Discovery of Ceratosphaeridium (Acritarcha) from the Ediacaran Doushantuo Formation in Yangtze Gorges, South China and its biostratigraphic implication

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Ceratosphaeridium Grey, 2005 is a key taxon of ECAP (Ediacaran complex acritarch palynoflora) in the Officer and Amadeus basins, South Australia. Recently, several specimens of Ceratosphaeridium were fortuitously observed from the Member III of the Ediacaran Doushantuo Formation in the Yangtze Gorges, South China. The discovery of Ceratosphaeridium and other associated acritarchs from the Doushantuo Formation suggests that this taxon is widely distributed and with potential for inter-continental correlation of Ediacaran strata. Acritarch assemblages in Member III of the Doushantuo Formation in Yangtze Gorges can now be correlated with the Ediacaran Complex acanthomorphic palynoflora (ECAP) of South Australia. At present, the ECAP cannot be correlated with the lower microfossil assemblage of the Ediacaran Doushantuo Formation of the Yangtze Gorges (characterized by the key taxon Tainzhushania and this interval may be missing in South Australia. • Key words: Ediacaran, Acritarcha, Yangtze Gorges, South Australia, Ceratosphaeridium, stratigraphical correlation.


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Acritarchs belong to an informal group of microorganisms with mostly unknown phylogenetic origins (Evitt 1963). It is commonly agreed that they are polyphyletic and many are considered to be resting cysts of single-celled, eukaryotic phytoplankton. Since acritarchs are widespread and evolved rapidly, they are widely used for Phanerozoic biostratigraphy. Previous studies suggest that acritarch records in Ediacaran successions show rapid diversification and replacement of taxonomically diverse assemblages over short intervals (Knoll & Ohta 1988, Yin & Liu 1988, Vidal 1990, Knoll 1992, Zang & Walter 1992, Moczydłowska et al. 1993, Tiwari & Knoll 1994, Yuan & Hofmann 1998, Zhang et al. 1998, Grey 2005, Moczydłowska 2005, Veis et al. 2006, Willman et al. 2006, Zhou et al. 2007, Willman & Moczydłowska 2008). Some Ediacaran acritarch taxa, such as Papillomembrana compta and Tanarium conoideum, seem to have short stratigraphic ranges and a wide distribution on several palaeocontinents; thus their potential for Ediacaran biostratigraphic subdivision and global correlation is becoming increasingly important.

Four assemblage zones of the Ediacaran complex acanthomorphic acritarch palynoflora (ECAP) were identified in the Officer and Amadeus basins, South Australia and Northern Territory, and to a lesser extent on the Stuart Shelf, adjacent to the Adelaide Rift Complex of South Australia (Grey et al. 2003, Grey 2005). Among them, the genus Ceratosphaeridium, characterized by a single process is one of the most important taxa of ECAP in the Officer and Amadeus basins, South Australia. Recently, several specimens of Ceratosphaeridium were fortuitously found from the Ediacaran Doushantuo cherts in the Yangtze Gorges, South China (Fig. 1). Prior to this report, the specimens of genus Ceratosphaeridium have only been found in the Officer and Amadeus basins, South Australia. So, the discovery of Ceratosphaeridium from the Doushantuo chert suggests that this taxon is widely distributed and with potential for inter-continental correlation of Ediacaran strata.

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Due to an abundance of fossils and a long research history, the Ediacaran succession in the Yangtze Gorges, South China, is one of the most important Ediacaran successions in the world. The Ediacaran Doushantuo Formation in South China is underlain by the Cryogenian Nantuo diamictite and overlain by upper Ediacaran dolostone of the Dengying Formation. The age of the Doushantuo Formation has been constrained between 635.2 ± 0.6 Ma and 551.1 ± 0.7 Ma (Fig. 1) by zircon U-Pb ages obtained from interbedded ash beds (Condon et al. 2005, Yin et al. 2005, Zhang et al. 2005). Generally, the Doushantuo Formation in the Yangtze Gorges area consists of four members. These members are, in ascending order, (1) ~5 m thick cap carbonate overlying glacial deposits of the Nantuo Formation; (2) 80–120 m thick black shale intercalated with medium-bedded dolostone and muddy dolostone with abundant chert nodules; one obvious erosional unconformity (younger than 614.0 ± 7.6 Ma; Liu et al. 2009a) can be seen in the middle part of this member at many sections (Zhu et al. 2007); (3) 40–60 m thick medium-bedded dolostone with chert bands or lenticles and banded dolostone; (4) ~10 m thick black shale with large dolomitic concretions (Fig. 1).

Previous studies indicated that the Doushantuo Formation in the Yangtze Gorges area was deposited in subtidal environments and the chert nodules were formed just below the water-sediment interface during early diagenesis (Xiao 2004). Abundant silicified microfossils, including acritarchs, coccolid and filamentous cyanobacteria, multicellular algae, embryos and some tubular microfossils have been reported from chert nodules or lenticles in both Member II and III (Zhang et al. 1998, Yin 1999, Xiao 2004, Yin et al. 2007, Zhou et al. 2007, Liu et al. 2009b). Black shales of Member IV at Miaohe (see Fig. 1 for location) contain abundant macroscopic carbonaceous compressions (Chen et al. 1994, Xiao et al. 2002, Tang et al. 2008). In addition, large numbers of Chuaria-like carbonaceous compressions and a dichotomously branching algal thallus (Entermorphites see Zhu & Chen 1984) were found from black shales in Member II at the Jiulongwan section (see Fig. 1 for location, Tang et al. 2006). The reported specimens of Ceratosphaeridium were found from the lower part of Member III at the Wangfenggang and Xiaofenghe sections (see Fig. 1 for location).

**Ceratosphaeridium in Yangtze Gorges, South China**

**Ediacaran stratigraphy of Yangtze Gorges, South China**

The genus *Ceratosphaeridium* was established by Grey (2005) based on specimens found from the Wilari Dolomite.
Member and Tanana Formation in the Officer Basin and the Pertatataka Formation in the Amadeus Basin, South Australia. It is characterized by a medium to large vesicle, circular to subcircular in outline (probably originally spherical), bearing a single, prominent, hollow, tapering process, with closed distal end and communicating proximally with the vesicle cavity. The vesicle wall is single-layered, thin, and either granular or smooth. The two species, *Ceratosphaeridium mirabile* (type species) and *C. glaberosum*, are distinguished by whether or not they have grana on the surface of the vesicle. In the case of *C. mirabile*, the whole surface of the vesicle is covered by small, densely scattered grana, but the grana are not present on the process. By contrast, both the vesicle wall and process of *C. glaberosum* is smooth (Grey 2005).

Two distinctive palynofloras, the Ediacaran leiosphere palynoflora (ELP) and the Ediacaran complex acritarch palynoflora (ECAP), were identified in the Officer and Amadeus basins, South Australia (Grey et al. 2003, Grey 2005). The ECAP was subdivided into four assemblage zones and each assemblage zone is based on three key species. In ascending order, they are (1) *Appendisphaera barbata-Alicesphaeridium medusoidum-Gyalosphaeridium pulchrum* Assemblage Zone; (2) *Tanarium coneoidum-Schizofusa risoria-Variomargosphaeridium litoschum* Assemblage Zone; (3) *Tanarium irregular-Ceratosphaeridium glaberosum-Multifronsphaeridium pelorium* Assemblage Zone; and (4) *Ceratosphaeridium mirabile-Distosphaera australica-Apodastoidas verobturatus* Assemblage Zone (Grey et al. 2003, Grey 2005). Obviously, the genus *Ceratosphaeridium* plays an important role in the third and fourth assemblage zones.

So far, nine specimens of *Ceratosphaeridium* have been identified from thin sections of chert nodules in the Chinese successions (Fig. 2). Their vesicles are medium to large, and circular to subcircular in outline. The diameters vary from 42 to 230 µm (average 128 µm, nine measurements). Vesicle walls are generally thin, single-layered with smooth surfaces and a single, prominent process. The process is hollow, tapering with closed ends and freely communicating with the vesicle cavity. The length of processes varies from 15 to 78 µm (average 39 µm, nine...
measurements), with a base of 4.5–13 µm in diameter (average 11.8 µm, nine measurements). These characteristics of all specimens are similar to *Ceratosphaeridium glaberosum* Grey, 2005 found from the Officer and Amadeus basins, South Australia (Grey 2005, Willman & Moczydłowska 2008). Thus, all specimens from the Doushantuo Formation are assigned to *Ceratosphaeridium glaberosum*.

Two different acritarch assemblages were identified in the Ediacaran Doushantuo Formation of the Yangtze Gorges, South China, which separately appear in the Member and lower Member III (Yin et al. 2009). The carbon isotope composition ($\delta^{13}C_{carb}$) of the Doushantuo Formation shows three prominent negative excursions (EN1–EN3) separated by generally positive values (EP1 and EP2) (Zhou & Xiao 2007, Zhu et al. 2007). Two microfossil assemblages of the Doushantuo Formation in the Yangtze Gorges appear generally within the positive values parts (EP1 and EP2) respectively. The lower assemblage is characterized by *Tianzhushania* and a high diversification of large acanthomorphic acritarchs. The upper assemblage is distinguished from the lower assemblage by (1) being devoid of *Tianzhushania*; (2) by the first occurrence of abundant 50–150 µm, smooth-walled spherical microfossils; (3) by the first occurrence of diverse new acanthomorphic acritarchs (they will be reported later); and (4) the first occurrence of tubular microfossils, such as *Sinocyclocylicus guizhouensis* (Yin et al. 2009). In particular, *Tanarium* is a key taxon in the upper assemblage.

The lack of easily identifiable and geographically widespread fossils, however, makes it relatively difficult for Ediacaran biostratigraphic correlation between South

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**Figure 3.** Acritarchs associated with *Ceratosphaeridium glaberosum* Grey, 2005 from the Doushantuo Formation in Yangtze Gorges. A–C – *Tanarium anozos* Willman & Moczydłowska, 2008. A – WFG095, thin section WFG8421-8b, coordinates 47.5 × 87.7; B – NP III 069, thin section NP III b-8, coordinates 39.4 × 91.9; C – NP III 052, thin section NP III b-4, coordinates 32.5 × 93.2. D–G – *Tanarium conoideum* Kolosova, 1991. D – NP III 168, thin section NP III b-23, coordinates 51.9 × 99.9; E – WFG423, thin section WFG80816-3-31, coordinates 34.5 × 88, EB is an enlarged view of marked with arrow in EA; F – XFH332, thin section X71013-4-061, 40.5 × 99.5; G – NP III 053, thin section NP III b-4, coordinates 32.5 × 93.2. Single and double bars represent 100 µm and 25 µm, respectively.

Ceratosphaeridium glaberosum is a key species of ECAP in the Officer and Amadeus basins, South Australia, and it mainly appears in the upper ECAP (in both the Tanarium irregular-Ceratosphaeridium glaberosum-Multitrichosphaeridium pelorium and Ceratosphaeridium mirabile-Distosphaera australica-Apodostoides veroburatus assemblage zones; Grey 2005). The discovery of Ceratosphaeridium glaberosum from Member III (upper acritarch assemblage) of the Doushantu Formation in the Yangtze Gorges, South China suggests that this taxon is widely distributed and has potential for inter-continental correlation. In addition, the acritarchs Tanarium conoideum, T. anozos (Fig. 3) and some new taxa (they will be described in a separate paper) have also been found in the Member III of the Doushantu Formation. Specimens of both Tanarium conoideum and T. anozos are very abundant in chert nodules; in particular, 77 specimens of T. anozos have been observed in one thin section (thin section NP IIIb-23). The taxon Tanarium conoideum is a widely distributed species and has found from the Vendian of the Siberian Platform (Moczydłowska 2005), and particularly in the Tanarium conoideum-Schizofusa risoria-Variomargosphaeridium litorale Assemblage Zone of ECAP in South Australia (Grey et al. 2003, Grey 2005, Willman & Moczydłowska 2008). Prior to this report, Tanarium anozos, which was established by Willman & Moczydłowska (2008), was only found from the Tanana Formation (upper ECAP) in the Giles 1 drillhole of the Officer Basin, South Australia (Willman & Moczydłowska 2008). Thus, the acritarch assemblage in Member III (upper microfossils assemblage) of the Doushantu Formation in the Yangtze Gorges shows good correlation with the ECAP from South Australia. The fossil assemblage can correlate with lower microfossil assemblage in the Yangtze Gorges may be missing in South Australia.

Conclusions


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References


