b yields rare sporaric **Retispora lepidophyta** var. **tenera**. Also, this part of the section contains **Pseudopolygnathus fusiformis** and **Siphonodella praesulcata** conodonts and is compared with the Upper portion of **LN** (= **LCr**) zone in the western Europe and, probably, corresponds to the upper portion of **PM** zone in Byelorussia, in which numerous **Tumulispora malevkensis** and solitary **Retispora lepidophyta** var. **minor** are present. The upper portion of the Dzhanganin suite (members 3, 4), in which **Acutimitoceras prorsum** ammonoids and **Siphonodella sulcata** conodonts are present, is compared with the **VI** zone in western Europe.

The correlation between **M** zone (**Tumulispora malevkensis**) from the Malev horizon in the Russian Platform and **VI** zone in western Europe has been already substantiated (BYVSCHEVA et al., 1984). Samples from the upper part of the **M** zone from the Pripyat Depression , Byelorussia, are correlated with the **HD** zone - **Kraeuselisporites hibernicus - Umbonatisporites distinctus** of western Europe, based on the presence of the first index species (this correlation is above the top of fig. 2).

CONCLUSIONS

The most significant changes within the palynological assemblages during the Devonian -Carboniferous transition were taking place at two levels: **(1)** At the base of **P** zone (Russian Platform) or **LN** zone (western Europe); **(2)** at the base of **M** zone or **PMi** subzone (Russian Platform) equivalent to **VI**zone (western Europe) or within the similar interval at the top of **PM** subzone (Byelorussia) or **LN** (**LCr**) zone (western Europe).

The Devonian-Carboniferous boundary defined according to the ammonoid and conodont evolution is characterized by a changeable specific composition within the palynological assemblages and also a percentage variability among some spore species. Thus, in the central part of the Russian Platform, **Vallatisporites pusillites** dominates whereas **Retispora lepidophyta** is absent (**PMi** subzone). In the territory of Byelorussia the percentage of **V. pusillites** is still high, and the amount of **T. malevkensis** increases drastically while **R. lepidophyta** is represented mainly by **minor** variety and sometimes by **tenera** variety and is present sporadically. In the east of the Russian Platform (Udmurtiya) and in the Mugodzhar mountains the assemblage is dominated by **T. malevkensis**, whereas **V. pusillites** and **R. lepidophyta** (mainly **tenera** variety) occur sporadically as solitary specimens. In western Europe this interval corresponds to the upper portion of **LN** zone (= **LCr** VAN VEEN, 1981) because it contains a decreasing percentage of **R. lepidophyta** and **V. hystricosus** and more abundant **Verrucosisporites nitidus**.

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V. I. AVCHIMOVITCH
Bel NIGRI, Staroborisovsky trakt
220600 Minsk, USSR

K. HIGGS
Dept. of Geology, University College
Cork, Ireland

T. V. BYVSCHEVA
VNIGNI, 124, Shosse Entuziastov
105275 Moscow E-275, USSR

M. STREEL
Paleontology, State University
7, Pl. du XX août, B-4000 Liège

V. T. UMNOVA
PGO "Tsentrgeologiya"
Moscow, USSR

PLATE 1

All figures x 500 unless stated otherwise
(9342 = sample, E21-2 = New England Finder Coordinate)

Fig. 1. **Punctatisporites irrasus** HACQUEBARD
9342, E21-2

Fig. 2. **Punctatisporites solidus** HACQUEBARD
9360, E37-1

Fig. 3. **Punctatisporites glaber** (NAUMOVA) PLAYFORD
9360, Y33-1

Fig. 4. **Retusotriletes witneyanus** (CHALONER) STREEL
9364, M25-3

Fig. 5-6. **Retusotriletes incohatus** SULLIVAN
5. 505 103/17 289 m; S31-1
6. 9342, A19-4

Fig. 7. **Retusotriletes digressus** PLAYFORD
9202, P20-4

Fig. 8. **Camptotriletes paprothii** HIGGS & STREEL
9363, W36-2

Fig. 9. **Apiculiretusispora verrucosa** (CARO-MONIEZ) STREEL
9342, P24-4

Fig. 10-11. **Umbonatisporites abstrusus** (PLAYFORD) CLAYTON
10. 9363, G35-4
11. 9363, G35-4 (x1250)

Fig. 12. **Raistrickia variabilis** DOLBY & NEVES
9364, T24-3

Fig. 13 **Raistrickia minor** (KEDO) DOLBY & NEVES
9364, U25-3

Fig. 14. **Pustulatisporites dolbii** HIGGS, CLAYTON & KEEGAN
9342, L35-3

Fig. 15. **Raistrickia corynoges** SULLIVAN
9364, B36-2

Fig. 16. **Raistrickia ramiformis** (KEDO) AVCHIMOVITCH & HIGGS comb. nov.
9364, B30-3

Fig. 17. **Umbonatisporites** cf. **distinctus** CLAYTON
9363, L32-2

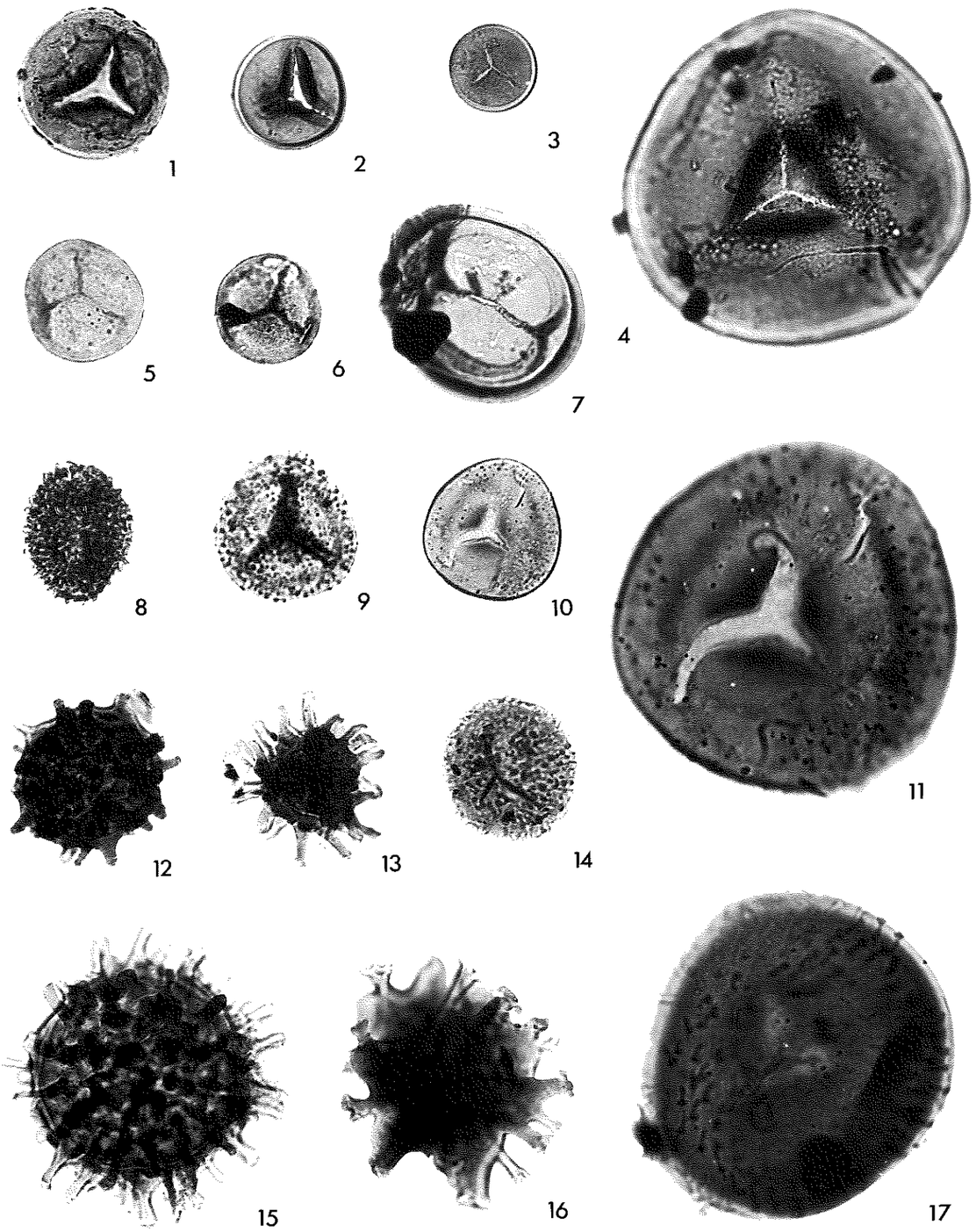

PLATE 2

All figures x 500

Fig. 1-2. **Lophozonotriletes excisus** NEUMOVA
1. 9203, H21-3
2. 9364, S41-1

Fig. 3-4. **Verrucosisporites mesogrumosus** (KEDO) BYVSCHEVA
3. 9364, V24-2
4. 9202, Q22-4

Fig. 5-6. **Verrucosisporites nitidus** (NAUMOVA) PLAYFORD
5. 9360, S29-4
6. 9360, S24-3

Fig. 7. **Dictyotriletes scrobiculatus** KEDO
9153, N34-2

Fig. 8. **Convolutispora** cf. **cerebra** BUTTERWORTH & WILLIAMS
9360, D23-3

Fig. 9, 12. **Convolutispora ampla** HOFFMEISTER, STAPLIN & MALLOY
9. 9342, U22-3
12. 9364, B30-1

Fig. 10. ? **Secarisporites** sp.
505. 103/17 289 m, R36-4

Fig. 11. **Corbulispora cancellata** (WALTZ) BHARADWAJ & VENKATACHALA
9364, Q21-3

Fig. 13. **Convolutispora mellita** HOFFMEISTER, STAPLIN & MALLOY
9360, G25-3

Fig. 14-15. **Cyrtospora cristifera** (LUBER) VAN DER ZWAN
14. 9363, K30-2
15. 9360, M39-1

Fig. 16-17. **Convolutispora usitata** PLAYFORD
16. 9342, E19-2
17. 9202, E26-2

Fig. 18. **Convolutispora major** (KEDO) TURNAU
9363, W20-1

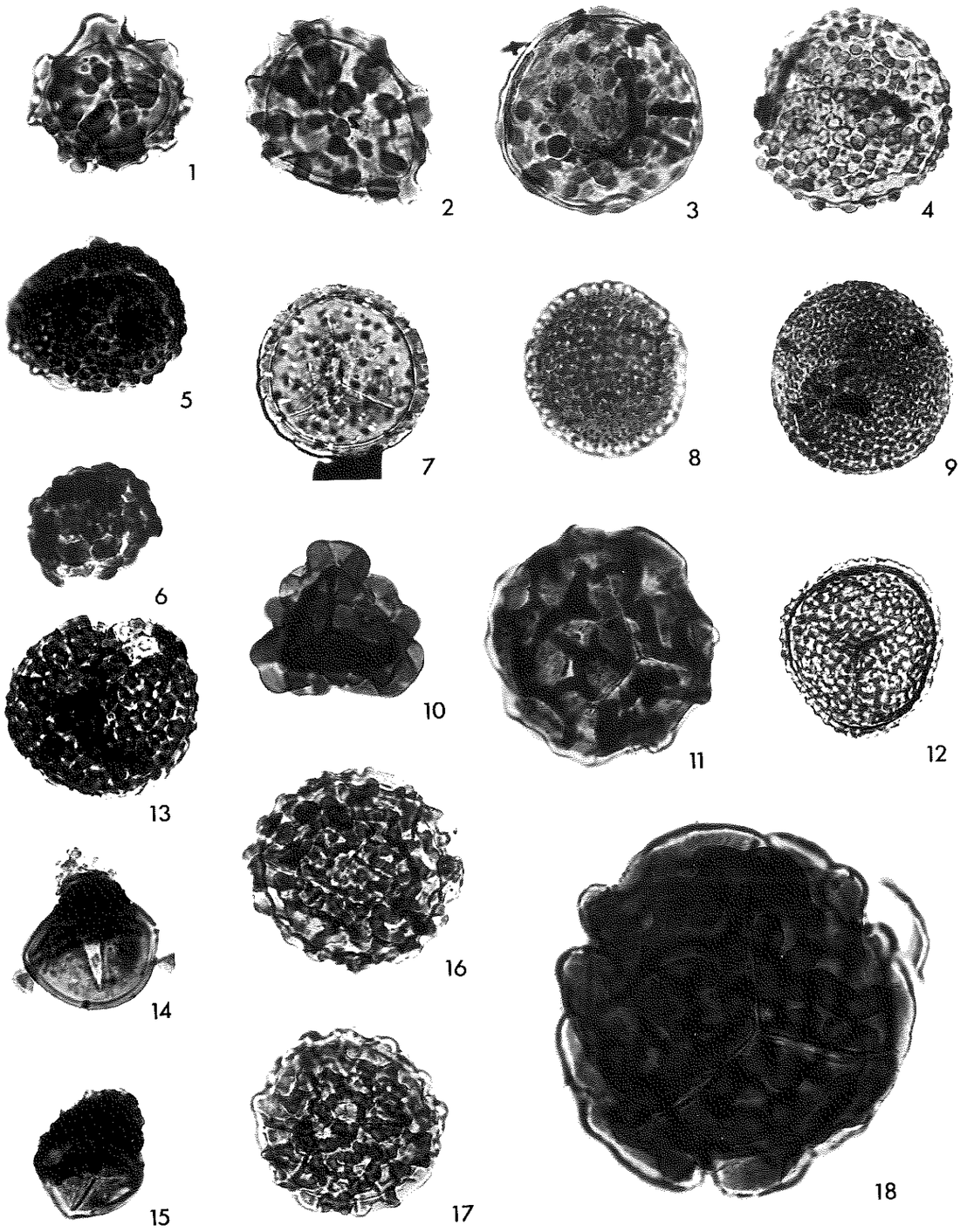

PLATE 3

All figures x 500

Fig. 1. **Knoxisporites incrassatus** (KEDO) HIGGS comb. nov.
9342, D36-4

Fig. 2-3. **Knoxisporites literatus** (WALTZ) PLAYFORD
2. 9342, Q40-4
3. 9364, W31-3

Fig. 4. **Stenozonotriletes conformis** NAUMOVA
9342, H19-4

Fig. 5-6. ? **Tumulispora** sp.
9364, G26-2

Fig. 7. **Stenozonotriletes meyenii** STREEL, HIGGS & AVCHIMOVITCH sp. nov.
9363, B18-4 (holotype)

Fig. 8-9. **Tumulispora malevkensis** (KEDO) TURNAU
8. 505 103/17 289 m, R36-4
9. 9363, F31-3

Fig. 10, 14. **Tumulispora variverrucata** (PLAYFORD) STAPLIN & JANSONIUS
10. 9342, H38-3
14. 9342, Z38-2

Fig. 11. ? **Knoxisporites** sp.
9364, B30-1

Fig. 12-13. **Tumulispora rarituberculata** (LUBER) POTONIÉ
12. 9153, R43-1
13. 9153, B43-4

Fig. 15. **Tumulispora varia** (KEDO) BYVSCHEVA comb. nov.
9364, E26-2

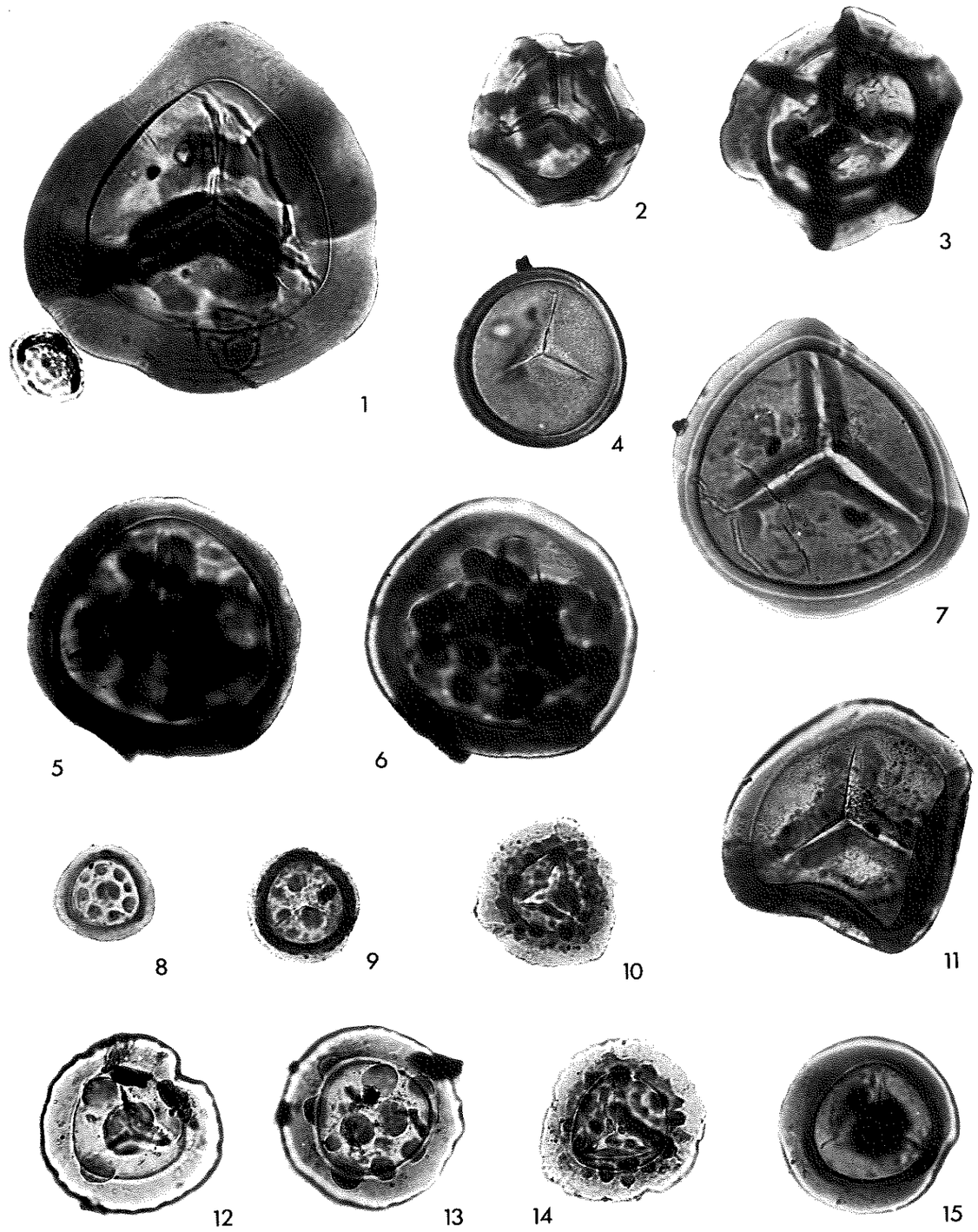

PLATE 4

All figures x 500

Fig. 1. **Diducites mucronatus** (KEDO) VAN VEEN
9153, Y35-3

Fig. 2. **Diducites versabilis** (KEDO) VAN VEEN
9153, U33-3

Fig. 3. **Diducites poljessicus** (KEDO) VAN VEEN
9153, T37-3

Fig. 4. **Diducites commutatus** (NAUMOVA) AVCHIMOVITCH comb. nov.
9364, U40-2

Fig. 5. **Retispora lepidophyta** (KEDO) PLAYFORD
9153, U36-1

Fig. 6. **Endoculeospora gradzinskii** TURNAU
9364, U32-1

Fig. 7-8. **Endoculeospora setacea** (KEDO) AVCHIMOVITCH & HIGGS comb. nov.
7. 9364, T27-1
8. 9364, P40-2

Fig. 9. **Tholisporites esenensis** BYVSCHEVA
505 103/17 289 m, 032-4

Fig. 10. **Spelaeotriletes crustatus** HIGGS
9363, T37-4

Fig. 11. **Diaphanospora rugosa** (NAUMOVA) BYVSCHEVA
9364, 021-1

Fig. 12. **Diaphanospora submirabilis** (KEDO) BYVSCHEVA
9342, N35-3

Fig. 13. **Convolutispora lactucosa** HIGGS, CLAYTON & KEEGAN
9360, C17-4

Fig. 14. **Auroraspora evanida** (KEDO) AVCHIMOVITCH comb. nov.
9342, N19-1

Fig. 15. **Auroraspora asperella** (KEDO) VAN DER ZWAN
9364, R19-2

Fig. 16-17. **Rugospora radiata** (KEDO) BYVSCHEVA
16. 9363, K35-4
17. 9363, S23-4

Fig. 18. **Grandispora echinata** HACQUEBARD
9364, 035-1

Fig. 19. **Grandispora senticosa** (ISCHENKO) BYVSCHEVA
9364, P33-4

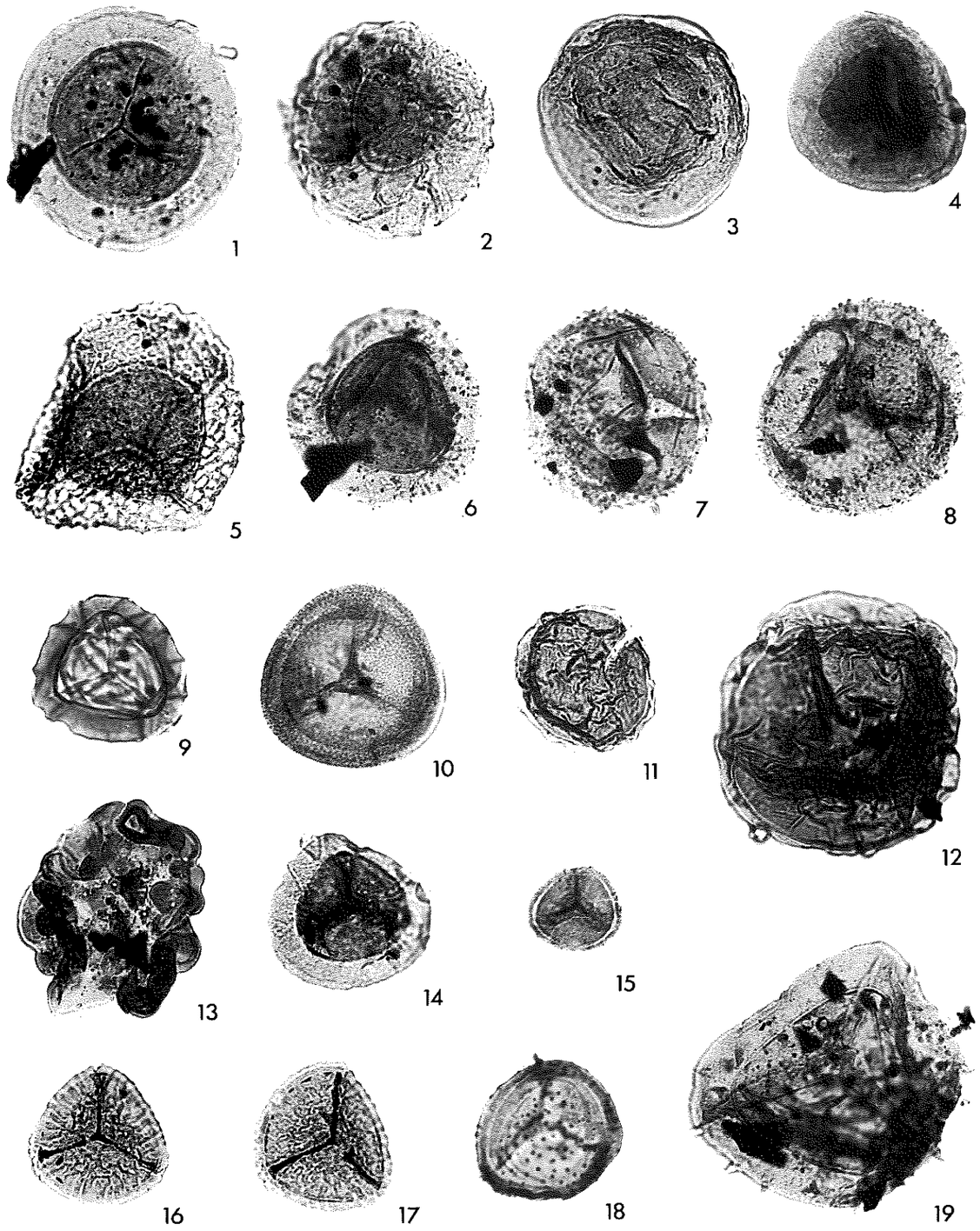

PLATE 5

All figures x 500

Fig. 1-2. **Cymbosporites menendezii** (MENENDEZ & AZCUY) HIGGS comb. nov.
1. 9342, M40-4
2. 9342, M38-3

Fig. 3. **Cymbosporites** sp.
9360, Q34-3

Fig. 4. **Cymbosporites magnificus** (Mc GREGOR) Mc GREGOR & CAMFIELD
9363, R21-3

Fig. 5-6. **Bascaudaspora mischkinensis** (BYVSCHEVA) BYVSCHEVA comb. nov.
5. 9363, F35-4
6. 9360, R39-2

Fig. 7. **Cymbosporites minutus** (KEDO) AVCHIMOVITCH & STREEL comb. nov.
9202, M28-3

Fig. 8. **Vallatisporites verrucosus** HACQUEBARD
9360, G25-3

Fig. 9. **Vallatisporites vallatus** HACQUEBARD
9360, W30-2

Fig. 10-13, 16. **Vallatisporites pusillites** (KEDO) DOLBY & NEVES emend. BYVSCHEVA
10. 9363, K21-1
11. 9363, T24-4
12. 9342, D36-4
13. 9363, W36-1
16. 9360, Y24-1

Fig. 14. **Vallatisporites hystricosus** (WINSLOW) BYVSCHEVA
9360, U27-2

Fig. 15. **Kraeuselisporites** sp.
9342, K27-1

Fig. 17. **Kraeuselisporites hibernicus** HIGGS
505 97/14B 272 m, L31-3

Fig. 18. **Hymenozonotriletes explanatus** KEDO
9363, 039-1

Fig. 19. **Ancyrospora ? capillata** DOLBY & NEVES
9363, S29-4