Mesozoic 001 (3): 331–339
https://www.mapress.com/mz/

Article

ISSN 3021-1859 (print edition)
MESOZOIC
ISSN 3021-1867 (online edition)

https://doi.org/10.11646/mesozoic.1.3.13
http://zoobank.org/urn:lsid:zoobank.org:pub:390F582F-2B6E-496B-9C3F-A012057C3581

An Early Cretaceous radiolarian assemblage from the strata south to the Zhongba microterrane in the Zhongba area, southern Tibet

ZHI-HAO HE[1], XIN LI[2, *], YA-LIN LI[1, *] & JIAN-BO CHENG[3]
[1]*State Key Laboratory of Biogeology and Environmental Geology, School of Earth Sciences and Resources, China University of Geosciences (Beijing), Beijing 10084, China*
[2]*State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China*
[3]*School of Earth Sciences and Engineering, Taiyuan University of Technology, Taiyuan 030024, China*
hzh13287083911@163.com; https://orcid.org/0009-0000-0155-9904
xinli@nigpas.ac.cn; https://orcid.org/0000-0002-4413-4137
liyalin@cugb.edu.cn; https://orcid.org/0000-0002-9757-9092
chengjianbo1104@163.com; https://orcid.org/0009-0006-9312-8098
**Corresponding authors*

Abstract

The presence of the Zhongba microterrane causes the Yarlung–Tsangpo suture zone to be bifurcated into two parts in its western segment: the Northern Ophiolitic Belt and Southern Ophiolitic Belt. This indicates that the evolution of the Neo-Tethys Ocean in the western segment is more complex than previous interpretation. Between the Southern Ophiolitic Belt and the Zhongba microterrane, there exists a successive stratigraphic sequence. In this study, a total of 15 genera belonging to 20 species of radiolarians were identified from the siliceous strata of the Dangxin Formation within this sequence, constraining the age of the Dangxin Formation to the Barremian, Early Cretaceous. Additionally, a stratigraphic column was constructed based on the basic understanding of this stratigraphic sequence from regional geological surveys, and it was compared with deep-water sediments in the Tethyan Himalaya. The results show that this sequence can be correlated with the Rilang, Duobeng, Chuangde, and Zongzhuo formations, which were deposited on the passive margin of the Indian plate.

Keywords: Yarlung–Tsangpo suture zone, radiolarians, Early Cretaceous, Zhongba microterrane

Introduction

The Yarlung–Tsangpo suture zone (YTSZ) is the youngest and southernmost tectonic suture in Tibet, which marks the boundary between the Indian and Eurasian plates. Neo-Tethys subduction and subsequent India-Asia collision have been the focus of research in recent decades. Most of the Neo-Tethys oceanic crust was subducted and consumed, and only a few fragmented remnants of a few kilometers in width were preserved as accretionary complexes within the YTSZ (Aitchison *et al*., 2000, 2003; McDermid, 2002; McDermid *et al*., 2002; Fig. 1). The siliceous rocks are widely distributed in the Yarlung–Tsangpo suture zone and its vicinity. These rocks represent oceanic remnants within the Neo-Tethys, which were deposited from various environments, ranging from oceanic basin to continental margin. Radiolarians within the siliceous rocks have provided crucial age constraints for reconstructing the stratigraphy of oceanic plates. Reconstruction of the Ocean Plate Stratigraphy (OPS) based on radiolarian biostratigraphy thus helps us understand the evolution of the Neo-Tethys. Since the 1980s, numerous studies on radiolarians have provided age constraints and offered new insights into the evolution, subduction, and accretion of the Neo-Tethys. The YTSZ can be subdivided into three structural segments: the western segment stretching from Kohistan-Ladakh to Saga, the central segment extending from Sangsang to Renbu, and the eastern segment extending from Zedong to Namjagbarwa (Liu *et al*., 2021a). The existence of the Zhongba microterrane has led to a more complex evolution of the western section of the Neo-Tethys Ocean. The Zhongba area belongs to the western segment of the YTSZ. Studies on the Zhongba area have been largely focused on strata in the southern ophiolitic mélange and the Tethyan Himalaya (Li *et al*., 2013, 2017, 2019, 2023; Zhong *et al*., 2017), reports on the northern ophiolitic

Submitted: 14 Sept. 2024; accepted by D.-Y. Huang: 25 Sept. 2024; published: 27 Sept. 2024

mélange and deep-water deposits south to the Zhongba microterrane remain sparse and fragmented. This leads to a limited understanding of the stratigraphy in this region. This paper aims to supplement the radiolarian records from deep-water deposits south to the Zhongba microterrane in the Zhongba area and provide further age constraints on stratigraphic units with disputed chronology.

Geological setting

Six geological units can be identified from north to south in the Zhongba area: the Xigaze forearc basin, the Northern Ophiolitic Belt, the Zhongba microterrane, the deep-water sedimentary, the Southern Ophiolitic Belt, and the Tethyan Himalaya.

The Xigaze forearc basin in southern Tibet formed during northward subduction of the Neo-Tethys slab and was filled by a thick sedimentary succession passing upward from upper Aptian to Santonian deep-marine turbidites (Chongdui and Ngamring formations) to Campanian-Maastrichtian shelf and fluvio-deltaic sediments (Padana and Qubeiya formations) (Dai *et al.*, 2015).

The Northern Ophiolitic Belt appears as an irregular and narrow discontinuous strip, with rocks being heavily dismembered and fragmented. The ophiolitie is primarily composed of mantle peridotites (mostly harzburgite

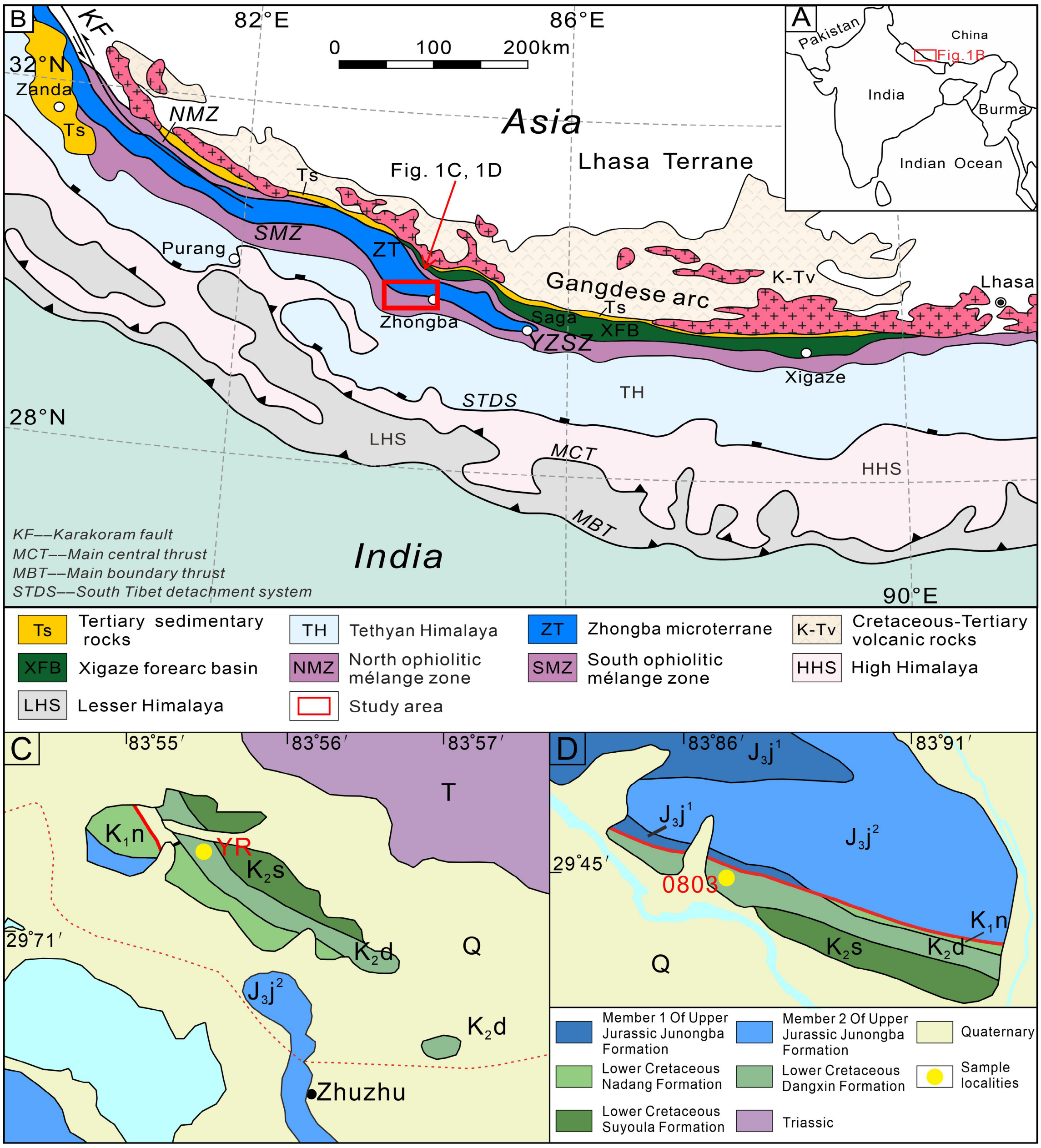

FIGURE 1. Simplified geological map and geodetic structure location map. **A**, Sketch map showing the location of the studied area in southern Tibet. **B**, Geological map (modified after Xu *et al.*, 2015). **C**, **D**, Geological map showing the sections.

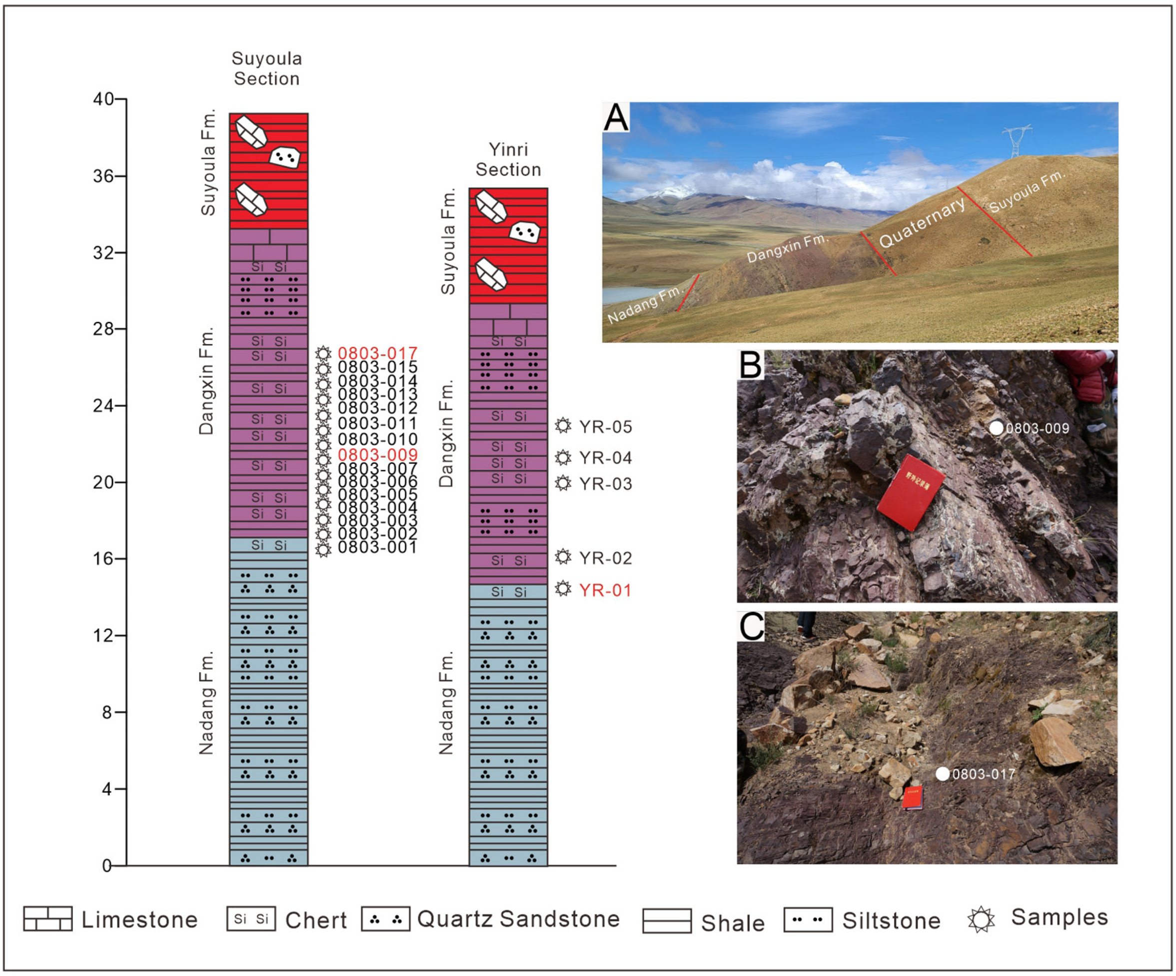

FIGURE 2. Suyoula and Yinri sections and field photographs. **A**, Macroscopic photos of section and stratigraphic grouping. **B**, Red chert (Sample 0803-009). **C**, Red chert (Sample 0803-017).

with minor lherzolite), mafic dykes, and minor cumulate gabbro. The Northern Ophiolitic Belt, along with the forearc basin of Xigaze to the north and the Gangdese magmatic arc, constitutes a complete trench-arc-basin system (Dai *et al*., 2012; Zheng *et al*., 2017; Liu *et al*., 2018).

The Zhongba microterrane is bounded by the Zhada-Zhongba-Chacang Fault in the north and the Qonggo-Munse Fault in the south. The Zhongba microterrane is dominated by Silurian/Ordovician–Triassic sedimentary and/or slightly metamorphosed carbonate-clastic deposits (Li *et al*., 2014).

The Southern Ophiolitic Belt is relatively continuous and mainly exposes several large, rounded mantle peridotite bodies, including the Dongbo, Pulan, Dangqiong, Xiugugabu, and Zhongba massifs. The ophiolitie consists of harzburgite with minor mafic dykes, and locally, cumulate gabbro bodies larger than 1 km in width are observed. These peridotites formed during the Early Cretaceous (Dai *et al*., 2012; Zheng *et al*., 2017; Liu *et al*., 2018).

The Tethyan Himalayan Sequence represents the Ordovician-Eocene passive margin sediments that were deposited on the northern margin of the Indian Plate before and after its separation from East Gondwana. The Tethyan Himalaya is separated from the High Himalaya by the South Tibet Detachment System (STDS). Based on stratigraphy, sedimentary characteristics, and structural features, the Tethyan Himalaya can be divided into southern and northern sub-belts. (Zhu *et al*., 2008, 2009).

Between the Zhongba microterrane and the Southern Ophiolitic Mélange Belt, there exists a sequence of deep-water sedimentary. New research on the deep-water sedimentary is limited to insights gained from 1:50000 regional geological surveys in 2010, and precise recognition has yet to be established. The regional geological survey results indicate that, the sequence from bottom to top can be subdivided into the Nadang Formation, Dangxin Formation, and Suyoula Formation. Due to the insufficient understanding of the age, provenance, and other characteristics of this sequence, it is the focus of this study.

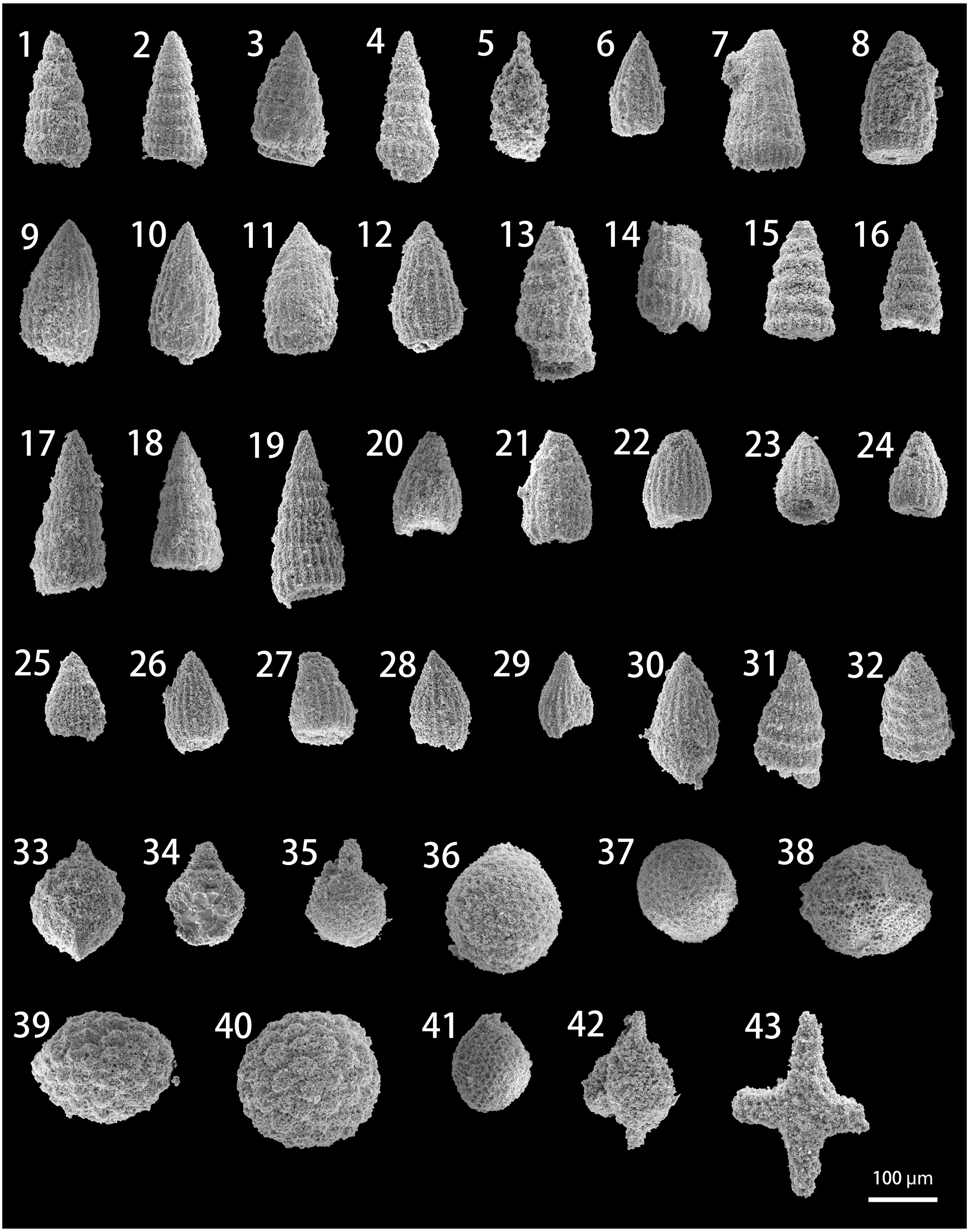

FIGURE 3. Scanning electron micrographs of the Early Cretaceous radiolarians from sample 0803-017 from the Suyoula section. Scale bar: 100 μm. (1, 2) *Pseudodictyornitra lodogaensis* Pessagno; (3) *Pseudodictyomitra carpatica* (Lozyniak); (4) *Pseudodictyornitra hornatissirna* (Squinabol); (5) *Pseudoeucyrtis* sp.; (6–9) *Archaeodictyomitra mitra* Dumitrica; (10–12) *Archaeodictyomitra pseudomulticostata* (Tan); (13–19) *Dictyomitra communis* (Squinabol); (20–28) *Thanarla brouweri* (Tan); (29) *Thanarla elegantissima* Cita; (30) *Mictyoditra lacrimula* (Foreman); (31) *Svinitzium* sp.; (32) *Xitus* sp.; (33) *Hiscocapsa grutterinki* (Tan); (34, 35) *Squinabollum* cf. *S. asseni* (Tan); (36–38) *Holocryptocanium tuberculatum* Dumitrica; (39, 40) *Holocryptocanium* sp.; (41) *Stichocapsa* sp.; (42) *Archaeospongoprunum* sp.; (43) *Crucella* sp.

Material and methods

Section

The stratigraphic units in both the Yinri and Suyoula sections are consistent. The Suyoula section is located to the west of the Zhongba County, while the Yinri section is near Zhuzhu village to the west of the Zhongba County. From bottom to top, the stratigraphy includes the Nadang Formation, Dangxin Formation, and the Suyoula Formation. The lithology of the Nadang Formation is dominated by lithic sandstone with minor siliceous shale, while the Dangxin Formation mainly consists of thin to medium-bedded purplish-red and bluish-gray foraminiferal limestone, bioclastic limestone, chert, and siliceous shale. The Suyoula Formation is a set of sedimentary mélanges. In this study, 20 chert samples were collected from the siliceous layers of the Dangxin Formation in both sections for radiolarian biostratigraphic analysis.

Radiolarian analysis

A total of 20 chert samples were processed with standard radiolarian extraction techniques (hydrofluoric acid method), as described by Pessagno and Newport (1972). Each sample was broken into approximately 2–3 cm^3 sized pieces and packed in plastic netting. Before being immersed in a 4 % HF solution for 12–24 h, the pieces were washed several times under running water to remove surface sediment. After that, the acid residues were sieved into 63–425 μm fractions, and the radiolarian-containing residues concentrated on the 63 μm sieve were carefully washed and dried. This procedure was repeated 5–7 times to obtain as many radiolarian-bearing residues as possible. Radiolarian fossils were picked from the residues under a binocular microscope, and then well-preserved specimens were selected to be mounted on a stub that was later coated with platinum for subsequent examination under a Hitachi TM3030 Scanning Electron Microscope (SEM) at the State Key Laboratory of Palaeobiology and Stratigraphy. More than 600 SEM images were captured. All radiolarian specimens are deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences.

Identification and age assignment follow taxonomy and zonation of Early Cretaceous radiolarians (Takemura, 1986; Matsuoka, 1992, 1995; Baumgartner *et al.*, 1995;

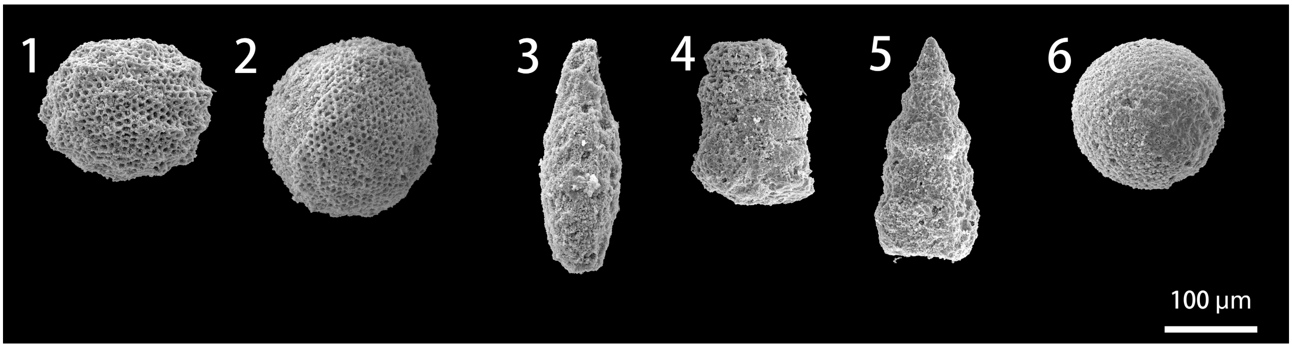

FIGURE 4. Scanning electron micrographs of the Early Cretaceous radiolarians from sample 0803-009 from the Suyoula section. (1, 2) *Holocryptocanium tuberculatum* Dumitrica; (3) *Pseudoeucyrtis* sp.; (4) *Stichomitra communis* Squinabol; (5) Spumellaria gen. et sp. Indet.; (6) *Holocryptocanium barbui* Dumitrica.

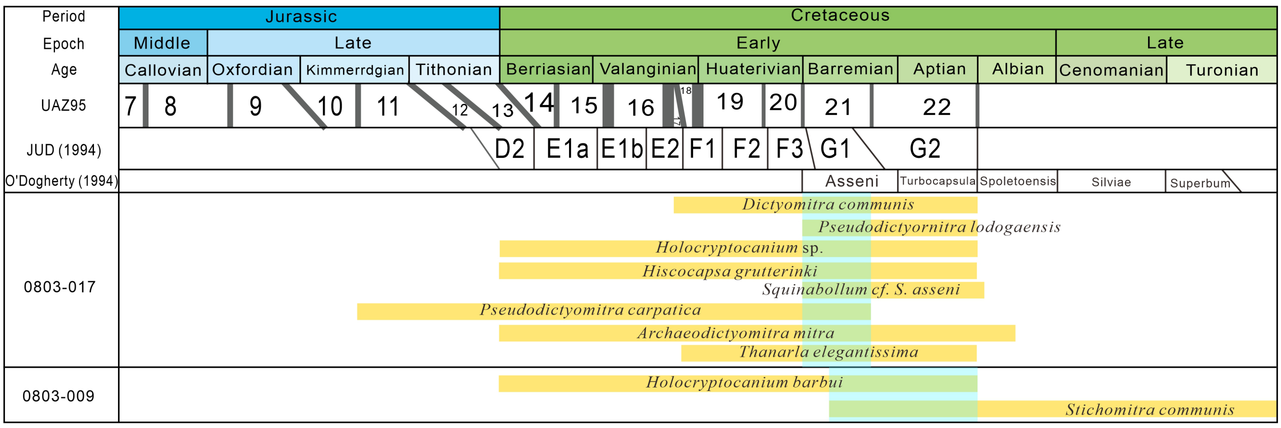

FIGURE 5. Ranges of age diagnostic radiolarian taxa from chert samples (Ranges refer to Jud, 1994; O'Dogherty, 1994; Baumgartner *et al.*, 1995).

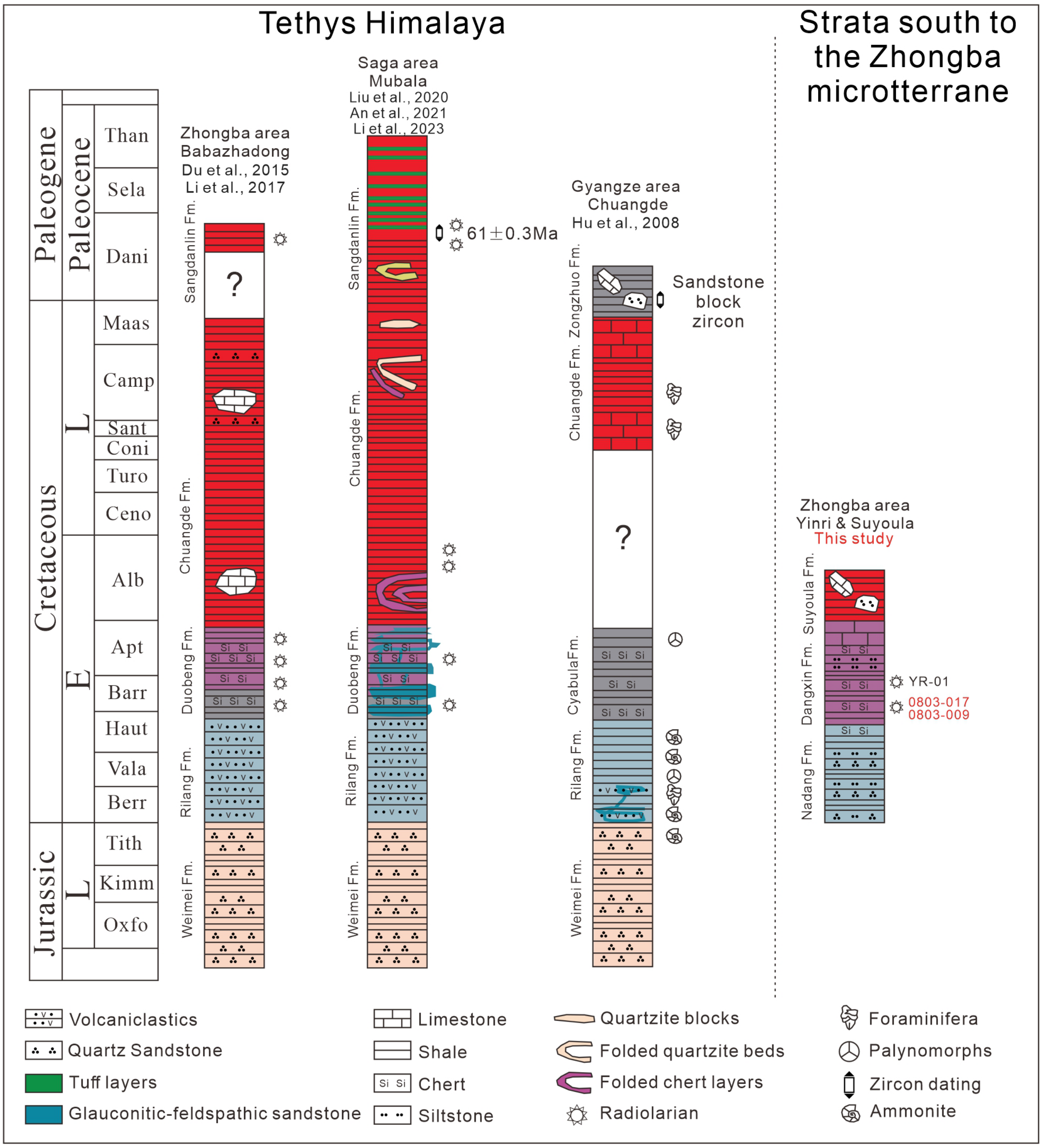

FIGURE 6. Reconstruction of deep-water sediments in Saga and Zhongba areas based on radiolarian assemblages and zircon age (Hu *et al*., 2008; Du *et al*., 2015; Li *et al*., 2017, 2023; Liu *et al*., 2020b; An *et al*., 2021).

O'Dogherty *et al*., 2009, 2017) in the Tethys and Pacific regions.

Results

Radiolarian biostratigraphy

After experimental processing, we selected three samples (0803-003, 0803-017, and YR-01) with high radiolarian content for radiolarian biostratigraphy dating. Samples 0803-009 and 0803-017 come from the Suyoula section. Sample YR-01 comes from the Yinri section, but the preservation of radiolarians in the Yinri section is too poor to be of chronological significance.

The radiolarians in sample 0803-017 are characterized by the occurrence of *Dictyomitra communis* (Squinabol), *Pseudodictyornitra lodogaensis* Pessagno, *Xitus* sp., *Holocryptocanium* sp., *Hiscocapsa grutterinki* (Tan), *Holocryptocanium tuberculatum* Dumitrica, *Squinabollum* cf. *S. asseni* (Tan), *Pseudodictyomitra carpatica* (Lozyniak), *Archaeodictyomitra mitra* Dumitrica, *Thanarla brouweri* (Tan), *Archaeospongoprunum* sp., *Svinitzium* sp., *Pseudodictyornitra hornatissirna* (Squinabol),

TABLE 1. Occurrence of the Early Cretaceous radiolarians from the Suyoula section.

Samples Radiolarian species	0803-017	0803-009
Holocryptocanium tuberculatum Dumitrica	●	●
Pseudoeucyrtis sp.	●	●
Stichomitra communis Squinabol		●
Holocryptocanium sp.	●	●
Holocryptocanium barbui Dumitrica		●
Dictyomitra communis (Squinabol)	●	
Pseudodictyornitra lodogaensis Pessagno	●	
Xitus sp.	●	
Hiscocapsa grutterinki (Tan)	●	
Squinabollum cf. *S. asseni* (Tan)	●	
Pseudodictyomitra carpatica (Lozyniak)	●	
Thanarla brouweri (Tan)	●	
Archaeospongoprunum sp.	●	
Svinitzium sp.	●	
Pseudodictyornitra hornatissirna (Squinabol)	●	
Mictyoditra lacrimula (Foreman)	●	
Archaeodictyomitra pseudomulticostata (Tan)	●	
Crucella sp.	●	
Thanarla elegantissima Cita	●	
Stichocapsa sp.	●	

Mictyoditra lacrimula (Foreman), *Pseudoeucyrtis* sp., *Archaeodictyomitra pseudomulticostata* (Tan), *Crucella* sp., *Thanarla elegantissima* Cita, and *Stichocapsa* sp. (Fig. 3; Table A). The co-occurrence of *Squinabollum* cf. *S. asseni* (Tan), *Pseudodictyornitra lodogaensis* Pessagno, and *Pseudodictyomitra carpatica* (Lozyniak) (Fig. 3) suggests that the age assignment of the Barremian.

The radiolarians in sample 0803-009 are characterized by the occurrence of *Holocryptocanium tuberculatum* Dumitrica, *Pseudoeucyrtis* sp., *Stichomitra communis* Squinabol, *Holocryptocanium* sp., Spumellaria gen. et sp. Indet., and *Holocryptocanium barbui* Dumitrica (Fig. 4; Table 1). The co-occurrence of *Holocryptocanium barbui* Dumitrica and *Stichomitra communis* (Fig. 4) suggests an age assignment of the early Barremian to Aptian.

Discussion

Stratigraphic correlation

Current understanding of the Nadang Formation, Dangxin Formation, and Suyoula Formation is primarily based on regional geological surveys. In this study, radiolarian biostratigraphic analysis was conducted on the siliceous layers of the Dangxin Formation, constraining the age of the siliceous strata to the Barremian. In terms of lithology and stratigraphic age, the Nadang, Dangxin, and Suyoula Formations can be compared with the Rilang, Duobeng, Chuangde, and Zongzhuo formations of the Tethyan Himalaya in Saga and Zhongba areas (Du *et al*., 2015; Li *et al*., 2013, 2017, 2019, 2023). The Nadang Formation, consisting of massive volcaniclastic sandstone from the Early Cretaceous in the Zhongba region, is highly comparable to the Rilang Formation of the Tethyan Himalaya. The Dangxin Formation is mainly composed of thin to medium-bedded purplish-red and bluish-gray foraminiferal limestone, bioclastic limestone, chert, and siliceous shale. The lower part of the Dangxin Formation can be compared with the Duobeng Formation and the upper part can be compared with the Chuangde Formation. The Suyoula Formation, characterized as a sedimentary mélange, shares lithological characteristics with the Zongzhuo Formation in the Tethyan Himalaya.

Sedimentary background analysis

In previous studies, Qin *et al*. (2019) conducted radiolarian biostratigraphy analysis on deep-water sedimentary strata and palaeomagnetic analysis on the Dangxin Formation strata. However, the time range limited by radiolarian dating results was relatively vague (Early Berriasian–late Cenomanian). This study is the first attempt to provide age constraint on the Dangxin Formation with moderately preserved radiolarians (Barremian). Qin *et al*. (2019) believed that the deep-water sediments south to the Zhongba microterrane is the northern edge of the India plate. However, due to insufficient research at present, the sedimentary background of deep-water sedimentary strata needs further study.

Conclusions

In this study, a total of 15 genera and 20 species of radiolarians were identified from the Dangxin Formation within the orderly sediments to the southern side of the Zhongba microterrane, constraining its age to the Barremian. Radiolarians are discovered from the lower part of the Dangxin Formation, which is characterized by red chert interbedded siliceous shale. Additionally, based on basic understanding of this orderly sediments according to regional geological surveys, we reconstructed a stratigraphic column and compared it with strata in the Tethyan Himalaya. The results indicate that the Nadang Formation, Dangxin Formation, and Suyoula Formation south to the Zhongba microterrane near Zhongba can be correlated with the Rilang, Duobeng, Chuangde, and Zongzhuo formations in the Tethyan Himalaya near Zhongba and Saga areas.

Acknowledgments

We thank Dr Hanting Zhong and Dr Xiaohui Cui for carefully and critically reviewing our paper. This research was supported by the Second Tibetan Plateau Scientific Expedition and Research (2019QZKK0803, 2019QZKK0706), the National Natural Science Foundation of China (42272018).

References

Aitchison, J.C., Davis, A.M., Liu, J., Luo, H., Malpas, J.G., McDermid, I.R. & Zhou, M.F. (2000) Remnants of a Cretaceous intra-oceanic subduction system within the Yarlung–Zangbo suture (southern Tibet). *Earth and Planetary Science Letters*, 183 (1-2), 231–244. https://doi.org/10.1016/S0012-821X(00)00287-9

Aitchison, J.C., Davis, A.M., Abrajevitch, A.V., Ali, J.R., Badengzhu Liu, J., Luo, H., McDermid, I.R.C. & Zyabrev, S.V. (2003) Stratigraphic and sedimentological constraints on the age and tectonic evolution of the Neotethyan ophiolites along the Yarlung–Tsangpo suture zone, Tibet. *The Geological Society of London - Special Publications*. 218 (1), 147–164. https://doi.org/10.1144/GSL.SP.2003.218.01.09

An, W., Hu, X.M, Garzanti, E., Wang, J.G. & Liu, Q. (2021) New precise dating of the India-Asia collision in the Tibetan Himalaya at 61 Ma. *Geophysical Research Letters*, 48, e90641. https://doi.org/10.1029/2020GL090641

Baumgartner, P.O., Bartolini, A., Carter, E.S., Conti, M., Cortese, G., Danelian, T. & Yao, A. (1995) Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on Unitary Associations. *In*: "Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology". *In Memoires de Geologie (Lausanne, Switzerland) Edited by: InterRad Jurassic-Cretaceous Working Group*, 23, 1013–1048.

Dai, J.G., Wang, C.S. & Li, Y.L. (2012) Relicts of the Early Cretaceous seamounts in the central-western Yarlung Zangbo Suture Zone, southern Tibet. *Journal of Asian Earth Sciences*, 53, 25–37. https://doi.org/10.1016/j.jseaes.2011.12.024

Dai, J.G., Wang, C.S., Zhu, D.C., Li, Y.L., Zhong, H.T. & Ge, Y.K. (2015) Multi-stage volcanic activities and geodynamic evolution of the Lhasa terrane during the Cretaceous: Insights from the Xigaze forearc basin. *Lithos*, 218-219, 127–140. https://doi.org/10.1016/j.lithos.2015.01.019

Du, X.J., Chen, X., Wang, C.S., Wei, Y.S., Li, Y.L. & Jansa, L. (2015) Geochemistry and detrital zircon U-Pb dating of Lower Cretaceous volcaniclastics in the Babazhadong section, Northern Tethyan Himalaya: implications for the breakup of Eastern Gondwana. *Cretaceous Research*, 52, 127–137. https://doi.org/10.1016/j.cretres.2014.08.002

Hu, X.M, Jansa, L. & Wang, C.S. (2008) Upper Jurassic-Lower Cretaceous stratigraphy in south-eastern Tibet: a comparison with the western Himalayas. *Cretaceous Research*, 29 (2), 301–315. https://doi.org/10.1016/j.cretres.2007.05.005

Jud, R. (1994) Biochronology and systematics of Early Cretaceous Radiolaria of the western Tethys. *Université de Lausanne, Institut de géologie et paléontologie*, 19, 147 pp.

Li, X., Li, Y.L., Wang, C.S. & Matsuoka, A. (2013) Late Jurassic radiolarians from the Zhongba melange in the Yarlung–Tsangpo suture zone, southern Tibet. *Science Reports of Niigata University (Geology)*, 28, 23–30.

Li, X., Matsuoka, A., Li, Y.L. & Wang, C.S. (2017) Phyletic evolution of the mid-Cretaceous radiolarian genus *Turbocapsula* from southern Tibet and its applications in zonation. *Marine Micropaleontology*, 130, 29–42. https://doi.org/10.1016/j.marmicro.2016.11.002

Li, X., Matsuoka, A., Li, Y.L., Wei, Y.S. & Wang, C.S. (2019) Radiolarian-based study on the fabric and the formation process of the Early Cretaceous mélange near Zhongba,

Yarlung–Tsangpo Suture Zone, southern Tibet. *Island Arc*, 28, 1–21.
https://doi.org/10.1111/iar.12282

Li, X., Hu, X.M., An, W., Liu, Q., Garzanti, E. & Meng, J. (2023) From Neo-Tethyan convergence to India-Asia collision: radiolarian biostratigraphy of the Cretaceous to Paleocene deep-water Tethys Himalaya. *Newsletters on Stratigraphy*, 56 (1), 33–52.
https://doi.org/10.1127/nos/2022/0707

Li, X.H., Wang, C., Li, Y., Wei, Y. & Chen, X. (2014) Definition and Composition of the Zhongba Microterrane in Southwest Tibet. *Acta Geologica Sinica*, 88, 1372–1381. [In Chinese with English abstract]

Liu, F., Dilek, Y., Xie, Y., Yang, J. & Lian, D. (2018) Melt evolution of upper mantle peridotites and mafic dikes in the northern ophiolite belt of the western Yarlung–Zangbo suture zone (southern Tibet). *Lithos*, 10, 109–132.
https://doi.org/10.1130/L689.1

Liu, F., Dilek, Y., Yang, J.S., Lian, D.Y., Li, G.L. & Wu, Y. (2021a) A middle Triassic seamount within the western Yarlung zangbo suture zone, Tibet: The earliest seafloor spreading record of Neo-tethys to the North of East Gondwana. *Lithos*, 388, 106062.
https://doi.org/10.1016/j.lithos.2021.106062

Liu, Q., Kneller, B., An, W. & Hu, X.M. (2021b) Sedimentological responses to initial continental collision: triggering of sand injection and onset of mass movement in a syn–collisional trench basin, Saga, southern Tibet. *Journal of the Geological Society*, 178 (6), jgs2020–178.
https://doi.org/10.1144/jgs2020-178

Matsuoka, A. (1992) Jurassic and Early Cretaceous radiolarians from LEG 129, SITES 800 and 801, western Pacific Ocean. In Proceedings of the ocean drilling program, scientific results *Ocean Drilling Program*, 129, 203–220.
https://doi.org/10.2973/odp.proc.sr.129.121.1992

Matsuoka, A. (1995) Jurassic and Lower Cretaceous radiolarian zonation in Japan and the western Pacific. *Island Arc*, 4, 140–153.
https://doi.org/10.1111/j.1440-1738.1995.tb00138.x

McDermid, I.R.C. (2002) Zedong terrane, south Tibet. PhD thesis. *University of Hong Kong*, 421 pp.

McDermid, I.R., Aitchison, J.C., Davis, A.M., Harrison, T.M. & Grove, M. (2002) The Zedong terrane: a Late Jurassic intra-oceanic magmatic arc within the Yarlung–Tsangpo suture zone, southeastern Tibet. *Chemical Geology*, 187 (3-4), 267–277.
https://doi.org/10.1016/S0009-2541(02)00040-2

O'Dogherty, L. (1994) Biochronology and Paleontology of Mid–Cretaceous Radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). *Section des sciences de la terre, Université de Lausanne*, 21, 415 pp.

O'Dogherty, L., Carter, E.S., Dumitrica, P., Gorican, S., De Wever, P., Bandini, A.N., Baumgartner, P.O. & Matsuoka, A. (2009) Catalogue of Mesozoic radiolarian genera. Part 2: Jurassic-Cretaceous. *Geodiversitas*, 31, 271–356.
https://doi.org/10.5252/g2009n2a4

O'Dogherty, L., Goričan, S. & Gawlick H.J. (2017) Middle and Late Jurassic radiolarians from the Neotethys suture in the Eastern Alps. *Journal of Paleontology*, 91 (1), 25–72.
https://doi.org/10.1017/jpa.2016.96

Qin, S.X., Li, Y.X., Li, X.H., Xu, B. & Luo, H. (2019) Paleomagnetic results of Cretaceous cherts from Zhongba, southern Tibet: New constraints on the India-Asia collision. *Journal of Asian Earth Sciences*, 173, 42–53.
https://doi.org/10.1016/j.jseaes.2019.01.012

Takemura, A. (1986) Classification of Jurassic Nassellarians (Radiolaria). *Palaeontographica Abt. A*, 195, 29–74.

Xu, Z., Dilek, Y., Yang, J., Liang, F., Liu, F., Ba, D., Cai, Z., Li, G., Dong, H. & Ji, S. (2015) Crustal structure of the Induse Tsangpo suture zone and its ophiolites in southern Tibet. *Gondwana Research*, 27, 507–524.
https://doi.org/10.1016/j.gr.2014.08.001

Zheng, H., Huang, Q.T., Kapsiotis, A., Xia, B., Yin, Z.X., Zhong, Y. & Shi, X.L., (2017) Early Cretaceous ophiolites of the Yarlung Zangbo suture zone: Insights from dolerites and peridotites from the Baer upper mantle suite, SW Tibet (China). *International Geology Review*, 59 (11), 1471–1489.
https://doi.org/10.1080/00206814.2016.1276867

Zhong, H.T., Dai, J.G., Wang, C.S., Li, Y.L. & Wei, Y.S. (2017) Middle Jurassic–early Cretaceous radiolarian assemblages of the western Yarlung Zangbo Suture Zone: Implications for the evolution of the Neo-Tethys. *Geoscience Frontiers*, 8 (5), 989–997.
https://doi.org/10.1016/j.gsf.2016.09.006

Zhu, D.C., Mo, X.X., Pan, G.T., Zhao, Z.D., Dong, G.C., Shi, Y.R., Liao Z.L., Wang L.Q. & Zhou, C.Y. (2008) Petrogenesis of the earliest Early Cretaceous mafic rocks from the Cona area of the eastern Tethyan Himalaya in south Tibet: Interaction between the incubating Kerguelen plume and the eastern Greater India lithosphere? *Lithos*, 100, 147–173.
https://doi.org/10.1016/j.lithos.2007.06.024

Zhu, D.C., Zhao, Z.D., Pan, G.T., Lee, H.Y., Kang, Z.Q., Liao, Z.L. & Liu, B. (2009) Early Cretaceous subduction-related adakite-like rocks of the Gangdese Belt, southern Tibet: products of slab melting and subsequent melt–peridotite interaction? *Journal of Asian Earth Sciences*, 34 (3), 298–309.
https://doi.org/10.1016/j.jseaes.2008.05.003