ORDOVICIAN ACRITARCHS FROM THE MEITAN FORMATION OF GUIZHOU PROVINCE, SOUTH-WEST CHINA

by LI JUN

ABSTRACT. An early Arenig acritarch assemblage is described from the Meitan Formation of Tongzi, Guizhou Province, south-west China. Twenty-four species belonging to twenty genera are included. One new genus, *Tongzia*, and four new species, *Rhopaliophora membrana*, *Pirea sinensis*, *Schizodiacrodium? multiramiferum*, and *Tongzia meitana* are proposed. The assemblage belongs to the Mediterranean Province and shows that a homogeneous Arenig assemblage extended from east Newfoundland through the Mediterranean to south-west China.

COMPARED with other areas, notably Europe, Palaeozoic acritarchs have been neglected in China apart from some pioneering work. Cambrian sphaeromorphs from south-west China were described by Ouyang Shu *et al.* (1974). Xing Yusheng (1980, 1982) reported on seven genera from the Dachengsi Formation (Arenig) of Sichuan and on Lower Cambrian acritarchs from near Kunming of Yunnan, both in south-west China. Zhong Guofang (1981) described an assemblage from the Dawan Formation (late Arenig) from Hubei Province recording six genera of non-sphaeromorph acritarchs. Seven genera were recorded (Li Zaiping 1982) from the Machiakou Formation (late Arenig/Llanvirn) of Hebei Province, northern China.

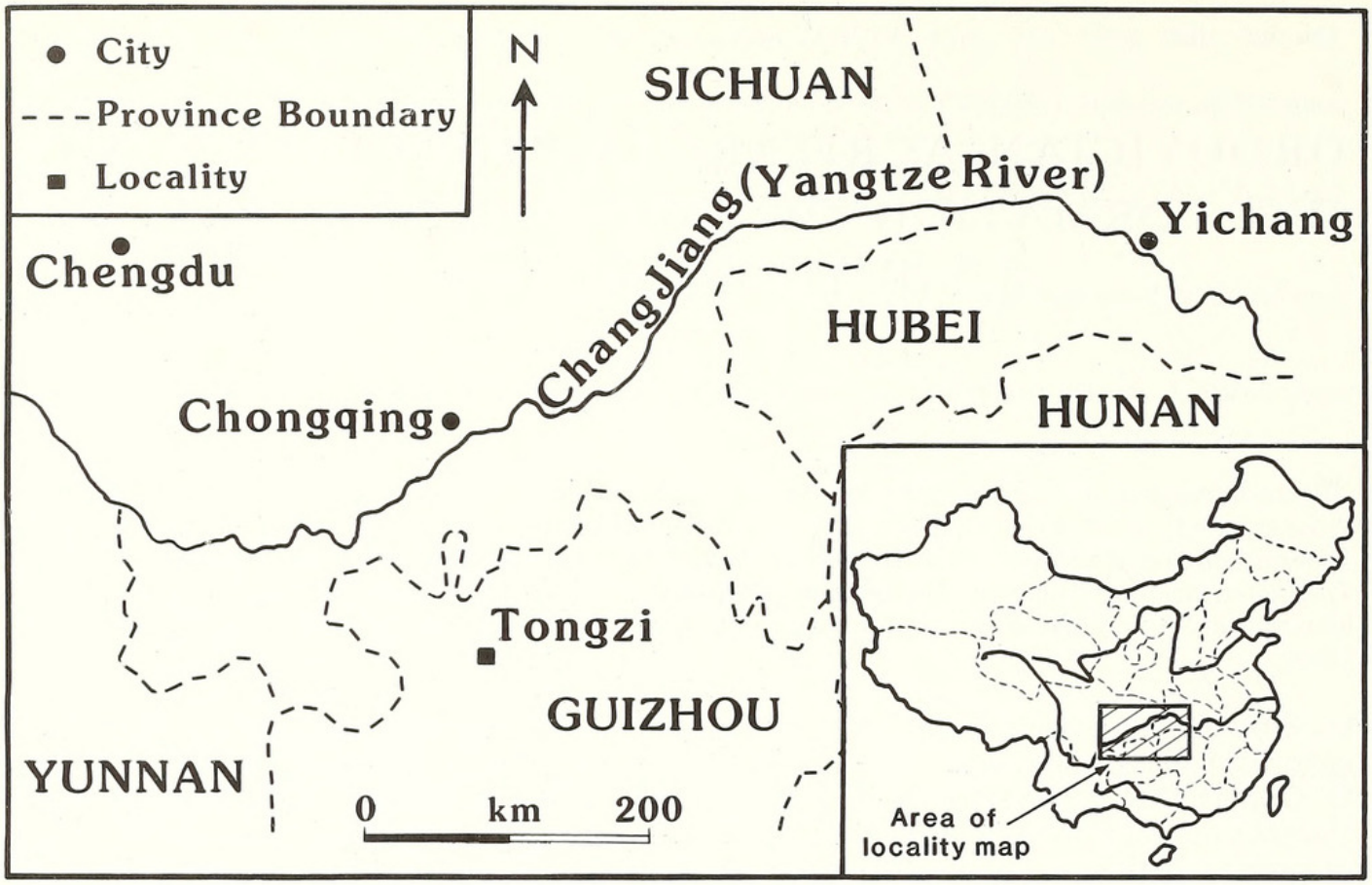
The present paper describes acritarchs from the Meitan Formation of Guizhou Province (text-fig. 1). In Arenig times this locality lay towards the centre of the Upper Yangtse Paraplatform about 350 km south-east of Xing Yusheng's locality on the Mount Emei Shan and about 550 km south-west of Zhong Guofang's locality in Yichang also in the same paraplatform. Li Zaiping's material came from north China about 1500 km to the north-east.

MATERIAL

Two samples of yellow-grey shale from the Meitan Formation from the Honghuayuan section at Tongzi were provided by Dr Geng Liangyu of the Nanjing Institute of Geology and Palaeontology. The section is at Honghuayuan (106° 51′ E., 28° 4′ N.), about 7 km south of Tongzi County, on the west slope of a hill: the beds dip at 7° to the north-east (bearing about 50°). The Ordovician consists of, in descending order, the Wufeng, Jiantsaokou, Pagoda, Shihtzupu, Meitan, Hunghuayuan, and Tungtzu formations. According to the description of the section by Zhang and Chen (1964), the Meitan Formation is 180 m thick and comprises a 92 m thick lower part, consisting of yellow-grey shales, and an 88 m thick upper part, consisting of yellow-grey sandy shales, both with thin-bedded limestone intercalations. Four graptolite biozones were set up within the lower part of the Meitan Formation, i.e. from base to top, *Didymograptus filiformis* Biozone, *D. protobifidus* Biozone, *D. deflexus* Biozone, and *Azygograptus suecicus* Biozone. These represent 15·5 m, 48 m, 23·5 m and 5·0 m respectively in terms of thickness. Sample MDZ, from the *D. deflexus* Biozone, is located 70 m above the base of the formation; sample MAZ from the *A. suecicus* Biozone is located 85 m above the base.

The material was prepared in the Department of Geology, University of Sheffield using standard palynological techniques. Organic residues were then sieved through a 20 μm mesh screen and mounted on slides. Acritarchs are well preserved, abundant, and yellow-brown in colour. Some dark-brown to black Chitinozoa were also seen. Specimens on strew slides are located by sample, slide, and co-ordinate code, for example, MAZ 44, T22/4 is sample MAZ, slide number 44, England Finder reference co-ordinate T22/4. The

[Palaeontology, Vol. 30, Part 3, 1987, pp. 613–634, pls. 68–72.]



TEXT-FIG. 1. Map of China showing the Tongzi locality.

types and illustrated material are housed in the collections of Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing, China.

SYSTEMATIC PALAEONTOLOGY

For brevity, only name changes are listed in synonomies

Group ACRITARCHA Evitt, 1963

Genus ACANTHODIACRODIUM Timofeev, 1958 emend. Deflandre and Deflandre-Rigaud, 1962

Type species. Acanthodiacrodium dentiferum Timofeev, 1958.

Acanthodiacrodium? tasselii Martin, 1969

Plate 71, figs. 5, 7, 8

Description. The vesicle is hollow and elongate oval in outline; the wall is single-layered and bears eight to fifteen processes at each pole. These may either be solid or hollow with their interior communicating with the inner cavity. The surface of the vesicle is ornamented by longitudinal ribs. No opening was observed.

Dimensions (five specimens). Length of vesicle 20–42 μm, breadth of vesicle 17–26 μm, ratio of vesicle length to breadth 1:0·8, rib spacing 1–3 μm, length of processes 3–8 μm.

Remarks. Actinotodissus Loeblich and Tappan (1978) differs from *Acanthodiacrodium* by having processes that communicate freely with the vesicle interior. When Martin (1969) established the species *A. tasselii* she did not mention whether or not the processes communicate with the vesicle

interior. The present specimens, which resemble those described by Martin (1969) and Vavrdová (1972), are thus assigned to the genus *Acanthodiacrodium* with reservation.

Genus ADORFIA Burmann, 1970

Type species. Adorfia firma Burmann, 1970.

Adorfia cf. *firma* Burmann, 1970

Plate 70, fig. 7

Description. The vesicle is polygonal in outline; the wall is single-layered and carries irregularly distributed processes. These are short, plump, and communicate freely with the inner cavity. Distally they are manate with capitate pinnae mainly at the distal portion of the processes. No opening was observed.

Dimensions (two specimens). Diameter of vesicle 20–50 μm, process length 5–12 μm, process breadth 1·5–3·0 μm, process number peripherally about fourteen, length of pinnae 1–2 μm.

Remarks. The specimens here differ from type material of *Adorfia firma* Burmann 1970 from later Arenig of GDR by having more processes. They are distinguished from *Vogtlandia multiradialis* Burmann, 1970 (Arenig, GDR) and *Evittia flosmaris* Deunff, 1977 (Llanvirn, Morocco) by the presence of capitate pinnae.

Genus ARBUSCULIDIUM Deunff, 1968

Type species. Arbusculidium destombesii Deunff, 1968.

Arbusculidium filamentosum (Vavrdová) Vavrdová, 1972

Plate 68, figs. 1, 3, 5

1965 *Dasydiacrodium filamentosum* Vavrdová, pp. 355–356, pl. 3, fig. 3; pl. 4, fig. 1; text-fig. 4*a–c*.
1972 *Arbusculidium filamentosum* (Vavrdová); Vavrdová, p. 81, pl. 1, fig. 3.
1980 *Dasydiacrodium filamentosum* Vavrdová; Xing, p. 438.

Description. The vesicle is hollow, ellipsoidal to subcylindrical in outline. The processes are restricted to the polar areas; one pole carries three to five simple processes which are broad-based, hollow, communicating freely with the vesicle cavity. They taper gradually towards closed, pointed tips. The opposite pole bears a set of branching, anastomosing filose processes which are arranged in a circle around the pole, forming a collar-shaped net. The vesicle wall is about 0·5 μm and decorated by longitudinal ribs. No opening was observed.

Dimensions (eleven specimens). Length of vesicle 35–40 μm, breadth 25–32 μm, rib spacing 2–5 μm, process length 15–20 μm, length of the collar 10–20 μm.

Previous records. Arenig, Czechoslovakia (Vavrdová 1965); Arenig, GDR (Burmann 1968); ?Upper Arenig or lower Llanvirn, Morocco (Cramer, Allam *et al.* 1974); Wenlock (reworked?), Belgium (Martin 1969); Arenig, France (Rauscher 1974); Arenig–Llanvirn, East Newfoundland (Martin, in Dean and Martin 1978); Arenig, China (Xing 1980).

Genus BALTISPHAERIDIUM (Eisenack 1958) emend. Eisenack, 1969

Type species. Baltisphaeridium (as *Ovum hispidum*) *longispinosum* Eisenack, 1931. Holotype lost. Neotype: *B. l.* (as *filifera*) *longispinosum* Eisenack, 1959.

Baltisphaeridium longispinosum longispinosum (Eisenack 1931) Staplin *et al.*, 1965

Plate 72, fig. 2

1931 *Ovum hispidum longispinosum* Eisenack, p. 110, pl. 5, figs. 6–12, 14–17.
1938 *Hystrichosphaeridium longispinosum* (Eisenack) Eisenack, p. 12, pl. 1, figs. 4, 6, 7.
1959 *Baltisphaeridium longispinosum filifera* Eisenack, p. 195, pl. 15, fig. 1.

1965 *Baltisphaeridium longispinosum* Eisenack; Eisenack, p. 134, pl. 13, figs. 1 and 2.
1965 *Baltisphaeridium longispinosum longispinosum* (Eisenack) Staplin *et al.*, p. 190, pl. 20, figs. 11 and 15; text-fig. 11.

Description. The vesicle is hollow, circular to subcircular in outline. The wall is single-layered, bearing regularly arranged processes. These are hollow, shut off from the inner cavity, and closed distally. The length of processes is variable, usually equal to or exceeding the vesicle diameter. No opening was observed.

Dimensions (five specimens). Vesicle diameter 48–56 μm, length of process 35–60 μm, breadth of process 1·0–2·5 μm.

Remarks. This taxon, although characteristic of the Baltic Province, appears to have a world-wide distribution.

Previous records. Upper Arenig to upper Llandovery, Baltic (Eisenack 1931); Upper Llanvirn to Llandeilo, Sweden (Eisenack 1965; Staplin *et al.* 1965); Upper Arenig and Caradoc, Poland (Gorka 1969); Caradoc to Ashgill, Belgium (Martin 1974); Llanvirn, France (Rauscher 1974).

Genus CORYPHIDIUM Vavrdová, 1972

Type species. Coryphidium bohemicum Vavrdová, 1972.

Coryphidium bohemicum Vavrdová, 1972

Plate 72, figs. 5 and 9

1972 *Coryphidium bohemicum* Vavrdová, pp. 84–85, pl. 1, figs. 1 and 2; text-fig. 4.

Description. The vesicle is hollow, subquadrate in outline, with round corners. The wall is single-layered, about 0·5 μm thick and is ornamented by striate ribs, densely spaced (approximately 1–2 μm) and parallel to the edges. Numerous processes decorate the surface; they are proximally opened, truncated or bifurcate distally. The process distribution is more or less regular over the surface, with some concentration at the corners. On some specimens, a round to oval opening occurs.

Dimensions (more than thirty specimens). Length of vesicle edge 24–34 μm, rib spacing 0·5–1·0 μm, process length 3–9 μm, process number at each corner eight to fifteen.

Previous records. Arenig, Llanvirn, Czechoslovakia (Vavrdová 1972); Arenig, France (Rauscher 1974; Cocchio 1982); Upper Arenig to lower Llanvirn, Morocco (Cramer, Allam *et al.* 1974); Arenig to Llanvirn, Belgium (Martin and Rickards 1979); Arenig, east Newfoundland (Martin, in Dean and Martin 1978); Arenig, China (Xing 1980); Arenig to lower Llanvirn, Britain (Downie 1984); Arenig, Sardinia (Albani, Di Milia *et al.* 1985).

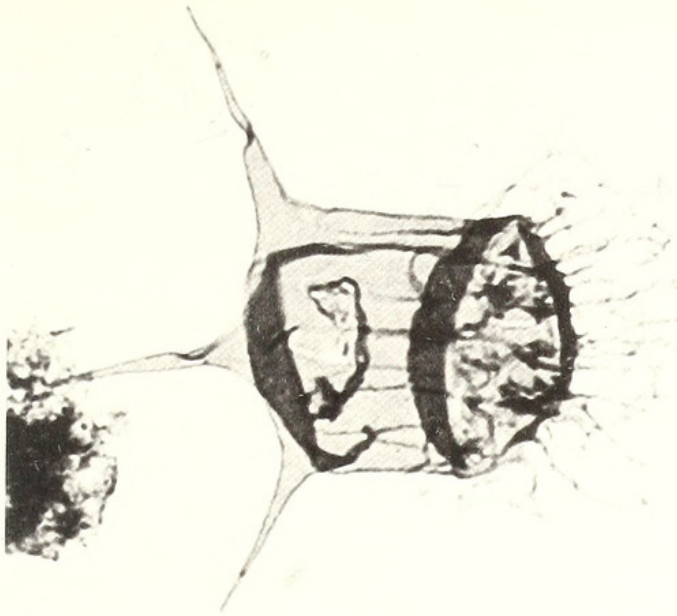
Genus CRISTALLINIUM Vanguestaine, 1978

Type species. Cristallinium cambriense (Slavikova) Vanguestaine, 1978.

EXPLANATION OF PLATE 68

All figures × 1000.

Figs. 1, 3, 5. *Arbusculidium filamentosum* (Vavrdová) Vavrdová, 1972. 1, MAZ 46, M40/1; 3, MDZ 1, N27; 5, MDZ 1, F22/2.
Fig. 2. *Veryhachium trispinosum* (Eisenack 1935) Deunff, 1954 ex. Downie, 1959. MAZ 46, M24/3.
Fig. 4. *Leiosphaeridia tenuissima* Eisenack, 1958. MDZ 1, K43/1.
Fig. 6. *Cristallinium dentatum* (Vavrdová) Martin, 1982. MDZ 35, P33/4.



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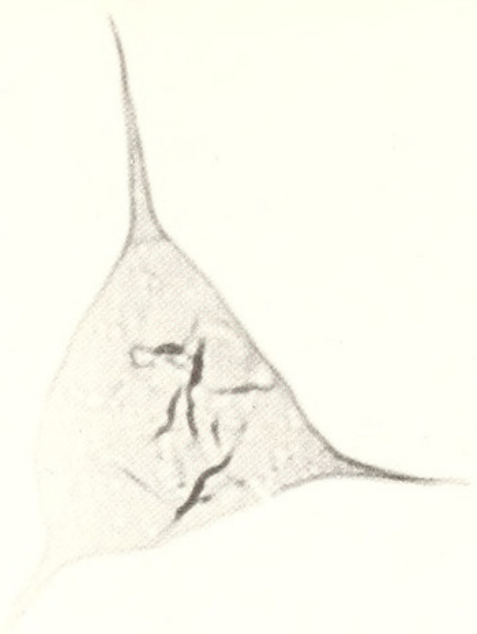

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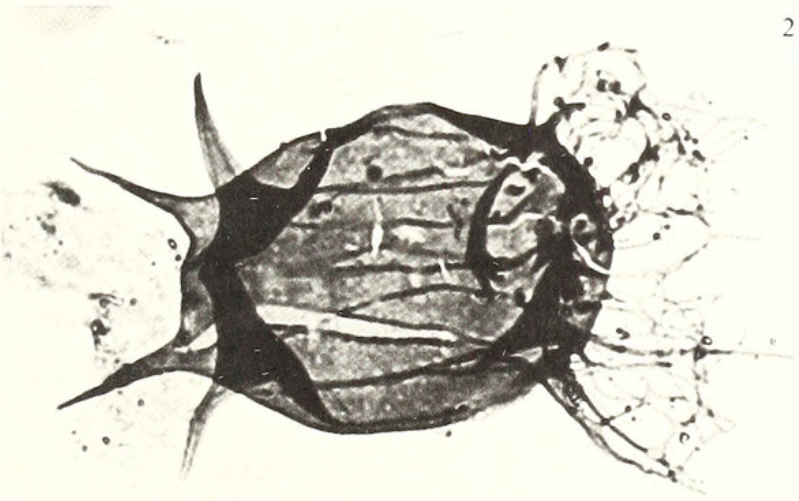

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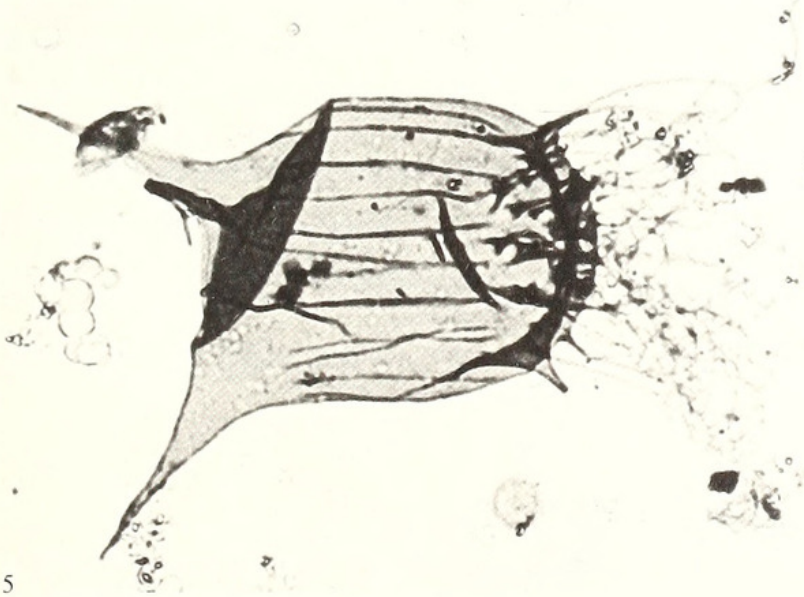

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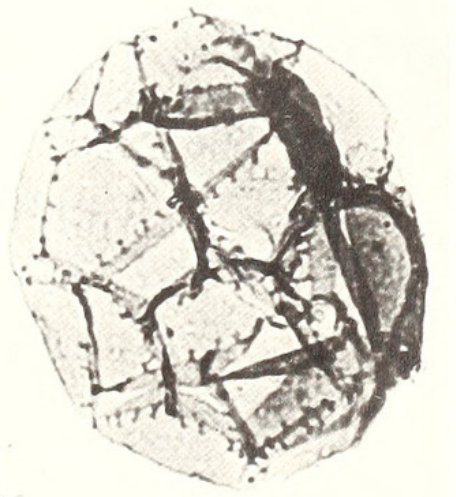

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LI JUN, *Ordovician acritarchs*

Cristallinium dentatum (Vavrdová) Martin, 1982

Plate 68, fig. 6

1976 *Staplinia dentata* Vavrdová, p. 58, pl. 2, figs. 5 and 6; text-fig. 5.
1978 *Dictyotidium? dentatum* (Vavrdová) Martin, in Dean and Martin, p. 8, pl. 3, figs. 14 and 28.
1982 *Cristallinium dentatum* (Vavrdová) Martin, p. 36.

Description (based on a single specimen). The vesicle is subcircular to polygonal in outline. The wall is thin and divided into numerous polygonal fields. The edges of the polygonal fields bear several short, solid and capitate processes.

Dimensions. Diameter of vesicle 40–45 μm, height of processes about 1 μm, process number at each edge six to nine.

Previous records. Upper Arenig, Czechoslovakia (Vavrdová 1976); Arenig, east Newfoundland (Martin 1982).

Genus CYMATIOGALEA (Deunff 1961) Deunff, Gorka and Rauscher, 1974

Type species. *Cymatiogalea margaritata* Deunff, 1961.

Cymatiogalea cf. *cristata* (Downie 1958) Deunff, Gorka and Rauscher, 1974

Plate 72, figs. 3 and 4

Description. The vesicle is hollow, circular or hemicircular in outline; wall is usually divided into polygonal areas by low sutural ridges. Four to six processes are arranged along each side, they are decorated with lateral spines which branch into two to four pinnae distally; in some cases second-order branching can be seen. Excystment is by a large subpolygonal to round opening.

Dimensions (eighteen specimens). Diameter of vesicle 24–45 μm, size of opening 14–38 μm, length of processes 5–12 μm, length of branching 1–3 μm.

Remarks. The specimens here differ from the Tremadoc type material of *Cymatiogalea cristata* from England by the presence of lateral processes and second-order branching and the lack of flanges on the vesicle wall.

Cymatiogalea cuvillieri? (Deunff 1961) Deunff, 1964

Plate 72, fig. 8

Description. The single specimen recorded has a vesicle with subcircular outline, the surface of the vesicle is divided into polygonal fields, the boundaries of which are formed by short spines, 2–3 μm in height, and about three to five spines can be seen on each boundary. The wall is simple and *c*. 0·5 μm thick, decorated by small verrucae. At one pole of the vesicle an opening occurs, the diameter of which is *c*. 18 μm, approximately three-quarters the size of the vesicle.

Remarks. The single poorly preserved specimen is questionably assigned to *Cymatiogalea cuvillieri*, a species usually recorded from the Tremadoc.

Genus LEIOSPHAERIDIA (Eisenack 1958) Downie and Sarjeant, 1963

Type species. *Leiosphaeridia baltica* Eisenack, 1958*a*.

Leiosphaeridia tenuissima Eisenack, 1958*b*

Plate 68, fig. 4

1958*b* *Leiosphaeridia tenuissima* Eisenack, pp. 391–392, pl. 2, figs. 1 and 2.

Description. The vesicle is hollow and circular in outline, the wall is single-layered, very thin (*c*. 0·2 μm thick), without process and ornamentation, although some compressional folds occur. No opening was observed.

Remarks. Sphaeromorphs are not common and are represented in the present study only by this species and *Synsphaeridium* cf. *gotlandicum* Eisenack, 1965.

Previous records. Tremadoc, USSR (Eisenack 1958*a*); undivided Palaeozoic, North Africa (Combaz 1966); Caradoc, England (Turner 1984).

Genus MULTIPLICISPHAERIDIUM (Staplin 1961) Lister, 1970

Type species. Multiplicisphaeridium ramispinosum Staplin, 1961.

Multiplicisphaeridium cf. *irregulare* Staplin, Jansonius and Pocock, 1965

Plate 70, figs. 9 and 10

Description. The vesicle is subcircular in outline; the wall is thin, about 0·5 μm thick, and carrying numerous processes. These are conical, hollow, and communicate freely with the inner cavity. Distally they are simple or branching. Branching occurs in an irregular manner at any distance from the process base. No opening was observed.

Dimensions (seven specimens). Diameter of vesicle 12 μm, process length 11–13 μm, number of processes peripherally fourteen to twenty-two.

Remarks. The specimens here are considerably smaller than the typical ones from Anticosti Islands (vesicle diameter 25–35 μm, Staplin *et al.* 1965). Jacobson and Aïcha (1985) argued that the depth of 3005 ft from which *Multiplicisphaeridium irregulare* was recorded, was not the Middle Ordovician Trenton Formation as originally reported, but the Upper Ordovician (lower–middle Ashgillian) Vaureal Formation.

Genus PETALOFERIDIUM Jacobson, 1978

Type species. Petaloferidium stigii Jacobson, 1978.

Petaloferidium florigerum (Vavrdová 1977) Jacobson, 1978

Plate 72, fig. 7

1977 *Evittia florigera* Vavrdová, p. 116, pl. 4, figs. 1–10; text-fig. 6*a*, *b*.
1978 *Petaloferidium florigerum* (Vavrdová) Jacobson, p. 296.

Description (based on single specimen). The vesicle is hollow and subcircular to polygonal in outline. The wall is single-layered, laevigate, and carries processes which are open to the inner cavity but are closed distally, where there is a pronounced swelling and a darker spot.

Dimensions. Vesicle diameter 20 μm, process length 3–5 μm, process number fourteen.

Remarks. This species may need to be subdivided since specimens from early Llanvirn of Czechoslovakia (Vavrdová 1977, 1982) included both laevigate and striate forms, multi-process and two-process forms. Single specimen here fits Vavrdová's multi-horn but has no striations.

Previous records. Early Llanvirn, Czechoslovakia (Vavrdová 1977, 1982).

Genus PETEINOSPHAERIDIUM Staplin, Jansonius and Pocock, 1965

Type species. Peteinosphaeridium trifurcatum trifurcatum ex *P. bergstromii* Staplin, Jansonius and Pocock, 1965.

Peteinosphaeridium trifurcatum intermedium Eisenack, 1976

Plate 72, fig. 9

1976 *Peteinosphaeridium trifurcatum intermedium* Eisenack, p. 195, pl. 4, figs. 8–11.
1976 *Peteinosphaeridium trifurcatum* Eisenack; Kjellstrom, p. 36, fig. 29.
1984 *Peteinosphaeridium trifurcatum intermedium* Eisenack; Turner, pp. 132–133, pl. 9, figs. 1, 4–6.

Description. The vesicle is circular in outline, the wall is firm, single-layered, *c.* 1 μm thick, carrying numerous processes; these are solid, distally trifurcate or quadrifurcate and bear delicate, more or less transparent longitudinal membranes. The vesicle wall is granulate. Excystment is by means of a pylome.

Dimensions (eighteen specimens). Diameter of vesicle 32–46 μm, process length 6–12 μm, branch length 1–4 μm, number of processes peripherally twenty-five to thirty-eight.

Remarks. Eisenack (1976) attributed two infraspecific taxa to the species *Peteinosphaeridium trifurcatum*, i.e. *P. trifurcatum intermedium* and *P. trifurcatum hypertrophicum*. Only the former was found in the present study.

Previous Records. Arenig, Baltic (Eisenack 1976); Llanvirn–Llandeilo, Sweden (Kjellstrom 1976); Caradoc, Kentucky, USA (Jacobson 1978); Caradoc, England (Turner 1984).

Genus PIREA Vavrdová, 1972

Type species. Pirea colliformis (Burmann) Vavrdová, 1977.

Pirea sinensis sp. nov.

Plate 70, figs. 1–4

Derivation of name. Sinae (Latin), Chinese.

Holotype. Plate 70, fig. 1 (MAZ 44, X49).

Isotypes. Plate 70, fig. 2 (MAZ 44, Q23); fig. 3 (MAZ 46, D23); fig. 4 (MAZ 44, E23/4).

Locality and horizon. West slope of Honghuayuan Hill in Tongzi County, Guizhou, China; 85 m above the base of Meitan Formation, Arenig, Ordovician.

Diagnosis. Vesicle pear-shaped with a single process drawn out from apical end, wall decorated by solid spines, randomly distributed in the antapical part but apically forming longitudinal rows. Excystment by a pylome at the antapical end.

Dimensions (eleven specimens). Vesicle length 62–78 μm, vesicle breadth 36–45 μm, process length 11–15 μm, process breadth 7–10 μm, spine length 0·5–1·0 μm, spine spacing *c.* 1 μm, spacing of longitudinal rows 1·0–1·5 μm. Diameter of pylome 8–12 μm.

Description. The vesicle is hollow, thin walled, and ovate in outline. A single process is drawn out from the apical end. This is hollow, communicating with the vesicle, and is distally closed and slightly expanded. The wall of the test in the lower three-quarters is densely covered with uniform, small, solid, often capitate spines distributed randomly. At the apical end they form longitudinal rows. Excystment is by a pylome at the antapical end, with or without operculum.

Comparison. The new species resembles *Pirea ornatissima* Cramer and Diez, 1977, but can be distinguished by the ornamentation. *P. ornatissima* is also decorated with solid sculptural elements on the lower part of the vesicle; but apically the wall is smooth, with about a dozen longitudinal folds. *P. sinensis* is ornamented by capitate spines randomly distributed in the lower part of the vesicle, and the spines are arranged in longitudinal rows that extend onto the process at the apical end.

Genus POLYGONIUM Vavrdová, 1966

Type species. Polygonium gracilis Vavrdová, 1966.

Polygonium gracile Vavrdová, 1966

Plate 72, fig. 1

1966 *Polygonium gracilis* Vavrdová, p. 413, pl. 1, fig. 3; pl. 3, fig. 1; text-fig. 4*a*, *b*.
1972 *Polygonium gracile* Vavrdová, p. 80.

Description. The vesicle is hollow, polygonal or subpolygonal in outline, with sides more or less equal in length and slightly concave. The wall is single-layered, with long, simple processes drawn out at corners. They number twelve to fifteen, communicate freely with inner cavity and are closed distally, with wide bases and pointed tips. No opening was observed.

Dimensions (thirty-two specimens). Diameter of vesicle 24–31 μm, length of process 10–18 μm.

Remarks. The commonest species in the present study, with related species of *Tectitheca* which may integrate with *Polygonium*, it makes up more than 30% of the total assemblage.

Previous records. Arenig, Czechoslovakia (Vavrdová 1966, 1972); Arenig, France (Rauscher 1974); Later Arenig to early Llanvirn, Morocco (Cramer, Allam *et al.* 1974); Upper Cambrian to lower Llanvirn, Britain (Downie 1984).

Genus RHOPALIOPHORA Tappan and Loeblich, 1971

Type species. Rhopaliophora foliatilis Tappan and Loeblich, 1971.

Rhopaliophora membrana sp. nov.

Plate 71, figs. 1 and 3

Derivation of name. Referring to the membrane-like processes.

Holotype. Plate 71, fig. 1 (MAZ 45, N32/1).

Isotype. Plate 71, fig. 3 (MDZ 3, P33/3).

Locality and horizon. West slope of Honghuayuan Hill in Tongzi County, Guizhou, China; 70 and 85 m above the base of the Meitan Formation, Arenig, Ordovician.

Diagnosis. Vesicle circular to subcircular in outline, with membrane-like processes appearing as irregular extension; excystment by means of pylome.

Description. The vesicle is *c.* 1 μm thick, with membrane-like processes of varying shape, width, number, and extension; the vesicle surface is ornamented by microgranules. Excystment is by a round pylome with an elevated rim. Double pylome occurs on some specimens, and free opercula have been seen in some cases.

Dimensions (twelve specimens). Vesicle diameter 28–46 μm, process length 3–16 μm, pylome diameter 13–16 μm.

Remarks. This species differs from other species of *Rhopaliophora* by the membrane-like processes.

Rhopaliophora palmata (Combaz and Peniguel) Playford and Martin, 1984

Plate 71, figs. 4 and 6

1972 *Peteinosphaeridium palmatum* Combaz and Peniguel, p. 136, pl. 2, figs. 4, 9–12.
1984 *Rhopaliophora palmata* (Combaz and Peniguel) Playford and Martin, pp. 210–212, fig. 9A–N.

Description. The vesicle is hollow and circular to subcircular in outline. The wall is single-layered, carrying numerous short, stout processes. The processes may be variable in shape and length, separated from inner cavity. The body surface is psilate. Excystment is by a circular pylome with elevated rim.

Dimensions (eight specimens). Vesicle diameter 27–32 μm, length of process 2–5 μm, process spacing 5–8 μm, pylome diameter 5–9 μm.

Previous records. Arenig to Llanvirn, Canning Basin, Australia (Combaz and Peniguel 1972; Playford and Martin 1984).

Genus SCHIZODIACRODIUM Burmann, 1968

Type species. Schizodiacrodium ramiferum Burmann, 1968.

Schizodiacrodium? *multiramiferum* sp. nov.

Plate 69, figs. 4–6

Derivation of name. multi (Latin), numerous; *ramiferum* (Latin), branched. Referring to presence of numerous processes.

Holotype. Plate 69, fig. 4 (MAZ 46, T22/4).

Isotype. Plate 69, fig. 6 (MAZ 47, F43).

Locality and horizon. West slope of Honghuayuan Hill in Tongzi County, Guizhou, China; 85 m above the base of the Meitan Formation, Arenig, Ordovician.

Diagnosis. Vesicle polyhedral, slightly elongated, with numerous processes arranged on polar areas; processes bifurcate, trifurcate, or multifurcate, all branches recurved.

Description. The vesicle is slightly elongate, polyhedral in outline and somewhat centrally constricted. The wall is thin, *c.* 0·3 μm thick and carries numerous processes on polar areas. These are arranged in a circle, are broadly based, communicating freely with the inner cavity, and branched distally. The branching angle varies from 80 to 150°. Branching is bifurcate, trifurcate, or multifurcate. All branches are slender, characteristically recurved, with closed tips. Occasionally second-order branches occur. No opening was observed.

Dimensions (nine specimens). Vesicle length 32–38 μm, breadth 20–25 μm, process breadth 2–5 μm, process number at each pole nine to eleven, branch length 5–7 μm, branch breadth 0·2–0·5 μm.

Remarks. In some cases polar differentiation is weak (see Pl. 70, fig. 5) and therefore this taxon is questionably assigned to genus *Schizodiacrodium*. The present species differs from others of *Schizodiacrodium* in having strikingly recurved branches. *Multiplicisphaeridium maroquense* Cramer, Allam *et al.*, 1974 and *Vogtlandia flos* Martin, 1978 also have similarly recurved branches, the former may differ from the new species by having fewer processes (four to seven) and the latter by radial symmetry instead of axial symmetry.

Genus STRIATOTHECA Burmann, 1970

Type species. Striatotheca principalis Burmann, 1970.

Striatotheca principalis parva Burmann, 1970

Plate 70, fig. 5

1970 *Striatotheca principalis parva* Burmann, p. 300, pl. 8, fig. 6.

Description. The vesicle is quadrate to rectangular in outline, with approximately straight sides, each corner passes into a gradually tapering process. The processes communicate freely with the inner cavity and are closed distally. The body surface is decorated by subparallel ribs, which extend on to the proximal quarter of the processes. No opening was observed.

Dimensions (twenty-four specimens). Vesicle length 25–34 μm, rib spacing 1 μm, rib breadth 0·5–0·8 μm, process length 16–20 μm.

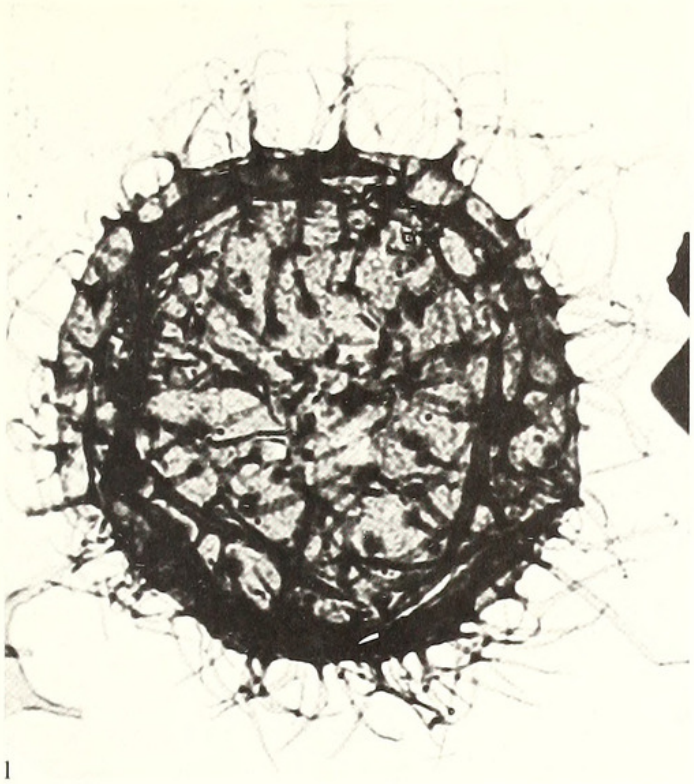
Previous records. Arenig, GDR (Burmann 1970); Arenig, France (Rauscher 1974); Upper Arenig, Italy (Tongiorgi and Di Milia 1984); Upper Arenig, Hungary (Albani, Lelkes-Felváry *et al.* 1985).

EXPLANATION OF PLATE 69

All figures × 1000.

Figs. 1–3. *Tongzia meitana* gen. et sp. nov. 1, holotype, MAZ 45, L48; 2, MAZ 44, T52/4; 3, MAZ 45, X54.

Figs. 4–6. *Schizodiacrodium*? *multiramiferum* sp. nov. 4, holotype, MAZ 46, T22/4; 5, MAZ 46, M12; 6, MAZ 47, F43.



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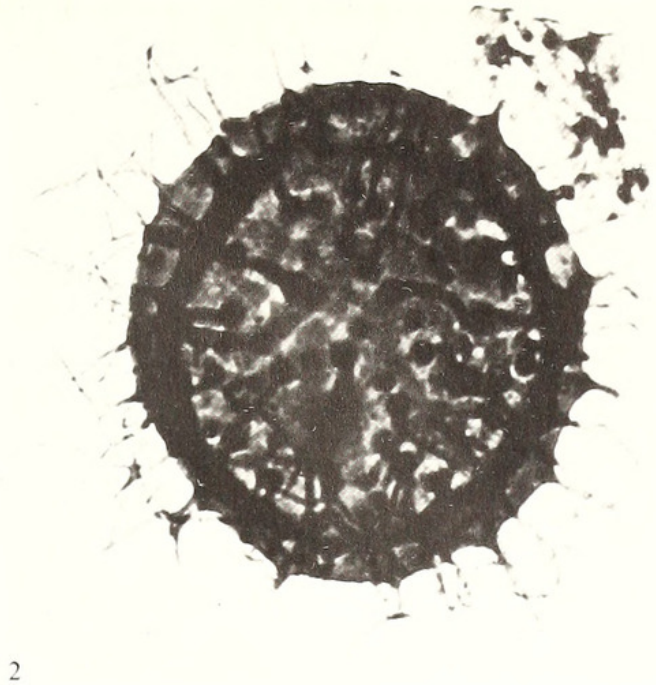

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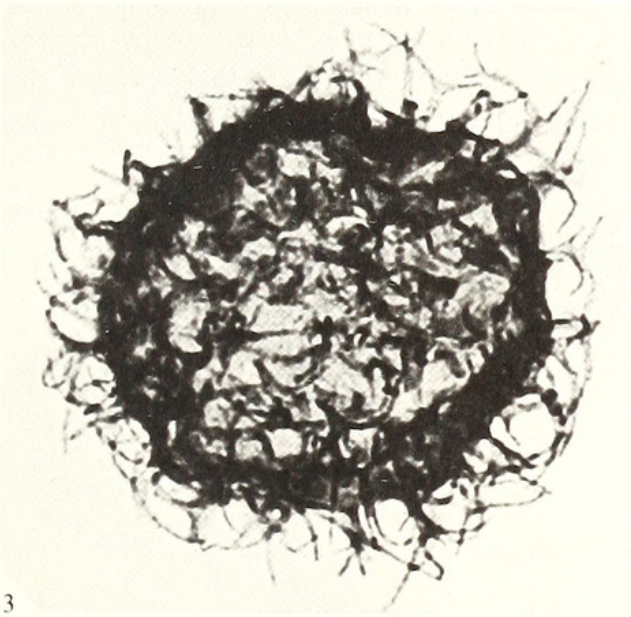

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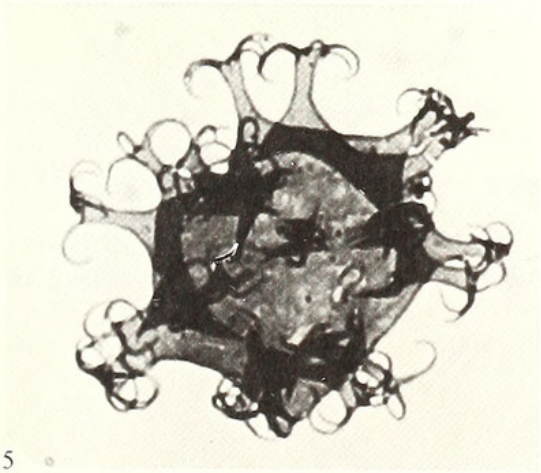

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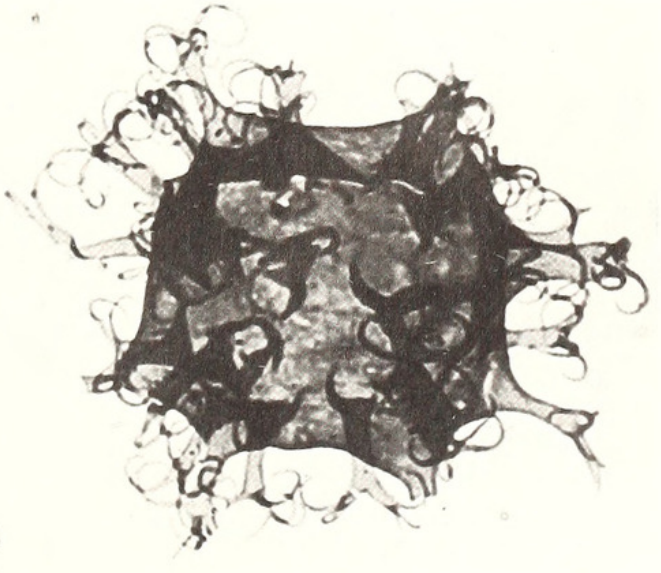


6

LI JUN, *Tongzia, Schizodiacrodium?*

Striatotheca quieta (Martin 1969) Rauscher, 1974

Plate 70, fig. 6

1969 *Veryhachium quietum* Martin, pp. 101–102, pl. 5, fig. 225; pl. 6, fig. 293; text-fig. 48.
1970 *Striatotheca acutiuscula* Burmann, p. 303, pl. 8, figs. 3 and 4.
1974 *Rugulidium quietum* (Martin) Cramer, Allam *et al.*, p. 60, pl. 25, fig. 12; pl. 26, figs. 15–17.
1974 *Striatotheca quieta* (Martin) Rauscher; p. 76, pl. 3, fig. 10.

Description. The vesicle is quadrate on outline, with slightly bulging sides. The processes, which are short, conical, hollow, and with obtuse tips, extend from each corner. The surface of the vesicle is ornamented by subparallel, fine, closely spaced ribs.

Dimensions (four specimens). Length of vesicle 26–30 μm, rib breadth 0·5 μm, rib spacing 1 μm, length of process 2–5 μm.

Previous records. Late Arenig or early Llanvirn, Morocco (Cramer, Kanes *et al.* 1974); Arenig, France (Rauscher 1974); Upper Arenig, Italy (Tongiorgi and Di Milia 1984); Late Llanvirn, GDR (Burmann 1970); Caradoc (reworked), England (Turner 1982); Wenlock (reworked?), Belgium (Martin 1969).

Striatotheca cf. *transformata* Burmann, 1970

Plate 70, fig. 8

Description. The vesicle is pentagonal in outline. The wall is single-layered, *c.* 0·3 μm thick. Five processes are drawn out at corners; they communicate with the inner cavity and are closed distally, with pointed tips. Surface of vesicle is decorated by ribs, which cover the entire surface of the body and extend to the base of the processes. They are subparallel to the edges, forming incomplete pentagons. No opening was observed.

Dimensions (two specimens). Height of the pentagon 20–30 μm, breadth of rib 0·3 μm, rib spacing 1·0–1·5 μm, length of edge 17–23 μm, length of process 10–15 μm.

Remarks. Like *Striatotheca transformata* from GDR, which is also Arenig in age, the specimens here have five processes, but differ in having pentagonal outlines instead of a quadrate one.

Genus SYNSPHAERIDIUM Eisenack, 1965

Type species. Synsphaeridium gotlandicum Eisenack, 1965.

Synsphaeridium cf. *gotlandicum* Eisenack, 1965

Plate 71, fig. 2

Description. The individual bodies are subcircular to ellipsoidal in outline, and form irregularly shaped clusters. The wall is single-layered, decorated with hairs. No opening was observed.

Dimensions (two clusters). Individual body diameter 19–30 μm, number of individuals on each cluster fifteen to thirty, cluster diameter 60–100 μm, length of hairs 0·5–1·0 μm.

EXPLANATION OF PLATE 70

Unless otherwise specified, all figures × 1000.

Figs. 1–4. *Pirea sinensis* sp. nov. 1, holotype, MAZ 44, X49; 2, MAZ 44, Q23; 3, MAZ 46, D23; 4, MAZ 44, E23/4.

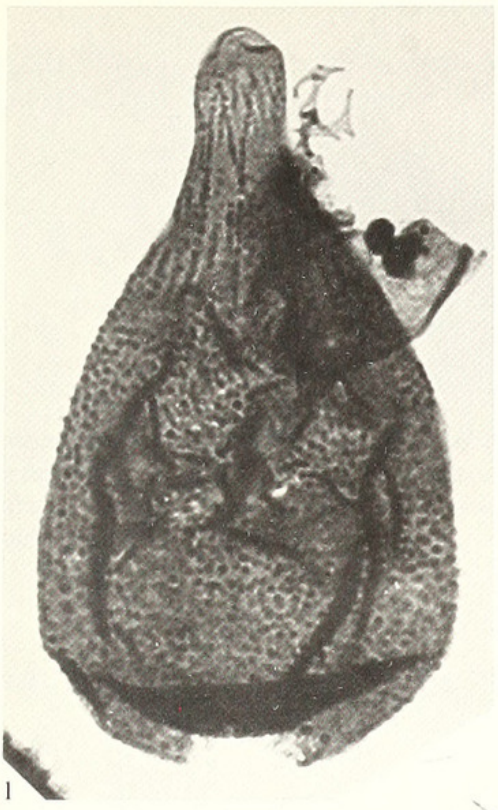
Fig. 5. *Striatotheca principalis parva* Burmann, 1970. MAZ 44, B34, × 900.

Fig. 6. *S. quieta* (Martin) Rauscher, 1974. MAZ 44, G44.

Fig. 7. *Adorfia* cf. *firma* Burmann. MAZ 46, L26/3.

Fig. 8. *S.* cf. *transformata* Burmann. MAZ 44, R39, × 900.

Figs. 9 and 10. *Multiplicisphaeridium* cf. *irregulare* Staplin *et al.* 1965. 9, MAZ 44, Q43; 10, MAZ 45, C42/2.



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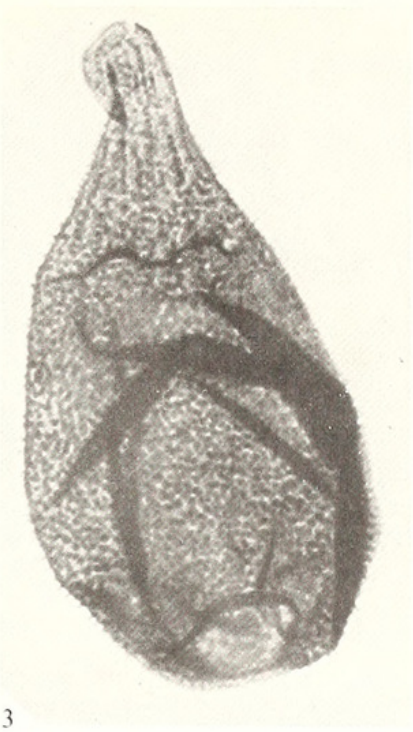

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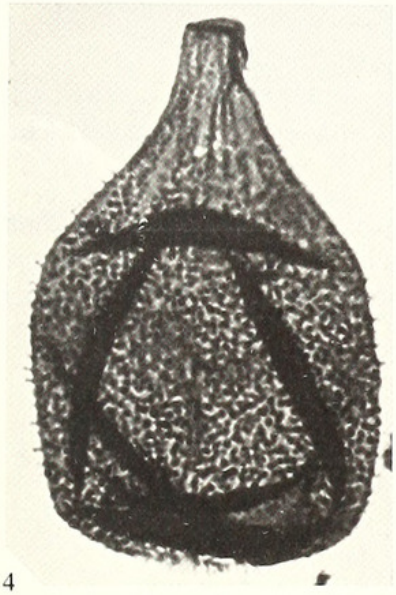

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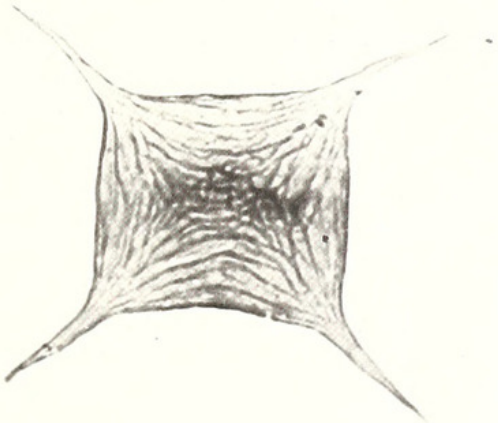

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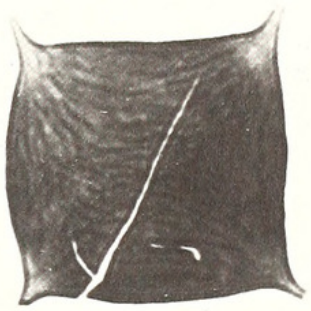

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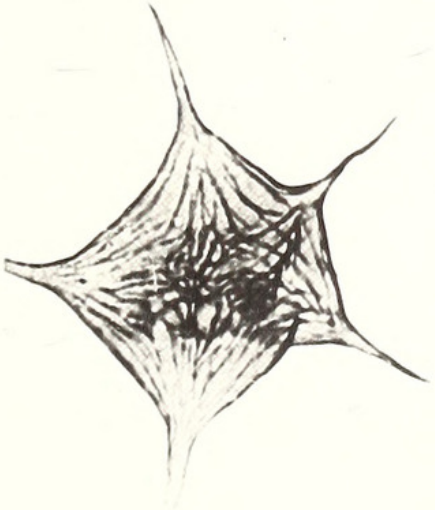

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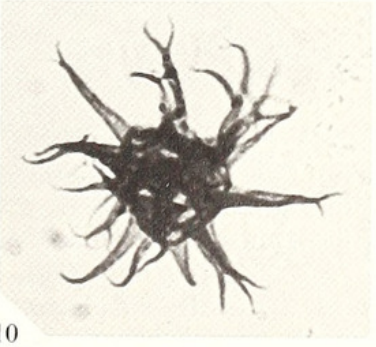


10

LI JUN, *Ordovician acritarchs*

Remarks. The individual bodies here correspond to those of *Synsphaeridium gotlandicum* in shape and ornamentation but are smaller than the type material. The type material is Silurian, but the genus has also been reported from the Arenig of Bohemia (Vavrdová 1973, p. 286).

Genus TECTITHECA Burmann, 1968

Type species. Tectitheca valida Burmann, 1968.

Tectitheca cf. *additionalis* Burmann, 1968

Plate 72, fig. 6

Description. The vesicle is hollow and subpentagonal in outline, comprising a shortened upper part extending into a long, rapidly tapering apical process with a conically expanded base. In the middle part are four processes with six to seven similar processes around the basal line. The processes are closed distally and communicate freely with the inner cavity. Both vesicle and process surface are thin and faintly granulose. No opening was present.

Dimensions (six specimens). Diameter of vesicle 23–27 μm, length of process 20–25 μm.

Comparison. The specimens here differ from the type material from upper Arenig or lower Llanvirn of GDR in the more broadly based processes.

Genus TONGZIA gen. nov.

Derivation of name. From Tongzi County.

Type species. Tongzia meitana sp. nov.

Diagnosis. Vesicle circular to subcircular in outline, bearing radiating processes that are hollow, and plugged at the base. All processes bifurcate in a similar fashion. No second-order branching was seen. Surface of vesicle and processes decorated with granules.

Remarks. The method of opening is not known. This new genus is distinguished from *Baltisphaeridium* by always having bifurcate processes. *Ordovicidium* Tappan and Loeblich, 1971 differs from the new genus by having multifurcate processes. *Skiagia* Downie, 1982 has processes with funnel-shaped ends.

Tongzia meitana sp. nov.

Plate 69, figs. 1–3

Derivation of name. After the Meitan Formation.

Holotype. Plate 69, fig. 1 (MAZ 45, L48).

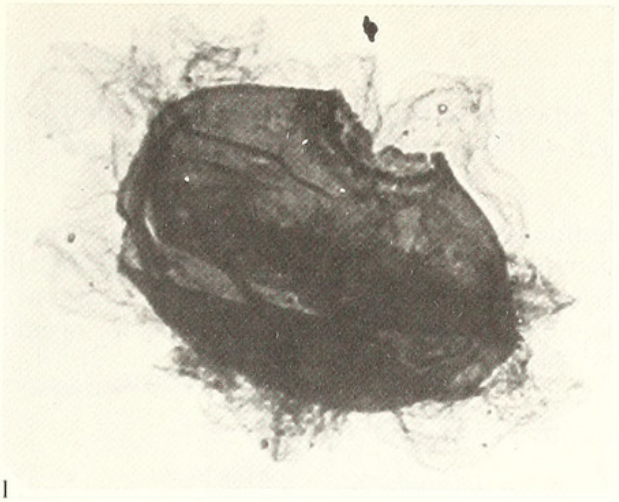
Isotypes. Plate 69, fig. 2 (MAZ 44, T52/4); fig. 3 (MAZ 45, X54).

Locality and horizon. West slope of Honghuayuan Hill in Tongzi County, Guizhou, China; 85 m above the base of the Meitan Formation, Arenig, Ordovician.

EXPLANATION OF PLATE 71

Unless otherwise specified, all figures × 1000.

Figs. 1 and 3. *Rhopaliophora memdrana* sp. nov. 1, holotype, MAZ 45, N32/1; 3, MDZ 3, P33/3.
Fig. 2. *Synsphaeridium* cf. *gotlandicum* Eisenack, 1965. MDZ 1, Q31/4.
Figs. 4 and 6. *R. palmata* (Combaz and Peniguel) Playford and Martin, 1984. 4, scanning electron micrograph, × 1800; 6, MAZ 45, C36.
Figs. 5, 7, 8. *Acanthodiacrodium*? *tasselii* Martin, 1969. 5, MAZ 48, F32; 7, MAZ 46, H11/2; 8, MAZ 44, H51.
Fig. 9. *Peteinosphaeridium trifurcatum intermedium* Eisenack, 1976. MAZ 44, Q35.



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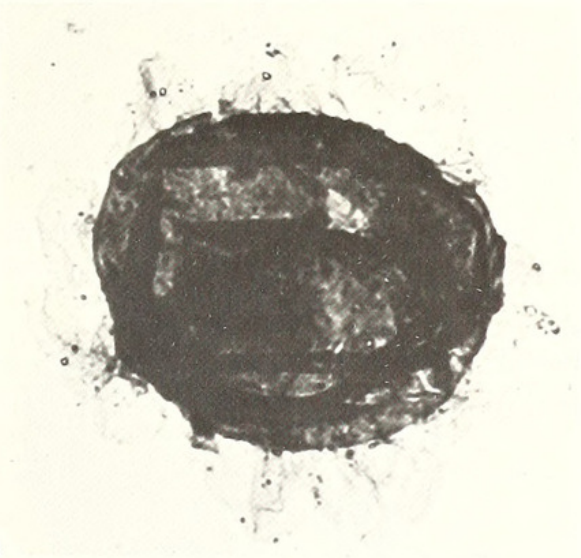

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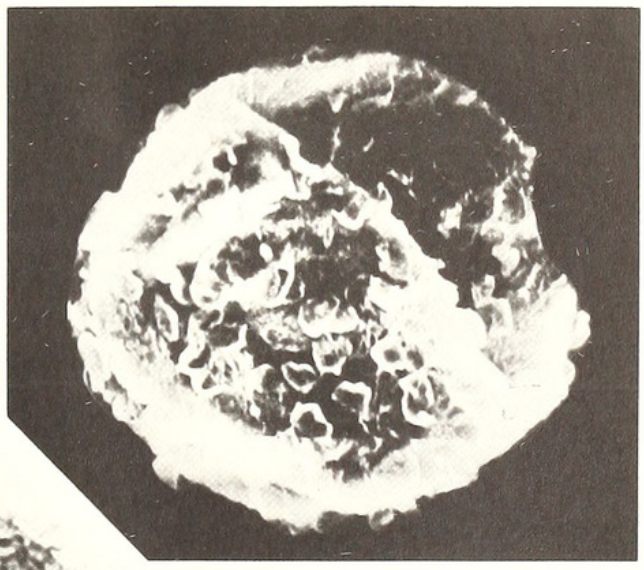

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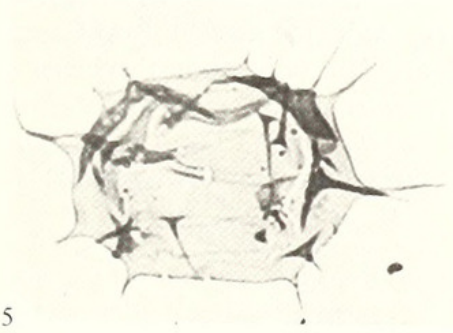

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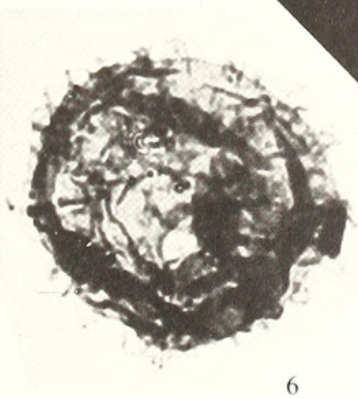

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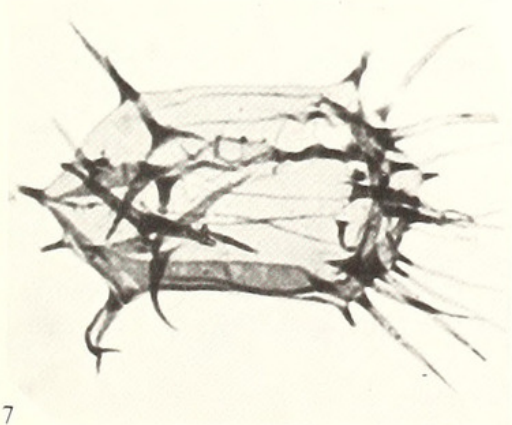

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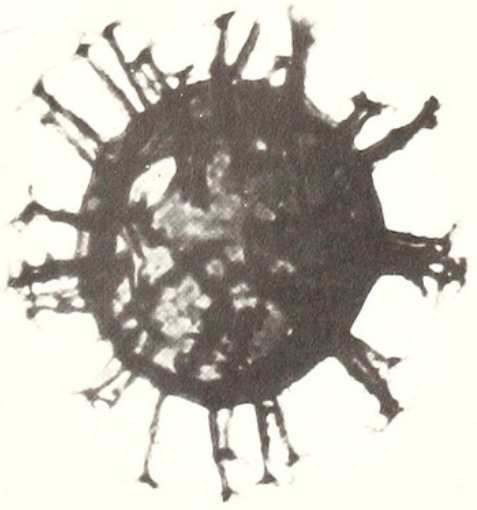

9

LI JUN, *Ordovician acritarchs*

Diagnosis. As for genus.

Dimensions (twelve specimens). Diameter of vesicle 44–56 μm, process spacing 3–8 μm, granule spacing 0·5–1·0 μm, process length 4–7 μm, occasionally 14 μm, branch length 4–10 μm, ratio of process to vesicle diameter *c.* 0·1:1.

Description. The vesicle is hollow, circular to subcircular in outline. The wall is firm, single-layered, and carries numerous hollow, evenly distributed processes. These do not communicate with the cavity and bifurcate distally, with pointed and closed tips. The branching angles varied from 60 to 160°, usually 110°. Surface of vesicle, process, and branches are ornamented by densely arranged granules. No second-order branching nor opening were observed.

Genus VERYHACHIUM (Deunff 1951) Deunff, 1954 ex. Downie, 1959

Type species. Veryhachium trisulcum (Deunff) Deunff, 1954.

Veryhachium trispinosum (Eisenack 1935) Deunff, 1954 ex. Downie, 1959

Plate 68, fig. 2

1938 *Hystrichosphaeridium trispinosum* Eisenack, p. 16, fig. 2.
1959 *Veryhachium trispinosum* (Eisenack) Downie, pp. 68–69, pl. 12, fig. 7.

Description. The vesicle is triangular in outline, with three long, hollow processes drawn out at corners. The wall is single-layered, 0·5 μm thick, without ornamentation. The processes are simple and closed distally with pointed tips. Some specimens show excystment by epityche.

Dimensions (twenty-two specimens). Vesicle diameter 25–32 μm, process length 17–29 μm.

Remarks. This is a common species from late Arenig to the Carboniferous. It first appears in the early Arenig where it is rare; it is common in the present study.

DISCUSSION

Composition of assemblages. The overall composition of the two assemblages is shown in Table 1. Although they are from different graptolite biozones *Didymograptus deflexus* (sample MDZ) and *Azygograptus suecicus* (sample MAZ), they are remarkably similar. The commonest species is *Polygonium gracile* which, with the closely related *Tectitheca* cf. *additionalis*, makes up 36 and 29% of the total. Also common are the genera *Striatotheca* (13 and 18%), *Veryhachium* (9 and 15%), and *Coryphidium* (6 and 8%). Total number of identified species is 24, 23 from MAZ and 21 from MDZ; 20 are common to both.

Age. As mentioned above, the samples came from the *D. deflexus* and the *A. suecicus* Biozones respectively. The *D. deflexus* Biozone occurs in Britain, and the *A. suecicus* Biozone, which is just above the former, was correlated with the *Isograptus gibberulus* and *D. nitidus* Biozones of Britain

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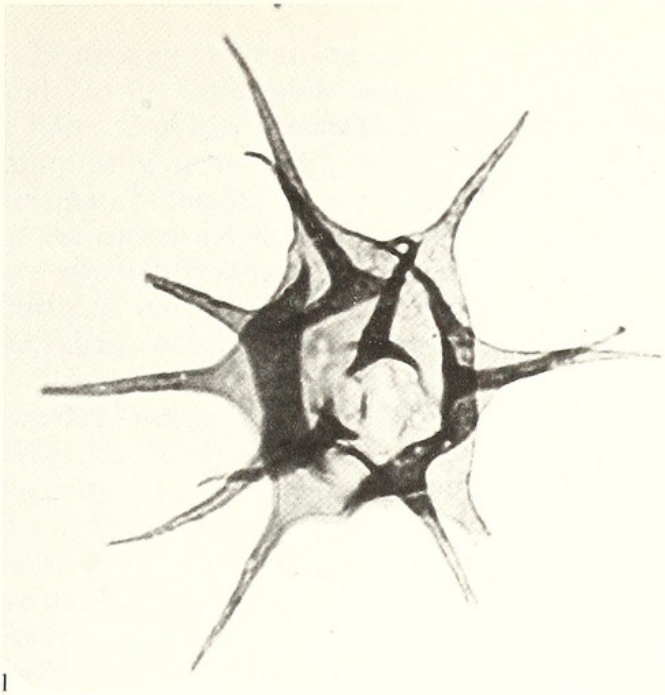
EXPLANATION OF PLATE 72

Unless otherwise specified, all figures × 1000.

Fig. 1. *Polygonium gracile* Vavrdová, 1966. MAZ 44, C49/2.
Fig. 2. *Baltisphaeridium longispinosum longispinosum* (Eisenack) Staplin *et al.* 1965. MAZ 44, B34, × 600.
Figs. 3 and 4. *Cymatiogalea* cf. *cristata* (Downie) Deunff *et al.*, 1974. 3, MDZ 3, H21/4; 4, MAZ 44, H46/2.
Figs. 5 and 9. *Coryphidium bohemicum* Vavrdová, 1972. 5, MDZ 1, P49/3; 9, MDZ 1, R35/3.
Fig. 6. *Tectitheca* cf. *additionalis* Burmann, 1968. MAZ 45, C52/4.
Fig. 7. *Petaloferidium florigerum* (Vavrdová) Jacobson, 1978. MAZ 44, E38/3.
Fig. 8. *Cymatiogalea cuvillieri*? (Deunff) Deunff, 1964. MAZ 44, C51.



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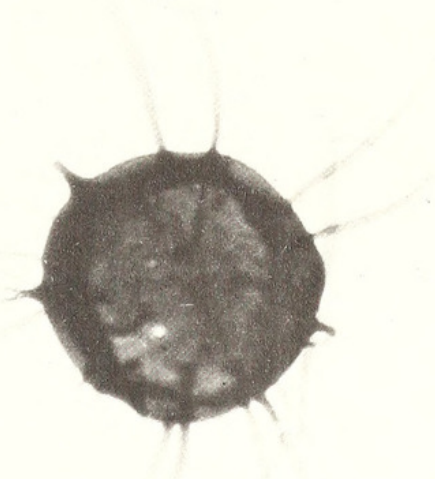

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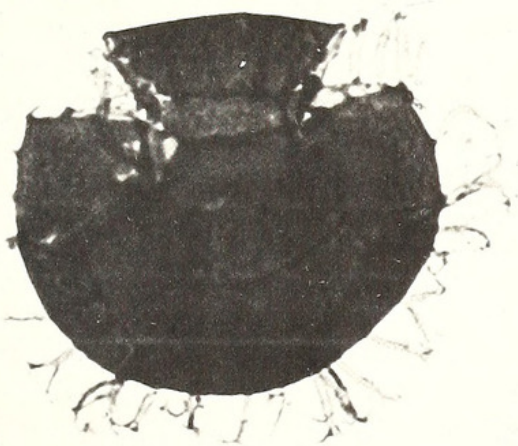

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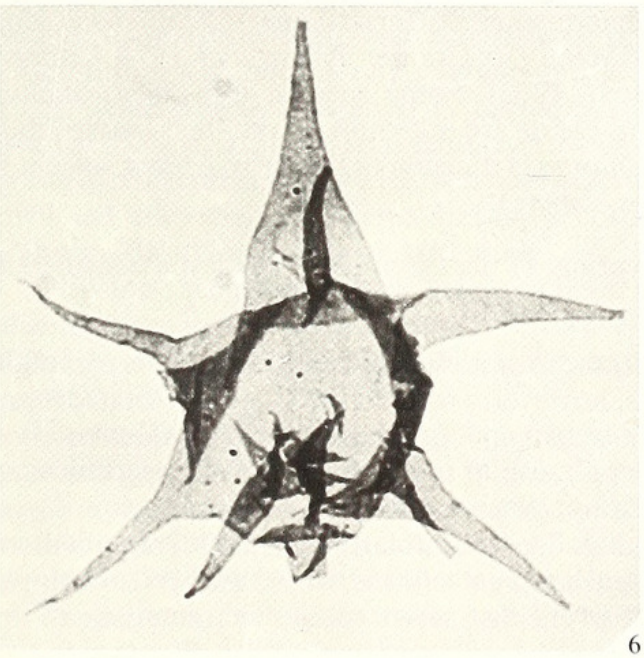

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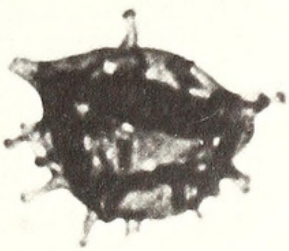

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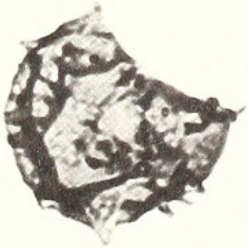

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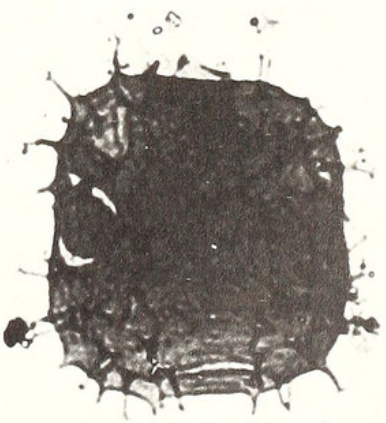

9

LI JUN, *Ordovician acritarchs*

TABLE 1. Composition of assemblages from two horizons in the Meitan Formation, Tongzi, Guizhou Province, south-west China.

Species present	Composition of assemblages (%) MAZ	MDZ
Acanthodiacrodium? tasselii	2	1
Adorfia cf. *firma*	5	—
Arbusculidium filamentosum	3	2
Baltisphaeridium longispinosum longispinosum	1	1
Coryphidium bohemicum	6	8
Cristallinium dentatum	—	1
Cymatiogalea cf. *cristata*	1	1
C. cuvillieri?	4	—
Leiosphaeridia tenuissima	2	2
Multiplicisphaeridium cf. *irregulare*	1	2
Petaloferidium florigerum	3	—
Peteinosphaeridium trifurcatum intermedium	3	1
Pirea sinensis	3	2
Polygonium gracile	32	24
Rhopaliophora membrana	1	3
R. palmata	1	4
Schizodiacrodium? multiramiferum	1	7
Striatotheca principalis parva	8	11
S. quieta	2	2
S. cf. *transformata*	3	5
Synsphaeridium cf. *gotlandicum*	2	1
Tectitheca cf. *additionalis*	4	5
Tongzia meitana	3	2
Veryhachium trispinosum	9	15

(Mu Enzhi *et al.* 1979; Zhang Wentang *et al.* 1982). Graptolites from the section indicate an early Arenig age (Harland *et al.* 1982, p. 14). The acritarchs support the age determination. The assemblages characterized by diagnostic acritarch genera such as *Coryphidium*, *Striatotheca*, and Pirea are clearly from the Arenig/Llanvirn (Burmann 1968, 1970; Cramer, Allam *et al.* 1974; Cramer, Kanes *et al.* 1974; Cramer and Diez 1977; Vavrdová 1972). Some species, e.g. *Arbusculidium filamentosum*, *Cristallinium dentatum*, and *S. principalis parva*, are not known from the Llanvirn thus confirming an Arenig age. The abundance of *V. trispinosum* is unusual in the early Arenig since it is generally very rare until the late Arenig (Downie, *pers. comm.*).

Environment. This was marine and the richness and variety of the assemblage suggest a continental shelf site of deposition.

Provincialism. Comparison within China is limited to three localities. The Tongzi locality is some 350 to 550 km from the nearest of these. The two localities, however, are still in the Upper Yangtse Paraplatform of deposition. Xing Yusheng (1980) listed *Coryphidium bohemicum* and *A. filamentosum*, two very characteristic species in an assemblage apparently similar to that of Tongzi. Zhong Guofang (1981) described an assemblage which is more difficult to compare due to poor preservation. *Coryphidium* and *Arbusculidium* were not recorded by Zhong. The assemblage described from northern China consists largely of sphaeromorphs and *Baltisphaeridium* and *Micrhystridium* (Li Zaiping 1982). It is in the North China Platform and has none of the distinctive species characteristic of the Tongzi assemblage.

In making comparison with other regions of the world, most of the data come from Europe and North Africa. Vavrdová (1974) divided the European Arenig/Llanvirn assemblages into a Baltic Province and a Mediterranean Province. According to her division, the Baltic Province comprising the northern part of the Soviet Union, Sweden, Poland, northern Germany, and probably part of the British Isles is characterized by the dominance of acanthomorphs with many species of *Baltisphaeridium*, *Peteinosphaeridium*, and *Goniosphaeridium*. Representatives of diacromorphs are apparently absent. The Mediterranean Province extending from Belgium, France, Spain, northern Africa to southern Germany, central Bohemia, and Bulgaria is characterized by the prevalence of diacrodians such as *Arbusculidium*, *Coryphidium*, and *Striatotheca*.

Elements of the Mediterranean flora have been described from GDR (Burmann 1968, 1970), Czechoslovakia (Vavrdová 1965, 1966, 1972, 1977), Hungary (Albani, Lelkes-Felvary and Tongiorgi 1985), Sardinia (Albani, Di Milia *et al.* 1985), Bulgaria (Kalvacheva 1982), Ireland (Smith 1981), Britain (Turner 1982; Downie 1984), France (Rauscher 1974), Belgium (Martin 1977), and Spain (Cramer and Diez 1976). That described from Czechoslovakia by Vavrdová is the richest, comprising some forty-two Arenig species and fifty-eight from the Llanvirn. A rich Arenig to Llanvirn assemblages of more than fifty species is reported from Morocco (Cramer, Allam *et al.* 1974; Cramer, Kanes *et al.* 1974; Cramer and Diez 1977). This includes many characteristic Mediterranean genera listed by Vavrdová (1974) with a number of new species. The occurrence of *Coryphidium* species in Libya and Saudi Arabia (Cramer and Diez 1976) indicates that the two localities should be included in the Mediterranean Province. Martin (*in* Dean and Martin 1978) lists forty-one species belonging to twenty-one genera from east Newfoundland. The presence of the genera *Arbusculidium*, *Coryphidium*, and *Striatotheca* shows a clear affinity with the Mediterranean Province.

This assemblage from the Upper Yangtze Paraplatform clearly has a greater affinity with the Mediterranean Province than with the Baltic. It has fewer species than Czechoslovakia and Morocco. Of twenty genera recognized in Tongzi only two, *Tongzia* gen. nov. and *Rhopaliophora*, have not been found in the Mediterranean Province. Comparison with the Baltic Arenig shows that only *B. longispinosum*, *P. trifurcatum intermedium*, and *Leiosphaeridia tenuissima* are in common and they occur rarely. The assemblage from the North China Platform (Li Zaiping 1982) appears more similar to the Baltic one but the data are not good enough to make a satisfactory comparison.

Little can be said about the rest of the world. Arenig to Llanvirn assemblages from the Canning Basin, north-west Australia (Combaz and Peniguel 1972; Playford and Martin 1984) contain mostly new species not known elsewhere. The acritarchs are thus difficult to compare with Baltic and Mediterranean assemblages although similar assemblages are recorded from the western part of North America (K. J. Dorning, *pers. comm.*). Of the species with widespread records, *P. trifurcatum* and *B. longispinosum* are characteristic of the Baltic Province, but appear to have a world-wide distribution. *Veryhachium trispinosum* and *V. lairdii* are widespread across the Mediterranean belt. *V.* cf. *oklahomense*, similar to *V. lairdii*, is stated to have an ornament of fine ribs (Playford and Martin 1984, p. 215) and so resembles *Striatotheca* species. *Pirea*, a species recorded previously only in the Mediterranean Province, was also described. *Rhopaliophora*, a genus originally described from the late Ordovician of Indiana and not recorded in Europe and Africa, was recognized both in the Canning Basin and in the present study.

With the exception of east Newfoundland there are few detailed published accounts of Arenig assemblages from North America. However, *Rhopaliophora* (Tappan and Loeblich 1971) and *Petaloferidium* (Jacobson 1978) from the central United States are two genera also recorded in the present study.

The significance of this assemblage from south-west China, in terms of palaeogeography, cannot be definitely ascertained because of the absence of adequate knowledge of Arenig acritarchs from large areas of the world, but it seems to indicate the presence of a fairly homogeneous Arenig assemblage extending from east Newfoundland through the Mediterranean area and the Middle East to south-west China (the Mediterranean Province of Vavrdová).

The primary factor controlling acritarch provincialism was thought to be palaeotemperature which is mainly determined by palaeolatitude (Cramer and Diez 1974). The Mediterranean Province

was believed to represent a cold belt (Vavrdová 1982). Based on trilobites, a Lower Ordovician *Selenopeltis* Province characteristic of cool waters is recognized (Whittington and Hughes 1972). The extent of the *Selenopeltis* Province is roughly the same as that of the Mediterranean Province. The Chinese trilobite fauna is classified as of 'uncertain affinity' because it appears to belong in the *Selenopeltis* Province at the family level but not so at the generic level (Whittington and Hughes 1972). Plotting the distribution of *Neseuretus*, a trilobite genus considered to be a good indicator of epicontinental seas at relatively high latitudes, rather than comparing whole faunas at the generic level, the existence of a broadly united Gondwanan continent in the early Ordovician, including southern Europe attached to North Africa, and including also the southern part of China, has been proposed (Fortey and Morris 1982). The present study supports this to some extent. Lu Yanhao *et al.* (1976) argued that no Ordovician latitudinal and climatic differentiation could be derived from the distribution of Chinese faunas because they, both shelly and graptolitic, showed a mixture of elements belonging to different provinces. The Ordovician graptolite fauna of south-west China is believed to link up with those of Europe, North Africa, and South America, and the climate of the Ningkuoan (equivalent of Arenig and Llanvirn) might have been warm and arid (Mu Enzhi *et al.* 1979). We should take these arguments into account and need more data for a better understanding of bioprovincialism and differentiation of climatic zones.

Acknowledgements. The author is extremely grateful to Professor C. Downie for instructive discussion, reading, and correcting the manuscript; to F. Martin, D. Edwards, and K. Dorning for their advice; and to Professor J. B. Dawson for permission to use the facilities of the Department of Geology, University of Sheffield. The author thanks Mr S. J. Ellin, Mr M. Cooper, and Mrs D. Darwin for their willing technical assistance, and Miss P. Mellor for her careful typing. The author is indebted to Dr Geng Liangyu for his kind provision of the samples and stratigraphical information. Financial support, jointly from the British Council and Academia Sinica, made the author's visit to the Department of Geology, University of Sheffield possible.

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Typescript received 5 November 1985
Revised typescript received 21 November 1986