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Radiation of Meso-Neoproterozoic and early Cambrian protists inferred from the microfossil record of China

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Abstract

Marine protists can be affected by and reflect changes in the ecological environment. Based on available microfossil evidence from late Mesoproterozoic–Early Cambrian rocks of China, radiations of protists and related changes in ecological environments are discussed in the paper. Remarkable development of protists had occurred by as early as the Mesoproterozoic. Protist diversity significantly decreased in the middle Neoproterozoic due to disruption of the ecological environment that may have been caused by global glaciations. The Doushantuo microfossil assemblage records high diversity and radiation of protists during the early to middle Ediacaran. An acritarch assemblage of *Asteridium–Comasphaeridium–Heliosphaeridium–Megathrix*, which is contemporaneous with the lowermost Meishucunian small shelly fossil assemblage — *Anabarites trisulcatus–Protohertzina anabarica*, is widely distributed in the lowermost Cambrian strata of South China and the Tarim Basin and is useful for biostratigraphic correlation with Baltica and other areas.

Keywords: Radiation; Protists; Neoproterozoic; Early Cambrian; China

1. Summary of the organic-walled microfossil record

In recent years, many microfossils, including animal embryos, larvae, eggs, cnidarian remains, and putative bilaterian animals, have been reported from phosphorite of the late Neoproterozoic Doushantuo Formation of South China. These fossils open a new window into life before the ‘Cambrian explosion’.

Protists played fundamental roles in ancient ecosystems. Therefore, development and radiation of marine protists could be affected by and could reflect changes in the ecological environment. Remarkable radiations of eukaryotes during the Neoproterozoic and Early Cambrian can be recognized on the basis of available microfossils of China and elsewhere of the world.

In the Mesoproterozoic, various microorganisms, including protists, had already developed relatively high morphological diversity. Most previously known Mesoproterozoic microfossils are characterized by cyanobacteria-like coccoids and mat-building filaments, preserved in cherts (see summary by Knoll and Sergeev, 1995). However, organic-walled microfossils obtained from the shale of the Mesoproterozoic Ruyang Group (ca. 1300 Ma) of Shanxi, China include morphologically diverse forms, such as acanthomorphic acritarchs, netromorphic acritarchs, multicellular filaments and algal thalli (Yin, 1997; Xiao et al., 1997; Yin and Yuan, 2003b).

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According to their morphological features, organic-walled microfossils of the Ruyang Group can be categorized into several groups:

1) Sphaeromorphic acritarchs, such as *Leiosphaeridia* (Eisenack) Turner, 1984 (Fig. 1.5), *Valeria lophostriata* Jankauskas, 1982 (Fig. 1.4), *Dictyosphaera delicata* Hu and Fu, 1982 (Fig. 1.1), etc.
2) Netromorphic acritarchs, *Spiromorpha segmentata* (Prasad and Asher, 2001) emend. and comb. Yin et al. (2005) (Fig. 1.3), which is characterized by spiral stripes on vesicle wall.
3) Acanthomorphic acritarchs, *Shuiyousphaeridium* (Yan) emend. Yin, 1997 (Fig. 1.6) and *Tappania* Yin, 1997 (Fig. 1.2).
4) Other various and uncertain multicellular organic remains.

Recent study undertaken by transmission electron microscope (TEM) and organic geochemistry reveals that *Dictyosphaera delicata* and *Shuiyousphaeridium* of the Mesoproterozoic Ruyang Group may be dinoflagellate-like eukaryotes, based on their multi-layered vesicle wall with interlocking polygonal plates and triaromatic dinosteranes extracted from the rock sample containing these acritarchs (Yin and Yuan, 2003b; Meng et al., 2005). These microfossils, as well as other acritarchs (e.g. *Tappania*), have been interpreted as probable fungi by Butterfield (2005). Butterfield's interpretation was based on morphological comparison of acritarchs from the early Neoproterozoic Wynniatt Formation of northwestern Canada and the late Mesoproterozoic Ruyang Group of North China. However, no specimens of Ruyang acanthomorphic acritarchs (*Tappania* and *Shuiyousphaeridium*) obtained by repeated palynological analysis show septate, branching processes, which were considered by Butterfield to be key fungal features. Moreover, the biomarker lanostene characteristic of non-photosynthetic multicellular organisms such as fungi has not been detected from extracts of whole rock sample containing abundant *Shuiyousphaeridium* and *Dictyosphaera*. In addition, *Spiromorpha segmentata* bears morphological similarity to the extant conjugating green alga-*Spirotaenia*; both have spindle-shaped cells and spiral striae on their cell walls. This morphological similarity suggests that sexual reproduction by conjugation may have originated in the late Mesoproterozoic. Furthermore, multicellular algae and ribbon-like thalli with spiral helical micro-tubes also appear in the Ruyang Group (Yin and Yuan, 2003b). The Ruyang microfossil assemblage provides palaeontological evidence to understand the diversification of eukaryotic kingdoms in the Mesoproterozoic (Knoll, 1992; Douzery et al., 2004).

Similar microfossil assemblages have been discovered from Mesoproterozoic shale in Australia and India (Javaux et al., 2001; Prasad and Asher, 2001).

The correlation of the Neoproterozoic successions between North China and South China has long been an unresolved issue because of their different tectonic histories. Early Neoproterozoic organic-walled microfossils of North China are dominated by sphaeromorphic acritarchs, including *Leiosphaeridia* (Fig. 2.2 and 2.7), *Trachysphaeridium*, *Satka*, *Synsphaeridium* (Fig. 2.9), *Simia*, as well as some germinating cyst-like forms [e.g. *Germinosphaera* (Fig. 2.11)] and acanthomorphic acritarchs, such as *Trachyhystrichosphaera* (Yin and Guan, 1999). Organic-walled microfossil assemblages from Neoproterozoic successions in transitional areas between North China and South China, i.e. in the Huainan district of Anhui Province, eastern Liaoning Province and eastern Jilin Province, are also dominated by various sphaeromorphic acritarchs, most of which are similar to those found in early Neoproterozoic strata of North China. However, some different forms, such as *Pterospermopsimorpha insolita*, *P. pileiformis*, *Jilinella delicate*, *J. lepida*, *Larvimorpha mirusa* (Fig. 2.4 and 2.5), *Pololeptus biacris*, *P. rugosa* (Fig. 1.1 and 1.3), and *Strictosphaeridium rugosum* (Fig. 2.10), occur only in these assemblages (Yin and Yuan, 2003a).

In South China, above the Marinoan-age Nantuo diamictite, clastic rocks and carbonates of the Doushantuo and the Dengying Formations are widespread. A few specimens of possible algal fragments, named as *Vendotaenia antiqua*, *Polyporata microporosa*, *P. obsoleta*, have been reported from the pre-Cryogenian Liantuo Formation (Xing et al., 1985). Marine protists during Neoproterozoic glaciation were restricted by physical and chemical stresses. A microfossil assemblage has been obtained from manganese ore deposits and shale of the interglacial Datangpo Formation in eastern Guizhou and western Hunan provinces. Some cyanobacteria (Fig. 3.7, 3.10 and 3.11) and smaller vesicle acritarchs, such as *Eozygion*, *Trachysphaeridium* (Fig. 3.8), *Gloeocapsomorpha*, *Leiominuscula* (Fig. 3.5), *Leiosphaeridia* (Fig. 3.2, 3.6 and 3.9), *Micrhystridium*, *Microconcentrica*, *Protosphaeridium*, *Sphaerocongregus* (Fig. 3.1 and 3.3), and *Synsphaeridium* (Fig. 3.4), have been obtained from the Datangpo Formation (Yin, 1989, 1990). Broadly similar microfossil assemblages, including ?*Dictyotidium*, *Leiosphaeridia*, *Protoleiosphaeridium*, *Sinianella*, *Sphaerocongregus*, *Stictosphaeridium*, *Trachysphaeridium*, *Trematosphaeridium*, *Vandalosphaeridium*, and *Siphonophycus*, have also been discovered