EVALUATION OF THE ORDOVICIAN ACRITARCH GENUS

AMPULLULA RIGHI

Rainer BROCKE

(9 figures, 4 tables & 2 plates)

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ABSTRACT. The Ordovician acritarch genus Ampullula Righi 1991 is evaluated and emended based on a review of published literature and new studies on Arenigian material from the Dawan Formation, Upper Yangtze Region, Yangtze Platform, South China. Ampullula has been described as a monospecific genus with the type species A. suetica from Upper Arenigian to Llanvirnian sediments of Öland, Sweden. However, investigations on large populations from three South Chinese sections necessitate the attribution of two further species to the genus: Aremoricanium erchunense Fang Xiaosi 1986 = Ampullula erchunensis comb. nov., emend., which is revised in this paper and Ampullula princeps which is introduced as a new species. Cymatiogalea crassula Vavrdová 1990 is considered a junior synonym of A. erchunensis. The palaeobiogeographical relationships between South China, peri-Gondwana and Baltica are discussed. While the acritarch assemblages from South China contain some characteristic forms which have also been recorded from Bohemia and Morocco (i.e., the peri-Gondwanan Palaeoprovince), the lithological character of the Chinese sections is generally more comparable to those of Baltica.

KEYWORDS: Ordovician, Arenigian, South China, Yangtze Platform, acritarchs, Ampullula.


1. INTRODUCTION

Three sections from the Lower Arenigian Dawan Formation in the Upper Yangtze Region, Yangtze Platform, South China have been palynologically investigated. The stratigraphical interval of the Azygograptus sueticus graptolite Zone yields diversified and well preserved palynomorphs (acritarchs, chitinozoans and some scolocodons). In the upper part of this zone or probably the lowest Undulograptus sinodontatus graptolitic Zone the monospecific Ordovician acritarch genus Ampullula rarely occurs. The type species, A. suetica, is an easily recognizable acritarch and is distinctive from
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Figure 1. Location map of the sections investigated. Sample code is marked by a white star: Jianjiangping (JYP), Hubei Province; Wangjiacei (WJZ) & Datiamba (DTB), Sichuan Province.

most other species. However, the genus should be revised because its morphological variability was too restricted in the original description, thus excluding further species which are assignable to this genus.

Within the Chinese assemblages, more than 65 acritarch specimens which although highly variable, fit very well in the wider concept of Ampullula presented herein. Based on the present investigation of the Chinese material, two additional species should be included in the genus. These are Ampullula erchunensis (Fang Xiaoqi 1986) comb. nov., emend. (= Areomoricanium erchunense) and Ampullula princeps sp. nov., described herein. Currently, Ampullula is only known from Sweden and more recently from South China (Tongiorgi et al., 1995).

Palynological results from the Upper Yangtze Region have led to the suggestion that the Mediterranean Province sensu Vavrdová (1974), e.g., Avalonia, Gondwana and supposed terranes as there are, for instance, Iberia, Perunica, Armorica, might be extended up to South China (Li Jun, 1987). In addition to the typical Mediterranean or peri-Gondwanan (Martin & Dean, 1988; sensu Van der Voo, 1988) taxa, some species occur in the Chinese material, which have so far only been recorded from the Baltic Province (Scandinavia, Baltic States, NE-Poland, etc.). Some taxa which have so far been only described from Australian levels are also present. Only small part of the Chinese assemblages is possibly endemic. Therefore, the South Chinese material is not clearly related or exclusive to any "province", but shows strong affinities to Bohemia and Morocco, both of which are classical parts of the Mediterranean Province sensu Vavrdová (1974).

The systematic study of the genus Ampullula Righi 1991 is part of an intensive palynological investigation of Ordovician sediments from China. This material partly yields rich and diversified acritarch assemblages. First palynological results have been already published (Brocke, 1992; Brocke et al., 1995), and will be presented in the subsequent Ph.D. thesis (Brocke, 1997). The palynological investigation is involved in a research project between the Yichang Institute of Geology and Mineral Resources and the Technische Universität Berlin.

2. MATERIAL AND METHODS

2.1. SECTIONS IN THE STUDY AREA

During two field campaigns, samples from Cambrian to Silurian sediments of different localities in the Upper Yangtze Region, Yangtze Platform, South China were collected. In this paper, three localities of the Lower Ordovician Dawan Formation are discussed. The Datiamba and Wangjiacai sections are situated in the East Upper Yangtze Region, north of the town Xiushan, respectively west of the town Youyang, in the SE part of the Sichuan Province. The Jianjiangping section is located in the NW Upper Yangtze Region, near the Yangtze River north of Zigui, in Yichang area of the Hubei Province (Fig.1). These sections belong to a carbonate platform although they comprise of different lithological successions, indicated by the type of rocks and distinct thicknesses of the three members of the Dawan Formation (Fig. 2). The Lower Member of the Jianjiangping section is mainly composed of greyish nodular limestones and bioclastic limestones, intercalated with thin bedded marlstones and grey-green shales. The Middle Member is characterized by reddish to greyish nodular limestones, bioclastic limestones, marlstones and glauconite minerals. The Upper Member comprises of greyish marlstones, bioclastic limestones, that are partly reddish and nodular. Shales are less represented. The total thickness of the Jianjiangping section is about 32 m. The two faults in the upper
Figure 2. Three sections illustrating the lithostratigraphic division of the Arenigian Dawan Formation into a Lower, Middle and Upper Member. The corresponding biostratigraphical zonation is based on graptolites or conodonts (Middle Member). Observed specimens of the genus *Ampullula* are recorded in samples DTBDW-14 - 17 (Datianba section), JYPP-2 - 4 (Jiangjiangping section), and WIZDW-4,5, 12, 14 - 16 (Wangjiazei section).
part of the Lower Member do not show any evidence for a significant reduction of the thickness. Lithology and total thickness of the Jianjiangping sections are similar to the Daping section, which is about 37 m thick. The Huanghuachang section differs in the total thickness, which is about 63 m (Chen Xu et al., 1995). Both localities are in the Yichang area, ca. 70 km to the east of the Jianjiangping section. The sedimentology of the Daping section was described in detail by Lindström et al. (1991).

The two southern sections are both near the eastern Jiagnan Region (so-called Old lands, or Jiangan Islands), a complex of a Proterozoic Island Arc System (Xi Yaokun, 1985), probably active as a marginal uplift belt of the Yangtze Paraplatform (Ren Jishun et al., 1987: 56) during the Palaeozoic. The lithological successions are influenced by a greater portion of clastic input especially in the Upper Member. Typical sediments of the Lower Members are siltstones, shales and marlstones. In the middle part carbonate rocks dominate. The Middle Members are similar to the lithology in the Jianjiangping section, but reddish marlstones and shales are more abundant. The Upper Members show an increasing amount of siltstones. The sections described above are thicker than the Jianjiangping section, whereas the Lower and Middle Members of the Wangjiayazi section are particularly thick.

All the three localities are situated on a relatively stable shallow carbonate platform, which was part of the western shelf area of Gondwana (e.g., Scotese & Golonka, 1992) during the Early Ordovician. However, the differences documented by the lithological character of the rocks, as well as the thicknesses of the various members indicate a significant vertical and lateral variation during deposition of the Dawan Formation. This, in the first instance is due to a distinct facies differentiation on the platform itself, and secondly because of a general deepening on the platform, caused by a general transgression up to the Llanvirnian. In the sense of sequence stratigraphy, the two shale-rich intervals at the top of the Lower Member are interpreted as the maximum flooding surface (MFS) within the transgressive cycle, whereas the Upper Member represents the Highstand Systems Tract (HST). Sea level highstand is indicated by several discontinuity surfaces, phosphatic layers and glauconite minerals (Brocke, 1997). Lindström et al., 1991 described this phenomenon as a drowning carbonate platform.

2.2. PREVIOUS ACRI TARCH INVESTIGATIONS

Acritarchs from the Dawan Formation of the Upper Yangtze Region, e.g., Hubei Province, have been variously reported in the literature. Zhong Guofang (1981), Lu Lichang (1987), Li Jun (1991) and Yin Leiming (1994) reported acritarch assemblages from the Huanghuachang section, near Yichang. Brocke (1992) presented preliminary results from the Jianjiangping section. Tongiorgi et al. (1992, 1995) described a palynological assemblage (sample HD2) of the Daping section, 4 km north of Huanghuachang.

All of these papers concentrated particularly on palynological investigations from layers of the upper Didymograptus deflexus graptolite Zone to the Azygograptus suecicus graptolite Zone, which yields rich and well preserved acritarch assemblages. Authors studies on the whole Ordovician succession shows that these assemblages are obviously the most prolific of the Yangtze Platform. Therefore, most of the Ordovician acritarch work in South China is focused on this relatively short stratigraphical interval.

For instance, excellent material was described from the A. suecicus graptolite Zone of the Meitan Formation (Li Jun, 1987; Li Jun, 1991), Tongzi County, Guizhou Province, and the Jiuix Formation (Li Jun, 1990; Li Jun, 1991), Jishou, Hunan Province, which belongs to the SE parts of the Upper Yangtze Region (South China Plate).

Lower Ordovician acritarchs are also known from other parts of the Upper Yangtze Region as reported by Xing Yusheng (1980), Dachengsi Formation (upper Tremadocian and Arenigian) of Emeishan, Sichuan Province; Fu Jiayuan (1986), Xiliangsi Formation (Arenigian?, Llanvirnian) and Jiancaogou Formation (Upper Ordovician) from the Liangjiaqiao area of Zhenba County, Shaanxi Province; Fang Xiaosi (1986), Tangchi Formation (Tremadocian), Hongshiya Formation (Arenigian), and Qiaoqia Formation (Llanvirnian) of the Kunming-Luquan region, Yunnan Province; and Gao Lianda (1991), Hongshiya Formation (Arenigian) of Wuding, Yunnan Province.

Lower Ordovician acritarchs from the North China Plate are described by Yin Leiming (1985,
### Evaluation of the Ordovician Acrinarch Genus Ampullula Righi

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<td>S. diversus</td>
<td>P. proteus</td>
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**Figure 3.** Stratigraphic correlation chart of Arenigian to Caradocian stages in Britain, Baltica and South China. Stratigraphic units and zones are modified from: Column 1. Fortey et al. (1995); Column 2. Nölvak & Grahn (1993); Column 3. this paper; Column 4. Wang Xiaofeng et al. (1992); VandenBerg & Cooper (1992); Column 5. Wang Xiaofeng et al. (1992).

1986) and Martin & Yin Leiming (1988), Upper Cambrian - Tremadocian, from Hunjiang, Jilin Province; Li Zaiping (1982), Upper Machiakou Formation (Llanvirnian) from Central Hebei Province; and Hu (1986, cited in Li Jun, 1991) from Ziyang, Shaanxi Province.

Up to now, palynological data of the most northern part of the Upper Yangtze Region, the Lower Yangtze Region (northern border of the South China Plate) and of the transition belts to the Sino-Korean Plate and the Tarim Plate are still missing. The whole eastern border of the Yangtze Platform with the transition to the Jiangnan Islands and the Zhuijiang Basin (SE China Sea Trough) have not been studied and would be of great interest for palaeogeographical reconstruction.

### 2.3. Stratigraphy of the Dawan Formation

The studied sections of the Dawan Formation partly contain continuous successions from the underlying Tremadocian Fenxiang and Honghuayan Formations to the overlying Guniutan Formation, which roughly corresponds to the Llanvirnian. Only the equivalent parts of the upper Azygograptus filiformis graptolite Zone to the Undulograptus austrodenatus graptolite Zone are discussed and figured within this paper (Fig. 2).

Investigated samples of all sections come from rocks of the middle to upper part of the Lower Member of the Dawan Formation (A. suecicus graptolite Zone) and from the lower part of the Upper Member in the Wangjiazei section, dated by conodonts and chitinozoans. The Upper Member is stratigraphically equivalent to the upper part of the A. suecicus graptolite Zone or the lower Undulograptus sinodenatus Zone. This stratigraphic interval correlates to the upper part of the British Didymograptus nitidus Zone and the Didymograptus hirundo Zone or to the D. hirundo Zone in Scandinavia. However, a clear stratigraphical distinction between the A. suecicus graptolite Zone and the U. sinodenatus graptolite Zone still remains.
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<th>Species/Genus</th>
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<tr>
<td>Striaetheca principalis parva Burmann 1970</td>
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<tr>
<td>Striaetheca spp.</td>
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<tr>
<td>Veryhachium trispinosum group</td>
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<tr>
<td>Vogtlandia/Schizodiscodrum group</td>
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**Table 1.** This table contains 51 selected acritarch taxa from the three sections, Datianba (DTBDW), Wangjiizu (WJZDW), and Jianjiangping (JYPD). It shows the semi-quantitative distribution of the taxa. very rare = <5%; rare = 6-10%; common = 11-25%; abundant = >26%
problematical from the studied sections. The Middle Member of the Dawan Formation has been dated by cephalopods and conodonts. The index conodont of this stratigraphical interval is Parakostododus originalis. Figure 3 shows the correlation of the corresponding British, Scandinavian and Australian schemes with the litho- and biostratigraphy from the studied parts of the Yangtze Platform. The lithostratigraphy is based on Zeng et al. (1987) and the authors' observations during field work.

2.4. SAMPLES

Forty-nine samples from the Dawan Formation were collected and analyzed from the three sections mentioned above (Fig. 2). The material was processed by standard palynological methods, using HCl and HF treatment and were sieved with 10 μm screen, generally without oxidation of the organic residue. The samples WIZDW-15-17 have been slightly oxidized with HNO₃ to disperse the colloidal complexes of amorphous organic matter (e.g., degraded palynodebris). The palynological slides are deposited at the Technische Universität Berlin, Institut für Angewandte Geowissenschaften H.

Fifteen samples of parts of the Lower and Upper Members were particularly rich in well-preserved acritarchs whereas the material of the mainly carbonatic successions of the Lower Member are sterile or contain only rare and poorly preserved acritarchs. Fifty-one acritarch genera, species or "groups" from the 15 samples that yielded abundant acritarchs have been selected and listed in Table 1, indicating their semi-quantitative occurrences.

The samples JYPD of the Jianjiangping section are composed of lightly carbonic yellow-green to grey-green shales. The samples of the Datanba (DTBD) and Wangjiazai (WIZDW) sections are composed of grey-green silty shales with mica on the bedding plane (Fig. 2).

Stratigraphically, the samples JYPD-2 - 4, DTBDW-14 - 16 and WIZDW-4, 5, 7, 8, undoubtedly belong to the A. suecicus graptolite Zone. The samples DTBDW-17 and WIZDW- 12, 14 - 16 are considered to be part of the upper A. suecicus graptolite Zone or lower U. sinodontatus graptolite Zone. This time interval corresponds to the upper part of the P. originalis conodont Zone.

2.5. COMPOSITION AND PALAEOBIOGEOGRAPHICAL SIGNIFICANCE OF THE ACRITARCH ASSEMBLAGES

Table 1 shows the distribution of 51 selected, easily recognizable taxa in the 15 most prolific samples. All of these samples yielded acritarch assemblages containing more than 70 distinct taxa. The specimens have been assigned to previously described genera and species or to new taxa. This paper will not clarify the numerous taxonomical problems concerning the Ordovician acritarchs, but it will focus on the systematic study of the genus Ampullula. The other taxa from these samples will be described in detail in a subsequent paper (Brocke, 1997).


Some other acritarch taxa, which so far have only been reported from the Canning Basin, Western Australia (Combaz & Péniguel, 1972; Playford & Martin, 1984) and the Georgina Basin, Queensland, Australia (Playford & Wicander, 1988) are also present in the Chinese assemblages, including different species of such pylomate forms such as Peltinosphaeridium and Rhopaliphora. The species cf. Goniosphaeridium canningianum Playford & Martin 1984, Loeblichia heterorhabda

Vavrdová (1974) introduced the terms Mediterranean Province and Baltic Province to describe the differences of acritarch associations from Europe during the Arenigian and Llanvirnian. Her subdivision is based on the presence or absence of certain selected distinctive acritarchs within each of the provinces. Since Vavrdová introduced these terms several workers (e.g., Martin, 1982; Albani, 1989) have followed this concept of two acritarch provinces. The occurrence of taxa which are considered to be of Baltic affinities is documented, for instance, by some Baltisphaerids, peteinosphaerids and a great number of specimens which are either assignable to species Goniosphaeridium (Eisenack 1969) emend. Turner 1984 or to Polygonum Vavrdová 1966. However, because a clear distinction between these two genera is not possible, it is difficult to make a positive identification. In addition, numerous granulated and echinated taxa occur, which indicate transitional forms assignable to the genera Stellechinate Turner 1984 and Uncinisphaera Wicander 1974. A distinctive species, Peteinosphaeridium hymenoferum (Eisenack 1938) Eisenack 1969 is rare to common in these samples, and may be of palaeobiogeographical value. Several other distinctive peteinosphaerid taxa are tentatively identified herein as Peteinosphaeridium trifurcatum (Eisenack 1931) Eisenack 1969 or Peteinosphaeridium spp. Some of them may be conspecific with species described by Tongiorgi et al. (1995).

As noted earlier (Li Jun, 1990; Gao Lianda, 1991; Brocke, 1992; Yin Leiming, 1994; Tongiorgi et al., 1995) the character of the acritarch assemblages of the Arenigian Dawan Formation indicates biogeographical relations between the subtropical to tropical Yangtze Platform and the cold to cool peri-Gondwanan or Mediterranean so-called Palaeoprovince, with affinities to the Baltic and Australian assemblages. The two latter areas are generally characterized by the dominance of pylomate acanthomorphs and the absence of diacrodians and corymorphids (Playford & Wicander, 1988; Vavrdová, 1990).

Li Jun (1991) and Tongiorgi et al. (1992, 1995) discussed the palaeogeo graphical affinities of acritarchs and pointed out that the influence of cold water currents coming from the high palaeolatitudes of Gondwana, may have led to the dominance of typical peri-Gondwanan taxa in South China during Arenigian-Llanvirnian time. Tongiorgi et al. (1995) based their model on the results of one single sample (HD2), of which they described numerous species. Some of them are considered as new and representing a part of an endemic (Chinese) component, distinguished from Mediterranean, Baltic and Australian elements. According to these previous studies, it appears that during the Arenigian the Upper Yangtze Region yielded a mixed palynoflora including an endemic component and elements which have been so far considered as typical for the peri-Gondwanan, Baltic and Australian areas.

It is premature, however, to define an Australian Palaeoprovince, based on only a few published data from this area. Future studies will probably indicate that some of the taxa may also occur elsewhere in the world. Furthermore, the prevalence of the endemic Chinese component in the single sample HD2 of Tongiorgi et al. (1995) is not in agreement with the data from the investigated sections in the present study. For instance, some of their new taxa (e.g., species of Peteinosphaeridium and Pirea) might be included under the concept of a greater variability among the populations.

It is especially important, but partly very difficult to distinguish the palaeobiogeographical factors from local palaeoenvironmental effects (compare also Servais, 1995: 458). The comparison of different sections of the Yangtze Platform already shows major differences in the composition of the acritarch assemblages from samples of an equivalant age but from different localities. The Jianjiangping assemblages are characterized by the prevalence of specimens of the Goniosphaeridium/Polygonum group, Baltisphaeridium, e.g. cf. B. coolibahense Playford & Wicander 1988, Micrhystridium acuminosum Cramer & Díez 1977, and a relatively high diversity of species of Peteinosphaeridium and Rhopaliphora, species which also indicate Australian and Baltic affinities. Typical peri-Gondwanan forms such as Acanthodiacrodium vavrdovae Cramer & Díez 1977, Arborusclidium filamentosum, (Vavrdová 1965) emend. Fatka & Brocke 1996 (in press), Auroeotesta clathrata (Vavrdová 1972) emend., Brocke et al. 1996,
EVALUATION OF THE ORDOVICIAN ACIRARCH GENUS AMPULLULA RIGHI

Dactylofusa vetifera Cocchio 1982, Dicordiacrodium ancoriforme (Burmann) emend. Servais et al. 1996, Ericanthoe pollicipes Cramer & Diez 1977, Multiplisphaeridium rayii Cramer et al. 1974, and specimens of the Vogtlandia / Schizodiakrocrodium group are less represented or are even missing. Altogether the diversity of palynoflora and the number of recorded specimens is lower compared with those of the southern sections.

The latter described acritarch complex is partly represented by high number of specimens in the more southern situated Daitianba and Wangjiabei sections, where pylomate forms are relatively less frequent. The composition of the acritarch assemblage and its comparison to equivalent-aged assemblages elsewhere, lead to the conclusion that palaecobiogeographically the present SE part of the Upper Yangtze Region was more closely related to peri-Gondwana, and the NW part was more similar to Australia or even Baltica. However, so far no recent palaecogeographical reconstructions indicate such a position of the South China Plate. Therefore, based on the above information and data, not yet described from other sections (Brocke, in prep.), it seems to be more convincing to suspect that facies differentiation and ecological patterns (physical and chemical oceanic conditions, e.g., energy conditions, input of fines, temperature, salinity, nutrients etc.), are responsible for the local differences among the acritarch assemblages on the Yangtze Platform.

3. SYSTEMATIC PALEONTOLOGY

The genus Ampullula Righi 1991 is an easily recognizable Lower Ordovician acritarch, characterized by a spherical central body, which bears a single, calciform to cylindrical neck-like extension, but without further processes on the vesicle. This tubular, neck-like extension is regarded as the main diagnostic feature of this genus as proposed in the original diagnosis (Righi, 1991).

Up to now, only a single species of Ampullula, A. suetica, is known. It was orginally recorded from the late Arenigian to Llanvirnian "Lepidurus limestone", Hagudden section, Öland (Righi, 1991) and has recently been described from the uppermost Early Arenigian Dawan Formation, Daping section, Yangtze Gorges, Hubei Province, Southern China.

Figure 4. Idealized drawing of a specimen of Ampullula suetica, Daitianba section, slide DTBDW-17/3, Pl. 1, Fig. F, displaying the typical tubular neck-like extension with the widened and lobed distal termination. The circular pylome is situated on the opposite pole of that bearing the neck.

(Tongiorgi et al., 1995). Unfortunately A. suetica was only mentioned but not described in detail or illustrated in this publication.

Fang Xiaosi (1986: 135, 145, 153, Pl. 9, Figs 1, 2) named a new species Aremoricanium erchunense from the Arenigian Hongshiya Formation, Kunming-Luquan region, Yunnan Province. The two figured specimens show a more-or-less spherical body with numerous processes and a prominent tubular neck-like extension (prototuberance). Fang Xiaosi (1986) assigned the new species to the genus Aremoricanium Deunff 1955, because of its prominent tubular extension.

Yin Leiming (1994: 48, 51, Pl. 1, Figs. 5-7, Pl. 2, Figs. 1-4, 6) erected the new monospecific genus Stelomorpha based on the species A. erchunense (Fang Xiaosi 1986) from the Huanghuachang section, Yichang, Hubei Province, by a new combination and emendation of Fang Xiaosi's diagnosis. Unfortunately there are no comments remarked about the affinity to the genus Ampullula, and it is not clear from discussion, as to which are
the significant differences between *Aremoricanium* and *Stelomorpha*.

Tongiorgi *et al.* (1995: 22, Pl. 1, Figs. 1, 2, 4-7) found specimens of similar morphology to *A. erchunense* in the Daping section and " provisionally and doubtfully" transferred them to *Ampullula ? erchunensis* (Fang Xiaosi 1986) Tongiorgi *et al.*, 1995. Their diagnosis is based on the tubular extension, which in their opinion, closely recalls that of *Ampullula* Righi 1991. But the authors pointed out that *Ampullula* is devoid of further processes. They proposed emendation of *Ampullula* or the designation of a new genus very close to *Ampullula*. Remark: Because of the delay of their publication, which was already presented as a talk at the 8th International Palynological Congress, Aix en-Provence in 1992, *A. erchunensis* was transferred to *Stelomorpha erchunensis* Yin Leiming 1994 (Tongiorgi *et al.*, 1995, Addendum: 48).

Vavrdová (1990: 245, Pl. 2, Fig. 1, Fig. 6) described the species *Cymatiogalea crassula* from the late Arenigian Klabava Formation, Myto section near Rokycany, Bohemia. The specimen has very similar processes to the specimens pictured by Fang Xiaosi (1986), Yin Leiming (1994), and Tongiorgi *et al.*, (1995) but without a prominent tubular neck-like extension.

After examination of large populations from several stratigraphically comparable samples (*A. suecicus* graptolite Zone to *U. sinodentatus* graptolite Zone) from three different sections, it is obvious that the morphological variability at the specific and even the generic level is significant. The prominent apical "neck" or "tubular extension" considered as diagnostic, is not a sufficiently characteristic morphological feature to classify *Ampullula*. In 18 of the 40 observed specimens of *A. erchunensis* Fang Xiaosi 1986 comb. nov., emend. and 10 of the 25 specimens of *A. princeps* sp. nov. such a process is not observable. This is possibly a matter of preservation or maturity, but seemingly a primary characteristic feature too. Heteromorphic to homomorphic processes are present in a wide range of numbers and patterns of distribution on the vesicle. The type species, *A. suecica*, is regarded here as an extreme pole of the variability within the genus *Ampullula*, because no further processes besides the single neck-like extension exist. Whereas, the species *A. erchunensis*, with numerous processes on the vesicle represents the opposite pole of variation. The new species *A. princeps* may be considered as a linkage between both taxa. However, transitions between *A. suecica* and *A. princeps* have never been observed, while transitions between *A. princeps* and *A. erchunensis* exist (Pl. 1, Fig. G). But, because of numerous specimens observed with a clear bipolar or pseudobipolar orientation of the processes (see diagnosis of *A. princeps*), it seems justifiable to separate the two species.

Algae Incertae Sedis
Acritarcha Evitt 1963
Genus *Ampullula* Righi 1991 nov. emend.
Junior synonym: *Stelomorpha* Yin Leiming 1994
Type species: *Ampullula suecica* Righi 1991, by original designation.

**Original diagnosis** (Righi 1991: 121). Ellipsoidal to spherical vesicle, with a single calyciform to cylindrical distally widened neck, hollow and proximally not communicating with the vesicle cavity. Vesicle and neck wall relatively thin, seemingly one-layered. Vesicle surface smooth to scabrate or granulated. Distal edge of neck ornamented with protruding tubercles, thin spines, baculae to true distally bulbous to clavate processes of varying lengths. Neck base sometimes ornamented by radiating ridges and / or spines. Excystment observed in form of a pyleme situated at the opposite pole of that bearing the neck.

**Emended diagnosis.** Ellipsoidal to spherical vesicle, seemingly single-layered, psilate to granulate, bearing one or more homomorphic or heteromorphic processes. One of the processes may be developed as a prominent tubular, neck-like extension. Processes, including neck-like extension, hollow, proximally not communicating with the vesicle cavity; closed by plug-like feature or thin layer. Distal end open and mostly widened, sometimes branched, variably shaped and ornamented, often bearing short spines or pinnae. Processes either mainly concentrated on one or two poles and less numerous, or irregularly distributed on the central body and numerous. Excystment observed in form of a pyleme.

**Discussion**. The ellipsoidal to spherical vesicle is relatively thin. It appears to be unlayered and is generally folded, imitating irregular fields. These foldings may form strengthening rods, sometimes occupied by processes, which often stand in a line. The vesicle surface is psilate to granulate. Processes
are often thicker walled than the vesicle, cylindrical, but variably shaped in dimensions and distal terminations. They have no contact with the vesicle interior, and may show plug-like features at the proximal termination, resulting from a local thickening of the wall at the basal part. Additionally, some processes show a dark area around their contact to the vesicle. In some of the specimens observed, a thin layer may seal off the processes from the vesicle interior. In no case a double layered vesicle was clearly observed. Apparently a splitting of the wall into two "layers" is possible on the contact between the vesicle and the processes. Generally the processes seem to be hollow, at least at their distal end. The distal edge of the processes is funnel-like to calyciformly widened. The tip is usually serrated, lobed or irregularly ramified into two to five pinnae, sometimes ramifications are present up to the second order. Rarely they are plain, but sometimes slitted, and bearing spiny to bulbous ornamented terminations.

The "neck" or "tubular extension" or "protuberance" shows similar variable morphological features as the ordinary processes, but it is two to three times larger in its dimensions. However, this tubular extension is not visible in each specimen. Apparently, it is primarily not developed in any case and probably secondarily lost because of preservation conditions. The arrangement of the tubular extension in *A. suetica* and *A. princeps* relates to an "apical" localisation. Additionally, in *A. princeps* a few processes (4-12) are either concentrated on this pole or the opposite one. Processes in the equatorial part are very rare (max. 5). In *A. erchunensis*, the "apical" position of the tubular extension is sometimes marked by rarely distributed processes around it, but usually the processes are numerous and irregularly distributed over the whole vesicle and do not show any favourable localisation of the tubular extension.

Excystment structures occur in the form of a pyleome with an operculum ornamented with processes (observed in 2 specimens). They are situated at the opposite pole ("antapical" pole) of that bearing the extension or sometimes grouped processes. In *A. erchunensis*, the existence of the pyleome is often more difficult to observe than in *A. suetica* and *A. princeps* because processes are numerous or because the operculum is still closed. The "partial rupture" on specimens described by Yin Leiming (1994) appears to be of secondary origin.

**Dimensions.** The central body of *Ampullula* ranges between 43 μm (CB_{min}) and 116 μm (CB_{max}). The length of the tubular, neck-like extension (TP_{2}) is between 9-21 μm. Process lengths (P_{1}) range from 1 μm to 18 μm. These data are based on measurements of Fang Xiaosi (1986); Vavrdová (1990); Righi (1991); Yin Leiming (1994); Tongiorgi et al. (1995); Paalits (unpubl.) and present studies.

**Remarks.** The present study on large populations of *Ampullula* in comparison with published data from China (Fang Xiaosi, 1986; Yin Leiming, 1994; Tongiorgi et al., 1995), as well as reexamination of materials from Bohemia (Vavrdová, 1990; Fatka, unpubl. data), and investigations of specimens from the Moscow Basin (Paalits, unpubl. data) necessitate the erection of two additional species in the genus *Ampullula*.

**Comparison.** The genus *Aremoricanium* Deunff 1955, (type species *A. rigaudae* Deunff 1955) was originally described as being formed of two concentric layers, with the outer layer bears a cylindro-conical expansion. Loeblich & Mac Adam (1971) described six species of *Aremoricanium* from North America with neck-like extensions, which terminate in a pyleome. An operculum or a second pyleome on the opposite side of the pole bearing the tubular extension has never been observed. Morphologically the neck of *Ampullula* differs from that of *Aremoricanium* by being always more-or-less funnel-like to calyciform widened at the distal end and by possessing ornamentation.

*Leiosphaeridia tuberculosis* Eisenack 1963 differs from *Ampullula* by having a tube-like extension without any terminal widening and ornamentation. Eisenack described this feature as a pyleome! The opposite pole of that bearing the extension clearly shows a circular opening. However, only two specimens (Eisenack, 1963, 1965) have been published since that time. The description of further specimens could result in an intrageneric relationship to *Ampullula*.

The species *Ammonidium aduncum* Playford & Martin 1984 differs from *Ampullula* by having no tubular extension or excystment structure and typical bifurcate processes. However, heteromorphic processes of *A. aduncum* are within the morphological variety of the processes observed in
**Amphullula.** Playford & Martin (1984) noted that the process interiors do not communicate with the vesicle cavity. However, this is not according to the type species _Ammonium microcladum_ Lister 1970, where this feature is significant for generic definition. Excystment is characterized by a cryptostature, apically or near-equatorially situated. Thus, the affinities between _Ammonium aduncum_ and _Amphullula_ remain unclear.

The genus _Ordovicidium_ Tappan & Loeblich 1971 has hollow processes which do not communicate with the vesicle. It differs from _Amphullula_ in having a double-layered vesicle wall, with the hollow processes arising from the outer layer. The processes are not open at their distal end.

**Stratigraphical range indicated by graptolites and conodonts.** First appearance datum (FAD): upper lower Arenigian, _A. suessicus_ graptolite Zone, Lower Member of the Dawan Formation, Datianba and Wangjiazei sections, Sichuan Province; Jianjiangping, Huanghua-chang (Yin Leiming, 1994), Daping (Tongiorgi _et al._, 1995) sections, Hubei Province; Arenigian, Kunming - Luquan Region, Yunnan Province (Fang Xiaosi, 1986). Younger records: upper Arenigian, Upper Member of the Dawan Formation, Wangjiazei section. Stratigraphic position is not clearly verified by graptolites but chitinozoans (Chen Xiaohong, unpublished data) may indicate an age within the upper part of the _A. suessicus_ graptolite Zone or equivalent to the lower _U. sinodontatus_ graptolite Zone. Uppermost record: Llanvirnian, _Didymograptus bifidus_ graptolite Zone, Hagudden section, Öland, Sweden.

**Amphullula erchunensis** (Fang Xiaosi) Brocke, emend. et comb. nov. Pl. 1, Fig. G, Pl. 2: A, B, E, F, H, K; Fig. 5.

1986 _Aremoricanum erchunense_ Fang Xiaosi: 145, Pl.9, Figs. 1, 2.
1990 _Cymatiogalea crassula_ Vavrdo: 245, Fig. 6, Pl. 2, Fig. 6.
1994 _Stelomorpha erchunensis_ Yin Leiming: 51, Pl. 1, Figs. 5-7, Pl. 2, Figs. 1-4, 6.
1995 _Amphullula ? erchunensis_ Tongiorgi _et al._: 22, Pl. 1, Figs. 1, 2, 4-7.

**Holotype.** Fang Xiaosi 1986: 145, Pl. 9, Fig.1 (2).

**Basionym:** _Aremoricanum erchunense_ Fang Xiaosi 1986.


Vesicle oval with very thin, opaque wall, mostly showing 1-3 strong folds parallel to the longitudinal axis. From the vesicle extends a short, strong, hollow protuberance whose proximal and distal width is the same. Its distal end projects outwards. Around the protuberance, on the vesicle, short, squat processes are evenly distributed, whose bases are a little widened and whose tips are funnel-like and extend into a delicate branching tuft. The vesicle is 68 μm long; the process trunk 2 μm, the whole process 8 μm. The colour is darkish-yellow.

**Emended diagnosis.** Subspherical to ellipsoidal vesicle, seemingly single-walled, psilate to granulate, bearing homomorphic or heteromorphic processes. One of the processes may be developed as a tubular neck-like extension. Processes, including neck-like extension, hollow and distally open. Proximally processes do not communicate with the vesicle cavity. Processes sealed off from the vesicle sometimes by a plug-like feature or probably by a thin layer. Distal end widened, variably shaped and ornamented, sometimes bearing short spines or pinnae. Processes numerous and irregularly distributed on the central body, sometimes aligned. Excystment observed in form of a pyleome with processes on the operculum.

**Description.** The vesicle is usually subspherical to ellipsoidal with a probably original spherical outline. It is most probably single-walled and usually psilate, sometimes weakly granulate. The processes on the vesicle are heteromorphic to homomorphic, numerous (40 to approximately 100 in number) and irregularly distributed on the central body. Processes are sometimes standing in a line, which is marked by foldings. These folds may imitate irregular fields. A tubular neck-like extension sometimes occur and principally doesn’t differ from the processes, other than in size. Occasionally it is observed that there is an area around the neck which is lacking processes. Proximally there is no contact with the vesicle interior. In some cases a “plug” seems to be developed on the contact between the processes and vesicle, whereas a few specimens may show a thin layer which demarcates the processes from the vesicle interior. The processes are somewhat broadly based with a low angle contact to the
vesicle, but steeply ones also occur. Processes’ trunks are thicker walled than the vesicle and vary in length (3.5-11 μm) and width (1.3-5 μm). They are tube-like and tend to widen towards their distal termination. A funnel-like to calyciform outward projecting is widely distributed. Processes are hollow and opened at their distal end. The distal edge is variably shaped: plain, lobed, irregularly ramified or ornamented. Their tips are sometimes bearing short processes and pinnae up to the second order.

![Image of 30 μm](image)

**Figure 5.** A common representative of *Amphulla erichunensis*, Datianba section, slide DTBDW-16/5, Pl. 2, Fig. A. This specimen shows a prominent tubular extension and relatively long, hollow processes which are distally funnel-like widened and with serrated, partly spiny or filamentous edges. A few processes are simple or bifurcate.

**Dimensions.** Table 2 compares the measurement data of *A. erichunensis* from the literature and the 25 specimens studied by the author. The number of measured specimens from Fang Xiaosi and Vavrdova can not clearly verified. Yin Leiming's data are based on 19 specimens, whereas Tongiorgi *et al.* measured 35 specimens. The material from the Moscow Basin (Paalits, unpubl. data) is based on three specimens.

The measured parameters in column 1 are listed as abbreviations in Tables 2, 3 and 4.

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<td>300-400 even</td>
<td>300-400 even</td>
<td>ca. 25-50</td>
<td>ca. 40-100</td>
<td></td>
</tr>
</tbody>
</table>

* measurements based on three specimens  
* measurements not verified

**Table 2.** Comparison of published dimensions of *A. erichunensis* with those of investigated specimens.

end; PWdist - Process Width distal end; PTW - Process Trunk Width; POl - Process Ornamentation Length; PYl - Pylome Width; Np - Number of Processes.

**Remarks.** Studied specimens of *A. erichunensis* include all Chinese representatives (Fang Xiaosi, 1986; Yin Leiming, 1994; Tongiorgi *et al.*, 1995). There is great morphological variability in the observed specimens, including the processes, tubular neck-like extension and the vesicle. The proximal termination of the processes is mostly serrated. But, shapes (Fig. 6), numbers, and dimensions (Tab. 2) are also variable, resulting mostly in heteromorphic processes.

The neck-like extension is not observable in any specimen, which is regarded here as a variation within the species. Observed neck-like extensions are approximately two times larger than the processes, but within the range of variation as described for the processes. The vesicle seems to be originally spherical but it is often deformed and altered by compression folds. Table 2 shows the
different dimensions of the vesicle.
The specimen described as *Cymatogalea crassula*
Vavrdoúa 1990 shows similar morphology and
dimensions of the vesicle and the processes.
Vavrdoúa (1990) mentioned a questionable fine
striation on the process stems. Restudy of the
original material by the present author is in
agreement to the protologue that this feature is
uncertain and therefore should be regarded as of
minor taxonomical value. A striation has never been
observed in the Chinese material, but was described
for the base of the neck of some rare specimens of
*A. suetica* (Righi, 1991). A prominent tubular
extension is missing in *C. crassula* but this
corresponds to the morphological variability
observed within the Chinese populations.

Three specimens from core material of the
Moscov Basin (Paalits, unpublished data) are
seemingly conspecific with *A. erchunensis*, but a
prominent tubular extension has not been observed.
The age of the samples is not verified by
macrofossils, but an Arenigian age is supposed.

**Comparison.** *A. erchunensis* differs from *A. suetica*
in having numerous processes, a prominent tubular
neck occasionally occurs.

**Stratigraphical range indicated by graptolites and conodonts.** FAD: upper lower Arenigian, *A. sueticus* graptolite Zone, Lower Member of the
Dawan Formation, Datsianba and Wangjiazei
sections, Sichuan Province; Jianjiangping,
Huanghuachang (Yin Leiming, 1994), Daping
(Tongjiori *et al.*, 1995) sections, Hubei Province;
Arenigian, Kunming - Luquan Region, Yunan Province (Fang Xiaosi, 1986). Youngest records are
in the Wangjiazei section, upper Arenigian, Upper
Member of the Dawan Formation. The stratigraphic
position is not clearly verified by graptolites but
chitinozoans (Chen Xiaohong, unpublished data)
may indicate an age in the upper part of the *A.
sueticus* graptolite Zone or equivalent to the lower
*U. sinodentatus* graptolite Zone.

*Ampullula princeps* sp. nov.

**Derivation of name.** *Princeps* (Latin), prince, in
the meaning of emperour, according to the planet
with the monkey-bread trees on the cover of the book:
Le petit prince from A. de St' Exupery.
**Diagnosis.** Vesicle spherical or slightly elliptoidal,
wall thin and seemingly unlayered, psilate to
granulate. Homomorphic or heteromorphic
processes, cylindrical, distally hollow, funnel-like
expanded, sometimes simple or bifurcate and
variably shaped. One of the processes may be
developed as a prominent tubular extension.
Processes proximally clearly demarcated from the
vesicle by plug-like feature or thin layer, and do not
communicate with the vesicle cavity. Distal
termination of the processes widened, and with an
irregular serrated edge formed by bulbous to conical
spines of varying length and thickness, sometimes
furcated. Processes are concentrated on two areas
(pseudo-bipolar). A few processes might be
irregularly distributed on the vesicle. Excystment
aperture observed in form of a pylome with an
operculum.

**Holotype.** Pl. 1, Figs. A, B, Fig. 7.


**Locality and horizon.** Datsianba section, Sichuan Province, South China, Dawan Formation,
Arenigian, *Azzygopactus sueticus* graptolite Zone.

**Repository.** All samples are stored in the collection of the Technische Universität Berlin.

**Description.** The ellipsoidal to spherical vesicle
seems to be unlayered, is relatively thin and
generally folded, so that the vesicle appears to be
divided into irregular fields. These foldings may
form ridges, where processes are sometimes situated
in a row. The vesicle surface can be smooth,
microgranulate or unevenly granulate. The process walls are somewhat thicker than that of the vesicle, especially at their proximal part, and visible by an often dark area surrounding the process base. The vesicle bears processes in varying shape, number and arrangement. The processes do not communicate with vesicle interior. Proximally they are generally broad-based and sometimes separated from the vesicle cavity by a plug-like feature, probably resulting from local thickening of the wall. In a few specimens observed, a thin layer may separate the processes from the vesicle cavity. The processes are hollow, at least at their distal part, and some specimens bear thick-walled processes with a small cavity. The presence of solid forms of processes is questionable. The processes are predominantly funnel-shaped, widened towards their distal termination, and probably always distally opened. However, the distal edge shows variety in their contours, ranging from smooth to simply furcated. Most of the specimens show a crown-like denticulate margin, formed by tubercles, spiny ornaments and thin bulbous, to conical processes with occasionally filamentous elements.

The distinguishing feature of this species is the arrangement and the relatively low number of the processes. They may either be concentrated in two areas, so that the symmetry is homomorphic or they are not directly situated at opposite poles rendering them pseudohomomorphic. Sometimes the processes are closely arranged next to each other on both poles. Besides that a few processes (between 4 and 10) may be irregularly distributed on the vesicle. The total number of processes ranges between 10 and approximately 25.

**Dimensions.** \(CB_w\) 46-103 µm, \(TP_l\) 11.6-17.7 µm, \(P_L\) 1.0-6.7 µm, \(N_4\) 4-20.

Measurements of *A. princeps* are figured in detail in Table 3.

**Remarks.** *Ampullula princeps* sp. nov. displays great variation in the arrangement and the type of the processes on the vesicle. On one specimen may be found short, stout and thin simple furcating processes as well as long, wide, funnel-like forms with variably shaped edges, as well transitional forms between them.

**Comparison.** *A. suetica* is characterized by only one apical, prominent, neck-like extension without further processes on the vesicle. However, the neck is assigned to be principally homomorphic with the
### Table 3.
Dimensions of *A. princeps* are based on 17 specimens. A total of 28 specimens has been observed.

ordinary processes of the two other species, because we don’t know about the origin and meaning of such an elongated feature.

*A. princeps* differs from *A. erchunensis* in having a somewhat larger vesicle, thinner vesicle wall that is generally psilate to microgranulate and by having a small number of processes which are predominantly arranged on two poles, suggesting a separation into an “apical” and an “antapical” pole. If a prominent neck-like extension is developed it is situated at the “apical” position, whereas the pylom is on the opposite one. The pylome is usually distinctly visible. Transitional forms between *A. princeps* and *A. erchunensis* rarely occur. Probably because of the small amount of specimens in the Chinese samples transitional between *A. princeps* and *A. suetica* have not yet been observed.

Stratigraphical range indicated by graptolites and conodonts. FAD: upper lower Arenigian, *A. sueticus* Zone, Lower Member of the Dawan Formation, Datianba and Wangjiazei sections, Sichuan Province; Jianjiangping section, Hubei Province. Youngest records: upper Arenigian, Upper Dawan Formation, Wangjiazei section. Stratigraphic position of the youngest occurrence is not clearly verified by graptolites, but chitinozoans (Chen Xiaohong, unpublished data) indicate the age of the higher part of the *A. sueticus* graptolite Zone to be probably equivalent to the *U. sinodentatus* graptolite Zone.

### Table 4.
Measurements of *A. suetica*. Righi’s data are based on 79 specimens. Present measurements are based on three specimens.

**Measured parameters** | **Righi, 1991** | **present study**
--- | --- | ---
**CBW max** | 42-116μm Ø 64μm | 45.8-81μm Ø 63μm
**CBW min** | 37-91μm Ø 55μm | 44.5-78μm Ø 61.3μm
**TPL** | Ø 12μm | 9.3-18 Ø 13.7μm
**TPW base** | 3.5-12μm Ø 6μm | 5-8μm Ø 6.5μm
**OL** | ≤ 4μm | 0-3μm
Figure 9. The first appearance datum (FAD) of the three species of Ampullula. According to Tongiorgi et al. (1995) the FAD of *A. suetica* is in the Azygosgraptus sueticus graptolite Zone. However, it occurs in the Wangjiachie section in the upper part of this zone or probably in the lower part of the Undulograptus sinodentatus graptolite Zone. *A. erchuenensis* (Fang Xiaosi) comb. nov., emend. and *A. princeps* sp. nov. appear in the *A. sueticus* Zone.

only occurs in sample DTBDW-17 (three specimens). The rare occurrence of *A. suetica* is also in agreement with the observation of Tongiorgi et al. (1995) from their sample HD2 from the Daping section.

Stratigraphical range indicated by graptolites and conodonts. FAD: uppermost lower Arenigian, *A. sueticus* Zone, Lower Member of the Dawan Formation, Daping section, Yichang region, Hubei Province (Tongiorgi et al., 1995); Younger records in China: upper Arenigian, approximately *U. sinodentatus* Zone, Upper Dawan Formation, Datianba section, Sichuan Province (here). Uppermost record: Llanvirninian, *D. bifidus* Zone, Hagudden section, Öland, Sweden (Righi, 1991).

4. CONCLUSIONS

Three sections of the Lower Ordovician Dawan Formation from South China have been palynologically investigated. The former monospecific acritarch genus *Ampullula*, type species *A. suetica*, has been recorded from the Datianba section. Based on the revised diagnosis of *Ampullula*, two additional species, *A. erchuenensis* comb. nov., emend. and *A. princeps* sp. nov., are now included in the genus. Specimens of *A. erchuenensis* are also present in Bohemia and the Moscow Basin. However, *A. suetica* occurs only in Sweden and South China, but so far has not been reported from the cold to temperate peri-

<table>
<thead>
<tr>
<th>Chronostrat</th>
<th>Britain</th>
<th>Baltic</th>
<th>FAD of Species of Ampullula</th>
<th>South China (Sichuan / W. Hubei)</th>
</tr>
</thead>
</table>
| Stages      | Grgplt. | Grgplt. | Lith-
|             | Zones   | Zones  |  | 
| Ordovician  |         |        |    | Stenograpt. |
| Llanvirnin  | N. gracialis | N. gracialis | Dacian
| Arenigian   |         |        |    | Ba.
| D. marchioni |         |        |    | Ba.
| D. artus    |         |        |    | Ba.
| D. hirundo  |         |        |    | Ba.
| G. cernans  |         |        |    | Ba.
| D. deflexus |         |        |    | Ba.
| P. phyllograptoides | | | | Ba.
| A. suetica  |         |        |    | Ba.
| A. erchuenensis | |        |    | Ba.
| A. princeps |         |        |    | Ba.
| Litho-
|             | Stenogr.
|             |         |        |    |         |
|             |         |        |    |         |
|             |         |        |    |         |
|             |         |        |    |         |
|             |         |        |    |         |

Gondwanan region. It is therefore supposed, that *A. suetica* seems to be more typical for warmer, shallow water carbonate environments as they are documented in Sweden and on the Yangtze Platform during the Arenigian.

The first appearance datum (FAD) of the three species of *Ampullula* is illustrated in Fig. 9. *A. suetica* first appears in the Daping section (Tongiorgi et al., 1995) within the Azygosgraptus *sueticus* graptolite Zone, whereas it occurs later in the Datianba section, in the upper part of the *A. sueticus* graptolite Zone or probably the lower *Undulograptus sinodentatus* graptolite Zone. *A. erchuenensis* and *A. princeps* already appear in the lower part of the *A. sueticus* graptolite Zone.

The close palaeobiogeographical relationship between the Upper Yangtze Region and the peri-Gondwanan area during the Arenigian is indicated by the predominance of typical representatives of the peri-Gondwanan acritarch Palaeoprovince, whereas Baltic elements and representatives from Australia are less common but may be of regional increasing frequency (e.g., the Jianjiangping section). Endemic taxa are represented by relatively few species.

The studied acritarch assemblages of the Arenigian *A. sueticus* graptolite Zone shows distinct numbers of specimens and diversity of species from different areas in the Upper Yangtze Region. This result reflects facies differences on the carbonate
platform and sea-level fluctuations during a transgressive cycle from the Tremadocian to the Arenigian, which is also supported by sedimentological data. In addition, these primary environmental conditions are probably secondarily influenced by cold or cooler currents, coming from the high palaeolatitudes of peri-Gondwana, to the more temperate or even tropical South China Plate, as it was proposed by Tongiorgi et al. (1995). However, the reconstruction of such complicated oceanic circulation patterns for the Arenigian remains uncertain, as long as the palaeogeographical position of palaeoplates, for instance, South China and Baltica is still under discussion (e.g., Scotese & McKerrow, 1990, 1991, Scotese & Golonka, 1992, Torsvik & Trench, 1991).

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EVALUATION OF THE ORDOVICIAN ACритARCH GENUS AMPULLULA RIGHI


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PLATE 1

A - E; G - I Ampullula princeps sp. nov.

A, B. Slide DTBDW-16cd, England Finder Graticule coordinates M48; holotype, magnification x 750.
C DTBDW-15xy, F38/2; x 750.
D DTBDW-15xy, B49/4; x 750.
E DTBDW-16xy, S25/4; x 750.
G DTBDW-16cd, F48; black arrow shows the tubular extension. x 750.
H DTBDW-16/1, Y56/4; x 1000.
I DTBDW-16/1, V44/3 - V44/1; x 1000.
F Ampullula suetica Righi 1991. DTBDW-17/3, E49; x 750.
EVALUATION OF THE ORDOVICIAN ACRTARCH GENUS AMPULLULA RIGHI
PLATE 2

A. B, E, F, H, K

_Ampullula erichunensis_ (Fang Xiaosi 1986) comb. nov., emend.

A  Slide DTBDW-16/5, England Finder Graticule coordinates P54/2; magnification x 750.
B  DTBDW-16cd, Y45/2; x 750.
E  DTBDW-15xy, D25/4; x 750.
F  DTBDW-14xy, E43-E43/3; x 750.
H  DTBDW-14cd, R25/2-R26/1; x 800.
K  SEM DTBDW-14-2; x 750, enlargement of processes; x 4000, note the distal opening.
I  _Ampullula suetica_ Righi 1991, DTBDW 17-2, C 64; x 750.

_Ampullula princeps_ sp. nov.

C, D, G, J  SEM DTBDW-14-A.
C  Enlargement of one pole; x 2000
D  Enlargement of the process (white rectangle, Fig C.); x 10,000.
G  Enlargement of the process (white arrow, Fig. J); x 10,000.
J  Whole specimen; x 1000
M  SEM JYPD-3B-2; x 1300
L  Enlargement of the tubular extension; x 4000