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Biodiversity patterns of Early–Middle Ordovician marine microphytoplankton in South China

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ABSTRACT

Based on new materials from six sections and all available literature data, new diversity curves are presented for the phytoplankton (acritarchs) from South China, covering the Early–Middle Ordovician interval, when the Great Ordovician Biodiversification Event took place. The total diversity curve and the origination data imply that a major radiation of the phytoplankton occurred during the analysed interval. A peak of the total acritarch diversity curve appears in the *A. suecicus* graptolite biozone. The diversity changes vary in the different parts of the investigated area, most probably depending on the position of the analysed sections on the carbonate shelf or the slope, reflecting diversity differences due to the position on an inshore–offshore transect.

The Early–Middle Ordovician diversity pattern of the phytoplankton is compared with those of several marine invertebrate groups. Compared with the diversity curve peak of the acritarchs, the conodonts and brachiopods reached their highest diversities before the acritarchs, while the highest diversity of the chitinozoans appears slightly later. The graptolites show two peaks during the Early–Middle Ordovician, while the trilobites diversity curve shows a peak only in the Sandbian. The different fossil groups, such as chitinozoans, conodonts, graptolites, brachiopods and trilobites show therefore different evolutionary patterns to that of the acritarchs, that are not yet fully understood, and correlations are so far difficult.

The acritarch diversity changes can partly be compared to the local sea-level changes from four sections in South China. At a larger scale, the acritarch radiation coincides with a general transgression. At a regional or local scale, correlations are not straightforward, pointing out that more detailed data, based on both acritarch studies and more precise sea-level investigations, are necessary.

1. Introduction

The Great Ordovician Biodiversification Event (GOBE) is one of the most significant radiations of marine organisms during Earth history, showing a rapid increase in biodiversity and an important ecological evolution (Harper, 2006; Servais et al., 2008, 2009, 2010). Webby et al. (2004a) published a synthesis on the Ordovician radiation which documented the biodiversity curves of approximately 25 fossil groups.

In the Proterozoic and Palaeozoic fossil record, most acritarchs are considered to represent marine phytoplankton cysts which constitute the fossil record of one part of the base of the marine food chain. Servais et al. (2008) related 'the Ordovician plankton revolution' to the diversification of the phytoplankton as evidenced by the record of acritarchs and prasinophytes.

Although more than 40 papers were focused on the Ordovician acritarchs in South China, the Ordovician radiation of acritarchs is far from being completely understood. Most paper focused on biostratigraphy (Li et al., 2002b,c), and a few highlighted the importance of the South Chinese palaeogeography for palaeobiogeographical considerations of the acritarchs (Li, 1989, 1991; Li and Servais, 2002; Servais et al., 2003). In the last decade, several papers analysed the biodiversity of the South Chinese phytoplankton in the Ordovician. Tongiorgi et al. (2003) implied that the acritarch diversity changes in the Dawan Formation from the Daping section in Yichang may be affected by inshore–offshore and climatic trends. Servais et al. (2004) reviewed the global Ordovician acritarch literature and illustrated an acritarch diversity curve of South China. Li et al. (2004) discussed the inshore–offshore trend of acritarch distributions and acritarch diversity variations from seven South China localities during the interval of the *deflexus–suecicus* graptolite biozones. Yan et al. (2005) discussed the implication of the acritarch diversity changes from the Meitan Formation from the Honghuayuan section, Tongzi. Li and Yan (2006) reviewed the Ordovician acritarch diversity changes in South China and pointed out an acritarch biodiversity event in the Early–Middle Ordovician. The publication of Li et al. (2007)

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focused on the Ordovician acritarch diversity counted from the literature and sea-level change in China.

In recent years, marine biodiversity changes from China were investigated in the project on the 'Origination, Radiation, Extinction and Recovery in the Geological History' (e.g., Rong et al., 2007) concerning several taxonomic groups of Ordovician marine organisms in South China, such as graptolites (Zhang et al., 2007), brachiopods (Zhan et al., 2005, 2006), and trilobites (Zhou et al., 2007). The diversity of other fossil groups has also been investigated, such as that of chitinozoans (Paris et al., 2004; Wang and Chen, 2004), and conodonts (Wang and Wu, 2007; Wu et al., 2010).

Ordovician microphytoplankton biodiversity curves and their implications have been discussed from several other palaeocontinents. Vecoli and Le Hérissé (2004) provided a detailed Ordovician acritarch diversity curve from the northern margin of South Gondwana. They inferred that the acritarch diversity curve is hardly compared to the second order sea-level change, and the acritarch diversity changes would be well correlated to that of the chitinozoans during the Ordovician. Molyneux (2009) suggested an acritarch diversity evolutionary pattern based on investigations from deep-water settings in northern England. Ordovician acritarch diversity curves from the palaeocontinent Baltica have been studied by Hints et al. (2010). Diversity patterns of Ordovician acritarchs, chitinozoans and scolecodonts show some similarities in Baltica and the acritarch diversity curve can be related to that of other fossil groups in some extent (Hints et al., 2010).

The objective of the present paper is to analyse the Early–Middle Ordovician acritarch diversity in South China and its relationship with the diversity of other fossil groups and the sea-level change. The acritarch assemblages from six sections in South China have been prepared for diversity analysis herein. Acritarch diversity curves of South China analysed from the literature data are also presented.

2. Material and methods

2.1. New material

In order to understand acritarch diversity patterns in South China, 160 samples for palynological and diversity analysis were collected from six sections, 45 samples from the Meitan Formation, Honghuayuan section in Tongzi (Guizhou); seven samples from the Guanyinqiao section in Qijiang (Chongqing); 14 samples from the Dacao Formation and Yingpan Formation, Houping section in Chengkou (Chongqing); 34 samples from the Dawan Formation, Huanghuachang section in Yichang (Hubei); nine samples from the Dawan Formation, Daping section in Yichang (Hubei); and 51 samples from the Ningkou Formation, Huangnitang section in Changshan (Zhejiang) (Fig. 1).

During the Early and Middle Ordovician, from northwest to southeast, the South China tectonic plate comprised the Yangtze Platform, the Jiangnan Slope, and the Zhujiang Basin (Chen et al., 1995) and Early–Middle Ordovician rocks were deposited in southwest–northeast band-like zones (Zhang et al., 2002). The six sections investigated here are located in different lithofacies. The Honghuayuan section in Tongzi, the Guanyinqiao section in Qijiang and the Houping section in Chengkou are located in an inner-shelf mud–carbonate belt during the latest Early–earliest Middle Ordovician which is characterised by the dominance of carbonate sediments mixed with argillaceous and sandy intercalations (Zhang et al., 2002). The Huanghuachang and Daping sections in Yichang are located in a shallower outer-shelf

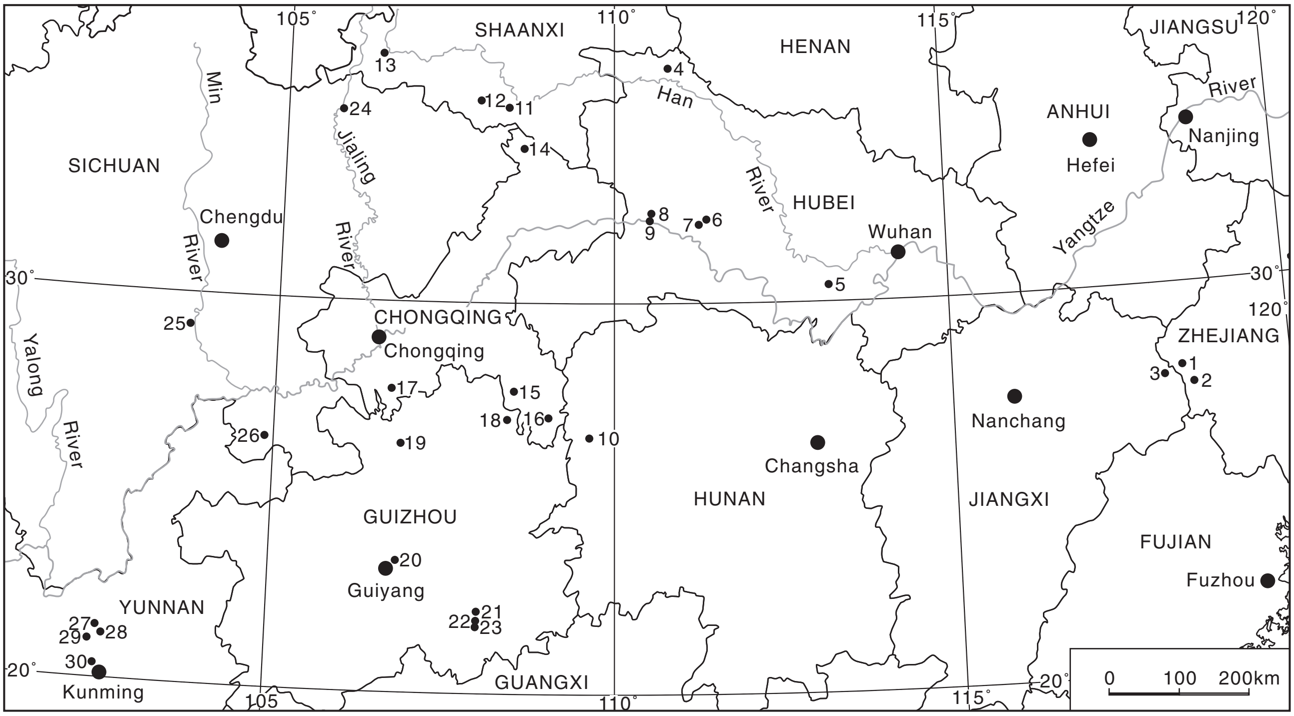

Fig. 1. Locality map of the Floian–Darriwilian sections where acritarchs have been studied in South China. 1. Huangnitang, Changshan (Yin and Playford, 2003; this work); 2. Hengtang, Jiangshan (Xu et al., 2002); 3. Chenjiawu, Yushan (Huang, 1991; Huang et al., 1994; Xu and You, 2001), 4. Chenjiazhuang, Yunxi (Sun, 1999); 5. Tonghaikou, Xiantao (He, 1998); 6. Daping, Yichang (Playford et al., 1995; Tongiorgi et al., 1995, 1998, 2003; Yan et al., 2010; this work); 7. Huanghuachang, Yichang (Li, 1991; Li et al., 2004; Lu, 1987; Tongiorgi et al., 1998; Yan et al., 2010; this work; Yin, 1994, 1995; Yin et al., 1998; Zhong, 1981, 1987) 8. Jiangyangping, Zigui (Brocke, 1997a,b; Brocke et al., 1999, 2000); 9. Xintan, Zigui (Xing and Liu, 1985); 10. Datuo, Jishou (Li, 1990a,b; Li et al., 2004); 11. Gaoqiao, Ziyang (Hu, 1986); 12. Liangjiaqiao, Zhenba (Fu, 1986); 13. Zhaojiaba, Ningqiang (Fang, 1990; Li, 1991; Li and Yuan, 1998; Li et al., 2004); 14. Houping, Chengkou (Yan et al., 2010; this work); 15. Wangjiazai, Youyang (Brocke, 1997a,b; Brocke et al., 1997, 1999, 2000); 16. Datianba, Xiushan (Brocke, 1997a,b; Brocke et al., 1997, 1999, 2000); 17. Guanyinqiao, Qijiang (Yan et al., 2010; this work); 18. Ganxi, Yanhe (Li, 1991); 19. Honghuayuan, Tongzi (Li, 1987; Li et al., 2000, 2004; Yan and Li, 2005; Yan et al., 2010; this work); 20. Huanghuachong, Guiyang (Li, 1991; Li et al., 2002a, 2004); 21. Wuliguan (Li, 1991), Sandu; 22. Xiayangao, Sandu (Xu, 1995, 1996, 1999, 2001; Xu et al., 1995); 23. Yangnengzai, Sandu (Li, 1991); 24. Tanjiagou, Guangyuan (Fang, 1990); 25. Emeishan (Xing, 1980); 26. Shuanghe, Changning (Li, 1991); 27. Wannike, Luquan (Fang, 1986a); 28. Yinchunli, Luquan (Fang, 1986a); 29. Renmingqiao, Wuding (Gao, 1991); 30. Ercun, Kunming (Fang, 1986a,b; Li, 1991; Li et al., 2004).