

## **Supplemental Material**

### **Biomineralization of the Cambrian chancelloriids**

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## FOSSIL DISTRIBUTION, PRESERVATION, AND REPOSITORY

Chancelloriid sclerites investigated in this study are collected from six rock successions that located in two continents (Tables S1 and S2; Fig. S1), including Xinji Formation (Cambrian Stages 3) in the Chaijiawa section (abbreviated to LC), southwestern margin of North China platform; Ajax Limestone (Stage 3) in the section AJX-M in Mt. Scott Range, Flinders Ranges of South Australia; Wirrapowie Limestone (lower Stage 3) and Mernmerna Formation (Stage 3) in the section MOG in the Moro Gorge, Arrowie Syncline, Flinders Ranges of South Australia; Mernmerna Formation in the section HUL, Flinders Ranges of South Australia; Mount Terrible Formation (Stage 2) in the Mt. Terrible area (MTF), Fleurieu Peninsula of South Australia; Monastery Creek Formation (Stage 4 to Wuliuan Stage) in the Georgina Basin of Queensland, Australia. Detailed geological and stratigraphical information was documented by Betts *et al.* (2017), Yun *et al.* (2016), Jacquet *et al.* (2016), and Dunster *et al.* (2007). The studied fossil taxa include *Chancelloria* cf. *eros* Walcott, 1920 (all from LC), *C. racemifundis* Bengtson in Bengtson *et al.*, 1990 (from AJX-M and HUL), *C. sp.* (from AJX-M, HUL, ROG-N and MOG), *Archiasterella hirundo* Bengtson in Bengtson *et al.*, 1990 (all from AJX-M), *Ar. pentactina* Sdzuy, 1969 (from AJX-M and LC), *Allonnia tripodophora* Doré & Reid, 1965 (from AJX-M and HUL), and *Eremactis mawsoni* Bengtson and Conway Morris in Bengtson *et al.*, 1990 (from MTF).

Specimens from North China are mostly preserved through preservational types 1 and 2, and usually possess fibrous features on the surface. Specimens from Australia are mainly preserved in types 3 and 4, composed of not only internal molds and steinkerns but also aggregations of blade-shaped phosphatic and clay minerals associated with the outer thin layer that displays as wrinkled and ornamented appearance (Fig 1 and Fig. S2A–J).

Soft-bodied specimens of *Allonnia phrixothrix* Bengtson & Hou, 2001 are from the Chengjiang biota (Yu'an Shan Formation, Cambrian Stage 3) in the Sanjiezi (SJZ) section, Kunming area, China (Zhang *et al.*, 2001).

Fossil specimens from the Xinji Formation and Chengjiang biota are stored in the Shaanxi Key Laboratory of Early Life and Environments (LELE), Northwest University, China. The prefix ELI of the collection number is short for the Early Life Institute of Northwest University. Specimens from the lower to middle Cambrian limestones of Australia are deposited in the Palaeobiological Lab of Macquarie University (prefix: MPAL), Australia.

## References Cited

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**Table S1.** Chancelloriid species investigated to reveal the microstructure. Information of the soft-bodied specimens is highlighted by grey shading.

Stage of Cambrian	Section	Formation	Location	Species
middle Stage 2	MTF	Mt. Terrible	Fleurieu Peninsula, Australia	<i>Eremactis mawsoni</i>
lower Stage 3	MOG	Wirrapowie Limestone	Flinders Ranges, Australia	<i>Chancelloria</i> sp.
lower to middle Stage 3	AJX-M	Ajax Limestone	Flinders Ranges, Australia	<i>Chancelloria racemifundis</i> , <i>C. sp.</i> , <i>Archiasterella hirundo</i> , <i>Ar. pentactina</i> , <i>Allonnia tripodophora</i>
middle Stage 3	HUL	Mernmerna	Flinders Ranges, Australia	<i>Chancelloria racemifundis</i> , <i>C. sp.</i> , <i>Al. tripodophora</i> , ? <i>E. sp.</i>
middle Stage 3	SJZ	Yu'anshan	Kunming, Yunnan Province China	<i>Allonnia phrixothrix</i>
uppermost Stage 3	LC	Xinji	Longxian County, Shaanxi Province, China	<i>Chancelloria</i> cf. <i>eros</i> , <i>C. sp.</i> , <i>Ar. pentactina</i> , <i>Al. tripodophora</i>
upper Stage 4 to Wuliuan Stage	ROG-N	Monastery Creek	Georgina Basin, Queensland, Australia	<i>Chancelloria</i> sp.

**Table S2.** Details of the figured specimens.

<b>Figure number specimen first shown</b>	<b>Specimen number</b>	<b>Species</b>	<b>Section</b>
figure 1A	MPAL 0736	<i>Chancelloria</i> sp.	AJX-M
figure 1B	Thin Section lc05-01-02	<i>Chancelloria</i> sp.	LC
figure 1C	ELI LC06-11011	<i>Chancelloria</i> cf. <i>eros</i>	LC
figure 1D	Thin Section lc05-02-03	<i>Chancelloria</i> sp.	LC
figure 1E	MPAL 0737	<i>Chancelloria</i> sp.	MOG
figure 1F	Thin Section lc05-02-01	<i>Chancelloria</i> sp.	LC
figure 1G	MPAL 0738	<i>Chancelloria</i> sp.	MOG
figure 1H	Thin Section lc05-07-01	<i>Chancelloria</i> sp.	LC
figure 2A	MPAL 0739	<i>Chancelloria racemifundis</i>	HUL
figure 2D	MPAL 0740	<i>Chancelloria racemifundis</i>	HUL
figure 2F	MPAL 0742	<i>Chancelloria</i> sp.	HUL
figure 2H	MPAL 0751	<i>Archiasterella hirundo</i>	HUL
figure 2J	MPAL 0743	<i>Chancelloria</i> sp.	MOG
figure 2K	MPAL 0744	<i>Archiasterella hirundo</i>	AJX-M
figure 2M	MPAL 0741	<i>Archiasterella hirundo</i>	AJX-M
figure 2Q	MPAL 0748	<i>Chancelloria</i> sp.	HUL
figure 2U	MPAL 0755	<i>Allonnia tripodophora</i>	AJX-M
figure 3A	ELI LC06-01026	<i>Chancelloria</i> cf. <i>eros</i>	LC
figure 3D	ELI LC06-04003	<i>Chancelloria</i> cf. <i>eros</i>	LC
figure 3F	ELI LC03-01059	<i>Chancelloria</i> cf. <i>eros</i>	LC
figure 3H	ELI LC06-04011	<i>Chancelloria</i> cf. <i>eros</i>	LC
figure 3J	MPAL 0745	<i>Chancelloria</i> sp.	ROG-N
figure 3L	ELI LC06-20079	<i>Chancelloria</i> cf. <i>eros</i>	LC
figure 3N	ELI LC06-27025	? <i>Chancelloria</i> cf. <i>eros</i>	LC
figure S2A	ELI LC06-07019	<i>Allonnia tripodophora</i>	LC
figure S2C	MPAL 0746	<i>Chancelloria racemifundis</i>	HUL
figure S2E	MPAL 0747	<i>Chancelloria</i> sp.	ROG-N
figure S2G	MPAL 0749	<i>Allonnia tripodophora</i>	HUL
figure S2I	MPAL 0750	<i>Chancelloria</i> sp.	HUL

figure S2K	MPAL 0752	<i>Chancelloria</i> sp.	HUL
figure S2M	MPAL 0753	<i>Chancelloria</i> sp.	HUL
figure S2O	MPAL 0754	<i>Archiasterella pentactina</i>	AJX-M
figure S3A	MPAL 0756	<i>Eremactis mawsoni</i>	MTF
figure S3C	ELI LC03-05076	<i>Chancelloria</i> sp.	LC
figure S3E	ELI LC06-23003	<i>Chancelloria</i> cf. <i>eros</i>	LC
figure S3H	MPAL 0757	<i>Chancelloria</i> sp.	ROG-N
figure 4A	ELI SJZ-B03-179A	<i>Allonnia phrixothrix</i>	SJZ

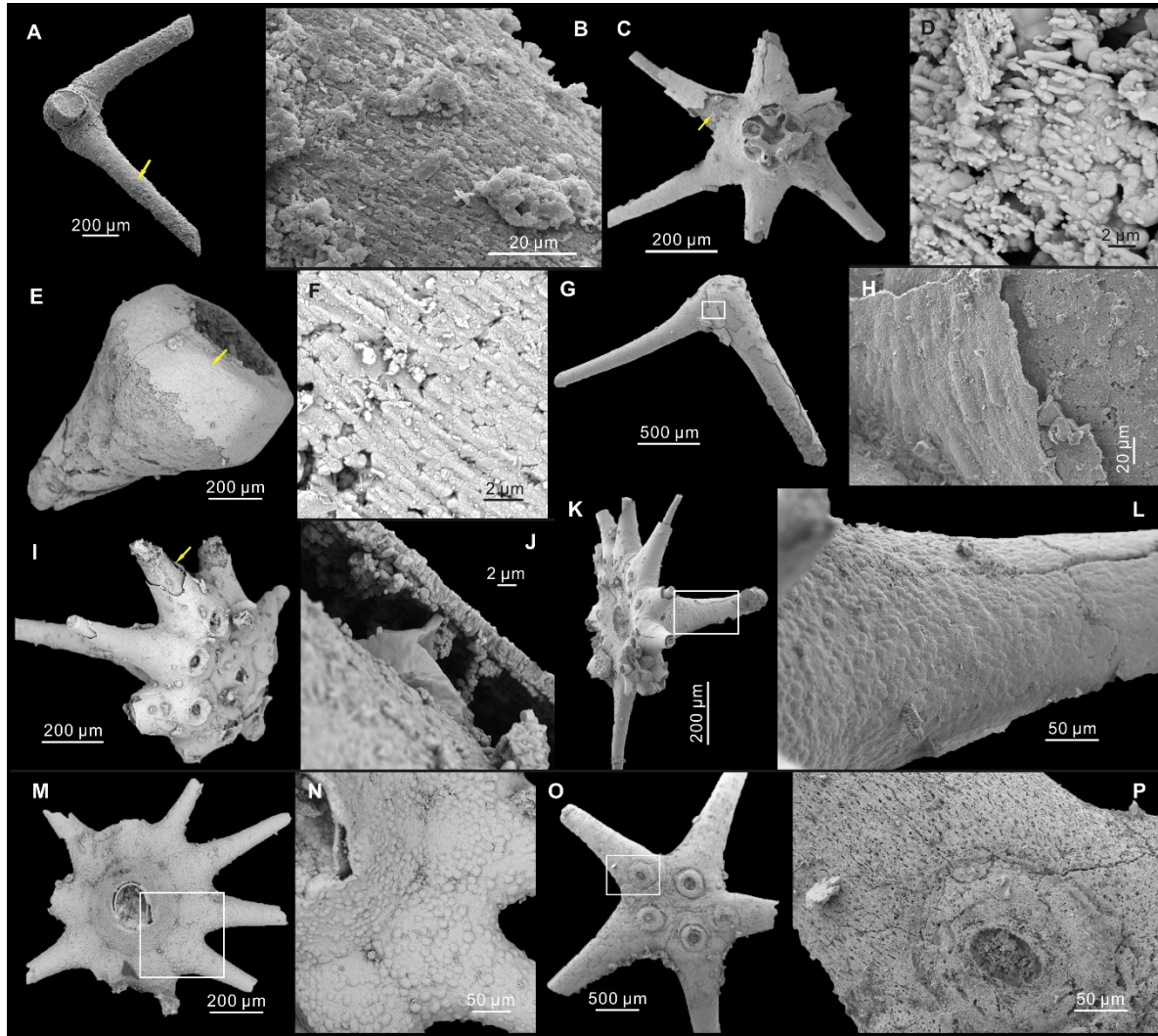
**Table S3.** Distribution of the microstructural features in different species. OL, organic layer; SLF, simple lamellar fibrous structure; BLF, bundled lamellar fibrous structure. FP, foramen peripheral.

Species	Microstructures				
	OL	SLF	BLF	Tubercles	FP granules
<i>Eremactis mawsoni</i>	√	√			√
? <i>Eremactis</i> sp.	√	√		√	
<i>Archiasterella pentactina</i>	√	√	?		
<i>Archiasterella hirundo</i>	√	√	?	√	
<i>Allonnia tripodophora</i>	√	√	√		√
<i>Chancelloria racemifundis</i>	√	√	?	√	√
<i>Chancelloria</i> cf. <i>eros</i>	√	√	√		
<i>Chancelloria</i> sp.	√	√	√	√	

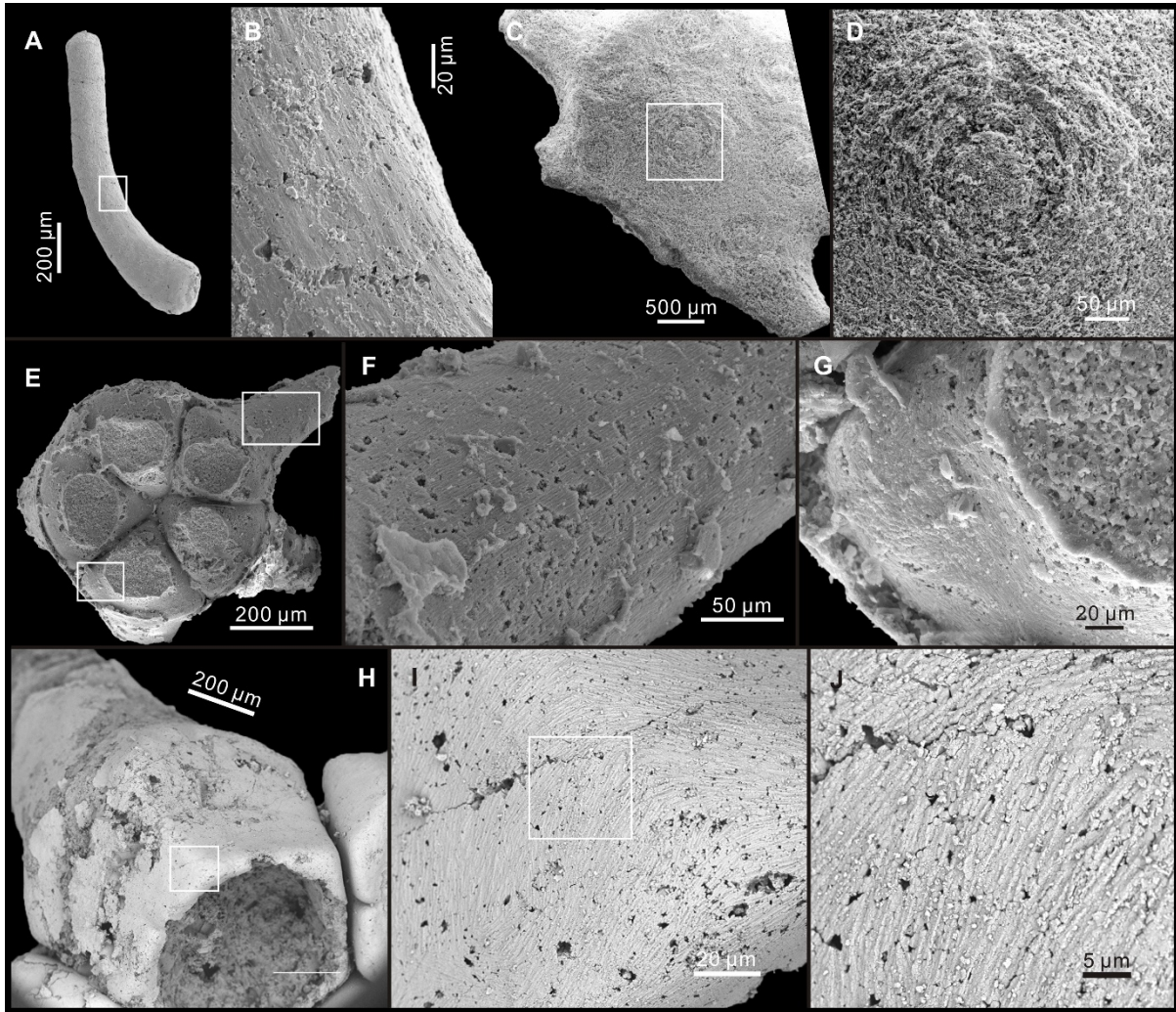
		South China		North China	Australia	
		SSF zones				SSF zones
Cambrian	Wuliuan				<i>Chancelloria</i> ; <i>Allonnia</i> ; <i>Archiasterella</i> Monastery Creek Fm	
	Stage 4	Canglangpuan			* <i>Chancelloria australilonga</i> Emu Bay Shale	
		<i>Pelagiella madianensis</i> - <i>Stenotheca drepanoida</i>		<i>Chancelloria</i> cf. <i>eros</i> ; <i>Allonnia tripodophora</i> ; <i>Archiasterella</i> Xinji Fm		
	Stage 3	Qiongzhusian	<i>Pelagiella subangulata</i>		<i>Chancelloria</i> ; <i>Allonnia</i> ; <i>Archiasterella</i> ; <i>Eremactis</i> Ajax Ls and Mernmerna Fm	<i>Daliyatia odyssei</i>
			* <i>Allonnia phrixothrix</i> , <i>Al. erjiensis</i> , Yu'anshan Fm			
	Stage 2	Meishucunian	<i>Sinosachites flabelliformis</i> - <i>Tannuolina zhangwentangi</i>			<i>Micrina etheridgei</i>
						<i>Kulparina rostrata</i>
			<i>Watsonella crosbyi</i>		<i>Chancelloria</i> ; <i>Allonnia</i> ; <i>Eremactis</i> Mt. Terrible Fm	
	Fortunian		<i>Paragloborilus subglobosus</i> - <i>Purella squamulosa</i>			
			<i>Anabarites trisulcatus</i> - <i>Protohertzina anabarica</i>			

**Figure S1.** Stratigraphical distribution of the studied specimens. Modified after Betts *et al.* (2017), Yun *et al.* (2016), and Jacquet *et al.* (2016). The asterisk indicates exceptionally-preserved fossils.





**Figure S2.** Preservation and surface ornaments of the cancelloriid sclerites. (A, B) *Allonnia tripodophora*, specimen ELI LC06-07019, a phosphatized steinkern with fibrous linings on the surface (preserved type 2); B is the close-up of the position pointed by a yellow arrow in A. (C, D) *Chancelloria racemifundis*, MPAL 0746, a phosphatized steinkern with fibrous linings plus a phosphatized replacement of the outer layer (preserved type 4); D is the close-up of the position pointed by a yellow arrow in C. (E, F) A steinkern of a central ray of *C. sp.*, MPAL 0747, showing distinct fibrous columns formed by compact amorphous and blade-shaped minerals; F is the close-up of the position pointed by a yellow arrow in E. (G, H) *Al. tripodophora*, MPAL 0749, showing the thin outer layer and wrinkles on the surface. (I, J) *Chancelloria sp.*, MPAL 0750, a thin layer wrapping the sclerites. (K–N) Dense tubercles on the sclerites of *C. sp.*; (K, L) MPAL 0752; (M, N) MPAL 0753. (O, P) *Archiasterella pentactina*, MPAL 0754, showing distinctive foremen peripheral ridges.



**Figure S3.** Additional represents of the fibrous microstructures of the sclerites. (A, B) *Eremactis mawsoni*, MPAL 0756, showing homogenous fibrous columns with their long axes parallel to the long axis of the ray. (C, D) *Chancelloria* sp., ELI LC03-05076, showing homogenous fibrous columns with their long axes along the tangential direction around the basal foramen of the sclerites. (E–G) *C. cf. eros*, ELI LC06-23003, showing fibrous columns with their long axes parallel to the long axis of the ray in the main part (F) and along the tangential directions around the foramen in the basal areas (G). (H–J) *C. sp.*, MPAL 0757, showing interlaced fibrous bundles distributed in the curved surface of the sclerites.