



Figure DR1. Field photographs of the Nantuo Formation at the Songluo Section. A: Stratigraphic boundary between Nantuo and Doushantuo formations, with the basal Doushantuo cap carbonate bracketed by dashed lines. Geologist for scale. B: Sharp contact between fossiliferous black shales and overlying massive diamictite. Contact identified by dashed line. Note glacially transported clast in ellipse. Scale bar is 1 m. C: Nantuo diamictite with poorly sorted and angular clasts in muddy matrix. Clasts are mostly derived from dolostone, sandstones, and slates. Rock hammer (28 cm) for scale. D: Striated clast with multiple sets of striations. Coin (2 cm) for scale. E: Ice rafted and faceted dropstone derived from fine-grained sandstone and embedded in silty mudstone. Pen cap (4.8 cm) for scale.

Table DR1. List of morphotaxa and their abundance in our collection of Nantuo fossils. Part and corresponding counterpart are counted as a single specimen.

Morphogroup	Morphotaxon	Number of specimens
Simple discoids or spheroids	<i>Chuaria</i>	21
Possibly benthic ribbons or siphonous forms	<i>Vendotaenia</i>	44
Benthic blade forms	<i>Baculiphyca</i>	4
Benthic dichotomous branching forms	<i>Konglingiphyton</i>	1
	<i>Enteromorphites</i>	4
	? <i>Doushantuophyton</i>	4
Benthic asymmetrically branching forms	<i>Wenghuiphyton</i> -like form	1
	<i>Parallelphyton</i> -like form	1
Other unclassified forms		29
Total		109

1 Table DR2. Compilation of Proterozoic carbonaceous macrofossils (mostly macroalgal fossils). The compilation was based on an extensive literature review, utilizing 52 publications and
 2 including 1,451 species occurrences from 32 stratigraphic units. The occurrences are assigned to five geochronological intervals (Paleoproterozoic, Mesoproterozoic, Early Neoproterozoic,
 3 Cryogenian, and Ediacaran) based upon the best age estimates of the stratigraphic units. The Kaili biota is used as a representative of Cambrian macroalgal assemblages. The compilation is an
 4 update of (Xiao and Dong, 2006) with addition of more recent publications.
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Age in Ma	Stratigraphic Interval	Biotas	References	Macroalgal assemblage	Representative taxa
Paleoproterozoic: 1900-1600 Ma	Negaunee Formation		(Han and Runnegar, 1992; Schneider et al., 2002)	<i>Grypania-Tyrasotaenia</i> assemblage	<i>Grypania</i> , <i>Tyrasotaenia</i> , <i>Vendotaenia</i> , <i>Chuaria</i> , <i>Tawuia</i>
	Chuanlinggou & Changzhougou Formation		(Hofmann and Chen, 1981; Du and Tian, 1986; Zhu et al., 2000; Du et al., 2009)		
	Tuanshanzi Formation		(Hofmann and Chen, 1981; Du and Tian, 1986; Yan, 1995; Zhu and Chen, 1995; Du et al., 2009)		
	Olive Shale (Koldaha Shale)		(Sharma, 2006)		
	Chorhat Sandstone		(Srivastava and Bali, 2006)		
Mesoproterozoic: 1600-1000 Ma	Rohtas Formation		(Kumar, 1995; Sharma and Shukla, 2009)	<i>Grypania-Chuaria-Tawuia</i> assemblage	<i>Grypania</i> , <i>Katnia</i> , <i>Chuaria</i> , <i>Tawuia</i>
	Suket Shale		(Kumar, 2001)		
	Gaoyuzhuang Formation		(Du et al., 1986; Walter et al., 1990; Niu, 1998)		
	Hongshuizhuang & Xiamaling Formation		(Du and Tian, 1986; Du et al., 2009)		
	Greyson Shale (Belt Supergroup)		(Walter et al., 1976; Walter et al., 1990)		
Early Neoproterozoic: 1000-720 Ma	Little Dal Formation	Little Dal Macrobiota	(Hofmann and Aitken, 1979; Hofmann, 1985)	<i>Chuaria-Tawuia</i> assemblage	<i>Chuaria</i> , <i>Tawuia</i> , <i>Grypania</i> , <i>Longfengshania</i> , <i>Tyrasotaenia</i>
	Changlongshan & Nanfen Formation	Longfengshan Biota	(Du, 1982; Duan, 1982; Du and Tian, 1985, 1986; Hong et al., 1991; Du et al., 2009)	<i>Chuaria-Tawuia-Longfengshania</i> assemblage	<i>Chuaria</i> , <i>Ellipsophysa</i> , <i>Tawuia</i> , <i>Longfengshania</i> , <i>Paralongfengshania</i>
	Liulaobei, Jiuliqiao, Shijia, Jinshanzhai, Weiji, Gouhou & Jingeryu Formation	Huainan Biota	(Zheng, 1980; Duan, 1982; Wang et al., 1984a; Wang et al., 1984b; Sun et al., 1986; Fu, 1989a, b; Zheng et al., 1993; Steiner, 1997; Dong et al., 2008; Qian et al., 2009)	<i>Chuaria-Ellipsophysa-Tawuia</i> assemblage	<i>Chuaria</i> , <i>Ellipsophysa</i> , <i>Tawuia</i> , <i>Vendotaenia</i> , <i>Protoarenicola</i>
	Wyniatt Formation		(Hofmann and Rainbird, 1994)	<i>Chuaria-Tawuia</i> assemblage	<i>Chuaria</i> , <i>Tawuia</i>
	Rewa Group		(Rai et al., 1997)		
	Dholpara Shale		(Srivastava, 2002)		
	Shilu Group		(Zhang et al., 1991; Zhang et al., 1995)		

Cryogenian: 654-635 Ma	Nantuo Formation		This paper	<i>Chuaria-Vendotaenia-Konglingiphyton</i> assemblage	<i>Chuaria, Vendotaenia, Konglingiphyton, Baculiphyca, Enteromorphites</i>
Ediacaran: 635-541 Ma	Lantian Formation	Lantian Biota	(Yan et al., 1992; Chen et al., 1994; Yuan et al., 1999; Yuan et al., 2011)	<i>Flabellophyton-Doushantuophyton</i> assemblage	<i>Chuaria, Flabellophyton, Doushantuophyton, Huangshanophyton, Anhuiphyton, Orbisiana</i>
	Doushantu Formation	Miaohe Biota	(Ding et al., 1996; Steiner, 1997; Xiao et al., 2002)	<i>Miaohephyton-Baculiphyca-Doushantuophyton</i> assemblage	<i>Baculiphyca, Beltanelliformis, Doushantuophyton, Konglingiphyton, Longifuniculum, Miaohephyton</i>
	Dengying & Liuchapo Formation	Wulingshan Biota	(Zhao et al., 1988; Chen et al., 1999; Chen and Wang, 2002; Tang et al., 2007)	<i>Baculiphyca-Vendotaenia</i> assemblage	<i>Baculiphyca, Beltanelliformis, Gesinella, Longfengshania, Longifuniculum, Vendotaenia</i>
Lower-Middle Cambrian	Kaili Formation	Kaili Biota	(Yang et al., 2000; Yang et al., 2001; Wu et al., 2010a; Wu et al., 2010b)	<i>Marpolia-Bosworthia</i> assemblage	<i>Chuaria, Sinocylindra, Bosworthia, Doushantuophyton, Longifuniculum, Marpolia, Parallelphyton, Enteromorphites</i>

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