

Upper Wenlock miospores and cryptospores derived from a Silurian volcanic island in the Prague Basin (Barrandian area, Bohemia)

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ABSTRACT - Highly-diversified assemblages of dispersed trilete miospores and cryptospores belonging to the *Artemopyra brevicosta*–*Hispanaediscus verrucatus* Assemblage Zone were recovered from upper Wenlock (Silurian) tuffitic shales and limestones in the Prague Basin (Bohemia). The fact that the numerous sporomorphs have only been found in the region of the Svatý Jan Volcanic Centre supports previous sedimentological evidence that this volcanic elevation was emerged during the uppermost Wenlock. Twenty-nine sporomorph forms were determined. One new genus, *Rugosiporites* gen. nov., and three new species, *Rugosiporites kozlicus* sp. nov., *Synorisporites maculosus* sp. nov. and *Artemopyra rugaticosta* sp. nov. are described. The comparison with other coeval assemblages is discussed. *J. Micropalaeontol.* 14(1): 67–79, April 1995.

INTRODUCTION

The objective of this paper is a study of upper Wenlock sporomorphs from the Prague Basin. No Silurian sporomorphs have been published from the basin prior to this study. The first trilete miospores described from the basin come from upper Pragian (Devonian) Dvorce–Prokop Limestone (McGregor, 1979; Vavrdová, 1989).

Facies development and land plant traces in the Silurian of the Prague Basin

During the Silurian the Prague Basin was a part of north Gondwanan shelf seas bordering the Rheic ocean, fairly distant from large emergent lands. Anoxic bottom conditions generally occurred across the shelves. During the Llandovery and lower Wenlock such conditions, represented by black shale facies, existed in nearly the whole Prague Basin (see in Kříž, 1991). In the deeper parts of the basin they persisted until the middle Devonian.

From the mid-Wenlock to the early Ludlow the sedimentation in the Prague Basin was influenced by volcanic activity related to deep syndimentary faults and their zones of intersections (Kříž, 1991). The accumulation and redeposition of volcanic material caused a considerable shallowing of the central segment of the Prague Basin resulting in the deposition of bioclastic limestones in the region of the Svatý Jan Volcanic Centre (Fiala, 1982; Horný, 1955; Kříž, 1991). These limestones contain within the *C. murchisoni* Graptolite Biozone the oldest trilete miospores (*Ambitisporites avitus* Hoffmeister and *Ambitisporites dilutus* Hoffmeister) so far discovered in the Silurian of the Prague Basin (Dufka, 1990). Volcanic activity together with late Wenlock (late Homerian) regression lead to continuous shallowing and consequent emergence of the top of the volcanic elevation (Kříž, 1991). The new island may have favoured the rapid development of early land plants.

Numerous dispersed sporomorphs produced by these plants were deposited in tidal flat sediments.

Lack of sporomorphs in a number of samples of lower Ludlow (Gorstian) sediments from the vicinity of the Svatý Jan Volcanic Centre suggests the extinction of the upper Wenlock land flora due to submergence of the island or further volcanic activity.

Sporomorphs in the upper Ludlow and lower Přídolí strata are absent or rare and poorly preserved. However, based on sedimentological evidence, the top of the island was probably still above the sea level during this period (Kříž, 1991). Additionally, occurrences of *Cooksonia*-like sporophytes from lower Přídolí rocks (Obrhel, 1962) suggest that the recurrence of an island flora could be possible and the absence of sporomorphs may be caused by lack of outcrops within the upper Silurian near-shore deposits.

COLLECTED DATA AND PALYNOLOGICAL TECHNIQUES

This paper on upper Wenlock sporomorphs is the outcome of the palynological investigations carried out within the new palaeontological and biostratigraphic study of the Wenlock/Ludlow boundary in the Prague Basin (Kříž, 1992).

The majority of accessible upper Wenlock (Homerian, Motol Formation) and lower Ludlow (lower Gorstian, Kopanina Formation) sections in the Prague Basin have been investigated for organic microfossils. Sporomorphs, however, have been recovered only from late Wenlock strata of the central part of the basin, in the area of Svatý Jan Volcanic Centre (*sensu* Kříž, 1991, p. 182). The Motol Formation is developed here in facies containing bioclastic and tuffitic limestones and tuffites ('Kozel' facies) associated with basalt and volcanoclastic rocks (Horný, 1955; Kříž, 1991). In contrast to lateral deeper parts of the Prague Basin, where the sedimentation of graptolite shales

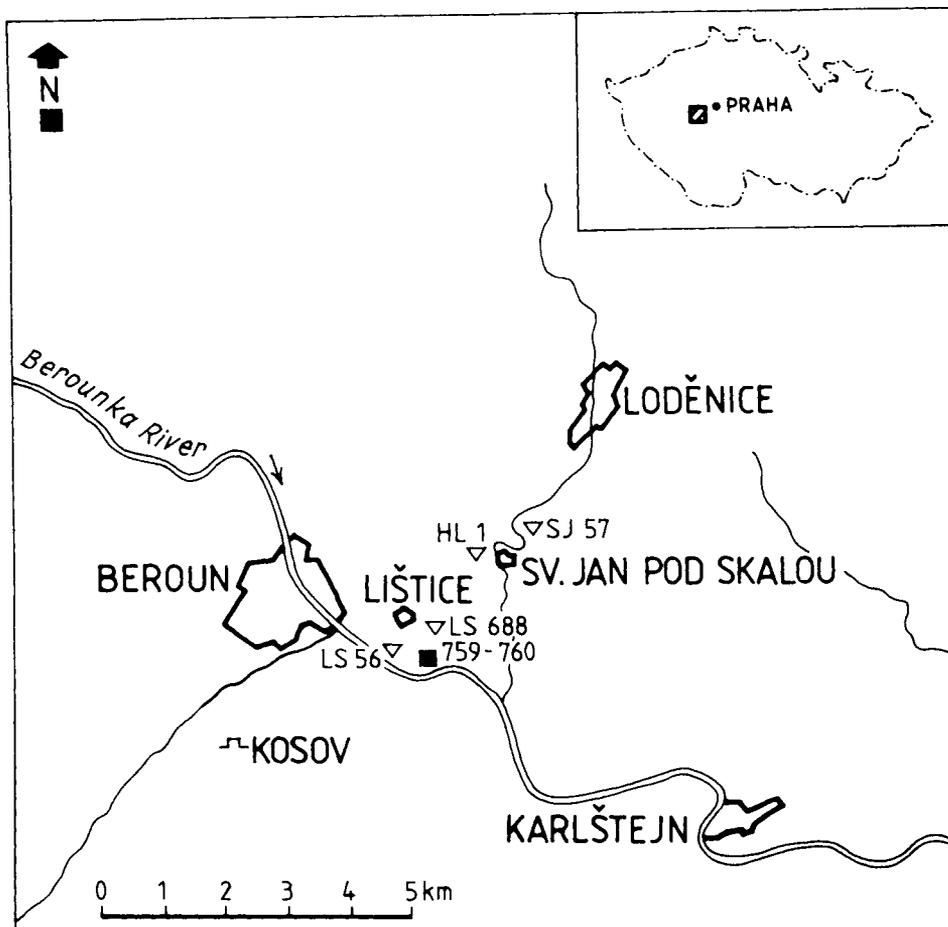


Fig. 1. Location of the outcrops with sporomorph occurrences.

continued, the richness of benthic fauna and dearth of graptolites characterise this volcano-carbonate facies.

Twenty-three samples from five outcrops have yielded some sporomorphs (Figs 1 and 2).

The most significant specimens of sporomorphs yet found come from tuffites, tuffitic shales and limestones forming the eastern part of the large rock outcrop above the Berounka river, near the village of Lištice. General study of these rocks was done by Horný (1955) and more detailed biostratigraphy was discussed by Kříž (1992). Kříž defined here two sections (759 and 760; for detail see Kříž, 1992) separated by layers of tuffitic shales and volcanoclastics, more than forty metres thick, covered with slope debris. Graptolites of the *C. lundgreni* Biozone (*M. priodon flemingii*) were found in the lower section no. 759 (Kříž, 1992). These graptolite data together with new intrabasinal correlation of the overlying volcanoclastics (J. Kříž, pers. comm.) suggest that the tuffites and bioclastic limestones of the section no. 760 may range from the *M. dubius parvus* Biozone to the *M. vulgaris* Biozone, Wenlock, Silurian.

Beside the first outcrop there were also a few samples containing sporomorphs taken from test pits situated near the Svatý Jan Volcanic Centre (Fig. 1). These samples are not dated by graptolites. According to previous studies

(Horný, 1955; Kříž, pers. comm.) the age of host rocks corresponds to Homerian. Following four samples were collected from dug holes: sample HL-1 (brachiopod limestone) Svatý Jan, 'Hliník' locality (Horný, 1955); sample SJ-57 (crinoid limestone) Svatý Jan, 'ruda' horizon; sample LS-56 (tuffite) Lištice; sample LS-688 (bioclastic limestone) Lištice, 'Hradiště' locality.

All samples were processed using standard palynological techniques (HCl-HF-HCl-heavy liquid separation). No oxidation was applied. Organic residue was sieved through 53 μm and 10 μm nylon sieves. Light microphotographs were made with a Zeiss-Fluoval. Electron Microscope (SEM) photos were taken with a TESLA BS 340 SEM.

CHARACTERISTICS OF THE PALYNOSPECTRA

Based on the relative abundance of sporomorphs and acritarchs, recorded in each sample, two upper Wenlock palynofacies with spores could be distinguished.

A. Section 759 (all samples), sample SJ-57, sample HL-1, sample LS-688

Trilete miospores and cryptospores are distinctly less abundant compared with marine microphytoplankton. Sporomorphs are mostly ill-preserved, except for the sample

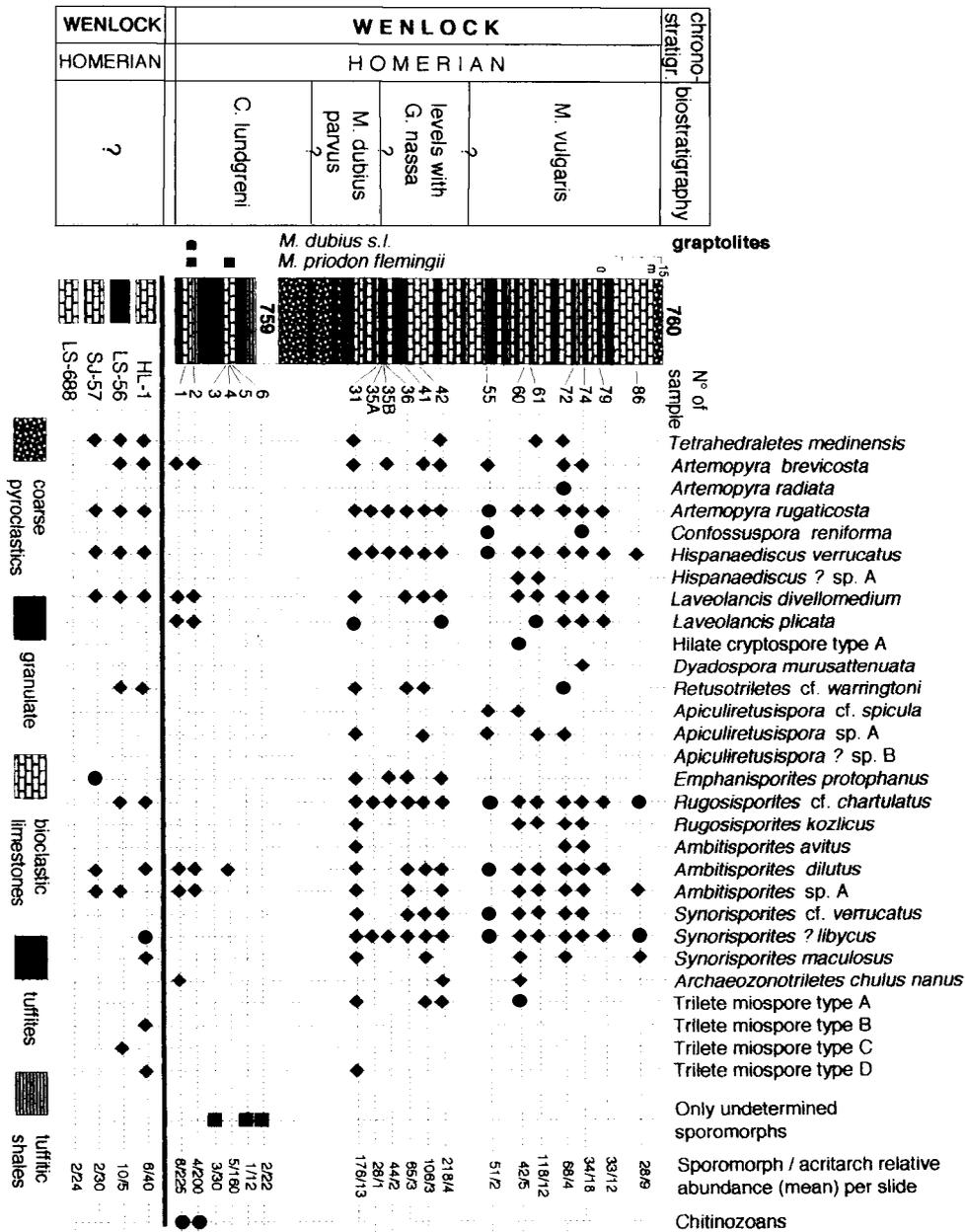


Fig. 2. Distribution of trilete miospores and cryptospores in the upper Wenlock strata of the Prague Basin.

HL-1, where the specimens are well-preserved. In spite of the low content of sporomorphs a high specific diversity including sculptured forms was recorded in samples HL-1 and SJ-57 (Fig. 2). Acritachs and prasinophycean-like sphaeromorphs dominate the palynospectra. Their absolute abundance, however, is fairly low (<50 specimens/g in sample HL-1). The distribution and number of acritarchs are similar to those of prasinophytes in all samples. Acritarchs are mostly light-yellow, excellently preserved and of high variability.

Chitinozoans were recovered only from two samples

of section 759 (Fig. 2). Two long-ranging species, *Ancyrochitina* group *ancyrea* Eisenack and *Conochitina tuba* Eisenack, were recognized.

B. Section 760 (all samples)

Trilete miospores and cryptospores clearly predominate over the marine microphytoplankton. Their mode of preservation ranges from well-preserved specimens that exhibit all fine details of the wall ornamentation to specimens destroyed by microbial attack or pyrite crystal growths. Sporomorph colour ranges between light and dark

Number of sample	TRILETE MIOSPORES				TETRADS	HILATE CRYPTOSPORES		
	Laevigate	Murornate	Apiculate	Verrucate		Laevigate	Murornate	Verrucate
								
72	17	21	2	19	2	9	6	24
61	11	10	1	33	<1	6	6	33
42	15	8.5	-	26	<1	6	8	36.5
41	7	9	2	23	-	11	7	41
36	10	13.5	<1	33	-	5.5	8	29.5
31	5	15.5	<1	29	2	6	10	32

Fig. 3. Percentages of various morphological groups of sporomorphs in selected samples from the section no. 760.

brown, depending on sample lithology and exine thickness. The abundance and species diversity of sporomorphs vary slightly in individual samples, nevertheless they have an approximately uniform character throughout the section. All samples are characterized by dominance of distally verrucate miospores and cryptospores, by the common occurrence of murornate and laevigate miospores and cryptospores and by the scarcity of 'permanently' fused cryptospore dyads and tetrads (Fig. 3).

Acritarchs are rare, but well-preserved. Together with prasinophycean-like algae they represent maximally 10% of counted palynomorphs, except for the uppermost three samples in the section where they constitute nearly 25% of recorded palynomorphs.

No chitinozoans have been found in the section.

Sample LS-56

Sporomorphs are scarce, but diversified. Acritarchs are also rare, represented by ill-preserved, small spherical forms with short simple processes (?*Michrystidium*, ?*Tylotopalla*). No chitinozoans were found. A substantially increased content of amorphous kerogen indicates anoxic bottom conditions.

In all studied samples the occurrence of further macerals was noted, but they are not yet classified. No mazuelloids have been found in sporomorph-containing samples. Scolecodonts are common. *Nematothallus*-type pseudocellular cuticles are commonly found compared with nematoclasts ('tubes') which are rare. In general, the number of sporomorphs does not increase together with the number of *Nematothallus*-type organoclasts. Similarly, the abundance of macroscopically fragments of organic matter formed by closely packed filaments (cf. *Prototaxites* Dawson) in upper Wenlock tuffitic shales and limestones can not be correlated with occurrences of sporomorphs.

SYSTEMATIC DESCRIPTIONS

Anteturma **Cryptosporites** Richardson *et al.*, 1984

Genus **Artemopyra** Burgess & Richardson, 1991

Artemopyra brevicosta Burgess & Richardson, 1991

Remarks. *Artemopyra* Burgess & Richardson, 1991 is regarded as a synonym of *Dicryptosporites* Strother, 1991. The publication dates give evidence that the genus *Artemopyra* has precedence over the genus *Dicryptosporites*. *Dicryptosporites radiatus* Strother, 1991 is transferred to the genus *Artemopyra* and *Dicryptosporites minus* Strother, 1991 is considered as a junior synonym of *Artemopyra brevicosta* Burgess & Richardson, 1991.

Artemopyra radiata (Strother, 1991) comb. nov.
(Pl. 1, fig. 6)

1991 *Dicryptosporites radiatus* Strother: 226, pl. 1, fig. 6.

Diagnosis. See Strother, 1991, p.226

Description. Hilate cryptospores seen only as separate grains. Amb circular to subcircular. Proximal hilum surrounded by thickened equatorial ring. Hilum ornament with radially arranged ribs running out from the equatorial ring, extending about 1/4 of spore diameter and then passing into the 'inner ring' of concentric muri or wrinkles. Hilum usually smooth in polar area. Distal exine laevigate.

Dimensions. 12 specimens measured: equatorial diameter (mean value of each specimen) 24(25)28 μm .

Remarks. *Artemopyra brevicosta* Burgess & Richardson has shorter radial muri sculpturing the equatorial ring rather than the surface of the hilum. *Artemopyra rugaticosta* sp. nov. has mainly convoluted and anastomosing muri usually distributed throughout the hilum without a discernable 'inner ring'.

Artemopyra rugaticosta sp. nov.

(Pl. 1, figs 2, 5, 11)

? 1973 *Emphanisporites* cf. *microratus* Richardson & Lister, Richardson & Ioannides: 275, pl. 3, fig. 4.

? 1978 *Emphanisporites protoannulatus* Rodriguez: 416, pl. 1, figs 22, 23.

1991 *Artemopyra* sp. A, Burgess & Richardson: 613, pl. 1, figs 10, 11.

Diagnosis. An *Artemopyra* with more or less radially orientated proximal muri (wrinkles), usually convolute and anastomosing or composing rugulate ornamentation.

Holotype. Pl. 1, fig. 11; sample 760/74; slide 760/74-J. Czech Geological Survey.

Paratype. Pl. 1, fig. 5; sample 760/41; slide 760/41-C. Czech Geological Survey.

Type locality and type horizon. Section 760 (Kříž, 1992), Lištica near Beroun, Prague Basin. Barrandian area, Czech Republic. Motol Formation, upper Homerian, Wenlock, Silurian.

Description. Hilate cryptospores, probably derived from loosely attached dyads, but all specimens seen are single grains. Amb circular to subcircular. Equatorial rim mostly distinct, 1–2 μm wide, surrounding the proximal hilum. Hilum sculptured with low muri or wrinkles distinctive by more or less radial orientation (at least close to the equator), convolute, anastomosing or rugulate patterns and gradual tapering to the proximal pole. Exceptionally, muri are nearly straight extending from the equator to the proximal pole (paratype). Distal exine is c. 1 μm thick, laevigate.

Dimensions. 30 specimens measured: equatorial diameter 20(24)34 μm .

Remarks. *Artemopyra radiata* (Strother) comb. nov. has shorter distinctly radial muri and smooth polar portions of the proximal exine.

Genus *Hispanaediscus* Cramer, 1966, emend. Burgess & Richardson, 1991

Hispanaediscus verrucatus Cramer 1966

Hispanaediscus ? sp. A

(Pl. 1, figs 12, 13)

Description. Hilate cryptospores found as separate grains. Amb subcircular. Proximal hilum sculptured with radial muri, straight or anastomosing, always converging at the proximal pole. Distal exine covered by low, sparse verrucae, circular or oval in outline.

Dimensions. 3 specimens measured: equatorial diameter 28, 30, 35 μm .

Remarks. *Hispanaediscus wenlockensis* Burgess & Richardson 1991 has closely packed distal verrucae and shorter proximal radial muri.

Hilate cryptospore type A

(Pl. 2, figs 1, 2)

Description. Proximally hilate cryptospores. Amb circular. Equatorial crassitude forms a narrow ring, about 1 μm wide. Proximal hilum rugulate. Distal exine sculptured

with regularly distributed shallow foveolae which are surrounded by low annular thickenings.

Dimensions. 2 specimens recorded: equatorial diameter 20 μm .

Anteturma **Sporites** H. Potonié, 1893

Turma **Triletes** Reintsch, 1891

Subturma **Azonotriletes** Lubert, 1935

Infraturma Apiculati Bennie & Kidston, emend. Potonié, 1956

Genus *Apiculiretusispora* Streeel, 1964

Apiculiretusispora brandtii Streeel, 1964

Apiculiretusispora sp. A

(Pl. 2, fig. 16)

Description. Amb subcircular to convex triangular. Laesurae straight, simple or accompanied with lips parallel with laesurae extending from 3/4 of to entire spore radius. Contact areas smooth, often distinct, delimited by well-defined curvaturae perfectae, smooth. Outside of contact areas exine ornamented with minute, dense grana or low spines.

Dimensions. 5 specimens measured: equatorial diameter 24(26)29 μm .

Remarks. *Apiculiretusispora* sp. A Richardson & Lister (1969) is much larger in diameter. *Apiculiretusispora* sp. A Richardson & Ioannides (1973) has a distinctly smaller contact area.

Apiculiretusispora ? sp. B

(Pl. 2, fig. 3)

1973 *Apiculiretusispora* sp. B Richardson & Ioannides: 274, pl. 2, fig. 6.

Description. Amb subcircular to broadly triangular. Laesurae mostly inconspicuous. Ornamentation consisting of small cones or spines, about 0.5 μm high.

Dimensions. 4 specimens measured: equatorial diameter 13–18 μm .

Infraturma Murornati Potonié & Kremp, 1954

Genus *Rugosisporites* gen. nov.

Rugosisporites chartulatus (McGregor) comb. nov.

Derivation of name. Latin *rugosus*, wrinkled

Diagnosis. Radial trilete miospores; amb subtriangular to subcircular. Proximal surface sculptured with short and low muri, rugulae or grana radially and/or randomly orientated. Equatorial crassitude inconspicuous, distal exine laevigate or with scattered minute grana.

Comparison. *Emphanisporites* McGregor has proximal muri which are predominantly radial, continuously tapering to the proximal pole.

Rugosisporites cf. *chartulatus* (McGregor 1979) comb. nov.

(Pl. 2, figs 9–14)

1973 *Emphanisporites* ? sp. D Richardson & Ioannides: 276, pl. 3, fig. 9.

1978 *Retusotriletes chartulatus* McGregor in McGregor & Narbonne: 1301, pl. 1, figs. 10–12.

1991 Trilete miospore type 1 Burgess & Richardson: 618, text fig. 3A–C.

Description. Amb subtriangular to subcircular. Equatorial crassitude narrow ($<2\ \mu\text{m}$). Laesurae distinct, more or less sinuous, simple or with inconspicuous lips, extending from 4/5 to entire spore radius. Curvaturae perfectae either coincident with the equator or slightly to distinctly invaginate. Proximal surface (contact area) rugulate, composed of numerous tiny muri or wrinkles, usually convolute and anastomosing which are somewhat randomly disposed, but in general radially aligned, predominantly near the equator. Distal exine laevigate or bearing scattered minute grana.

Dimensions. 55 specimens measured: equatorial diameter 20(25)31 μm .

Remarks. The specimens described by McGregor in McGregor & Narbonne (1978, p.1301) as well as the Trilete miospore type 1 of Burgess & Richardson (1991) are substantially larger than the forms of *Rugosisporites* cf. *chartulatus* from the Prague Basin. Nevertheless their morphological features are fairly similar.

Rugosisporites kozlicus sp. nov.

(Pl. 2, figs 15, 17)

Diagnosis. A *Rugosisporites* with straight Laesurae and minute proximal ornamentation, consisting of randomly orientated small rugulae and grana.

Holotype. Pl. 2, fig. 17, sample 760/61, slide 760/61-A. Czech Geological Survey.

Type locality and type horizon. Section 760 (Kříž, 1992), Lištice near Beroun, Prague Basin. Barrandian area, Czech Republic. Motol Formation, upper Homerian, Wenlock, Silurian.

Description. Amb circular to subcircular laesurae simple, straight, extending near or to the spore margin. Equatorial crassitude indistinct. Curvaturae perfectae coincident with the equator. Proximal surface sculptured with numerous, short, randomly orientated rugulae and grana. Distal exine laevigate.

Dimensions. 8 specimens measured: equatorial diameter 25(28)31 μm .

Remarks. *Rugosisporites* cf. *chartulatus* (McGregor) comb. no. has more distinct, radially orientated proximal rugulae and often invaginated curvaturae.

Subturma **Zonotriletes** Waltz, 1935 in Luber & Waltz (1938)

Infraturma **Crassiti** Bharadwaj & Venkatachala, 1961

Genus *Ambitisporites* Hoffmeister, 1959

Ambitisporites avitus Hoffmeister, 1959

Ambitisporites sp. A

(Pl. 3, fig. 11)

Description. Small *Ambitisporites* ($<20\ \mu\text{m}$ in diameter). Amb subtriangular to subsphaerical. Laesurae distinct, simple, extending near or to the spore margin. Curvaturae coincident with the equator. Exine laevigate.

Dimensions. 15 specimens measured: equatorial diameter 15(18)20 μm .

Remarks. *Ambitisporites* sp. A is closely similar to *Ambitisporites dilutus* Hoffmeister 1959, but substantially smaller than supposed for *A. dilutus*. For example, Burgess & Richardson (1991, p. 615) did not report a specimen of *A. dilutus* smaller than 22 μm among 100 specimens of *A. dilutus* from type Wenlock area.

Genus *Synorisporites* Richardson & Lister, 1969

Synorisporites downtonensis Richardson & Lister, 1969

Synorisporites cf. *verrucatus* Richardson & Lister, 1969

(Pl. 3, figs 5, 6)

1973 *Synorisporites* cf. *verrucatus* Richardson & Lister; Richardson & Ioannides: 278, pl. 6, figs. 11–16

Dimensions. 20 specimens measured: equatorial diameter 18(21)26 μm .

Remarks. Specimens referred to *Synorisporites* cf. *verrucatus* have a little more prominent and closely packed verrucae in comparison with forms assigned to *Synorisporites libycus* Richardson & Ioannides (see below).

Synorisporites ? *libycus* Richardson & Ioannides, 1973

(Pl. 3, figs 4, 7, 8, 12, 13)

Dimensions. 50 specimens measured: equatorial diameter 18(24)30 μm .

Remarks. The specimens referred here to *Synorisporites libycus*? are more or less conformable with the descriptions of Richardson & Ioannides (1973, p.280) and Burgess & Richardson (1991; *Synorisporites* cf. *S. ? libycus*, p. 617). They dominate among verrucate miospores in section 760 and may be discriminated from *Synorisporites* cf. *verrucatus* by lower and more separated verrucae confined within the equatorial thickening. However, the morphological characteristics of both the species from the Prague Basin appear to intergrade (more than those of the Libyan forms).

Synorisporites maculosus sp. nov.

(Pl. 3, figs 1–3)

Derivation of name. Latin *maculosus*, speckled.

Explanation of Plate 1

Homerian of the Prague Basin (see Fig. 4). Enlargement: all figs $\times 1500$ **Figs 1, 4.** *Artemomyra* cf. *brevicosta* Burgess & Richardson, 1991. Fig. 1. 760/42-E. Fig. 4. 760/31-J. **Figs 2, 5, 11.** *Artemomyra rugaticosta* sp. nov. Fig 2. 760/74-H. Fig. 5. Paratype, 760/41-C. Fig. 11. Holotype, 760/74-J. **Fig. 3.** *Artemomyra* cf. *rugaticosta* sp. nov., 760/74-H. **Fig. 6.** *Artemomyra radiata* (Strother, 1991) comb. nov., 760/72-D. **Fig. 7.** *Confossuspora reniforma* Strother, 1991, 760/74C. **Figs 8–10.** *Hispanaediscus verrucatus* Cramer, 1966, emend. Burgess & Richardson, 1991. Fig. 8. 760/60-G. Figs 9, 10. 760/74-B, proximal and distal focus respectively. **Figs 12, 13.** *Hispanaediscus*? sp. A, 760/35-B, proximal and distal focus respectively.

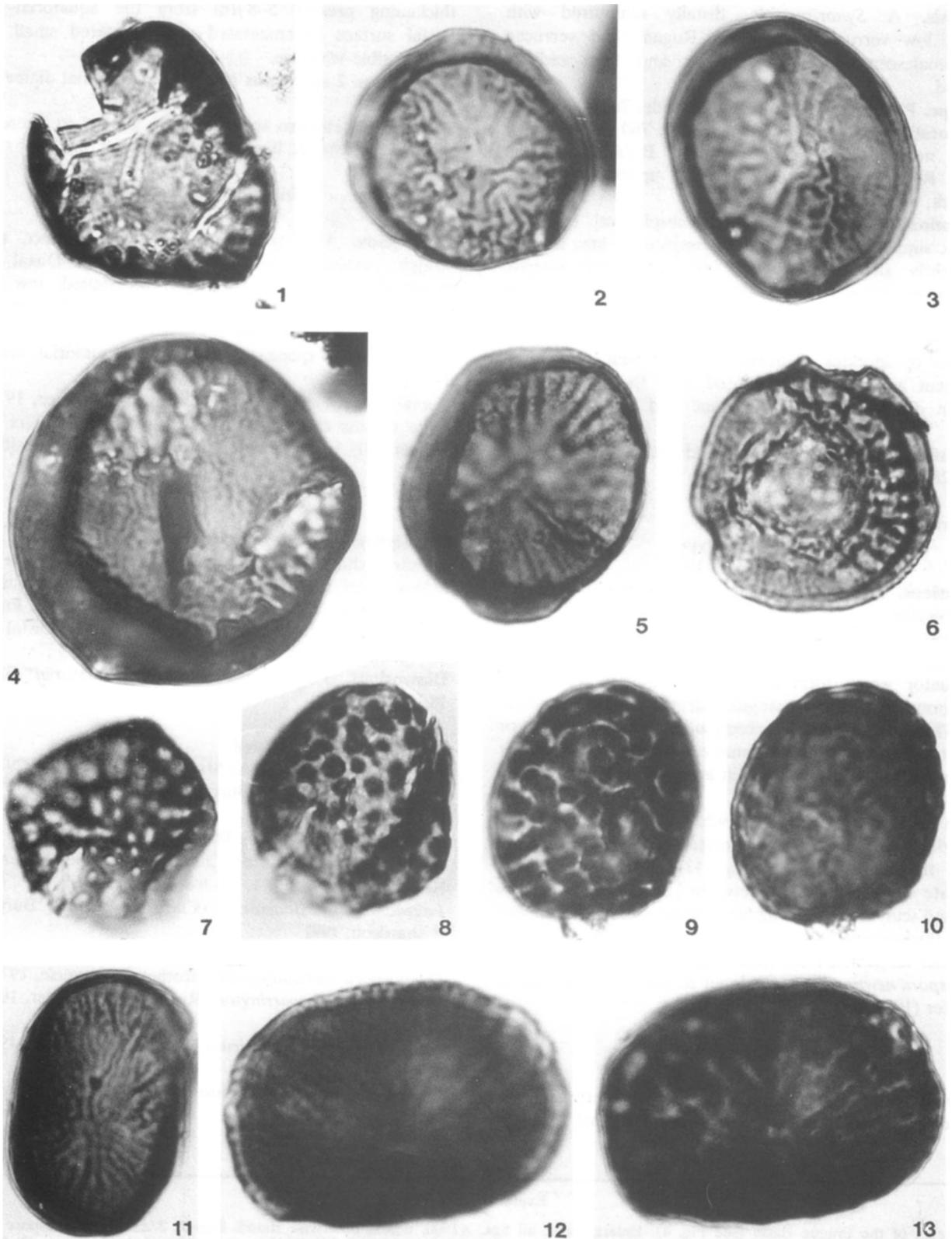


Plate 1.

Diagnosis. A *Synorisporites*, distally sculptured with rugulae, low verrucae and grana. Rugulae and verrucae often coalescent near the equator and then radially disposed.

Holotype. Pl. 3, fig. 1, sample 760/41, slide, 760/41-C.

Type locality and type horizon. Section 760 (Kříž, 1992), Lištice near Beroun, Prague Basin. Barrandian area, Czech Republic. Motol Formation, upper Homerian, Wenlock, Silurian.

Description. Amb subtriangular to subspherical. Laesurae distinct, simple or with narrow inconspicuous lips, straight or slightly sinuous, extending to the spore margin. Curvaturae coincident with the equator. Proximal exine mostly laevigate or covered with small grana and wrinkles. Distal surface ornamented with rugulae, grana and low verrucae or speckles of thickened exine which are often coalescent and radially orientated near the equator and rare on distal pole. Both proximal and distal walls are thin.

Dimensions. 13 specimens measured: equatorial diameter 23(25)28 μm .

Indeterminate trilete miospores

Trilete miospore type A

(Pl. 3, figs 16–18)

Dimensions. 12 specimens measured: equatorial diameter 31(33)38 μm .

Description and remarks. A group of trilete miospores characterized by narrow thickenings, more or less parallel to equator which form conspicuous equilateral triangle. Two forms bearing this triangular structure were recorded.

1. Thickenings distal, accompanied with granulate or rugulate ornamentation. Proximal exine smooth; curvaturae straight, extending to the margin and curvaturae coinciding to the equator (Pl. 3, fig. 16).

2. A triangle composing belts which seem to be proximal, bordering the trilete mark. Laesurae are sometimes sunk under thickenings (Pl. 3, fig. 17). Proximal exine is laevigate or microgranulate between Laesurae and thickenings, and sculptured with rugulae or short radial muri outside of the thickenings.

Similar tangential folds were described and illustrated on *Streelisporea newportensis* (Chaloner & Streel) by Richardson & Lister (1969, p. 230, pl. 41, fig. 3).

Trilete miospore type B

(Pl. 3, fig. 9)

Description. Amb subspherical. Laesurae slightly sinuous, extending nearly to spore margin. Proximal annular

thickening present 5–8 μm from the equatorial edge. Distal surface ornamented with spattered small grana and possible verrucae.

Dimensions. 2 specimens measured: equatorial diameter 26 and 27 μm .

Remarks. These two specimens are similar to Spore type D of Richardson & Ioannides (1973, pl. 9, fig. 2).

Trilete miospore type C

(Pl. 3, figs 14, 15)

Description. Amb subcircular. Laesurae distinct, mostly straight, extending to the spore margin. Distal exine provided with low, chaotically distributed low muri, convoluted and anastomosing to form irregular reticulum. Proximal surface probably smooth.

Dimensions. 4 specimens measured: equatorial diameter 19–21 μm .

Remarks. *Archaeozonotriletes vetustus* Rodriguez, 1977 has more or less similar distal sculpture, but it differs by its substantially larger size and a thick equatorial crassitude.

Trilete miospore type D

(Pl. 2, figs 4–6)

Description. Amb subtriangular with rounded apices. Laesurae short, extending maximally for 1/2 of the spore radius. Polar area delimiting laesurae convex and triangular in outline, smooth or sparsely microgranulate. Proximal radial ribs confined onto equatorial area. Distal exine laevigate.

Dimensions. 3 specimens measured: equatorial diameter 18, 20, 24 μm .

Other species determined

Tetraedraletes medinensis Strother & Traverse, 1979

Artemopyra brevicosta Burgess & Richardson, 1991 (Pl. 1, figs 1, 4)

Confossuspora reniforma Strother, 1991 (Pl. 1, fig. 7)

Hispanaedisca verrucatus Cramer, 1966, emend. Burgess & Richardson, 1991 (Pl. 1, figs 8–10)

Laveolancis divellomedium (Chibrikova, 1959) Burgess & Richardson, 1991

L. plicata Burgess & Richardson, 1991

Dyadosporea murusattenuata Strother & Traverse, 1979

Retusotriletes cf. *warringtoni* Richardson & Lister, 1969 (Pl. 2, fig. 18)

Apiculiretusispora cf. *spicula* Richardson & Lister, 1969 (Pl. 2, fig. 19)

Emphanisporites protophanus Richardson & Ioannides, 1973 (Pl. 2, figs 7, 8)

Explanation of Plate 2

Homerian of the Prague Basin (see Fig. 4). Enlargement: all figs. $\times 1500$, unless otherwise stated. **Figs 1, 2.** Hilate cryptospore type A, 760/60-B, proximal and distal focus respectively. **Fig. 3.** *Apiculiretusispora?* sp. B, HL-1/V2-2. **Figs 4–6.** Trilete miospore type D. Figs 4, 5. HL-1/V-5, proximal and distal focus respectively. Fig. 6. 760/31-C. **Figs 7, 8.** *Emphanisporites protophanus* Richardson & Ioannides, 1973, 760/31-C, proximal and distal focus respectively. **Figs 9–14.** *Rugosisporites* cf. *chartulatus* (McGregor) gen. et comb. nov. Fig. 9. 760/31-E. Fig. 10. 760/72-E. Fig. 11. 760/72-O. Fig. 12. 760/79-A, $\times 1750$. Fig. 13. 760/31-J. Fig. 14. 760/72-B. **Figs 15, 17.** *Rugosisporites kozlicus* gen. et sp. nov. Fig. 15. 760/61-H. Fig. 17. holotype, 760/61-A. **Fig. 16.** *Apiculiretusispora* sp. A, 760/72-B. **Fig. 18.** *Retusotriletes* cf. *warringtoni* Richardson & Lister, 1969, HL-1/U-1. **Fig. 19.** *Apiculiretusispora* cf. *spicula* Richardson & Lister, 1969, 760/55-C.

Upper Wenlock miospores and cryptospores

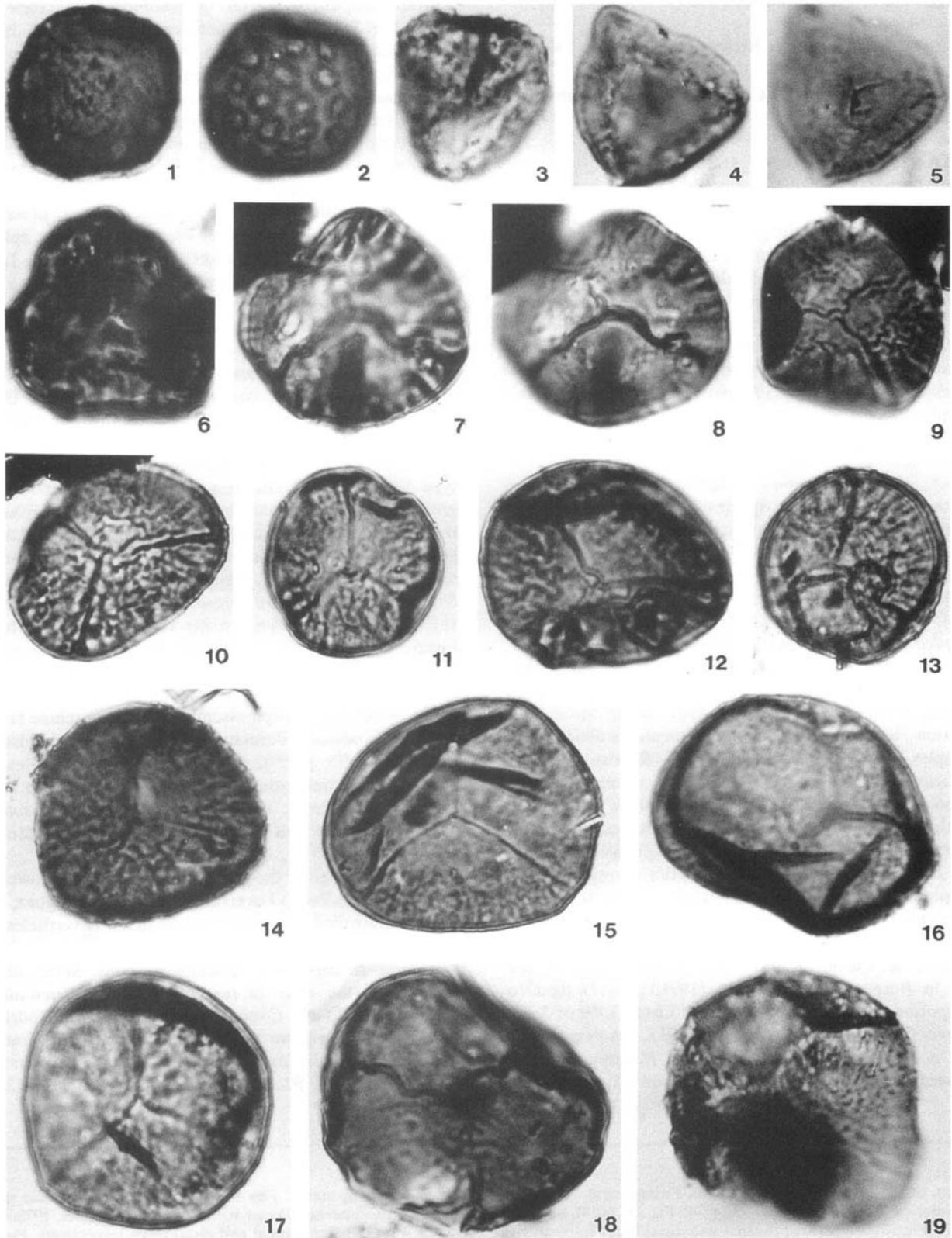


Plate 2.

Ambitisporites avitus Hoffmeister, 1959

A. dilutus Hoffmeister 1959

Synorisporites cf. *verrucatus* Richardson & Lister, 1969 (Pl. 3, figs 5, 6)

Archaeozonotriletes chulus (Cramer) var. *nanus* Richardson & Lister, 1969 (Pl. 3, fig. 10)

BIOSTRATIGRAPHY AND DISCUSSION

In the biozonal scheme proposed by Richardson & McGregor (1986) for Silurian and Devonian sporomorphs, the Wenlock strata encompass two assemblage zones of sporomorphs: *Archaeozonotriletes chulus* var. *chulus*–*A. chulus* var. *nanus* (late Llandovery to late Wenlock, Telychian to late Homeric) and ?*Emphanisporites* cf. *protophanus*–cf. *Synorisporites verrucatus* (late Wenlock to early Ludlow, late Homeric to early Gorstian). The latter was recently emended by Burgess & Richardson (1991) to *Artemopyra brevicosta*–*Hispanaediscus verrucatus* Assemblage Zone.

In the Prague Basin, scarce sporomorphs (150 specimens) from the section 759 may be assigned to *A. chulus* var. *chulus*–*A. chulus* var. *nanus* Assemblage Zone based on presence of characteristic species and total absence of sculptured forms. Other assemblages from the section 760 as well as from samples HL-1 and SJ-57 containing well-diversified ornamented sporomorphs belong to *A. brevicosta*–*H. verrucatus* Assemblage Zone.

A. brevicosta–*H. verrucatus* Assemblage Zone

Both index species, *Hispanaediscus verrucatus* Cramer, 1966, emend. Burgess & Richardson and *Artemopyra brevicosta* Burgess & Richardson, 1991, range throughout the section 760. However, while *H. verrucatus* is abundant in all samples, *A. brevicosta* is rather rare. *Rugosisporites* cf. *chartulatus* (McGregor) comb. nov. is a characteristic, commonly found, species ranging throughout the section 760. Fairly similar forms have been recently described from the Homeric of the type Wenlock area (Trilete miospore type 1; Burgess & Richardson, 1991). Thus this species may be considered as an additional significant taxon for this sporomorph Zone. Most of the distally verrucate miospores from section 760 are more similar to ?*Synorisporites libycus* Richardson & Ioannides, 1973 and *Synorisporites* cf. *S.?* *libycus* in Burgess & Richardson (1991, p. 617) than to *Synorisporites verrucatus* Richardson & Lister, 1969 or *S.* cf. *verrucatus* (Richardson & Ioannides, 1973). *Synorisporites?* *libycus* is mentioned by Richardson & McGregor (1986) only from the overlying Ludlow biozone (*Synorisporites*

libycus–?*Lophozonotriletes poecilomorphus*). New data from the Prague Basin, however, indicate that its first occurrence is already in the *A. brevicosta*–*H. verrucatus* Assemblage Zone. The forms of *S. verrucatus* (cf. *verrucatus*) having distinct equatorial thickenings and closely packed prominent verrucae have not been recovered from upper Wenlock samples in the Prague Basin. *Emphanisporites protophanus* Richardson & Ioannides, 1973 has been found in four samples of the section no. 760. This occurrence documents for the first time the early presence of *E. protophanus* in the late Wenlock. Unique apiculate miospores which are supposed to appear only in the Ludlow *S. libycus*–?*L. poecilomorphus* Assemblage Zone were recorded from several samples. However, their classification is vague due either to their scarcity or bad preservation.

Comparison with other assemblages

Scarce records of the upper Wenlock and lower Ludlow sporomorphs were summarized by Richardson & McGregor (1986, p. 8, 9) and Burgess & Richardson (1991, table 3).

The sporomorph assemblages recently described from the type Wenlock area (Burgess & Richardson, 1991) are of great importance for the correlation with sporomorphs from the Prague Basin, because they are independently dated by graptolites, including the interval of the first appearance of sculptured sporomorphs. Only three species described from Shropshire, *Dyadospora murusdensa* Strother & Traverse, 1979, *Archaeozonotriletes chulus* var. *chulus* Richardson & Lister, 1969 and *Hispanaediscus wenlockensis* Burgess & Richardson, 1991 are absent in the coeval sediments in the Prague Basin.

The lower sporomorph assemblage from borehole samples of the Tanezzuff Formation in Libya (Richardson & Ioannides, 1973; p.259), roughly dated by graptolites, also displays close similarities with assemblages from the Prague Basin. Except for *A. chulus* var. *chulus* and *Retusotriletes minor* Kedo, 1963 all Libyan species have been found in section 760.

The assemblage of the spore Zone 1a from the lowermost part of the San Pedro Formation in Spain (Rodríguez, 1978) is not controlled by index macrofauna, nevertheless the recorded palynosppectrum indicates presence of the *A. brevicosta*–*H. verrucatus* Assemblage Zone. Seven of nine forms from the zone 1a, excepting *Retusotriletes abundo* Rodríguez, 1978 and *Convolutispora sanpetrense* Rodríguez, 1978, are known from the Prague Basin. North American assemblages of the upper Wenlock (Strother & Traverse, 1979; Burgess & Richardson, 1991, p. 621) and Ludlow

Explanation of Plate 3

Homeric of the Prague Basin (see fig. 4). Enlargement: all figs. $\times 1500$, unless otherwise stated. **Figs 1–3.** *Synorisporites maculosus* sp. nov. Fig. 1. holotype, 760/41-C. **Fig. 2.** 760/41-A. Fig. 3. 760/31-B. **Figs 4, 7, 8, 12, 13.** *Synorisporites libycus* Richardson & Ioannides, 1973. Fig. 4. 760/61-H. **Figs. 7, 8.** 760/31, proximal and distal focus respectively. **Figs 12, 13.** 760/35B-C, proximal and distal focus respectively. **Figs 5, 6.** *Synorisporites* cf. *verrucatus* Richardson & Lister, 1969, 760/72H, proximal and distal focus respectively. **Fig. 9.** Trilete miospore type B, HL-1/B-II-4, $\times 2000$. **Fig. 10.** *Archaeozonotriletes chulus* (Cramer) var. *nanus* Richardson & Lister, 1969, 760/72-L. **Fig. 11.** *Ambitisporites* sp. A, 760/31-A. **Figs 14, 15.** Trilete miospore type C, LS-56/2, proximal and distal focus respectively. **Figs 16–18.** Trilete miospore type A. Fig. 16. 760/42-C. Fig. 17. 760/31, slide GSP-S-1, scanning electron microphotograph showing proximal surface with laesurae and tangential thickenings. Fig. 18. 760/31-F.

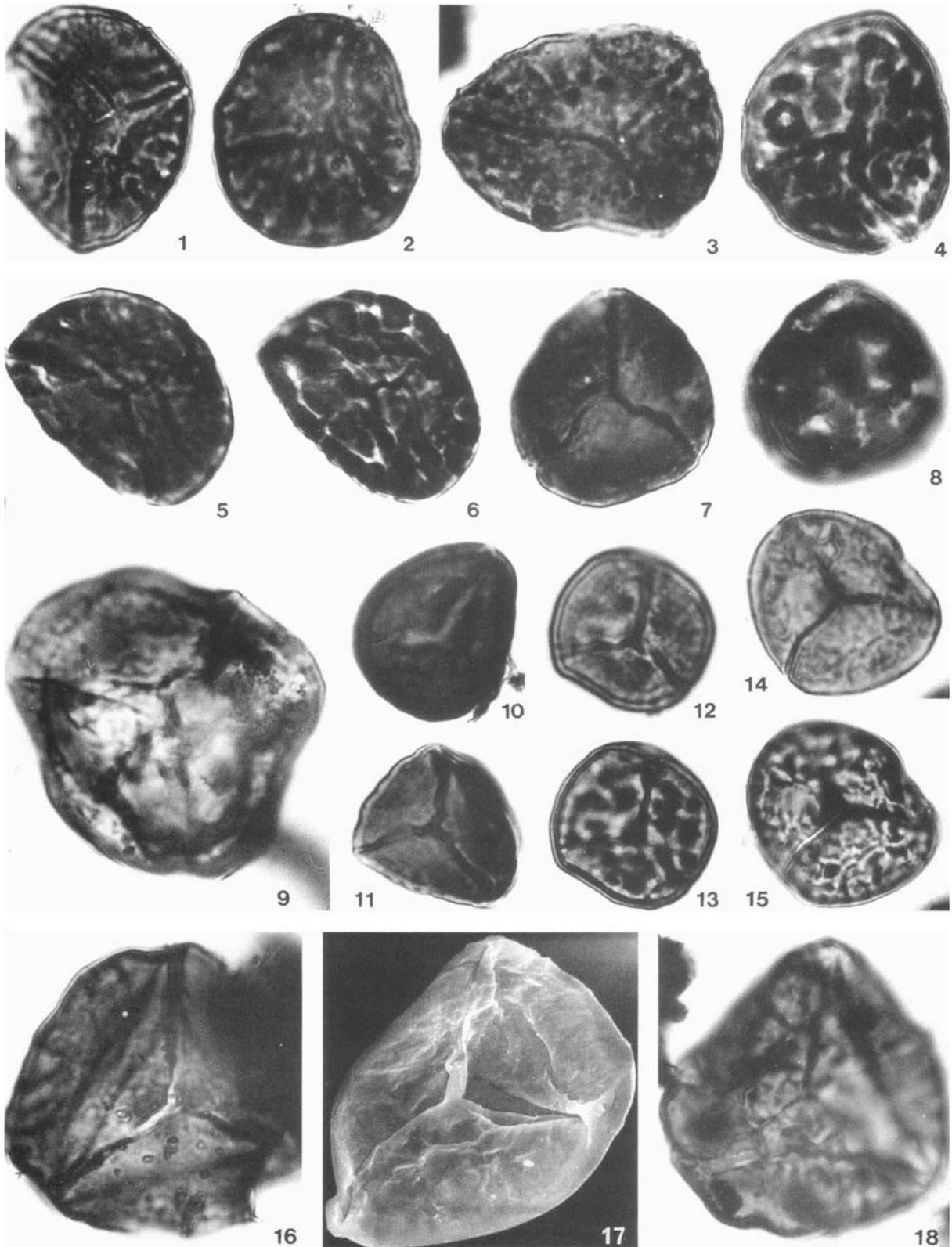


Plate 3.

	Bohemia	England	Libya	Spain	North America	
	This paper	Burgess & Richardson (1991)	Richardson & Ioannides (1973)	Rodriguez (1978)	Strother & Traverse (1979)	Mc Gregor & Narbonne (1978)
<i>Tetrahedraletes medinensis</i>	■	■	■		■	■
<i>Artemopyra brevicosta</i>	■	■	■		■	■
<i>Artemopyra radiata</i>	■					
<i>Artemopyra rugaticosta</i>	■	■	■			
<i>Confossuspora reniforma</i>	■	■			■	
<i>Hispanaediscus verrucatus</i>	■	■	■		■	■
<i>Laveolancis divellomedium</i>	■	■	■		■	■
<i>Laveolancis plicata</i>	■	■				
<i>Pletusotriletes cf. warringtoni</i>	■		■	■		?
<i>Apiculiretusispora cf. spicula</i>	■		■			■
<i>Emphanisporites protophanus</i>	■		■	■		
<i>Rugosisporites cf. chartulatus</i>	■	■	■			■
<i>Rugosisporites kozlicus</i>	■					?
<i>Ambitisporites avitus</i>	■	■	■	■	■	
<i>Ambitisporites dilutus</i>	■	■	■	■	■	?
<i>Synorisporites cf. verrucatus</i>	■		■	■		
<i>Synorisporites? libycus</i>	■	■	■	■		
<i>Synorisporites maculosus</i>	■					
<i>Archaeozonotriletes ch. nanus</i>	■	■	■	■		

Fig. 4. Selected Homeric sporomorphs from the Prague Basin and in upper Wenlock and lower Ludlow assemblages around the world.

(McGregor & Narbonne, 1978) which comprise index species of *A. brevicosta*–*H. verrucatus* Assemblage Zone show considerable resemblance in the species spectra and morphological variability of sporomorphs with the Homeric assemblages of the Prague Basin.

In spite of the rare occurrence of trilete miospores and cryptospores in the Prague Basin, there are significant similarities between these assemblages and coeval assemblages from England, Libya, Spain and North America (Fig. 4). A conformity of the species spectra may indicate some communication between those distant areas by means of spore dispersal. Sporomorphs might be transported over a great distance most probably by strong surface currents, similar to the transport of larvae of benthic fauna. However, because of their small size (mean diameter of sporomorphs below 25 μm), wind transport of spores cannot be excluded (for discussion see Fanning *et al.*, 1988). In general, the mentioned resemblance of upper Wenlock/lower Ludlow sporomorph assemblages supports the previous ideas about the uniform evolution of the land flora during the upper Silurian (e.g. Edwards, 1990), at least in the North Atlantic Region (*sensu* Boucot, 1990, fig. 1).

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