



## Supplementary Materials for

### **The dawn of the Phanerozoic: A transitional fauna from the late Ediacaran of Southwest China**

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#### **Other Supplementary Material for this manuscript includes the following:**

MDAR Reproducibility Checklist  
Data S1

## Materials and Methods

### Provenance

All specimens were collected from the Qingshuigou and Shanglijiao localities in Jiangcheng, Jiangchuan County, Yuxi City, Yunnan Province, China, by a team led by Fan Wei and Peiyun Cong, with Gaorong Li, Xiaodong Wang and Wenwen Wen during multiple sessions of fieldwork 2022-2025. Luke A. Parry and Frances S. Dunn joined one field trip in 2024. Fossil bearing horizons at both localities belong to the middle to upper part of the Jiucheng Member, Dengying Formation, constrained to the late Ediacaran (see below). All fossils in this study are deposited in Yunnan University as part of the collections of Yunnan Geology, Invertebrate Paleontology (YNGIP). The quantities of potential fossils of each animal taxon are detailed in Table S1. 35 specimens are shown in this study, with accession numbers ranging sequentially from YNGIP90301 to YNGIP90335. The fossils and all images can be accessed by contacting Peiyun Cong (cong@ynu.edu.cn).

### History of discovery and further details of geological setting

The Jiangchuan Biota was named in 1999 based on diverse macroalgae from the Ediacaran Jiucheng Member of the Dengying Formation at Qingshuigou(1, 54-56). The Upper Ediacaran in eastern Yunnan is recorded in the Dengying Formation and the underlying Lunasi Formation, with the former including the Donglongtan, Jiucheng, and Baiyanshao Members(57). The new fossils were all collected from the middle to upper part of the Jiucheng Member in Fuxian lake area, Yuxi, Yunnan Province, China (Fig. 1).

The study of the Jiangchuan Biota began in the 1980s, before it was named, when carbonaceous macroalgal fossils were first reported in Jiucheng Member siltstone(58). Further work in this century described the Jiangchuan Biota as characterized by macroalgae, with classical Proterozoic taxa *Longfengshania* and *Tawuia* dominating, alongside various unidentified macrofossils(1, 54). In recent years, several reports have described potential metazoan fossils such as *Lobodiscus* (a trilobozoan)(2-4, 55). In addition, the lower part of the Jiucheng Member has been shown to yield abundant *Shaanxilithes*(59), a tubular fossil now interpreted as a metazoan body fossil rather than as a trace fossil(60).

The Dengying Formation is exposed across the Yangtze block as three members which can be correlated lithostratigraphically. In the study region of eastern Yunnan, these are the Donlongtan, fossiliferous Jiucheng studied here and Baiyanshao members, whereas in southern Shaanxi they are the Algal dolomite, Gaojiashan and Beiwan members and in western Hubei they are the Hamajing, Shibantan and Baimatuo members(61, 62). Additionally, the occurrence of *Shaanxilithes* has been proposed as a potential biostratigraphic marker to correlate the Dengying Formation across these three regions(63-65). In southern Shaanxi, the Gaojiashan Biota occurs above *Shaanxilithes* in the Gaojiashan Member (64). The Jiangchuan Biota also sits above *Shaanxilithes* in the Jiucheng Member. In contrast, the Shibantan Biota from western Hubei is found below *Shaanxilithes* in the Shibantan Member(63, 66).

### Age constraints

The correlation based on *Shaanxilithes* among fossil localities across South China constrains the Jiucheng Member as a latest Ediacarian deposit (<ca. 550 Ma) (64, 65). This is consistent with the most recent U-Pb zircon CA-ID TIMS dating of the Jiucheng Member in Eastern Yunnan. The base of the Jiucheng Member was dated to  $\leq 554.3 \pm 0.6$  Ma (Feidatian-Dongdahe and Xiaolantian sections, Eastern Yunnan), with the middle part dated to  $546.3 \pm 0.7$  Ma (Yinchangpo section, Northeastern Yunnan) (52, 67). In the Qingshuigou section, the Jiangchuan biota occurs above the last occurrence of *Shaanxilithes* (4), which is also confirmed by our work in this section and the adjacent Shanglijiao section (Fig. 1A). However, the Jiangchuan Biota has not been reported from the Yingchangpo locality, so it remains somewhat ambiguous whether the  $546.3 \pm 0.7$  Ma age constrains its first occurrence (67). The contact between the Dengying and overlying Zhujiaping Formation is interpreted as the Ediacaran-Cambrian boundary (68), providing a minimum age of 539 Ma on the Jiucheng Member (52, 57, 69). Therefore, we can conclude that the Jiangchuan Biota must have been preserved during the terminal Ediacaran, at least between 554 and 539 Ma, and possibly between ~546 and 539 Ma.

### Methods

Optical photographs were taken under polarized light using a Canon EOS 80D camera fitted with Canon AF/MF 100 mm or Canon MP-E 65mm lenses.

Reflectance transformation images (RTI) were acquired with a Canon EOS 650D and AF/MF 100 mm lens through a Broncolor Scope D50 (Bron Elektronik AG, Switzerland) featuring 48 individual LED lights. RTI files were processed using RelightLab 2024.11 (70) and analyzed in RTIViewer 1.1.0 (71). Images were processed using specular enhancement mode to remove chromatic information and optimize contrast. Specimens were illuminated from the northwest (Fig. 2I) to enhance topographic features. Normals visualization (Fig. 2F, J) colors individual pixels based on the orientation of the vector that is normal to that pixel on the specimen surface, therefore providing information on the 3D structure of the specimen.

Fluorescence images were acquired using a Nikon SMZ25 stereomicroscope with fluorescence modules, employing excitation wavelengths of 450-490 nm (yellow) and 622-780 nm (red), with exposure durations up to 50-70 s.

Backscattered electron (BSE) micrographs and energy dispersive X-ray spectroscopy (EDS) elemental mapping were captured using an FEI Quanta 650 FEG electron microscope equipped with an EDAX energy-dispersive X-ray spectrometer under low-vacuum. BSE imaging parameters included 20 kv accelerating voltage, 13.3 mm working distance, 70 Pa chamber pressure. EDS elemental maps were acquired at 25-30 kv accelerating voltage, with 11-13 mm work distance, 70 Pa chamber pressure and an average count rate exceeding 8000 cps.

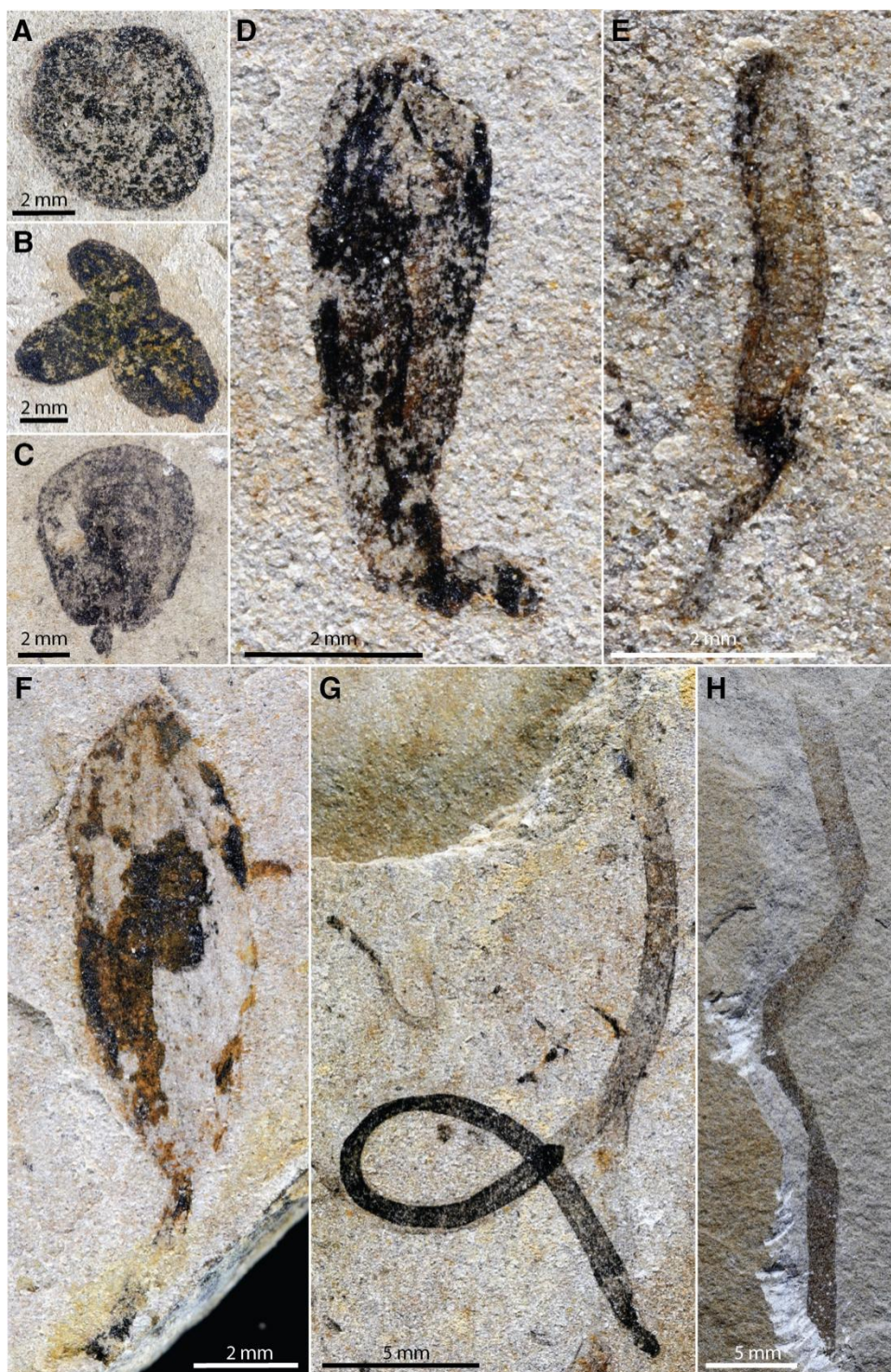
## Macroalgae and Animal co-occurrence

The Jiangchuan Biota comprises a mixed assemblage of macroalgae, Ediacaran-type, non-bilaterian, and bilaterian animals, with macroalgae dominating in volume. Macroalgal fossils exhibit a relatively widespread distribution within the Jiucheng Member, whereas animal fossils are concentrated on specific horizons. Superimposed occurrences of animals and macroalgae are exceedingly rare – we report only six instances of animals superimposed with macroalgal fossils. Macroalgae are predominantly benthic, sessile and small (commonly < 20 mm). Different morphologies and sizes of macroalgal fossils are often preserved on the same slab.

## Trace Fossils

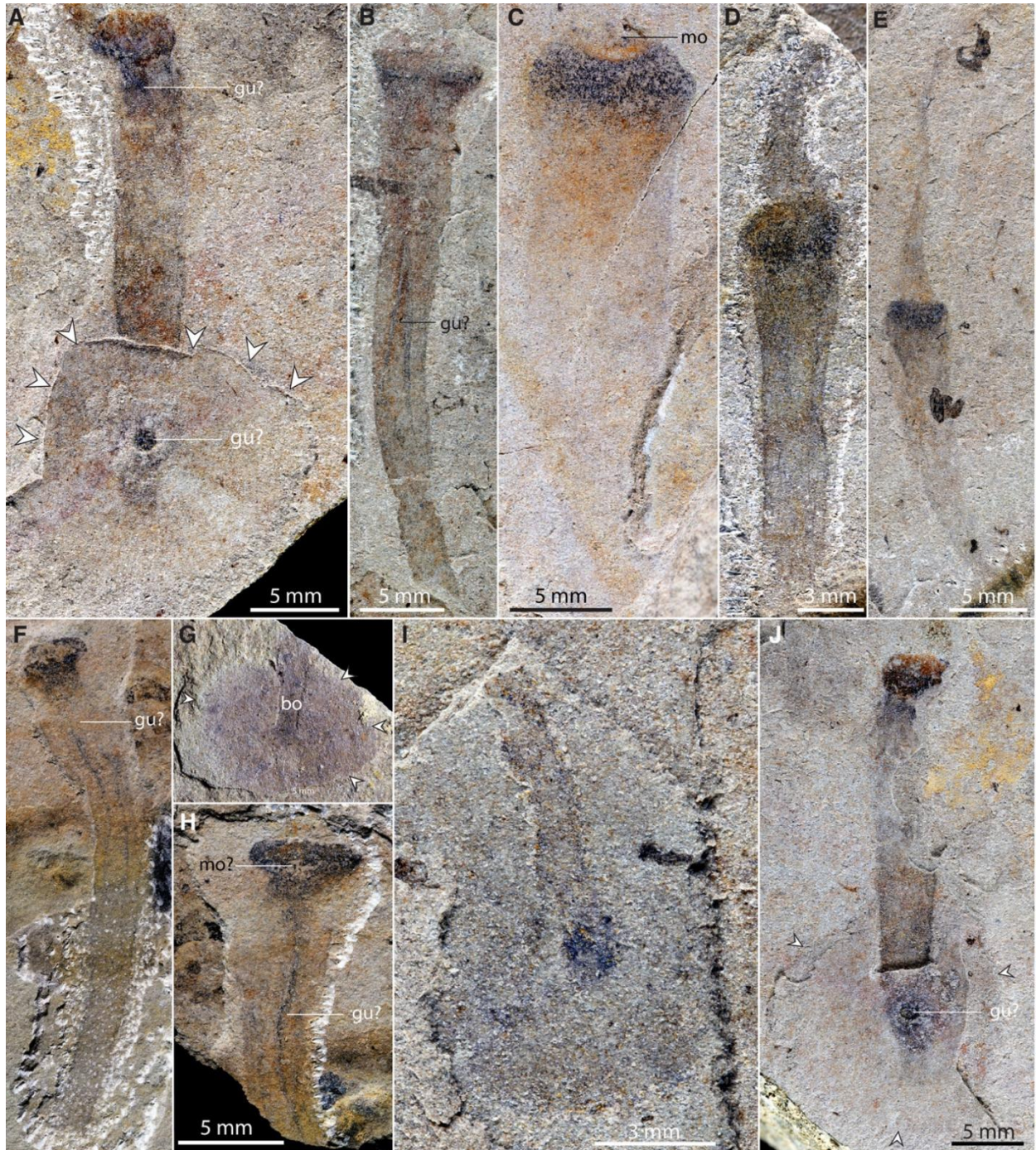
The Jiangchuan Biota includes a variety of metazoan traces, although not within the same beds as the body fossils (fig. S6). The trace fossils sit in positive relief to their thin-, medium-bedded, silty mudstone hosts and are meandering, linear, or sometimes intersecting with each other. They sit parallel to or slightly inclined to the sedimentary surface. The diameter of their exposed relief is irregular, even in the same specimen, ranging from 2.5-5.0 mm as the burrows are very shallowly interstratal, resulting in variations in exposed width during splitting. Their external surface is smooth, sometimes ornamented with subtle transverse striations. Trace fossil morphology is comparable to that of *Palaeophycus* which is recognized as *Domichnia* (72) and inferred to be formed by bilaterians(32).





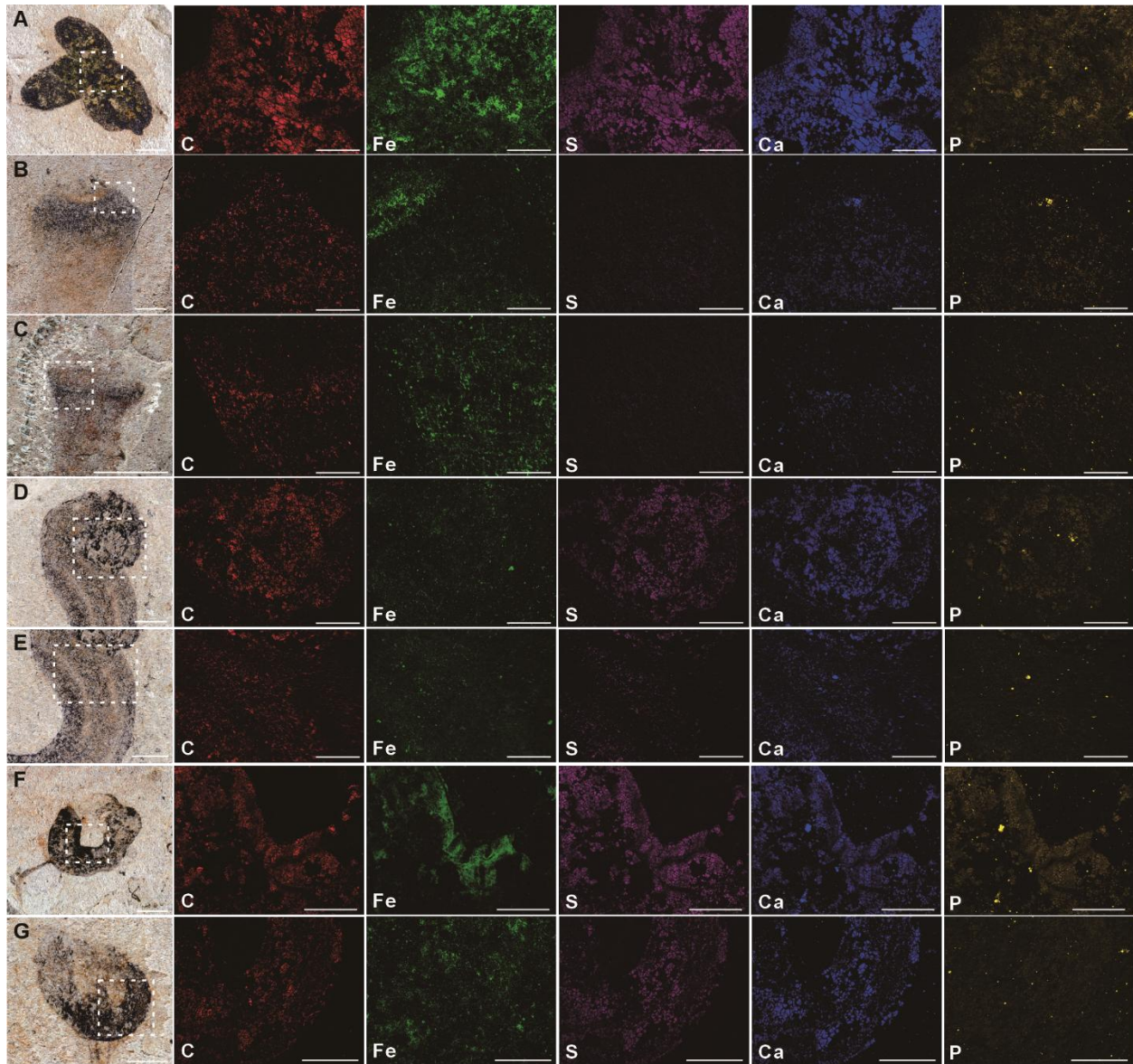
**Fig. S1. Details of representative macroalgal fossils from the Jiangchuan Biota.** (A) *Chuaria circularis*, YNGIP90317. (B) *Tauwia danlensis*, YNGIP90316. (C) *Longfengshania spheria*, YNGIP90318. (D) *Houjiashania yuxiensis*, YNGIP90319. (E) *Longfengshania elongata*, YNGIP90320. (F) *Longfengshania fusiformis*, YNGIP90321. G-H) *Vendotaenia antiqua*, YNGIP90322 and YNGIP90323.





**Fig. S2. Details of specimens of the vermiform bilaterian with holdfast disc.** (A, J) YNGIP90324, showing the holdfast disc, with possible gut (gu?) running down the length of the animal. Margins of the holdfast disc are indicated with white arrows. Anterior region is not everted (B-E) (YNGIP90307-90310) showing the transition from contracted to everted anterior region, with (E) showing the maximal eversion present in our fossil population. Anterior regions of the specimens in (B-E) are figured in main text Fig. 3, but images of the complete specimens are provided here. (F, H) YNGIP90331A/B. (G) YNGIP90332. (I) YNGIP90333.





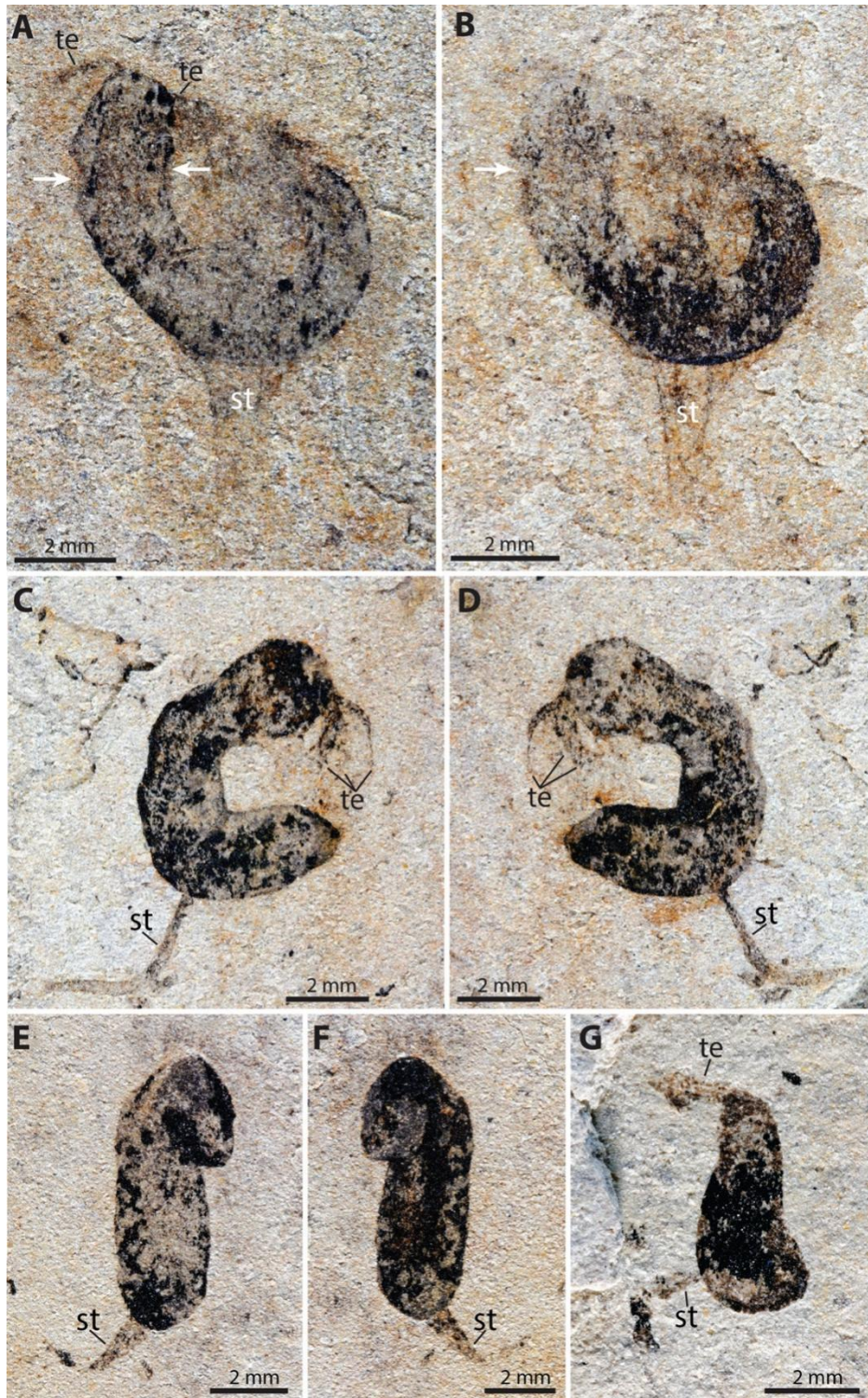
**Fig. S3. SEM-EDS elemental maps of fossils from the Jiangchuan Biota.** (A) Macroalgal fossil, *Tawuia*, YNGIP90316. (B-C) Bilateralian worm with eversible anterior region, YNGIP90308 and YNGIP90307. (D-E) Bilateralian worm with terminal mouth, YNGIP90311. (F-G) Possible cambroernid deuterostomes, YNGIP90315 and YNGIP90314. Carbon (C) is relatively enriched in macroalgae, exhibiting the thickest carbonaceous films, whereas its distribution in metazoans is more dispersed, with a slightly more concentrated distribution observed in potential Cambroernids. The distributions of iron (Fe), sulfur (S) and calcium (Ca) largely parallel that of carbon, though their concentrations are relatively lower in certain fossils e.g., (C) and (E). Phosphorus content and distribution is less pronounced reflecting limited phosphatization. Scale bars: 5mm (C), 2mm (A-B, D-G), 1mm (elemental maps).





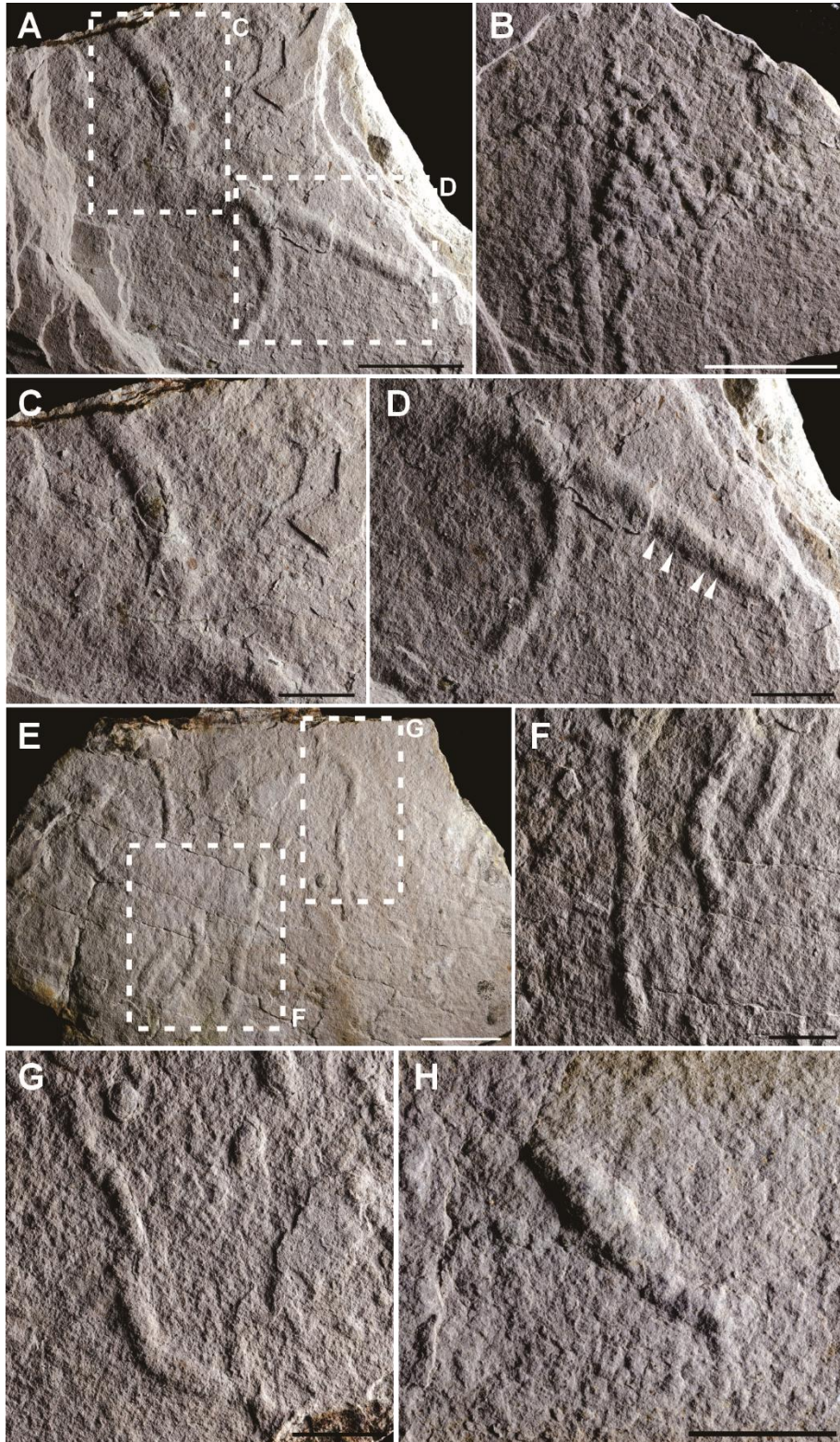
**Fig. S4. *Haootia*-like fossils from the Jiangchuan Biota.** (A-C) YNGIP90301(A-B) and YNGIP(C) are shown in Fig. 2 of the main text, where B is the counterpart of A. (D-E) Potential *Haootia*-like fossils, YNGIP90334 (D) and YNGIP 90335 (E), both of which exhibit an upper bifurcated morphology with filaments.



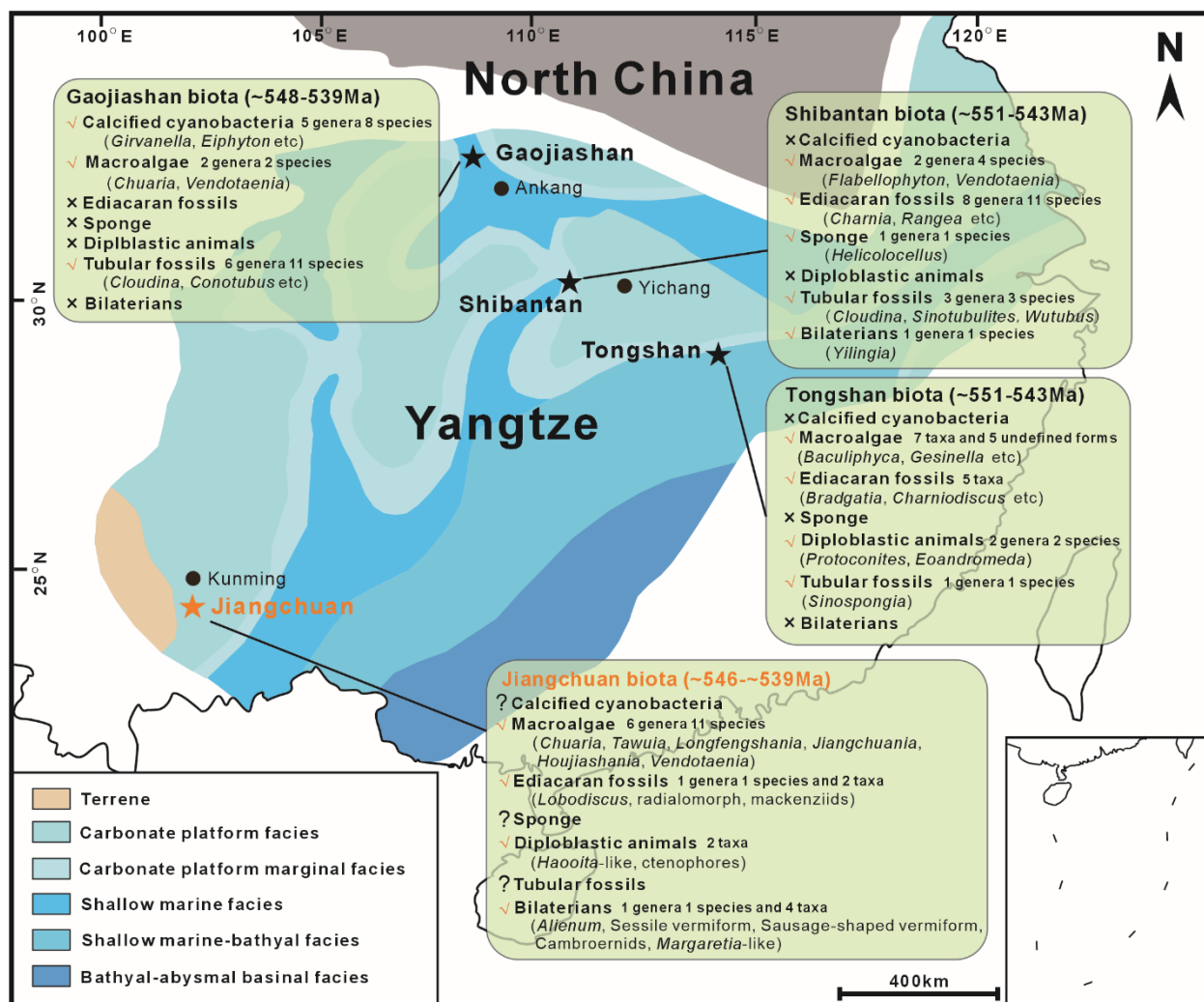


**Fig. S5. Deuterostome fossils from the Jiangchuan Biota.** (A-B) Part and counterpart of *Herpetogaster*-like animal (YNGIP90314) with a thick, central stalk similar to *Phlogites*. White arrows indicate invaginations between the head and trunk which may represent the location of pharyngeal pores, as in *Herpetogaster*. (C-D) Part and counterpart of *Herpetogaster*-like animal (YNGIP90315) with thin and sinuous stalk. (E-G) Cambroernid fossils (E-F = part and counterpart), YNGIP90329 (E-F) and YNGIP90330 (G), preserved in lateral or oblique view, so not all anatomical features are visible. Scale bars: 2mm. Abbreviations: te = tentacles, st = stalk.





**Fig. S6. Trace fossils from the Jiangchuan Biota.** (A-B, E, H) *Palaeophycus*-like trace fossils, YNGIP90325 (A), YNGIP90326 (B), YNGIP90327 (E) and YNGIP90328 (H). (C-D) Close-up of the white box in (A), showing faint transverse striations on the surface by white arrows in D. (F-G) Close-up of the white box in (E), indicating the raised sinuous morphology. Scale bars: 20mm (A, B, E); 10mm (C-D, F-H).



**Fig. S7. Sedimentary facies and locations of major Yangtze fossil assemblages with biodiversity during the Late Ediacaran.** Orange “✓” and black “×” indicate the presence or absence of each fossil type, respectively. For those fossils present, diversity data reported in the literature are listed, followed by representative genera. Sedimentary facies of South China during the Late Ediacaran is adopted from (73). Biodiversity data of the Jiangchuan Biota from this study and (1-4, 54, 59, 74), the Shibantan Biota from (32, 43, 66, 75-79), the Gaojiashan Biota from (80-85) and the Tongshan Biota is from (86).



**Table S1. The number of non-algal specimens for each taxon in the Jiangchuan Biota.**

<b>Taxon</b>	<b>Number of Specimens</b>
Radialomorph	1
<i>Haootia</i> -like specimens	6
Potential ctenophores	1
<i>Mackenzia</i> -like specimens	2
Sessile vermiform animal	185 (including 56 bodies with associated holdfast and 31 with probably guts)
Sausage-shaped vermiform animal	1
Cambroernids	4
<i>Margaretia</i> -like tubes	4
Trace fossils	15

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