A stem-group cnidarian described from the mid-Cambrian of China and its significance for cnidarian evolution

Supplementary Information

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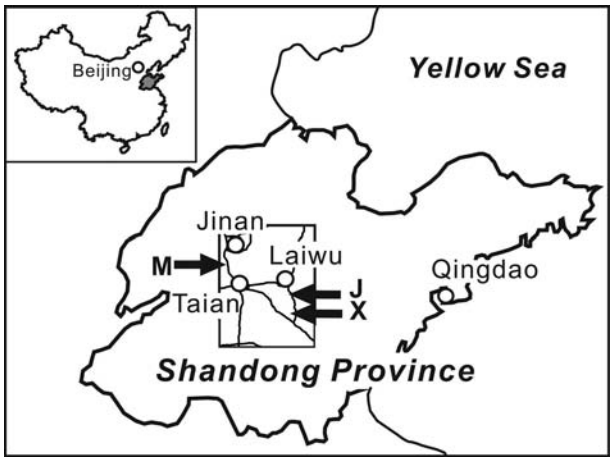
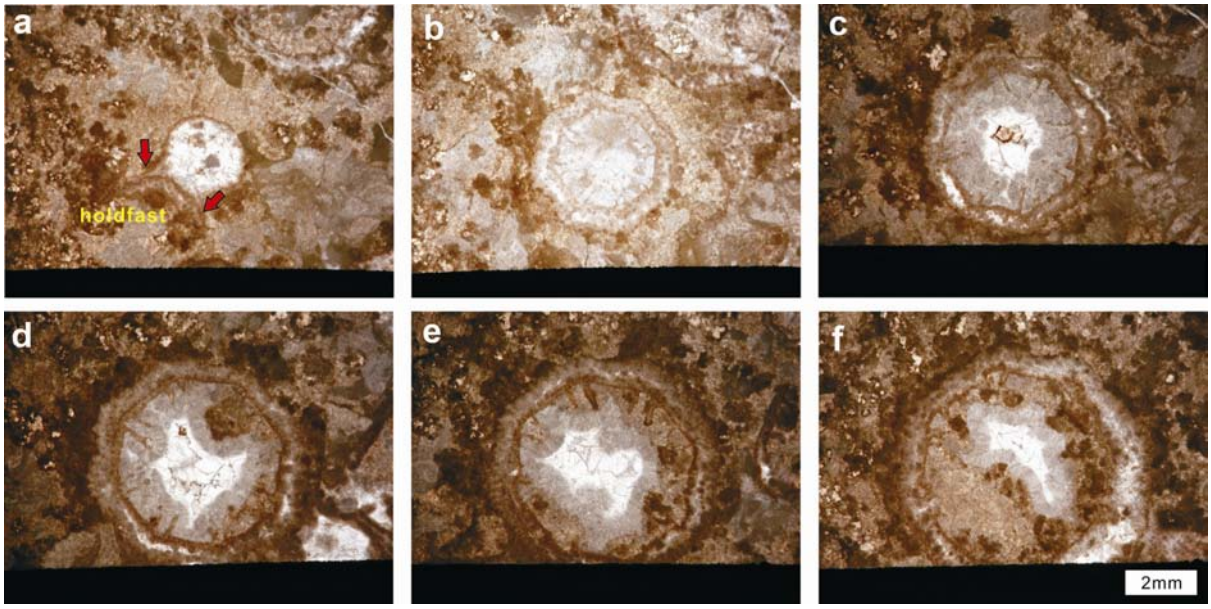
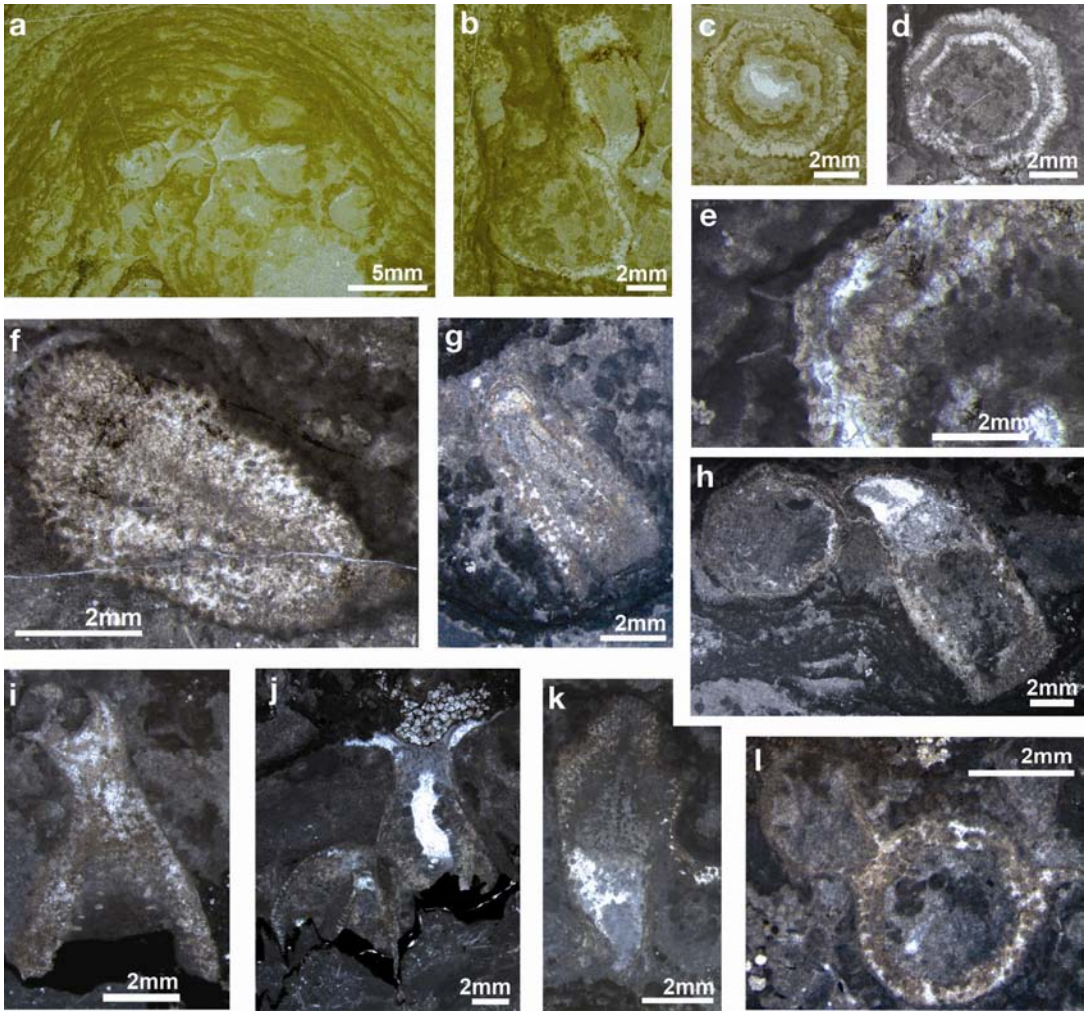
Supplementary Figures



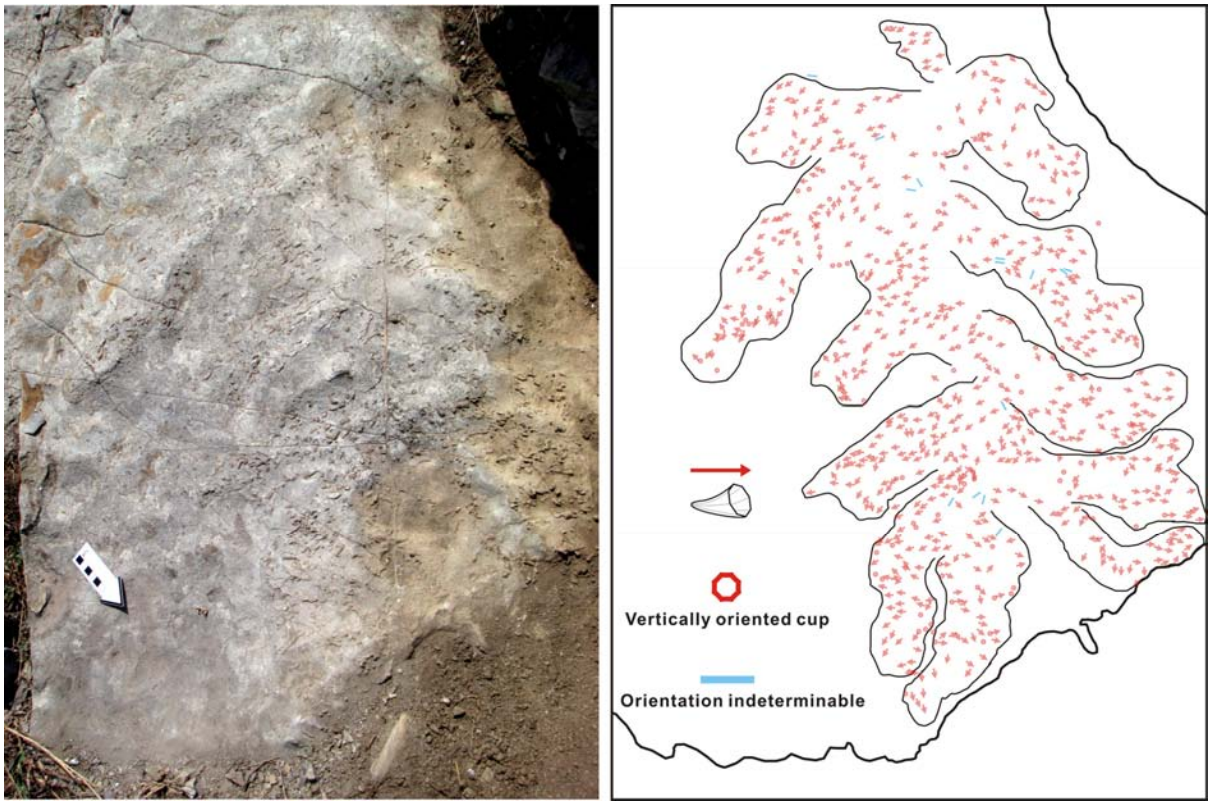
Supplementary Figure S1: Fossil localities in Shandong Province, China. M: Mantoushan section, J: Jiulongshan section, and X: Xintai section.



Supplementary Figure S2: Serial thin sections of an individual cup of *Cambroctoconus orientalis* showing the ontogeny. The distance between each transverse view is *ca.* 1.5 mm. **a**, SNUP7045. **b**, SNUP7046. **c**, SNUP7047. **d**, SNUP7048. **e**, SNUP7049. **f**, SNUP7050. Two arrows in **a** indicate the position of the holdfast. Note that paired septa project inwards from each corner. The bright area in the center may represent the basal cavity (**b**–**f**).

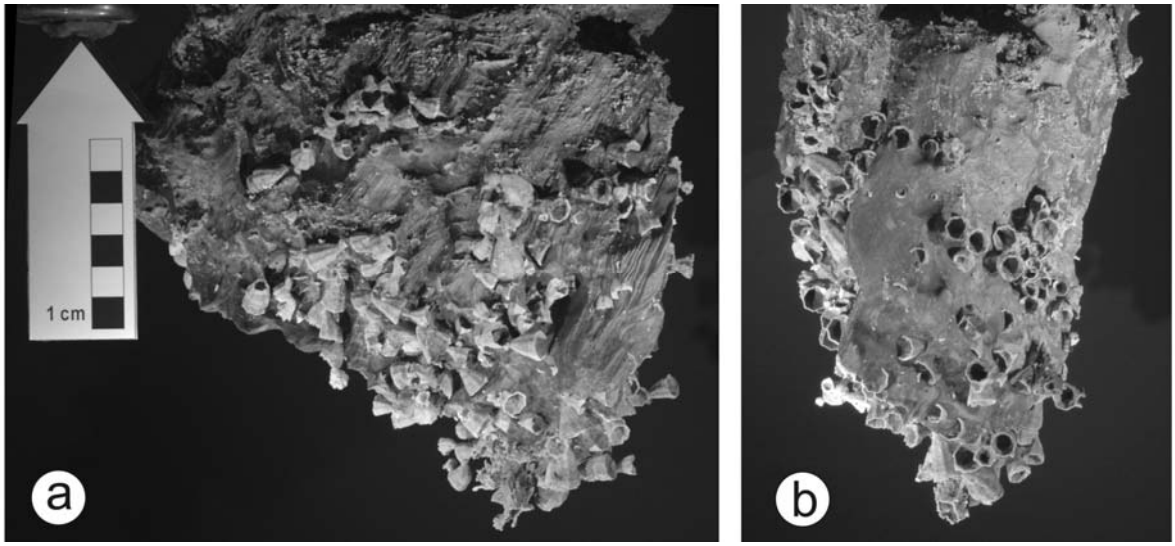


Supplementary Figure S3: Thin section photographs of the rock samples containing *Cambroctoconus orientalis*. a–f, Specimens from the Jiulongshan section. **a**, SNUP7029, a small colony encrusted by microbial films. **b,** SNUP7030, longitudinal-cut view of an offset budded from the outer surface of the parental cup. **c,** SNUP7031, transverse view of a cup. The bright area in the center indicates a basal cavity. **d,** SNUP7032, transverse view of a cup and its offset budded from the inside of the parental cup, showing a double-walled appearance. **e,** SNUP7033, a small offset budded from the outer surface of the parental cup. **f.** SNUP7034, tangentially-cut view of the wall showing perforated structure. **g–l,** specimens from the Xintai section. **g,** SNUP7035, a pendent individual. **h,** SNUP7036, an offset with sub-horizontal element, budded from the outer surface of the parental cup. The bright area represents a basal cavity. **i,** SNUP7037, a pendant individual. **j,** SNUP7038, a pendent individual and its offsets. **k,** SNUP7039, a specimen with sub-horizontal element. **l,** SNUP7040, an offset budded from the outer surface of the parental cup.

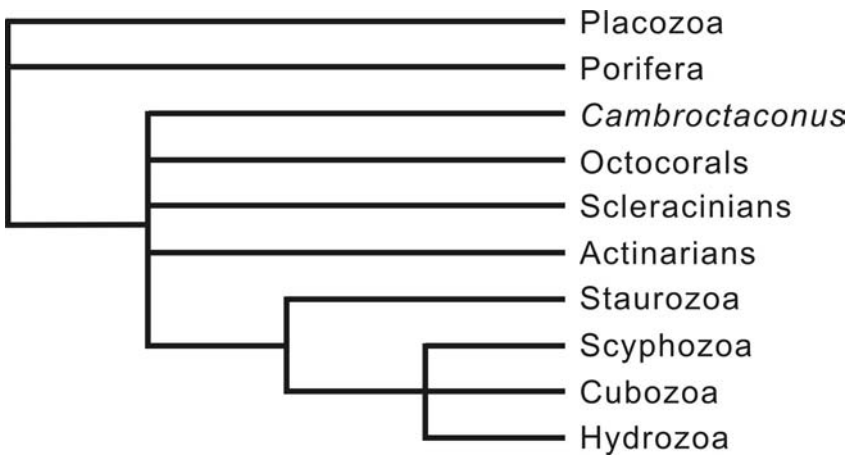


Supplementary Figure S4: Photograph of a bedding plane containing a colony of *Cambroctoconus orientalis*. An outcrop in the Xintai section (left) and a schematic drawing of the colony to show the orientation of cups (right). Black bars of the scale are 1 cm long.

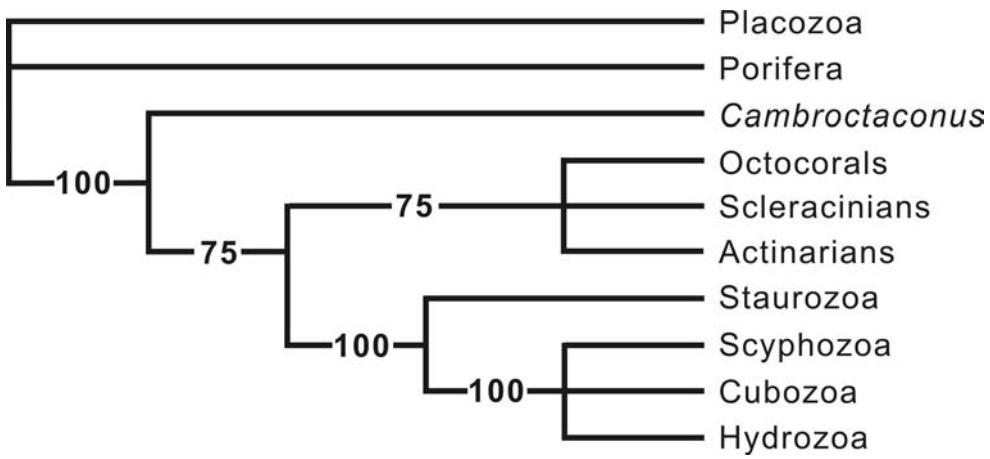
Supplementary Figure S5: The oblique lateral view of the bedding plane containing a colony of *Cambroctoconus orientalis* which is illustrated in Supplementary Figure S4.



Supplementary Figure S6: a, Partially dissolved-out rock sample containing many individual cups of *Cambroctoconus orientalis* from the Xintai section, SNUP7044. **b**, lateral view of the sample shown in **a**.



Supplementary Figure S7: The strict consensus tree of the twelve most parsimonious trees from the character-weighted second run of the cladistic analysis, showing the polytomy of *C. orientalis*, anthozoan groups, and the Medusozoa.



Supplementary Figure S8: Fifty per cent majority rule consensus tree of the twelve most parsimonious trees from the character-weighted second run of the cladistic analysis. Note that *C. orientalis* is placed as a stem-group cnidarian.

Supplementary Tables

Element	Weight%	Atomic%	Compd%	Formula
C K	13.78	21.96	50.47	CO2
Mg K	0.65	0.51	1.08	MgO
Ca K	34.63	16.54	48.45	CaO
O	50.95	60.98		
Totals	100.00			

Supplementary Table S1: Chemical composition of the skeleton of *Cambroctoconus* from the Mantoushan section.

Element	Weight%	Atomic%	Compd%	Formula
C K	3.74	5.94	13.71	CO2
Si K	40.34	27.39	86.29	SiO2
O	55.92	66.67		
Totals	100.00			

Supplementary Table S2: Chemical composition of the skeleton of *Cambroctoconus* from the Jiulongshan section. Note that the analysed point is mainly of silica.

Element	Weight%	Atomic%	Compd%	Formula
C K	2.93	4.70	10.74	CO2
Na K	0.28	0.24	0.38	Na2O
Si K	41.55	28.51	88.88	SiO2
O	55.24	66.55		
Totals	100.00			

Supplementary Table S3: Chemical composition of the skeleton of *Cambroctoconus* from the Xintai section. Note that the analysed point is mainly of silica.

Characters	1-5	6-10	11-15	16-20	21-25	26-28
Placozoa	000-0	-000	000--	0----	-----	---
Porifera	0/1 0/1 0/1 00	-0/1 00	000--	0----	-----	---
Cambroctoconus	11101	2101?	0??-?	0-??0	0----	---
Octocorals	00111	21111	11010	0-010	0----	---
Scleractinians	01111	11101	11010	0-010	0----	---
Actinarians	000-1	11110	11010	0-010	0----	---
Staurozoa	000-1	01011	11101	01000	0101`	10 0/1
Cubozoa	000-1	01001	11101	11010	1111`	111
Scyphozoa	000-1	01001	11111	10011	1101`	111
Hydrozoa	00 0/1-0	-1001	11101	1-110	1020 0/1	110

Supplementary Table S4: Character matrix used in cladistic analysis. The characters and states are described below.

1. Perforated wall: (0) absent; (1) present.

Most, but not all, sponges have a perforated wall, hence coded as polymorphic. *Cambroctoconus* possesses a perforated wall.

2. Mineralized skeleton: (0) absent; (1) present.

Some sponges (e. g. archaeocyathans) show a mineralized skeleton, while others do not. *Cambroctoconus* and scleractinian corals have a mineralized skeleton.

3. Life mode: (0) solitary; (1) colonial.

Some sponges with multiple oscula are often interpreted as colonies[35], hence the Porifera was coded as polymorphic.

4. Shared colonial tissue (coenenchyme): (0) absent; (1) present.

The colonial anthozoans, scleractinian corals, and octocorals have a coenenchyme to form and to support the colony, whereas the colony of *Cambroctoconus* lacks such tissue.

5. Presence of septa: (0) absent; (1) present.

6. Number of septa: (0) 8 or multiple of 8; (1) 6 or multiple of 6; (2) 4.

7. Axial symmetry: (0) absent; (1) present.

It is contentious whether the sponges bear a kind of symmetry or not, but the axial symmetry is considered as ancestral for Calcispongia[36, 37], hence coded as polymorphic for sponges.

8. Biradial symmetry: (0) absent; (1) present.

Biradial symmetry is known in anthozoans[38].

9. Octa-radial symmetry near oral end: (0) absent; (1) present.

Cambroctoconus possesses an eight-sided wall near the oral opening. The octocorals have eight tentacles, and the staurozoans have eight bunches of tentacles around the mouth. Although the scyphozoan ephyra are of octaradial shape, it is not coded as such, since the adult does not display the octaradial symmetry.

10. Gastro-vascular cavity: (0) absent; (1) present.

A gastro-vascular cavity is a representative cnidarian feature. It is hard to determine whether *Cambroctoconus* possesses the cavity. Given the fact that some offsets budded from the inner surface of the parental cup, the presence of a gastro-vascular cavity in *Cambroctoconus* seems unclear, hence coded "?".

11. Jelly-like mesenchyme: (0) absent; (1) present.

A jelly-like matrix placed between the epidermis and gastrodermis, called mesenchyme (mesoglea + cell products like fibers)[38], is a cnidarian feature. Although there is no soft part preserved, it can be inferred that *Cambroctoconus* lacked the jelly-like mesenchyme, considering that new offsets budded from both inner and outer surfaces of the parental skeletal cup.

12. Cnidae: (0) absent; (1) present.

The possession of cnidae is a synapomorphy of all cnidarians. Currently it is not known whether *Cambroctoconus* had cnidae or not, hence coded as "?".

13. Mitochondrial DNA: (0) circular; (1) linear.

Ref. (39), character number 2.

14. Mesoglea: (0) non-cellular; (1) cellular.

Ref. (39), character number 4.

15. Euryteles: (0) absent; (1) present.

Ref. (39), character number 8.

16. Life habit: (0) benthic adults; (1) planktonic adults.

Ref. (39), character number 17.

17. Type of apical medusa formation: (0) strobilation; (1) metamorphosis without transverse fission.

Ref. (39), character number 21.

18. Location of gonads: (0) gastrodermis; (1) epidermis.

Ref. (39), character number 25.

19. Planular ciliation: (0) absent; (1) present.

Ref. (39), character number 29.

20. Ephyrae: (0) absent; (1) present.

Ref. (39), character number 34.

21. Medusoid phase: (0) absent; (1) present.

Ref. (39), character number 49.

22. Rhopalia/rhopalioids: (0) absent; (1) present.

Ref. (39), character number 51.

23. Nerve ring: (0) absent; (1) one; (2) two.

Ref. (39), character number 53.

24. Gastric filament: (0) absent; (1) present.

Ref. (39), character number 54.

25. Stratocyst: (0) absent; (1) present.

Ref. (39), character number 69.

26. Manubrium: (0) absent; (1) present.

Ref. (39), character number 76.

27. Nervous system organization: (0) GFNN absent; (1) GFNN present.

Ref. (39), character number 77.

28. Ocelli: (0) absent; (1) present.

Ref. (39), character number 81.

Supplementary References

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