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EDITORIAL

Devonian palaeoecosystems and palaeoenvironments of South China

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Introduction

The Devonian (419.2–358.9 Ma) was a critical period for the evolution of life in both terrestrial and marine ecosystems. It witnessed the appearances of first forest and amphibian on land, the largest metazoan reef ecosystem in Earth history, and two greatest biocrisises of the Phanerozoic (the Frasnian-Famennian and Hangenberg mass extinctions). The colonization of land by vascular plants caused major changes with respect to processes in the geo-, hydro-, and atmosphere. Continental weathering became strongly influenced by chemical processes, and thereby causing changes in riverine nutrient flux (Algeo et al. 1995), and atmosphere CO_2 concentration dropped abruptly to near modern level (Foster et al. 2017), all of which exert major impacts particularly on marine ecosystems. As many as 25 global events, characterised by eustatic sea-level changes, anoxic/hypoxic events, and/or biological extinction/turnovers took place during the Devonian (Becker et al. 2012), demonstrating complex interactions between the Earth's biotic, climatic, and environmental systems. Understanding the different fossil groups and the evolution of Devonian marine ecosystems at global or regional scale would help us gain important insights for the interplay between life and environment in deep time.

South China is the most important area for the study of the Devonian system in China, where all the stratotype sections for the Chinese regional stages were established in shallow-water facies of this region (Hou and Ma 2005; Qie et al. 2019). Following the Kwangsian Orogeny (Chen et al. 2010), a transgression occurred in central Guangxi during the Lochkovian, and each sequences in South China starts with some siliciclastic sediment overlying a discontinuity surface. With intensified rifting, major differentiation of lithofacies and biofacies took place in the Emsian and Givetian stages, and the deposition of extensive carbonate platform was separated by deep-water interplatform basins (Figs. 1 and 2). As a result, there are numerous well-preserved Devonian stratigraphic successions recording a variety of lithofacies and biofacies in South China, providing excellent materials to investigate the biotic and environmental events and their possible causes and effects.

This special issue of *Palaeobiodiversity and Palaeoenvironments* is thematically dedicated to the "Devonian palaeoecosystems and palaeo-environments of South China." The eight contributions in this issue cover many different fossil groups, including tentaculitids, brachiopods, conodonts, tabulate corals, ostracods, and ammonoids. The geographic and stratigraphic ranges of these studies are shown in Figs. 1 and 2, respectively. We hope these contributions will advance our understanding of Devonian palaeoecosystems and palaeoenvironments of South China, with a special emphasis on interplay between different fossil groups and environments during this critical period of Earth history.

Contributions to the special issue

Tentaculitoids occurred in great numbers in the Silurian and Devonian, and have been proved especially useful in biostratigraphy as well as for analysis of facies and palaeoenvironmental patterns (Schindler 2012). In this issue, **Wei et al.** (2019) reported a tentaculitid assemblage from the Nagaoling Formation at Dashatian, Nanning, including six new species around the Lochkovian-Pragian boundary, such as *Tentaculites brevitenui* n. sp., *Lonchidium cylicus* n. sp., *Bicingulites nanningensis* n. sp., *Odessites aurisites* n. sp., *O. nahongensis* n. sp. and *Volynites nagaolingensis* n. sp.. Transitional skeletal characters

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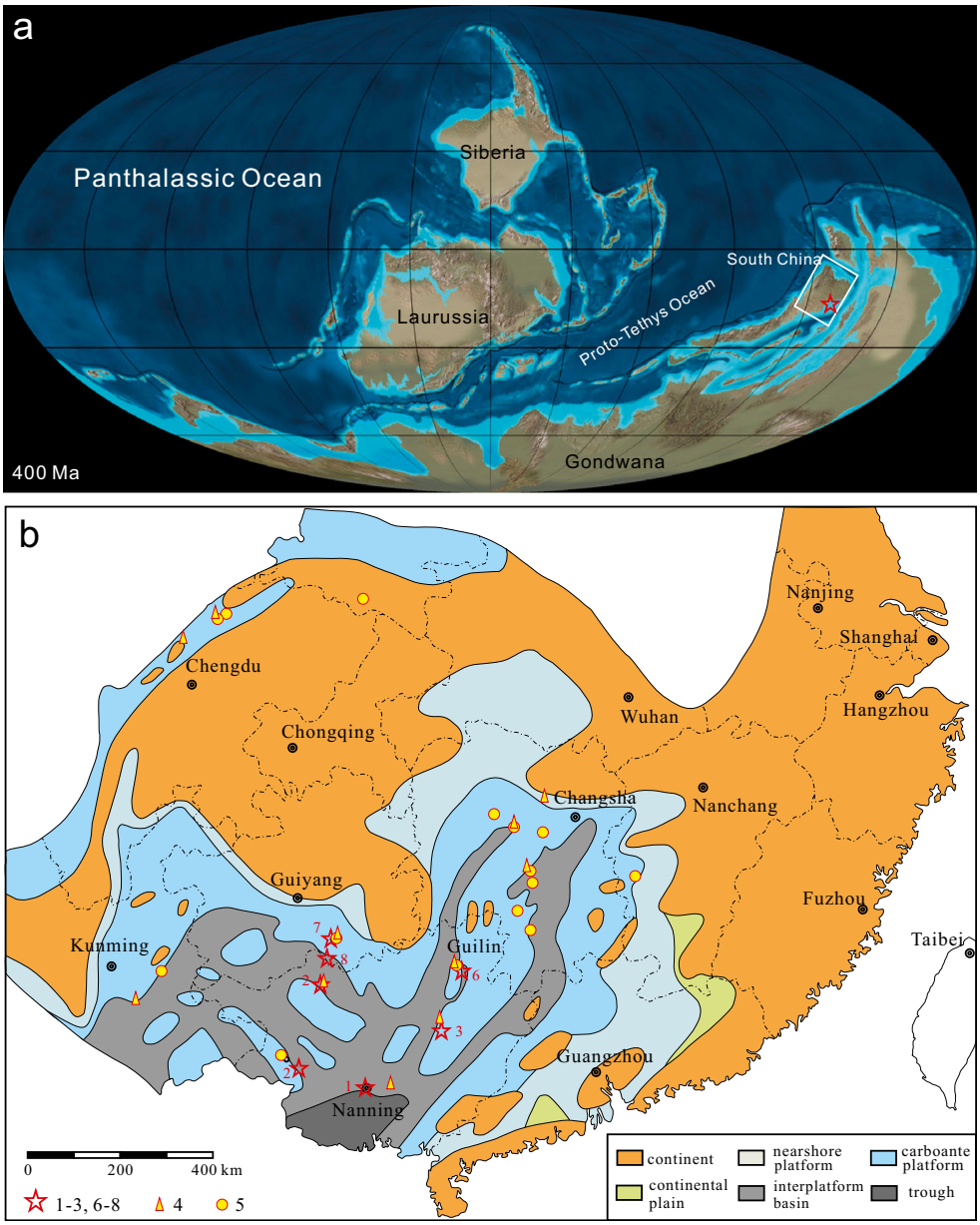
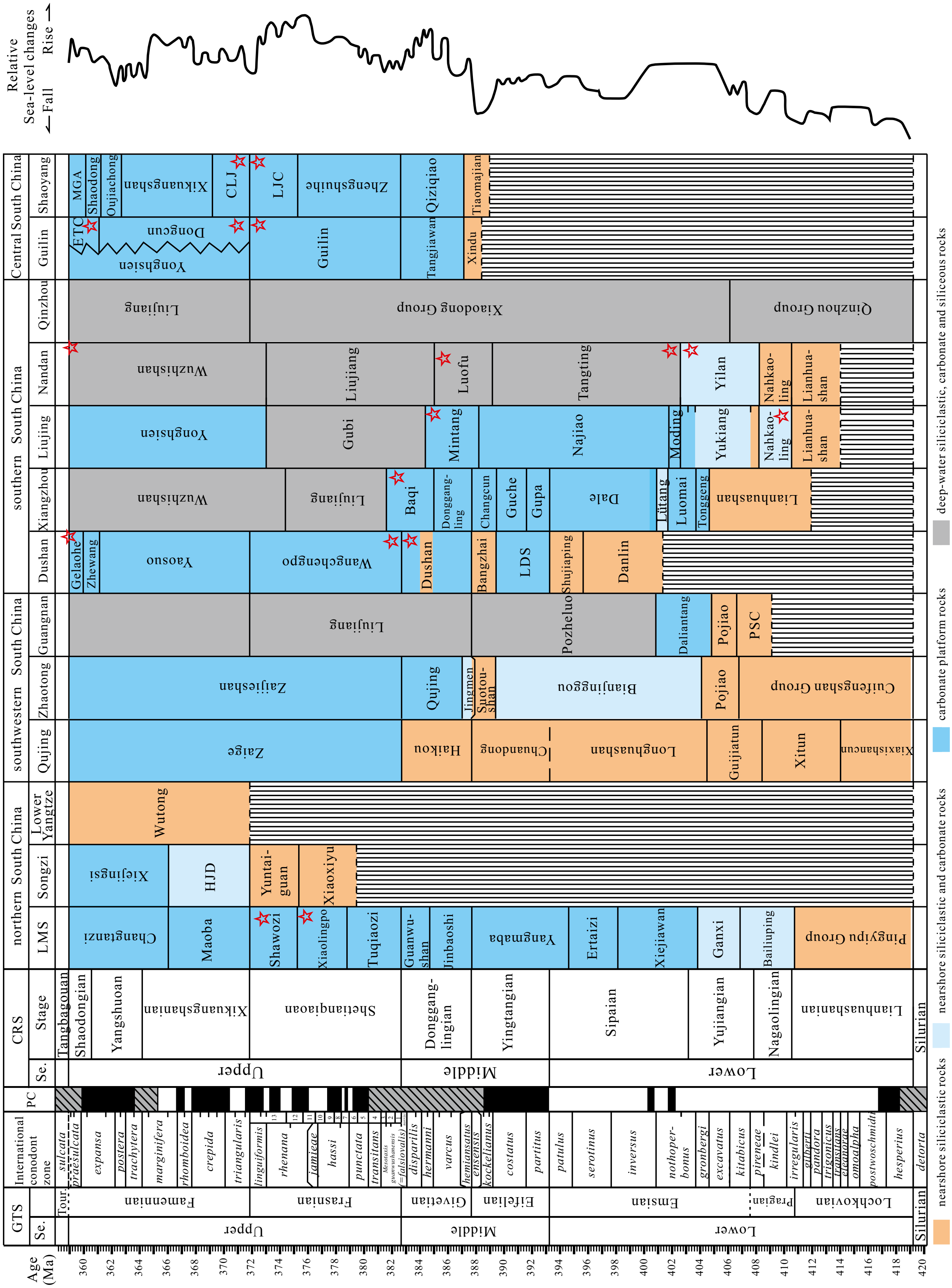


Fig. 1 **a** Early Devonian (400 Ma) global palaeogeographic reconstruction (base map courtesy of Ron Blakey, http://jan.ucc.nau.edu/~rcb7/) **b** Early Givetian palaeogeographic map of South China craton (modified after Jin et al. 1998) showing study section localities in this special issue. 1: the Dashatian section, Nanning in Wei et al. (2019), 2: the Mode and Poyuan sections in Guo et al. (2019), 3: the Ertang section, Wuxuan in Lu et al. (2019), 4: detailed description of section localities see Qiao and Qie (2019), 5: detailed description of section localities see Zhang and Ma (2019), 6: the Huilong section, Guilin in Liang et al. (2019), 7: the Baihupo section, Dushan in Song and Gong (2019), 8: the Jiarangtang section, Dushan in Zhang et al. (2019)

between benthic and planktonic tentaculitoids were recognised within the assemblage, indicating that tentaculitids generally evolved into homoctenids and tentaculitoids extended from shallow to deeper waters in the Early Devonian. The analyses of sedimentary and taphonomic facies as well as the fossil compositions support the idea that this fossil assemblage lived in an outer shelf region in the South China marginal sea (*Palaeobiodiversity and Palaeoenvironments* 99(1) Doi: https://doi.org/10.1007/s12549-018-0367-7).

The well-known "*Spirifer*" *tonkinensis* fauna is the most diverse and widespread Early Devonian brachiopod fauna in South China, and characterised by the occurrence of endemic *Rostrospirifer* and *Dicoelostrophia* as well as over 30 other associated genera (around 70 species), but its temporal and spatial distribution remain under debate (Wang and Rong 1986; Hou and Ma 2005). Through the studies on conodont and brachiopod biostratigraphy at the Mode and Poyuan sections, in combination with previous studies, **Guo et al.** (2019) suggested the entries of the "*Spirifer*" *tonkinensis* fauna were diachronous and consistent with the northeastward transgression in South China and adjacent areas during Early Devonian. The fauna may originated in northern Vietnam and then spread northwards into South China. With the further transgression, the nearshore, shallow-water environment with muddy substratum and rich terrigenous clastics disappeared, leading to the demise of the

Fig. 2 Devonian stratigraphic correlation chart between different palaeogeography in South China. International standard chronostratigraphy units, conodont zones and absolute ages are after Becker et al. (2012). Chinese regional chronostratigraphy units are after the stratigraphic chart of China (2014). The relative sea-level change curve is after Ma et al. (2009)



Relative Sea-level changes
Fall
Rise
Age (Ma)
GTS
Se.
International conodont zone
PC
CRS
Stage
northern South China
LMS
Songzi
Lower Yangtze
southwestern South China
Qujing
Zhaotong
Guangnan
southern South China
Dushan
Xiangzhou
Liujing
Nandan
Qinzhou
Central South China
Guilin
Shaoyang
Upper
Middle
Lower
Silurian
Tour.
Famennian
Frasnian
Givetian
Eifelian
Emsian
Pragian
Lochkovian
Tangbaguan
Shaodongian
Yangshuoan
Xikuangshanian
Shetianqiaoan
Dongganglingian
Yingtangian
Sipaian
Yujiangian
Nagaolingian
Lianhuashanian
Changtanzi
Maoba
Shawozi
Xiaolingpo
Tuqiaozi
Guanwushan
Jinbaoshi
Yangmaba
Ertaizi
Xiejiawan
Ganxi
Bailiuping
Pingyipu Group
Xiejingsi
HJD
Yuntaiguan
Xiaoxiyu
Wutong
Zaige
Haikou
Chuandong
Longhuashan
Guijiatun
Xitun
Xiaxishancun
Zaijieshan
Qujing
Jingmen
Suotoushan
Bianjingguo
Pojiao
Cuifengshan Group
Liujiang
Daliantang
PSC
Pozheluo
Gelaohe
Zhewang
Yaosuo
Wangchengpo
Dushan
Bangzhai
LDS
Shujiaping
Danlin
Wuzhishan
Baqi
Donggangling
Changcun
Guche
Gupa
Dale
Lütang
Luomai
Tonggeng
Lianhuashan
Yongshsien
Gubi
Mintang
Najiao
Moding
Yukiang
Nahkaoling
Luofu
Tangting
Yilan
Liujiang
Xiaodong Group
Qinzhou Group
ETC
Donggun
Guilin
Tangjiawan
Xindu
MGA
Shaodong
Oujiachong
Xikuangshan
CLJ
LJC
Zhengshuihe
Qiziqiao
Tiaomajian
nearshore siliciclastic rocks
nearshore siliciclastic and carbonate rocks
carbonate platform rocks
deep-water siliciclastic, carbonate and siliceous rocks

"*Spirifer*" *tonkinensis* fauna (*Palaeobiodiversity and Palaeoenvironments* 99(1) Doi: https://doi.org/10.1007/s12549-019-00371-w.

Lu et al. (2019) investigated the Emsian conodonts from the Lufengshan section, Guangxi, one of the best representative sections of the shallow water Xiangzhou facies in South China and the stratotype section for the lower part of the regional Sipaian Stage of China (Qie et al. 2019). Six species were reported in the Upper Member of the Ertang Formation, which is assigned to the conodont *nothoperbonus* zone. The conodont fauna is low in diversity and contains three new species, including '*Ozarkodina*'? *chenae*, '*O.*'? *wuxuanensis* and *Polygnathus praeinversus*. Comparision of conodont faunas at the Lufengshan, Liujing and Daliangtang sections suggests that the conodont biodiversity during this time interval was mainly bathymetrically controlled in South China, with higher biodiversity in the more distal, and deeper water facies (*Palaeobiodiversity and Palaeoenvironments* 99(1) Doi: https://doi.org/10.1007/s12549-018-0325-4).

Zhang and Ma (2019) compiled generic distribution data of Silurian-Devonian amboceolioids around the world, proposed a new classification scheme, and focused on the origin and diversification of the Amobocoeliidae in South China. The Ambocoelioidea is a strongly facies-controlled group, and its emergence and demise show a close relationship with sea-level changes. In South China, the first appearance of the ambocoelioids occurred in the late Emsian, and was consistent with the sea level rise during the Upper Zlichov Event; the radiation of the endemic rhynchospiriferids in the basal Mintang Formation was probably related to the transgression during the Kacak Event; the Ambocoelioidea reached the highest diversity in the late Eifelian and Early Givetian. Due to different adaptation strategy, ambocoeliids and rhynchospiriferids show different life modes and extinction patterns. The ambocoeliids inhabited deeper and dysoxic water environments and showed greater capabilities to survive extinctions, while rhynchospiriferids prefer a high-energy and well-oxygenated water environment and were more sensitive to local environmental perturbations and extinction events (*Palaeobiodiversity and Palaeoenvironments* 99(1) Doi: https://doi.org/10.1007/s12549-018-0333-4).

The Late Devonian Famennian-Frasnian (F-F) mass extinction, also known as the Kellwasser Crisis, represents one of the "Big Five" Phanerozoic biodiversity crises and wiped out ~ 80% of extant marine invertebrate species (Hallam and Wignall, 1997). Considerable studies have been conducted on the taxonomic loss, ecological severity, assemblage changeover and environmental perturbations, but with little attention paid on the relationship between biogeography and evolutionary dynamics. **Qiao and Qie** (2019) compiled revised brachiopod data from 15 sections in South China to detect occurrences of brachiopod faunas in different habitat, biogeographic variation, and dynamics through the upper Frasnian, lower, and middle Famennian. These data show that biogeographic structure underwent major changes in the distribution area, size, connections, and endemism during the F-F crisis, and exerted a significant impact on biodiversity loss and evolutionary dynamics (*Palaeobiodiversity and Palaeoenvironments* 99(1) Doi: https://doi.org/10.1007/s12549-018-0336-1).

Based on a multivariate morphometric analysis, **Liang et al.** (2019) identified four morphospecies of syringoporoid tabulate corals in the upper to uppermost Famennian Etoucun Formation at the Huilong section, Guilin, including *Chia hunanensis*, *Tetraporinus virgatus*, *Fuchungopora multispinosa*, and *F. huilongensis* n. sp. The corals are commonly tilted or overturned, indicating the tabulate corals settled on a soft substrate, and were subject to periodic high-energy conditions on the isolated Guilin carbonate platform. The two species of *Fuchungopora* display flexible growth strategies characterised by the fusion between corallites. The high diversity of syringoporids suggests an obvious recovery and radiation of tabulate corals in the uppermost Famennian following the F-F mass extinction in South China (*Palaeobiodiversity and Palaeoenvironments* 99(1) Doi: https://doi.org/10.1007/s12549-018-0363-y).

Song and Gong (2019) presented 37 ostracods species belonging to 25 genera from the Devonian-Carboniferous transitional interval at Baihupo, Dushan, Guizhou. A major changeover event in the ostracod assemblages is recorded across the Gelaohe and Tangbagou formation boundary. In the underlying Gelaohe Formation, the ostracods belong to the palaeocopid association and the smooth-podocopid association, which generally occupied nearshore-offshore palaeoenvironments, while in the overlying Tangbagou Formation, the ostracods assemblage belongs to a smooth-podocopid association indicating an offshore palaeoenvironment. The lithological and faunal changes across the Gelaohe and Tangbagou formational boundary suggest a transgression occurred during the latest Devonian to earliest Carboniferous and the Devonian-Carboniferous boundary is consistent with the Gelaohe and Tangbagou formation boundary (*Palaeobiodiversity and Palaeoenvironments* 99(1) Doi: https://doi.org/10.1007/s12549-018-0322-7).

At the Jiarantang section, **Zhang et al.** (2019) reported the first discovery of *Postclymenia* cf. *evoluta* in the regional Changshun Shale, which represents the Hangenberg Black Shale equivalents in South China. The new record documents a global *Postclymenia* distribution in low and middle palaeolatitudes of peri-Palaeotethys Ocean Region. The strong similarity with contemporaneous German *Postclymenia* cf. *evoluta* indicates a sudden spread of opportunistic disaster species during the main phase of the Hangenberg Crisis. A eustatically driven, transgressive-regressive couplet in the lower-middle crisis intervals was corroborated by the intercalation of the Changshun Shale between the shallow-water limestones in South China (*Palaeobiodiversity and Palaeoenvironments* 99(1) Doi: https://doi.org/10.1007/s12549-018-0348-x).

Concluding remarks

The new findings assembled here provided valuable fossil materials for the evaluation and assessment on the interactions between organisms and their living environments in Devonian times. This special issue presents exquisitely preserved fossils including tentaculitids, brachiopods, conodonts, tabulate corals, ostracods and ammonoids in various Devonian stages from South China, which is one of the most easily accessible regions containing abundant fossils and continuous sedimentary records of Devonian. Each of the papers offers important progress in analyzing the specific fossil groups and palaeobiodiversity and palaeoenvironmental changes and can be taken as examples on how to continue further researches in South China as well as many other regions of the world. These studies included in this special issue will advance our knowledge for the Devonian palaeoecosystems and palaeoenvironments.

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