Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL090282

Key Points:
- 1.2-Ga detrital zircon population is present in age-calibrated Ediacaran-Cambrian strata of western South China Block
- A major change in tectonic setting of the South China Block occurred in 0.56–0.54 Ga
- The connection between the South China Block and NW India Block started in the late Ediacaran

Supporting Information:
- Supporting Information S1

Correspondence to:
C. Yang and X.-H. Li,
chuany@bgs.ac.uk;
lixh@gig.ac.cn

Citation:
Yang, C., Li, X.-H., Li, Z.-X., Zhu, M., & Lu, K. (2020). Provenance evolution of age-calibrated strata reveals when and how South China Block collided with Gondwana. *Geophysical Research Letters*, *47*, e2020GL090282. https://doi.org/10.1029/2020GL090282

Received 12 AUG 2020
Accepted 18 SEP 2020
Accepted article online 28 SEP 2020

Provenance Evolution of Age-Calibrated Strata Reveals When and How South China Block Collided With Gondwana

Chuan Yang[1,2], Xian-Hua Li[1,3], Zheng-Xiang Li[4], Maoyan Zhu[3,5], and Kai Lu[1,3]

[1]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China, [2]British Geological Survey, Nottingham, UK, [3]College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing, China, [4]Earth Geodynamics Research Group, TIGeR, School of Earth and Planetary Sciences, Curtin University, Perth, WA, Australia, [5]State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, Nanjing, China

Abstract The South China Block (SCB) has been regarded by many as an integral part of Gondwana, but proposed timing and processes for its accretion to Gondwana vary and remain contentious, largely owing to the lack of reliable Pan-African age paleomagnetic data and tectono-magmatic records from the SCB. Integrated in situ U-Pb ages and Hf-O isotope analyses of detrital zircons from geochronologically well-calibrated Ediacaran-Cambrian sedimentary rocks of western SCB reveal age populations of 2.51, 1.85, 1.20, 0.80, and 0.52 Ga. Detrital zircon age spectra indicate a major tectonic transition for the SCB during 0.56–0.54 Ga, interpreted to reflect the beginning of the collision between SCB-Indochina and NW India blocks. The collisional event lasted until early Ordovician, leading to the suturing of the SCB-Indochina to the northern margin of East Gondwana.

Plain Language Summary The South China Block is thought to be a part of the Gondwana superterrane, which was composed of more than half of all continents 650–400 million years ago (Ma). However, questions of when and how the South China Block collided with Gondwana are yet to be answered. In this study, we conducted provenance analyses of sedimentary rocks whose depositional ages were known via radioisotopic dating and chemo-biostratigraphy in the western South China Block. The results reveal a change in tectonic setting of the South China Block at 560–540 Ma, interpreted as the onset of the collision between the South China Block and India along the northern margin of East Gondwana.

1. Introduction

Gondwana was assembled mainly during the Ediacaran-Cambrian period involving successive collisional orogens. The configuration of the core Gondwana is relatively well established, whereas the positions of marginal continents in the reconstruction remain controversial (Torsvik & Cocks, 2013). As one of the major continental blocks in East Asia, the South China Block (hereafter SCB) is proposed to be located against the northern margin of East Gondwana. However, its precise position relative to India and Australia, and when such connection(s) started, remains debated (e.g., Cawood et al., 2013; Yao et al., 2014). Existing reconstruction models, mainly based on stratigraphic and provenance analyses, suggest that the SCB either collided with the NW Indian Himalaya before migrating toward the NW Australia during the Neoproterozoic-Paleozoic transitional period (Z. Li et al., 2013; Yao et al., 2014; Zhang et al., 2015) or was connected with northern India block since at least early Neoproterozoic (Cawood et al., 2013; Jiang et al., 2003).

Previous work attempted to use detrital zircon U-Pb data from Ediacaran-Cambrian successions of the SCB to advance this debate (e.g., Wu et al., 2010; Xu et al., 2013; Yao et al., 2014). However, two critical limitations existed for those work: (1) the analyzed samples were mainly from the eastern part of the SCB, especially the Cathaysia block, making their geographic coverage limited; (2) the sampled stratigraphic intervals generally lack high-precision geochronological constraints on the time of sediment accumulation, thus limited the precision of the tectonic interpretation. Here, we report detrital zircon U-Pb data and Hf-O isotopes of sedimentary rocks from geochronologically well-constrained Ediacaran-Cambrian successions in the eastern Yunnan Province, western part of the SCB. Our new data, along with published detrital zircon U-Pb data from other continents/areas, provide new constraints on when and how the SCB collided with Gondwana.

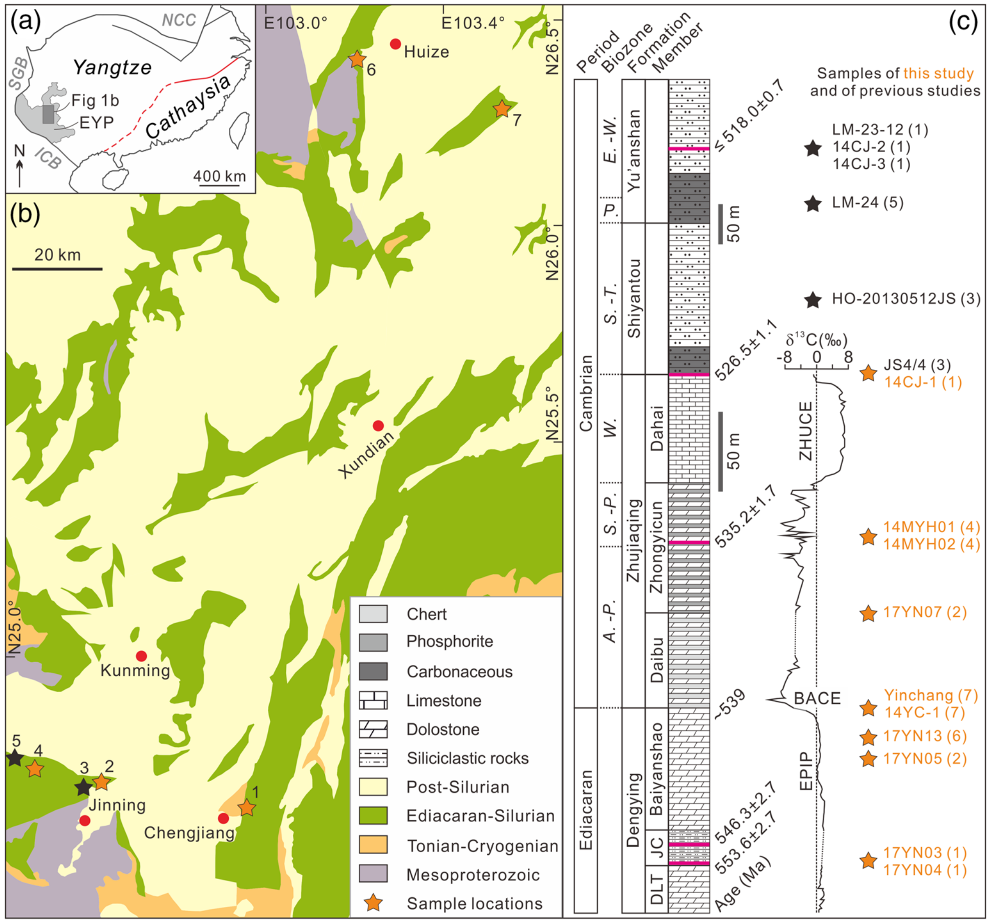

Figure 1. Geological setting and sampling. (a) A simplified regional map of the SCB, showing the study area in the western part of the block. The position of SCB in eastern Asia is shown in Figure S1. (b) Geological map of the study area and sample locations for both this study and previous studies (adapted from 1:500,000 map of Yunnan Province on the National Geological Archives of China, http://en.ngac.org.cn/). (c) Integrated Ediacaran-Cambrian transitional succession of the eastern Yunnan Province, with samples collected for detrital zircon analyses by Hofmann et al. (2016), Yang et al. (2018), and this study. Number in the bracket following the sample name indicates the sampling location shown in Figure 1b. Litho-chemo-biostratigraphic data are from Zhu et al. (2001) and D. Li et al. (2013). Radioisotopic dates are from Compston et al. (2008) and Yang et al. (2017, 2018). Abbreviations: NCC = North China Craton; SGB = Songpan-Ganzi Block; ICB = Indochina Block; EYP = Eastern part of the Yunan Province; DLT = Donglongtan; JC = Jiucheng; EPIP = Late Ediacaran positive carbon isotope plateau; BACE = Basal Cambrian negative carbon isotope excursion; ZHUCE = Zhujiaqing Carbon Isotope Excursion; A.-P. = *Anabarites trisulcatus-Protohertzina anabarica*; S.-P. = *Siphogonuchites triangularis-Paragloborilus subglobosus*; W. = *Watsonella crosbyi*; S.-T. = *Sinosachites-Tannuolina*; P. = *Parabadiella*; E.-W. = *Eoredlichia-Wutingaspis.*

2. Geological Background and Sampling

The SCB is separated from the North China Craton to the north by the Qinling-Dabie-Sulu Orogen, from the Indochina Block to the southwest by the Ailaoshan-Songma Fault, and from the Songpan-Ganzi Terrane to the west by the Longmenshan Fault (Figure 1). It was formed by the amalgamation of the Yangtze and Cathaysia blocks in the early Neoproterozoic, although the exact process of the assembly and the tectonic evolution of SCB during the Neoproterozoic-Paleozoic transition time remain debated (e.g., Cawood et al., 2018; Li, Li, et al., 2009; Yao et al., 2014). The widespread Ediacaran-Cambrian sedimentary rocks in the SCB provide a unique geological record for examining this process.

The Yangtze Block of the SCB during this period can be divided into a platform interior, a transitional zone, and slope-deep basins as the water deepened from the northwest to the southeast on a failed continental rift margin (Wang & Li, 2003; Zhu et al., 2007). In contrast, the contemporary facies over the Cathaysia Block was siliciclastic-dominated, shallow-marine successions (Yao et al., 2014). The eastern Yunnan Province is tectonically located in the platform interior of the Yangtze Block, at the western part of the SCB. The Ediacaran-Cambrian transitional deposits in this area include, in ascending order, the Doushantuo (635–551 Ma), Dengying (551–539 Ma), Zhujiaqing (539–526 Ma), Shiyantou (526–520 Ma), and Yu'anshan (520–515 Ma) formations (Figure 1; Zhu & Li, 2017). The Doushantuo Formation is mainly composed of sandstone in the lower part, carbonate in the upper part, and black shale at the top. The Dengying Formation is divided into three members including, in ascending order, the Donglongtan, Jiucheng, and Baiyanshao members. The Donglongtan and Baiyanshao members are dominated by dolostone. The Jiucheng Member mainly consists of sandstone and muddy siltstone interbedded with laminated silty dolomite in the upper part of the member. Overlying the Dengying Formation is the Zhujiaqing Formation which consists of the Daibu, Zhongyicun, and Dahai members. The Daibu Member comprises interbedded dolomitic cherts and siliceous dolostone. The Zhongyicun Member is dominated by phosphorite, and the Dahai Memerber carbonate. Above the Zhujiaqing Formation is the Shiyantou and Yu'anshan formations which are dominated by siltstone and shales. Geographic locations and stratigraphic horizons of samples for provenance analyses of both this and previous studies are shown in Figure 1.

3. Results

In situ zircon U-Pb and O isotope analyses were conducted using a CAMECA 1280HR (or 1280) SIMS at the Institute of Geology and Geophysics, Chinese Academy of Sciences, followed by in situ Hf isotope measurements on a LA-MC-ICPMS at the same institute. Analytical methods are described in the Supporting Information S1. Detrital zircon U-Pb and Hf-O data and sample GPS locations are given in the Data Repository in the National Geoscience Data Centre.

In general, samples from the Ediacaran-Cambrian transition strata (0.55–0.52 Ga) of the W SCB, analyzed by this study, have similar detrital zircon age spectra, with major peaks at 0.82–0.80 Ga and minor peaks at 0.52, 1.20, 1.60, 1.85, and 2.51 Ga (Figure 2). Most of these peaks are common for Neoproterozoic-Paleozoic strata of the SCB (Cawood et al., 2018; Li et al., 2014; Yang et al., 2015), except for the unique 1.20-Ga peak which previously has only been sporadically detected from Ediacaran-early Paleozoic strata of the SCB (e.g., Yao et al., 2014). It is noteworthy that in the study area, the 1.20-Ga detrital zircon peak first appears in the middle of the Dengying Formation (ca. 0.55 Ga), extends to the basal Shiyantou Formation (526.5 $\pm$ 1.1 Ma), and then disappears in the overlying Yu'anshan Formation (Figure 2a). Most zircons of this population are euhedral or subhedral in shape apart from a few anhedral grains. Their Th/U ratios range from 0.27 to 1.32. Zircons of the 1.20-Ga peak have a wide range of $\varepsilon_{Hf}(t)$ values (−11.3 to +12.6) but mainly cluster around the chondritic uniform reservoir line with two main peaks at −2.3 and +0.9 (Figure 3). Their $\delta^{18}O$ values vary from 1.6‰ to 9.0‰. Seventy-six percent of them are lower than the value of mantle zircon, with the main peak at 2.9‰ (Figure 3). Detrital zircon age distributions of samples from underlying strata in the study area are also presented for comparison. Detrital zircons from the Tonian Chengjiang Formation and the Ediacaran Doushantuo Formation show similar age distribution to the samples in this study, with a major peak at 0.80 Ga and a minor peak at 1.85 Ga but without the ca. 1.20-Ga peak (Figure 2a). Zircons from the late Mesoproterozoic-early Neoproterozoic Kunyang Group mainly cluster between 2.0 and 1.0 Ga, with two major peaks at 1.61 and 1.17 Ga (Figure 2a).

To compare the provenance of detritus in different areas, detrital zircon U-Pb data from Ediacaran-Cambrian strata of eastern SCB, Indochina, Australia, Himalayan areas, and Iran are also compiled and presented (Figure 2b).

4. Discussion and Conclusions

4.1. Provenance Analyses

Detrital zircons from samples of this study consist of a prominent 0.80-Ga population, subordinate 0.52- and 1.20-Ga populations, and minor 1.60-, 1.85-, and 2.51-Ga populations (Figure 2). Except for the 0.52- and 1.20-Ga populations, the others are common in the Neoproterozoic-Phanerozoic strata of the SCB and have been discussed in details elsewhere (e.g., Li et al., 2014; Yang et al., 2015).

10.1029/2020GL090282

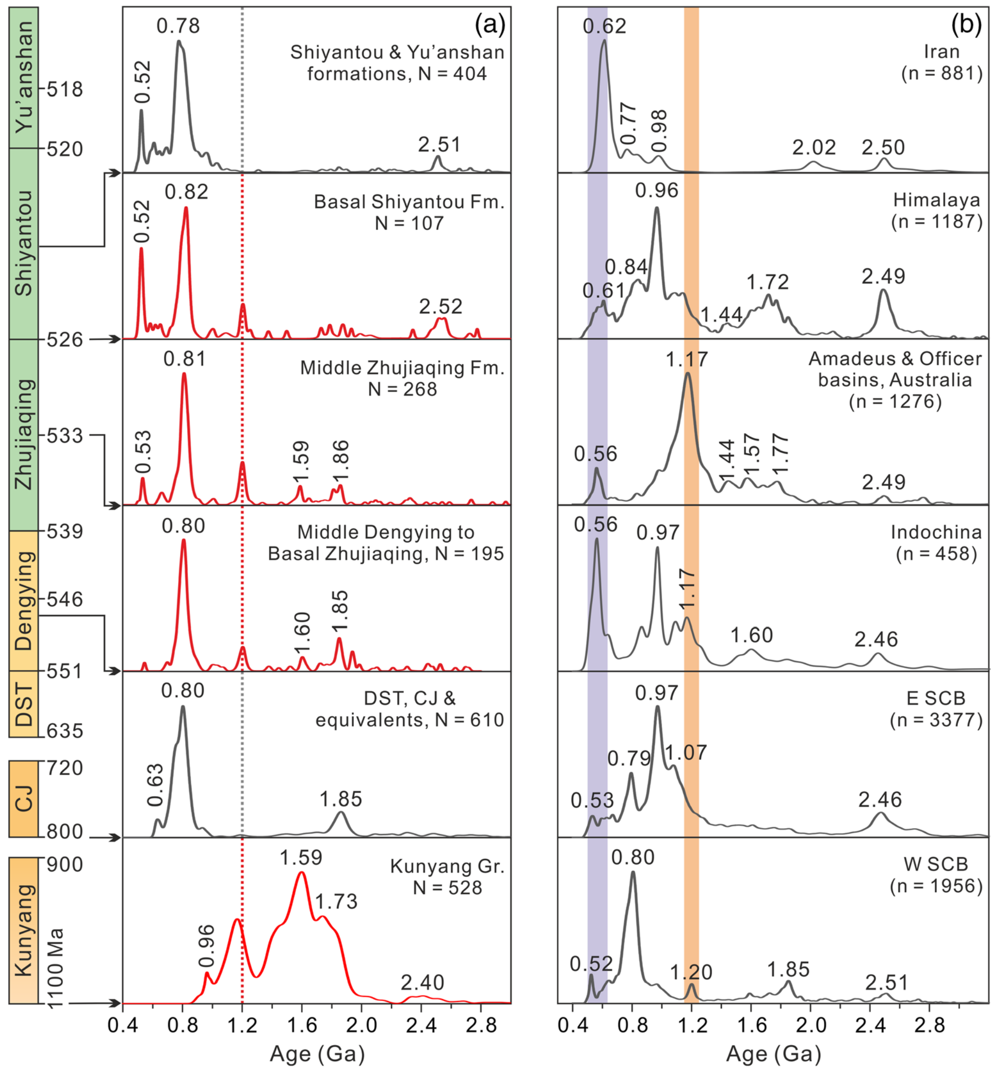

Figure 2. Detrital zircon U-Pb age spectra. (a) Stratigraphy and detrital zircon age spectra of late Mesoproterozoic-early Cambrian strata in eastern Yunnan Province of the SCB. The stratigraphic column with depositional ages are not to scale. The orange part of the column represents Precambrian units and the green Cambrian. The base line of each detrital zircon U-Pb age cumulative probability plot corresponds to the deposition time interval of the samples. Spectra with the ca. 1.20-Ga detrital zircon peak are shown in red. (b) Relative probability plots of detrital zircon ages for Ediacaran-Cambrian sedimentary rocks of SCB, Indochina, Australia, Himalaya, and Iran. Time interval of Gondwana assembly is highlighted in purple band, and the ca. 1.25- to 1.15-Ga age range in orange band. Abbreviations are: Gr = group; Fm = formation; DST = Doushantuo; CJ = Chengjiang. Data sources for detrital zircon U-Pb: (a) Kunyang Group (Liu et al., 2020; Sun et al., 2009; Wang et al., 2012), Chengjiang and Doushantuo formations and their equivalents (Wang et al., 2012; X. Zhou et al., 2018) and Shiyantou and Yu'anshan formations (Hofmann et al., 2016; Wang et al., 2012; Yang et al., 2018); (b) E SCB (Wang et al., 2010; K. Wang et al., 2018; Wang, Zeng, et al., 2018; Wu et al., 2010; Xu et al., 2013; Yao et al., 2014, 2015), Indochina (Kang et al., 2019; Wang et al., 2016; Zhao et al., 2017), Australia (Martin et al., 2017 and references therein; Yao et al., 2018), Himalaya (Gehrels et al., 2011; Martin et al., 2005; Myrow et al., 2010, 2016; Yin et al., 2010), and Iran (Etemad-Saeed et al., 2016; Honarmand et al., 2016; Horton et al., 2008).

A clear 1.20-Ga detrital zircon age peak is present in the Ediacaran-Cambrian transition strata (0.55–0.52 Ga) in the eastern Yunnan Province of the western SCB (Figure 2). Detrital zircon populations of that age from East Gondwana blocks have often been interpreted to be sourced from central and western parts of the Australian Continent (e.g., Keeman et al., 2020; Xu et al., 2013; Yao et al., 2018; Zhu et al., 2011), where late Mesoproterozoic igneous rocks are prevalent, such as those in the Musgrave Province and the Albany-Fraser Orogen (Keeman et al., 2020 and references therein). Although the 1.20-Ga detrital zircons from samples of this study share similar hafnium isotopes to those from Australia, zircons from the two areas

10.1029/2020GL090282

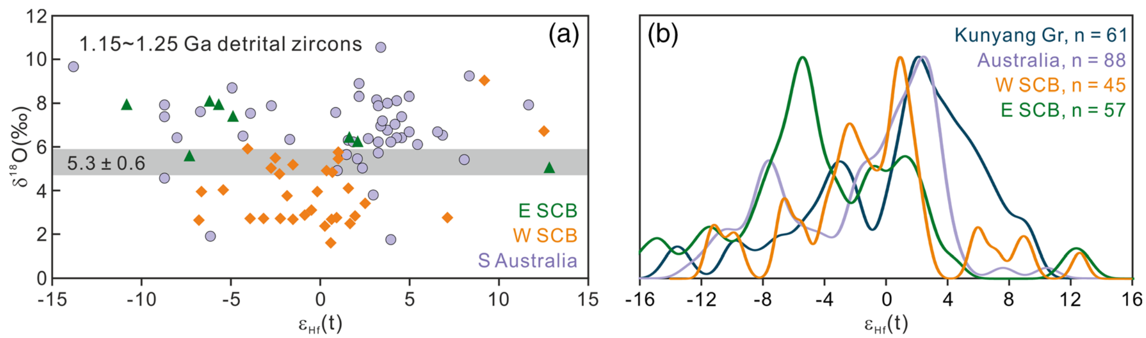

Figure 3. Detrital zircon Hf-O isotopic data of the 1.20-Ga population. (a) δ^{18}O values of ca. 1.15- to 1.25-Ga detrital zircons from the SCB and S Australia. (b) $\varepsilon_{Hf}(t)$ plots of ca. 1.15- to 1.25-Ga detrital zircons from Australia, Kunyang Group, and Ediacaran-Cambrian strata of the SCB. Data sources for (a) E SCB (Yao et al., 2014), W SCB (this study), and S Australia (Keeman et al., 2020); (b) Australia (Haines et al., 2016; Martin et al., 2017 and references therein), Kuangyang Group (H. Li et al., 2013; Liu et al., 2020), W SCB (this study), and E SCB (see data sources of their U-Pb data in Figure 2).

have different oxygen isotope signatures (Figure 3). Besides, Ediacaran-Cambrian strata of eastern SCB commonly lack this distinct age peak (Figure 2), and detrital zircons of 1.25–1.15 Ga from these strata show different hafnium isotopes from their counterparts in Australia (Figure 3). These differences indicate that the 1.20-Ga detrital zircon grains in the Ediacaran-Cambrian strata of the SCB were probably not derived from Australia.

A few late Mesoproterozoic magmatic rocks have been reported in western SCB, such as the 1.14-Ga Laowushan volcanic rocks in the eastern Yunnan Province (Greentree et al., 2006) and the 1.20- to 1.17-Ga intrusive rocks in the Ailaoshan-Diancangshan tectonic belt (Liu et al., 2020), which all show CHUR-like to depleted neodymium isotopes. The Mesoproterozoic-Neoproterozoic transitional Kunyang Group, widespread in western SCB, contains abundant late Mesoproterozoic detrital zircons with an age peak of 1.17 Ga (Liu et al., 2020; Sun et al., 2009; Wang et al., 2012). This zircon population in the Kunyang Group shares similar hafnium isotopes to the 1.20-Ga detrital zircon population reported in this study (Figure 3). The similarities in ages and Nd-Hf isotopes presented above indicate that the 1.20-Ga detrital zircons preserved in the Ediacaran-Cambrian transitional strata of eastern Yunnan Province were likely sourced from local late Mesoproterozoic magmatic rocks with possible additions from the recycled Kunyang Group zircons. This inference is consistent with the paleogeography of the western SCB during this time period, featuring a local uplift at the western margin of the SCB that provided detritus to northwestern Nanhua Basin (Figure 4; Hofmann et al., 2016; Liu and Xu, 1994).

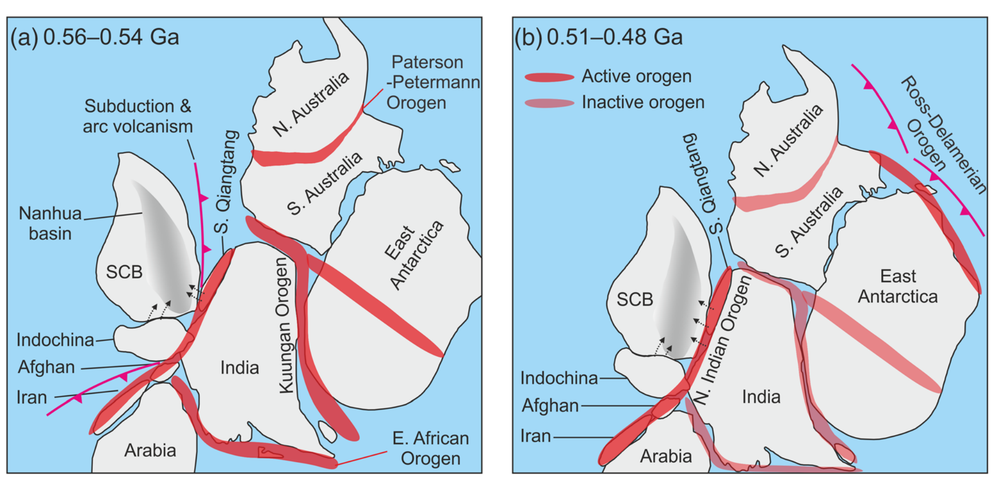

Figure 4. Paleogeographic reconstruction showing the assembly of East Gondwana during late (a) Ediacaran and (b) Cambro-Ordovician. Modified from Yao and Li (2016).

Detrital zircons of 0.52-Ga age from the Lower Cambrian strata have $\varepsilon_{Hf}(t)$ values ranging between −4.7 and +5.0 (mean value = −0.1) and a narrow range of $\delta^{18}O$ values between 6.8‰ and 8.9‰ (mean value = 7.6‰). No magmatic rocks with comparable ages have yet been identified in the SCB, except ash layers intercalated in the strata (e.g., Compston et al., 2008; Yang et al., 2017). It is noteworthy that tuff layers started to appear in western SCB Ediacaran-Cambrian strata from ca. 0.55 Ga (Figure 1c). The thickness of those ash layers, such as the 0.53-Ga ash layer in the Zhujiaqing Formation, can be as thick as several meters (Zhang et al., 1997), implying a proximal volcanic origin. We speculate that these Ediacaran-Cambrian transitional detrital zircons and ash beds were sourced from a syn-depositional magmatic arc associated with the collision of the SCB with Gondwanan (Figure 4).

4.2. When and how the SCB Collided With Gondwana?

Detrital zircon U-Pb data presented in this study illustrate that the provenance of clastic sediments in western SCB changed dramatically during the late Ediacaran (0.56–0.54 Ga), as shown by the appearance of both the unique 1.20-Ga zircon population from a local uplift and the 0.55- to 0.52-Ga tuff layers (Figure 2a). This sudden reappearance of volcanic ash deposits after tens of million years of nonvolcanic record (Yang et al., 2017; M. Zhou et al., 2018) close to the western margin of the SCB, along with the lack of same-aged volcanic activity in the SCB, can be best explained by the approaching of a magmatic arc to the SCB during that time. Together, these sudden changes in the sedimentary record indicate a significant change in the tectonic and paleogeographic environment for the western SCB; here, we interpret as reflecting the collision of the SCB with other Gondwanan blocks.

The appearance of the unique 1.20-Ga detrital zircon population in the SCB strata might be interpreted as representing the collision of the SCB with Australia (e.g., Cawood et al., 2013; W. Wang et al., 2018) during the assembly of Gondwana. However, as discussed above, detrital zircon Hf-O data do not support a collision of the SCB with Australia during the Ediacaran-Cambrian transitional period. Besides, Pan-African age detrital zircons with a peak of ca. 0.56 Ga (Figure 2) are found in post-orogenic Cambrian strata in northern Australia (Yao et al., 2018), but this detrital zircon population is absent in the Ediacaran-Cambrian strata of the SCB (Yao et al., 2014, 2015; this study). Instead, we prefer the zircons to have been sourced locally when a tectonic uplift formed at the western margin of the SCB caused by tectonic compression associated with the collision of SCB-Indochina with the assembling Gondwana from ca. 0.55 Ga (Figure 4a). The appearance of volcanic ashes in the study region (Figure 1) further support such an interpretation. We envisage that after break out from Rodinia after 0.72 Ga, the SCB started to approach an active magmatic arc north of the assembling Gondwana during the Ediacaran time (Z. Li et al., 2013). Although Yao et al. (2014) inferred a ca. 0.58-Ga starting age for the provenance connection between the SCB and Gondwana, our more precisely dated strata and unique tuff record from western SCB (Figure 1) refine this starting time to be ca. 0.55 Ga (Figure 4a).

Along the northern margin of the assembling East Gondwana, Ediacaran-Cambrian arc-related magmatic rocks were mainly reported from Iran (Moghadam et al., 2017), North Lhasa (Hu et al., 2018), and Himalayan areas (Cawood et al., 2007; Miller et al., 2001). The Iran Block was linked to northern margin of the East Gondwana neighboring the Arabia and Turkey blocks (Honarmand et al., 2016). The position of the Lhasa Block in East Gondwana is controversial. A distinctive detrital zircon population of ca. 1.17 Ga from Permian-Carboniferous metasedimentary rocks in the Lhasa Block has been interpreted as evidence supporting a Lhasa-NW Australia linkage in East Gondwana (Zhu et al., 2011). On the other hand, the spatial-temporal framework of the Ediacaran-Cambrian magmatism of the North Lhasa suggests that this block was likely located in the transitional area between the Arabian and Indian-Australian proto-Tethyan margins (Hu et al., 2018).

The tectonic transition from continental drift to collision during 0.56–0.54 Ga for the SCB coincides with the Cadomian magmatism preserved in Iran, North Lhasa, and Himalayan areas, indicating the SCB was probably located close to these areas during the Ediacaran-Cambrian transitional period. The SCB and Indochina were considered to be adjacent during the assembly of the Gondwana until they separated during the Devonian rifting (Torsvik & Cocks, 2013). Detrital zircon age spectra of Ediacaran-Cambrian samples from the SCB and Indochina (Figure 2) suggest that the united SCB-Indochina Continent has a closer provenance linkage with Himalayan areas. Accordingly, we propose that western SCB started its collision with NW India Block through Indochina at 0.56–0.54 Ga (Figure 4). This collision caused local uplift through far-field tectonic stress. The SCB-Indochina Continent then rotated clockwise relative to Gondwana during the Cambro-Ordovician period (Yao et al., 2014), leading to the closure of the V-shaped ocean and the formation of the 0.55- to 0.47-Ga North Indian Orogen (Figure 4). This configuration is consistent with the 0.56-Ga paleomagnetic data from the Yangtze Block (Zhang et al., 2015), 0.53-Ga metamorphism in the Cathaysia Block (Li et al., 2017), and sedimentary facies evolution of the Nanhua Basin (Yao and Li, 2016; Yao et al., 2015). However, the assembly model in this study is inconsistent with the proposed protracted SCB-India connection inferred by the 1.0- to 0.9-Ga detrital zircon population from Cryogenian-Paleozoic strata of the SCB (e.g., Cawood et al., 2018; Qi et al., 2018; Wang, Zeng, et al., 2018). This inconsistency could be reconciled given that at least part of the 1.0- to 0.9-Ga detrital zircons of SCB were locally derived as magmatic rocks with comparable ages are distributed in the SCB (Li et al., 2014, and references therein). Besides, paleomagnetic data (Zhang et al., 2015) and active continental margin along the northern India Block (Cawood et al., 2007; Miller et al., 2001) all argue against the proposed long-living SCB-India connection.

Data Availability Statement

Detrital zircon U-Pb age and Hf-O isotope data of this study are archived in the National Geoscience Data Centre (137485; https://www.bgs.ac.uk/services/ngdc/accessions/index.html?simpleText=137485).

Acknowledgments

This work was supported by the Strategic Priority Research Program (B) of the Chinese Academy of Sciences (XDB18030300) and the National Natural Science Foundation of China (41802029). Z. X. Li acknowledges the support of the Australian Research Council Laureate Fellow grant (FL150100133). The authors thank Prof. Lucy Flesch for editorial handling as well as Prof. Peter A. Cawood and an anonymous reviewer for constructive comments. This is a contribution to IGCP 648.

References

Cawood, P. A., Johnson, M. R., & Nemchin, A. A. (2007). Early Palaeozoic orogenesis along the Indian margin of Gondwana: Tectonic response to Gondwana assembly. *Earth and Planetary Science Letters*, *255*(1–2), 70–84. https://doi.org/10.1016/j.epsl.2006.12.006

Cawood, P. A., Wang, Y. J., Xu, Y. J., & Zhao, G. C. (2013). Locating South China in Rodinia and Gondwana: A fragment of greater India lithosphere? *Geology*, *41*(8), 903–906. https://doi.org/10.1130/G34395.1

Cawood, P. A., Zhao, G., Yao, J., Wang, W., Xu, Y., & Wang, Y. (2018). Reconstructing South China in Phanerozoic and Precambrian supercontinents. *Earth-Science Reviews*, *186*, 173–194. https://doi.org/10.1016/j.earscirev.2017.06.001

Compston, W., Zhang, Z. C., Cooper, J. A., Ma, G. G., & Jenkins, R. J. F. (2008). Further SHRIMP geochronology on the early Cambrian of South China. *American Journal of Science*, *308*(4), 399–420. https://doi.org/10.2475/04.2008.01

Etemad-Saeed, N., Hosseini-Barzi, M., Adabi, M. H., Miller, N. R., Sadeghi, A., Houshmandzadeh, A., & Stockli, D. F. (2016). Evidence for ca. 560 Ma Ediacaran glaciation in the Kahar formation, central Alborz Mountains, northern Iran. *Gondwana Research*, *31*, 164–183. https://doi.org/10.1016/j.gr.2015.01.005

Gehrels, G., Kapp, P., DeCelles, P., Pullen, A., Blakey, R., Weislogel, A., et al. (2011). Detrital zircon geochronology of pre-Tertiary strata in the Tibetan-Himalayan Orogen. *Tectonics*, *30*, TC5016. https://doi.org/10.1029/2011TC002868

Greentree, M. R., Li, Z. X., Li, X. H., & Wu, H. C. (2006). Late Mesoproterozoic to earliest Neoproterozoic basin record of the Sibao orogenesis in western South China and relationship to the assembly of Rodinia. *Precambrian Research*, *151*(1–2), 79–100. https://doi.org/10.1016/j.precamres.2006.08.002

Haines, P. W., Kirkland, C. L., Wingate, M. T. D., Allen, H., Belousova, E. A., & Gréau, Y. (2016). Tracking sediment dispersal during orogenesis: A zircon age and Hf isotope study from the western Amadeus Basin, Australia. *Gondwana Research*, *37*, 324–347. https://doi.org/10.1016/j.gr.2015.08.011

Hofmann, M. H., Li, X. H., Chen, J., MacKenzie, L. A., & Hinman, N. W. (2016). Provenance and temporal constraints of the early Cambrian Maotianshan shale, Yunnan Province, China. *Gondwana Research*, *37*, 348–361. https://doi.org/10.1016/j.gr.2015.08.015

Honarmand, M., Li, X. H., Nabatian, G., Rezaeian, M., & Etemad-Saeed, N. (2016). Neoproterozoic–early Cambrian tectono-magmatic evolution of the central Iranian Terrane, northern margin of Gondwana: Constraints from detrital zircon U–Pb and Hf–O isotope studies. *Gondwana Research*, *37*, 285–300. https://doi.org/10.1016/j.gr.2016.05.007

Horton, B. K., Hassanzadeh, J., Stockli, D. F., Axen, G. J., Gillis, R. J., Guest, B., et al. (2008). Detrital zircon provenance of Neoproterozoic to Cenozoic deposits in Iran: Implications for chronostratigraphy and collisional tectonics. *Tectonophysics*, *451*(1–4), 97–122. https://doi.org/10.1016/j.tecto.2007.11.063

Hu, P. Y., Zhai, Q. G., Wang, J., Tang, Y., Wang, H. T., & Hou, K. J. (2018). Ediacaran magmatism in the North Lhasa Terrane, Tibet and its tectonic implications. *Precambrian Research*, *307*, 137–154. https://doi.org/10.1016/j.precamres.2018.01.012

Jiang, G. Q., Sohl, L. E., & Christie-Blick, N. (2003). Neoproterozoic stratigraphic comparison of the Lesser Himalaya (India) and Yangtze Block (South China): Paleogeographic implications. *Geology*, *31*(10), 917–920. https://doi.org/10.1130/G19790.1

Kang, H., Li, D., Chen, Y., Song, L., Xue, G., Geng, J., et al. (2019). Micro-continental blocks in Gondwana assembly: Geological and geochemical evidence of the Indochina block, SE Tibetan Plateau. *Lithos*, *326–327*, 460–475. https://doi.org/10.1016/j.lithos.2019.01.002

Keeman, J., Turner, S., Haines, P. W., Belousova, E., Ireland, T., Brouwer, P., et al. (2020). New U-Pb, Hf and O isotope constraints on the provenance of sediments from the Adelaide Rift Complex—Documenting the key Neoproterozoic to early Cambrian succession. *Gondwana Research*, *83*, 248–278. https://doi.org/10.1016/j.gr.2020.02.005

Li, D., Ling, H. F., Shields-Zhou, G. A., Chen, X., Cremonese, L., Och, L., et al. (2013). Carbon and strontium isotope evolution of seawater across the Ediacaran–Cambrian transition: Evidence from the Xiaotan section, NE Yunnan, South China. *Precambrian Research*, *225*, 128–147. https://doi.org/10.1016/j.precamres.2012.01.002

Li, H. K., Zhang, C., Yao, C., & Xiang, Z. (2013). U-Pb zircon age and Hf isotope compositions of Mesoproterozoic sedimentary strata on the western margin of the Yangtze massif. *Science China Earth Sciences*, *56*(4), 628–639. https://doi.org/10.1007/s11430-013-4590-9

Li, L., Lin, S., Xing, G., Jiang, Y., & He, J. (2017). First direct evidence of Pan African Orogeny associated with Gondwana assembly in the Cathaysia block of southern China. *Scientific Reports*, *7*, 794. https://doi.org/10.1038/s41598-017-00950-x

Li, X. H., Li, W. X., Li, Z. X., Lo, C. H., Wang, J., Ye, M. F., & Yang, Y. H. (2009). Amalgamation between the Yangtze and Cathaysia blocks in South China: Constraints from SHRIMP U-Pb zircon ages, geochemistry and Nd-Hf isotopes of the Shuangxiwu volcanic rocks. *Precambrian Research*, *174*(1–2), 117–128. https://doi.org/10.1016/j.precamres.2009.07.004

Li, X. H., Li, Z. X., & Li, W. X. (2014). Detrital zircon U-Pb age and Hf isotope constrains on the generation and reworking of Precambrian continental crust in the Cathaysia Block, South China: A synthesis. *Gondwana Research*, *25*(3), 1202–1215. https://doi.org/10.1016/j.gr.2014.01.003

Li, Z. X., Evans, D. A., & Halverson, G. P. (2013). Neoproterozoic glaciations in a revised global palaeogeography from the breakup of Rodinia to the assembly of Gondwanaland. *Sedimentary Geology*, *294*, 219–232. https://doi.org/10.1016/j.sedgeo.2013.05.016

Liu, B., & Xu, X. (1994). *Atlas of lithofacies and paleogeography of South China* (p. 188). Beijing: Science Press. in Chinese with English abstract

Liu, H., Zi, J., Wang, Y., Cawood, P. A., Cui, X., & Zhang, L. (2020). Reconstructing South China in the Mesoproterozoic and its role in the Nuna and Rodinia supercontinents. *Precambrian Research*, *337*, 105558. https://doi.org/10.1016/j.precamres.2019.105558

Martin, A. J., DeCelles, P. G., Gehrels, G. E., Patchett, P. J., & Isachsen, C. (2005). Isotopic and structural constraints on the location of the main central thrust in the Annapurna Range, central Nepal Himalaya. *GSA Bulletin*, *117*(7), 926–944. https://doi.org/10.1130/B25646.1

Martin, E. L., Collins, W. J., & Kirkland, C. L. (2017). An Australian source for Pacific-Gondwanan zircons: Implications for the assembly of northeastern Gondwana. *Geology*, *45*(8), 699–702. https://doi.org/10.1130/G39152.1

Miller, C., Thoni, M., Frank, W., Grasemann, B., Klotzli, U., Guntli, P., & Draganits, E. (2001). The early Palaeozoic magmatic event in the northwest Himalaya, India: Source, tectonic setting and age of emplacement. *Geological Magazine*, *138*(3), 237–251. https://doi.org/10.1017/S0016756801005283

Moghadam, H. S., Li, X. H., Santos, J. F., Stern, R. J., Griffin, W. L., Ghorbani, G., & Sarebani, N. (2017). Neoproterozoic magmatic flare-up along the N. margin of Gondwana: The Taknar complex, NE Iran. *Earth and Planetary Science Letters*, *474*, 83–96. https://doi.org/10.1016/j.epsl.2017.06.028

Myrow, P. M., Hughes, N. C., Goodge, J. W., Fanning, C. M., Williams, I. S., Peng, S., et al. (2010). Extraordinary transport and mixing of sediment across Himalayan central Gondwana during the Cambrian–Ordovician. *GSA Bulletin*, *122*(9–10), 1660–1670. https://doi.org/10.1130/B30123.1

Myrow, P. M., Hughes, N. C., McKenzie, N. R., Pelgay, P., Thomson, T. J., Haddad, E. E., & Fanning, C. M. (2016). Cambrian–Ordovician orogenesis in Himalayan equatorial Gondwana. *GSA Bulletin*, *128*(11–12), 1679–1695. https://doi.org/10.1130/B31507.1

Qi, L., Xu, Y., Cawood, P. A., & Du, Y. (2018). Reconstructing Cryogenian to Ediacaran successions and paleogeography of the South China Block. *Precambrian Research*, *314*, 452–467. https://doi.org/10.1016/j.precamres.2018.07.003

Sun, W. H., Zhou, M. F., Gao, J. F., Yang, Y. H., Zhao, X. F., & Zhao, J. H. (2009). Detrital zircon U-Pb geochronological and Lu-Hf isotopic constraints on the Precambrian magmatic and crustal evolution of the western Yangtze Block, SW China. *Precambrian Research*, *172*(1–2), 99–126. https://doi.org/10.1016/j.precamres.2009.03.010

Torsvik, T. H., & Cocks, L. R. M. (2013). Gondwana from top to base in space and time. *Gondwana Research*, *24*(3–4), 999–1030. https://doi.org/10.1016/j.gr.2013.06.012

Wang, C., Liang, X., Foster, D. A., Fu, J., Jiang, Y., Dong, C., et al. (2016). Detrital zircon U–Pb geochronology, Lu–Hf isotopes and REE geochemistry constrains on the provenance and tectonic setting of Indochina Block in the Paleozoic. *Tectonophysics*, *677–678*, 125–134. https://doi.org/10.1016/j.tecto.2016.04.008

Wang, J., & Li, Z. X. (2003). History of Neoproterozoic rift basins in South China: Implications for Rodinia break-up. *Precambrian Research*, *122*(1–4), 141–158. https://doi.org/10.1016/S0301-9268(02)00209-7

Wang, K. X., Sun, L. Q., Sun, T., Huang, H., & Qin, L. S. (2018). Provenance, weathering conditions, and tectonic evolution history of the Cambrian meta-sediments in the Zhuguangshan area, Cathaysia Block. *Precambrian Research*, *311*, 195–210. https://doi.org/10.1016/j.precamres.2018.04.011

Wang, L. J., Yu, J., Griffin, W. L., & O'Reilly, S. Y. (2012). Early crustal evolution in the western Yangtze Block: Evidence from U-Pb and Lu-Hf isotopes on detrital zircons from sedimentary rocks. *Precambrian Research*, *222–223*, 368–385. https://doi.org/10.1016/j.precamres.2011.08.001

Wang, W., Zeng, M. F., Zhou, M. F., Zhao, J. H., Zheng, J. P., & Lan, Z. F. (2018). Age, provenance and tectonic setting of Neoproterozoic to early Paleozoic sequences in southeastern South China Block: Constraints on its linkage to western Australia-East Antarctica. *Precambrian Research*, *309*, 290–308. https://doi.org/10.1016/j.precamres.2017.03.002

Wang, Y. J., Zhang, F., Fan, W., Zhang, G., Chen, S., Cawood, P. A., & Zhang, A. (2010). Tectonic setting of the South China Block in the early Paleozoic: Resolving intracontinental and ocean closure models from detrital zircon U-Pb geochronology. *Tectonics*, *29*, TC6020. https://doi.org/10.1029/2010TC002750

Wu, L., Jia, D., Li, H. B., Deng, F., & Li, Y. Q. (2010). Provenance of detrital zircons from the late Neoproterozoic to Ordovician sandstones of South China: Implications for its continental affinity. *Geological Magazine*, *147*(6), 974–980. https://doi.org/10.1017/S0016756810000725

Xu, Y. J., Cawood, P. A., Du, Y., Hu, L., Yu, W., Zhu, Y., & Li, W. (2013). Linking South China to northern Australia and India on the margin of Gondwana: Constraints from detrital zircon U-Pb and Hf isotopes in Cambrian strata. *Tectonics*, *32*, 1547–1558. https://doi.org/10.1002/tect.20099

Yang, C., Li, X. H., Wang, X. C., & Lan, Z. W. (2015). Mid-Neoproterozoic angular unconformity in the Yangtze Block revisited: Insights from detrital zircon U-Pb age and Hf-O isotopes. *Precambrian Research*, *266*, 165–178. https://doi.org/10.1016/j.precamres.2015.05.016

Yang, C., Li, X. H., Zhu, M. Y., & Condon, D. J. (2017). SIMS U-Pb zircon geochronological constraints on upper Ediacaran stratigraphic correlations, South China. *Geological Magazine*, *154*(6), 1202–1216. https://doi.org/10.1017/S0016756816001102

Yang, C., Li, X. H., Zhu, M. Y., Condon, D. J., & Chen, J. Y. (2018). Geochronological constraint on the Cambrian Chengjiang biota, South China. *Journal of the Geological Society*, *175*(4), 659–666. https://doi.org/10.1144/jgs2017-103

Yao, W. H., & Li, Z. X. (2016). Tectonostratigraphic history of the Ediacaran–Silurian Nanhua foreland basin in South China. *Tectonophysics*, *674*, 31–51. https://doi.org/10.1016/j.tecto.2016.02.012

Yao, W. H., Li, Z. X., Li, W. X., Li, X. H., & Yang, J. H. (2014). From Rodinia to Gondwanaland: A tale of detrital zircon provenance analyses from the southern Nanhua Basin, South China. *American Journal of Science*, *314*(1), 278–313. https://doi.org/10.2475/01.2014.08

Yao, W. H., Li, Z. X., Li, W. X., Su, L., & Yang, J. H. (2015). Detrital provenance evolution of the Ediacaran–Silurian Nanhua foreland basin, South China. *Gondwana Research*, *28*(4), 1449–1465. https://doi.org/10.1016/j.gr.2014.10.018

Yao, W. H., Li, Z. X., Spencer, C. J., & Martin, E. L. (2018). Indian-derived sediments deposited in Australia during Gondwana assembly. *Precambrian Research*, *312*, 23–37. https://doi.org/10.1016/j.precamres.2018.05.006

Yin, A., Dubey, C. S., Webb, A. A. G., Kelty, T. K., Grove, M., Gehrels, G. E., & Burgess, W. P. (2010). Geologic correlation of the Himalayan Orogen and Indian Craton: Part 1. Structural geology, U-Pb zircon geochronology, and tectonic evolution of the Shillong Plateau and its neighboring regions in NE India. *GSA Bulletin*, *122*(3–4), 336–359. https://doi.org/10.1130/B26460.1

Zhang, J. M., Li, G. X., & Zhou, C. M. (1997). Advances in the study of the geological age of late Cretaceous strata in southwestern Henan. *Journal of Stratigraphy*, *21*(2), 91–99. (in Chinese with English abstract)

Zhang, S. H., Li, H., Jiang, G., Evans, D. A., Dong, J., Wu, H., et al. (2015). New paleomagnetic results from the Ediacaran Doushantuo Formation in South China and their paleogeographic implications. *Precambrian Research*, *259*, 130–142. https://doi.org/10.1016/j.precamres.2014.09.018

Zhao, T., Feng, Q., Metcalfe, I., Milan, L. A., Liu, G., & Zhang, Z. (2017). Detrital zircon U-Pb-Hf isotopes and provenance of late Neoproterozoic and early Paleozoic sediments of the Simao and Baoshan blocks, SW China: Implications for Proto-Tethys and Paleo-Tethys evolution and Gondwana reconstruction. *Gondwana Research*, *51*, 193–208. https://doi.org/10.1016/j.gr.2017.07.012

Zhou, M. Z., Luo, T., Huff, W. D., Yang, Z., Zhou, G., Gan, T., et al. (2018). Timing the termination of the Doushantuo negative carbon isotope excursion: Evidence from U-Pb ages from the Dengying and Liuchapo formations, South China. *Science Bulletin*, *63*(21), 1431–1438. https://doi.org/10.1016/j.scib.2018.10.002

Zhou, X., Yu, J. H., O'Reilly, S. Y., Griffin, W. L., Sun, T., Wang, X., et al. (2018). Component variation in the late Neoproterozoic to Cambrian sedimentary rocks of SW China–NE Vietnam, and its tectonic significance. *Precambrian Research*, *308*, 92–110. https://doi.org/10.1016/j.precamres.2018.02.003

Zhu, D. C., Zhao, Z., Niu, Y., Dilek, Y., & Mo, X. (2011). Lhasa Terrane in southern Tibet came from Australia. *Geology*, *39*(8), 727–730. https://doi.org/10.1130/G31895.1

Zhu, M. Y., Li, G. X., Zhang, J. M., Steiner, M., Qian, Y., & Jiang, Z. W. (2001). Early Cambrian stratigraphy of East Yunnan, southwestern China: A synthesis. *Acta Palaeontologica Sinica*, *40*(sup), 4–39.

Zhu, M. Y., & Li, X. H. (2017). Introduction: From snowball Earth to the Cambrian explosion-evidence from China. *Geological Magazine*, *154*(6), 1187–1192. https://doi.org/10.1017/S0016756817000644

Zhu, M. Y., Zhang, J. M., & Yang, A. H. (2007). Integrated Ediacaran (Sinian) chronostratigraphy of South China. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *254*(1–2), 7–61. https://doi.org/10.1016/j.palaeo.2007.03.025

References From the Supporting Information

Li, X. H., Liu, Y., Li, Q. L., Guo, C. H., & Chamberlain, K. R. (2009). Precise determination of Phanerozoic zircon Pb/Pb age by multicollector SIMS without external standardization. *Geochemistry, Geophysics, Geosystems*, *10*, Q04010. https://doi.org/10.1029/2009GC002400

Li, X. H., Long, W. G., Li, Q. L., Liu, Y., Zheng, Y. F., Yang, Y. H., et al. (2010). Penglai zircon megacrysts: A potential new working reference material for microbeam determination of Hf–O isotopes and U–Pb age. *Geostandards and Geoanalytical Research*, *34*(2), 117–134. https://doi.org/10.1111/j.1751-908X.2010.00036.x

Wu, F. Y., Yang, Y. H., Xie, L. W., Yang, J. H., & Xu, P. (2006). Hf isotopic compositions of the standard zircons and baddeleyites used in U–Pb geochronology. *Chemical Geology*, *234*(1–2), 105–126. https://doi.org/10.1016/j.chemgeo.2006.05.003