Geobiological Events in the Ediacaran Period

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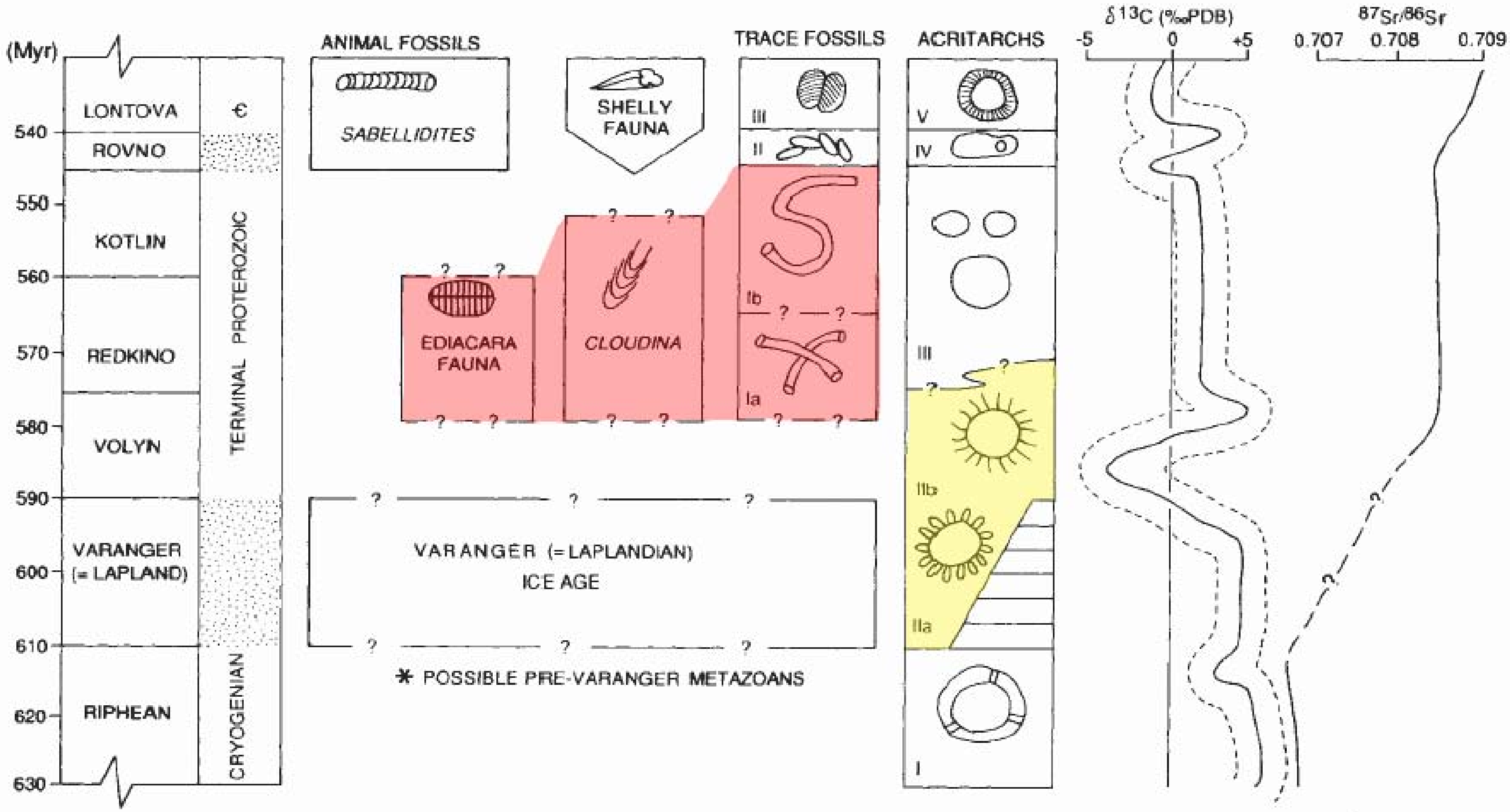
NSF; NASA; PRF; NSFC;
Virginia Tech Geobiology Group; CAS; UNLV; UCR; ASU; UMD; Amherst;
Subcommission of Neoproterozoic Stratigraphy;

Goals

To review biological (e.g., acanthomorphic acritarchs; animals; rangeomorphs; biomineralizing animals), chemical (e.g., carbon and sulfur isotopes, oxygenation of deep oceans), and climatic (e.g., glaciations) events in the Ediacaran Period;

To discuss integration and future directions in Ediacaran geobiology;

Knoll and Walter, 1992



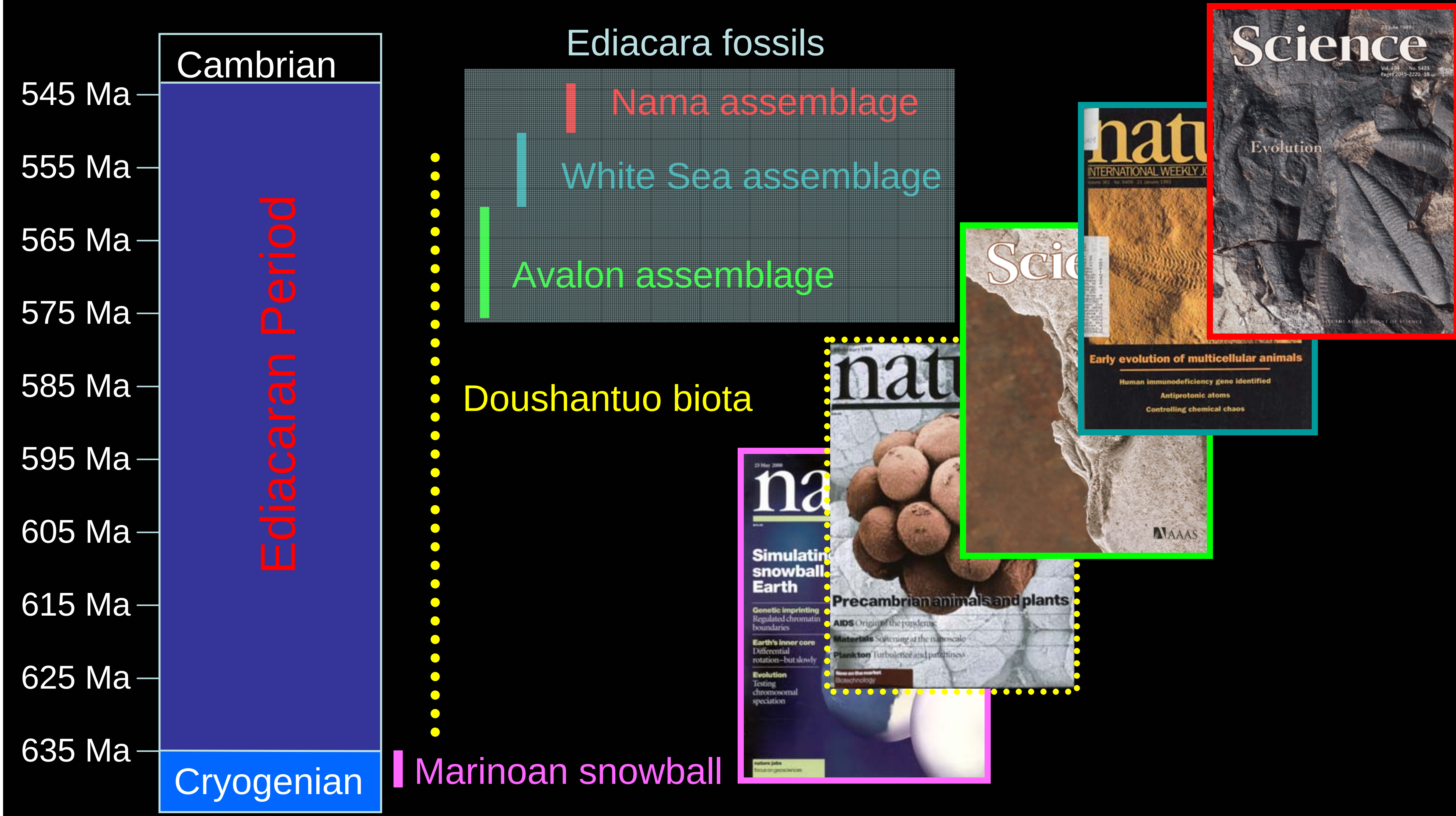
- Acanthomorphic acritarchs in early and Ediacara fauna in late Ediacaran Period;
- Strong carbon isotope variations;
- Varanger-Laplandian glaciation;
- What has happened since 1992?

Age Constraints: South China

	Cambrian			(538.2±1.5 Ma)
	541 Ma			
Neoproterozoic	Ediacaran	Sinian	Dengying	
				551.1±0.7 Ma
			Doushantuo	632.5±0.5 Ma
				635.2±0.6 Ma
	635 Ma			
	Cryogenian	Nanhuan	Nantuo (Tillite)	636 ± 5 Ma
			Datangpo	654 ± 4 Ma
				663±4 Ma
			Jiangkou Group	
	Tonian	Qingbaikouan	Banxi Group	725±10 Ma
	1000 Ma			

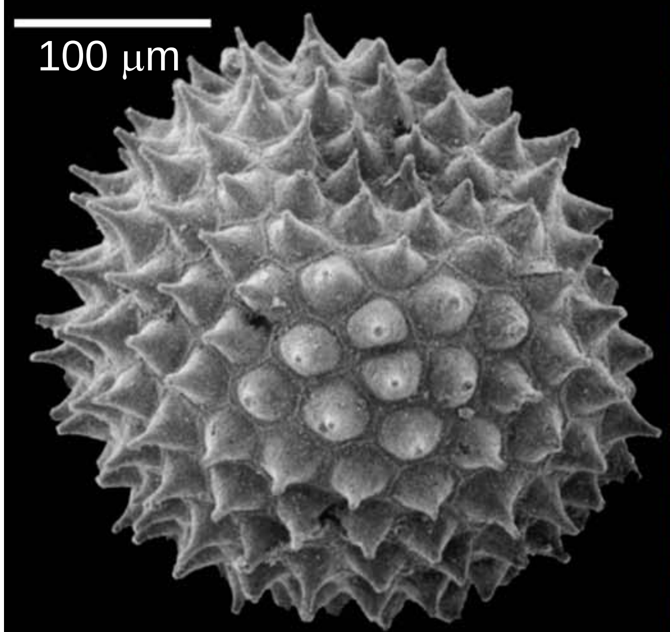
- South China radiometric ages: Condon et al., 2005; Hoffmann et al., 2004; Zhou et al., 2004; Bowring et al., 2007; S. Zhang et al., 2008; Q. Zhang et al., 2008;
- Additional ages from Nama Group (Namibia), Conception Group (Newfoundland), and Vendian (White Sea);

The Ediacaran Period

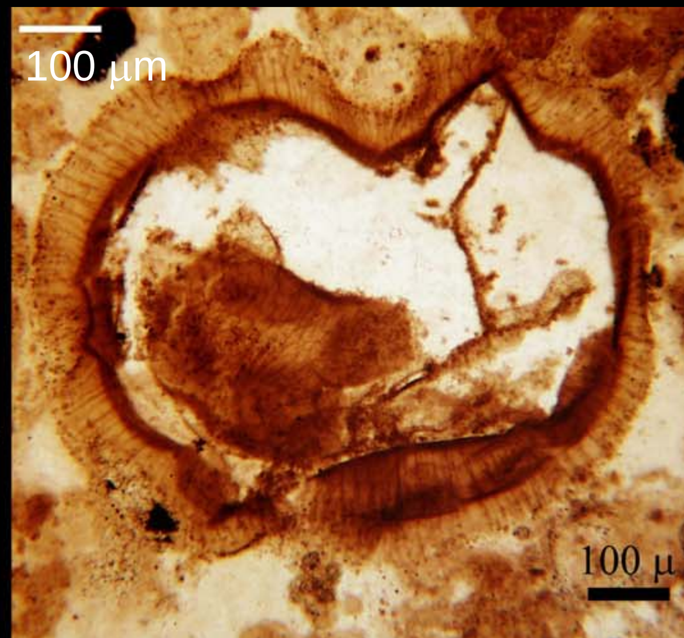


Doushantuo (635-551 Ma), Avalon (575-560 Ma), White Sea (560-550 Ma), Nama (550-542 Ma);

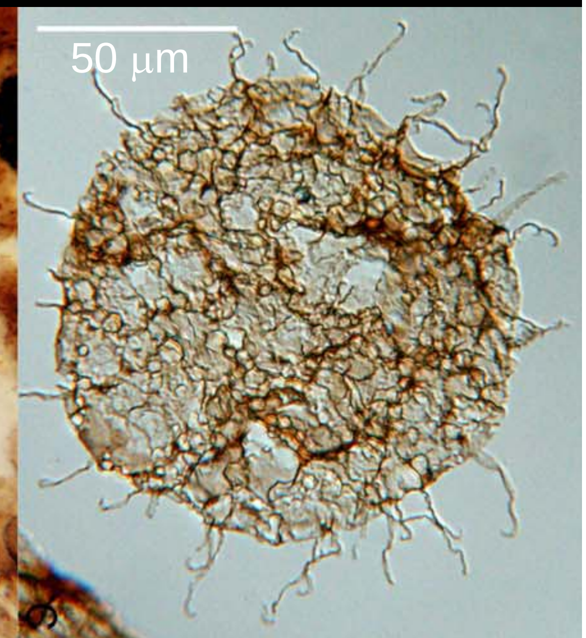
Acanthomorphs in different taphonomic windows



phosphatization



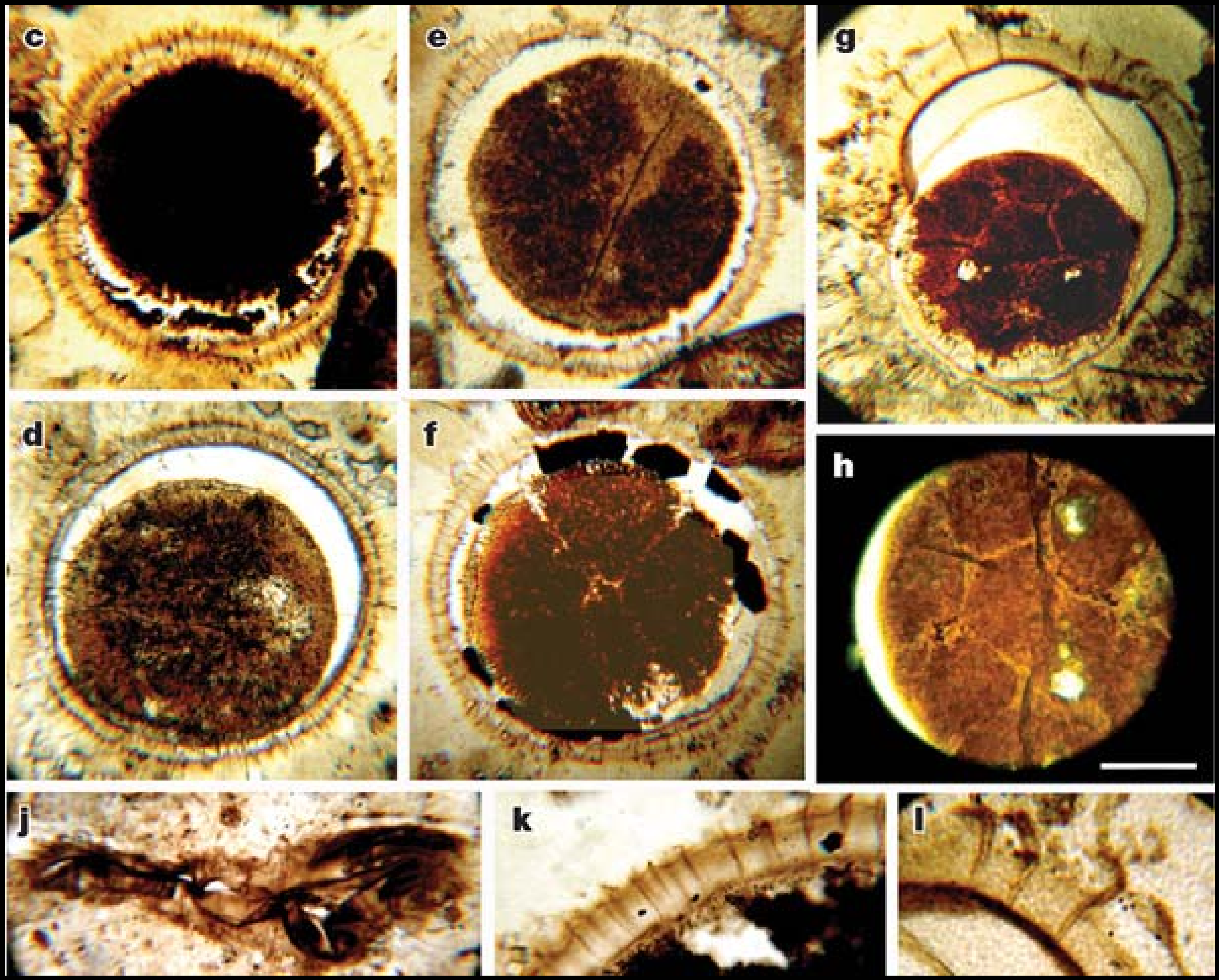
silicification



carbonaceous compression

- Taphonomic, geographic, and taxonomic diversity of Ediacaran acanthomorphs has been expanded significantly;
- Ediacaran acanthomorphs are found in Australia, South China, northern India, Svalbard, southern Norway, Siberia, East European Platform;
- They consistently post-date the Nantuo glaciation but predate Ediacara fossils, supporting Knoll and Walter (1992);

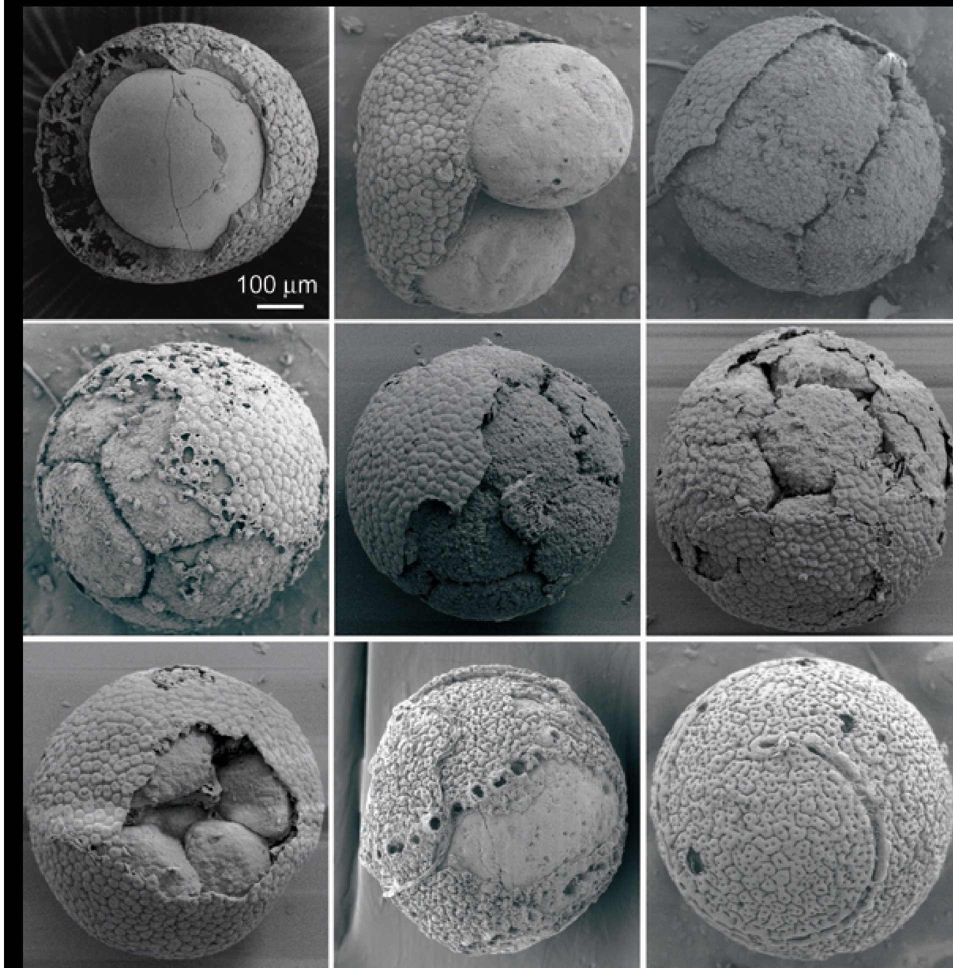
What are Ediacaran Acanthomorphs?



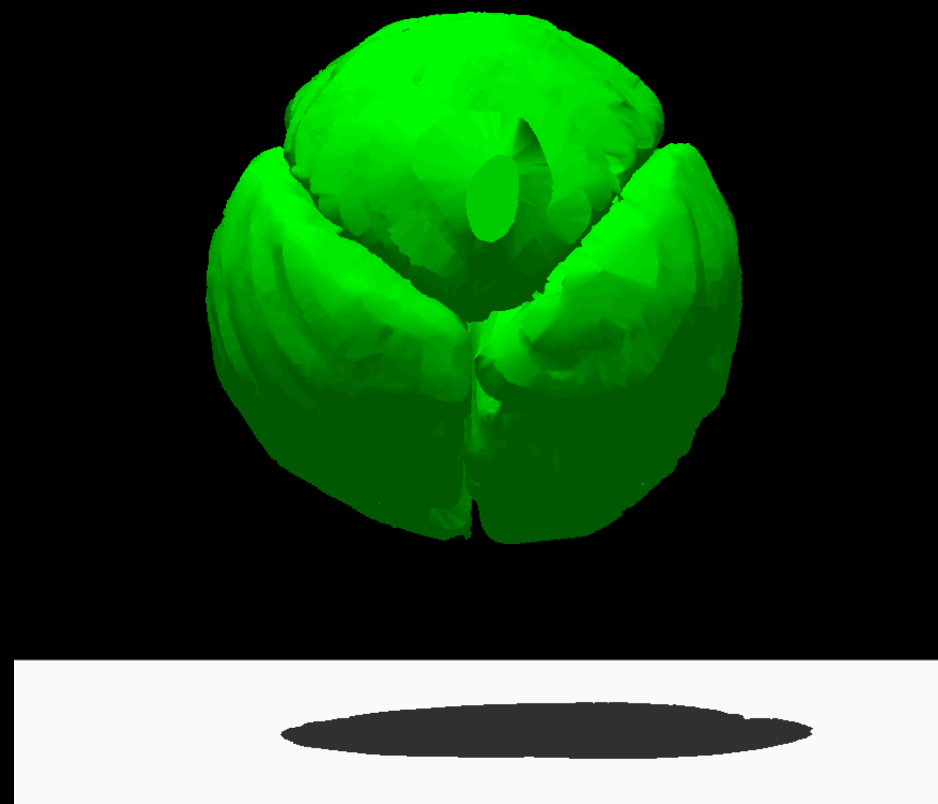
(Yin et al., 2007)

- Some Ediacaran acanthomorphs may represent animal embryos;
- They extend to the base of the Ediacaran Period, ~632 Ma;

Animal embryos also occur in upper Doushantuo



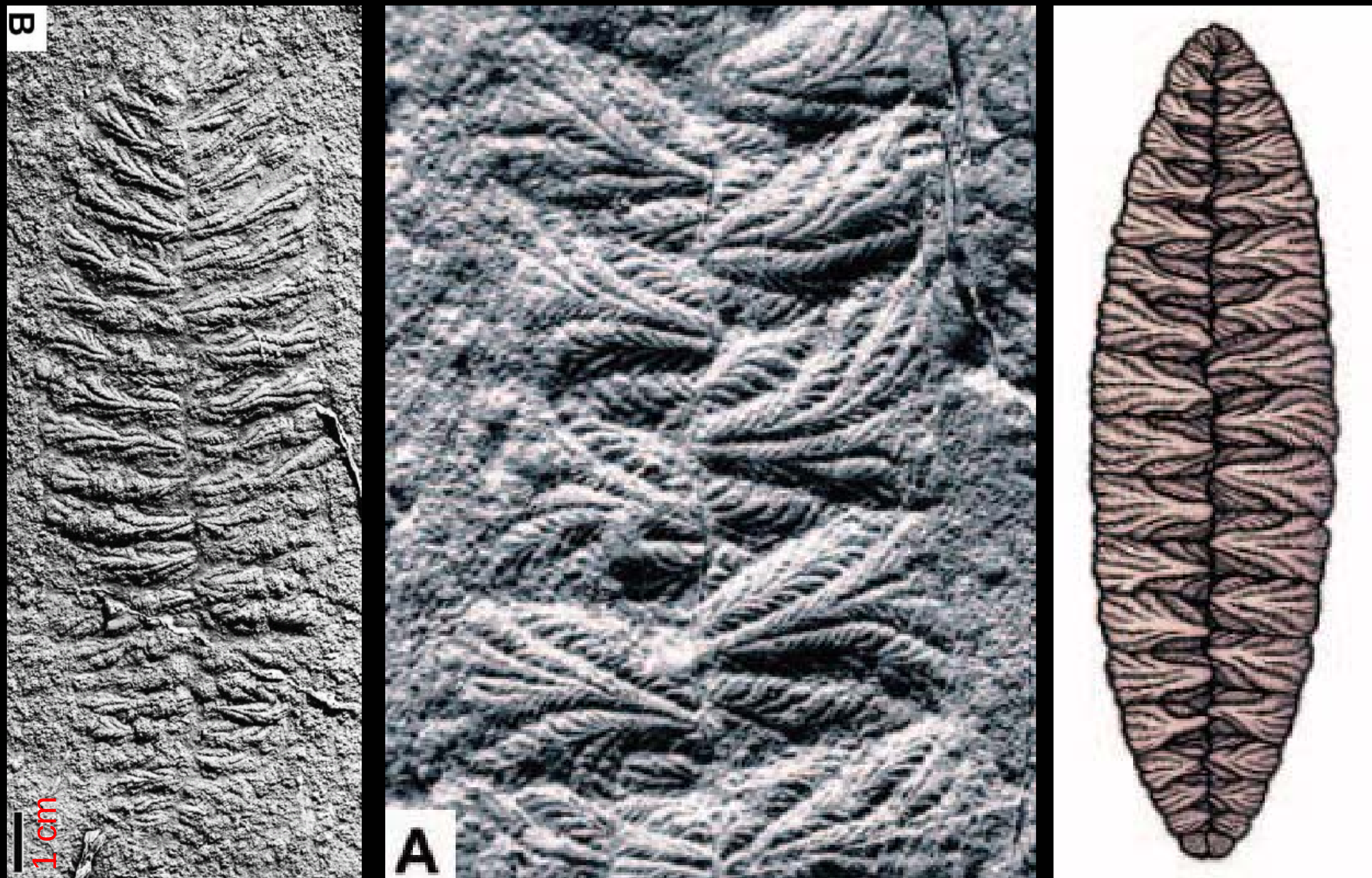
(Xiao et al., 2007)



(Hagadorn et al., 2006)

- Ages not well constrained, but probably ~600 Ma;
- Include blastulas and helical fossils;
- Cell and sub-cellular preservation through phosphate replication;

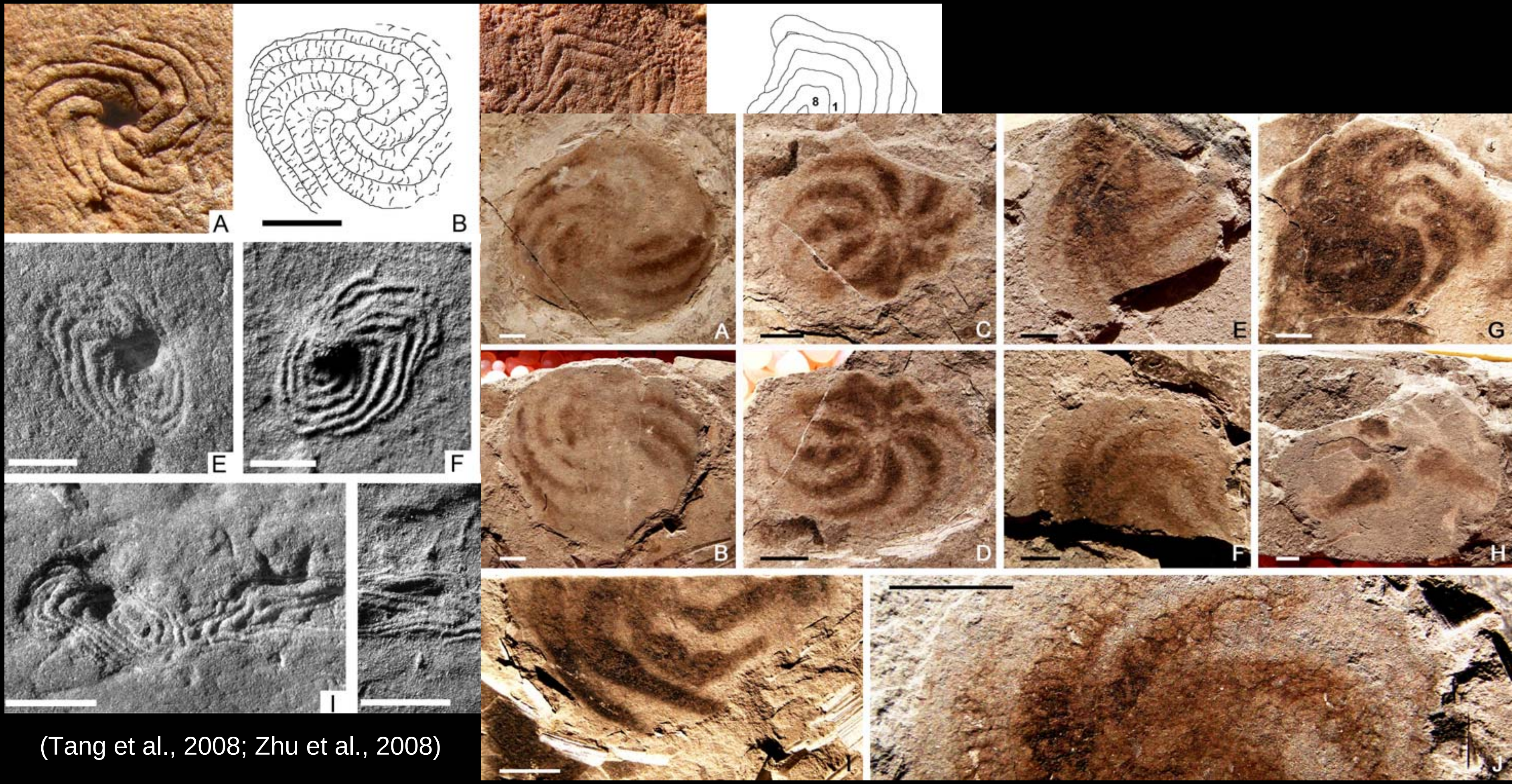
Avalon Assemblage: Rangeomorphs



(Gehling and Narbonne, 2007)

- Overlaps with Doushantuo in age, but different taphonomy, environment, and paleobiology;
- Rangeomorphs are most dominant;
- Modular organisms with possible relationship with animals;

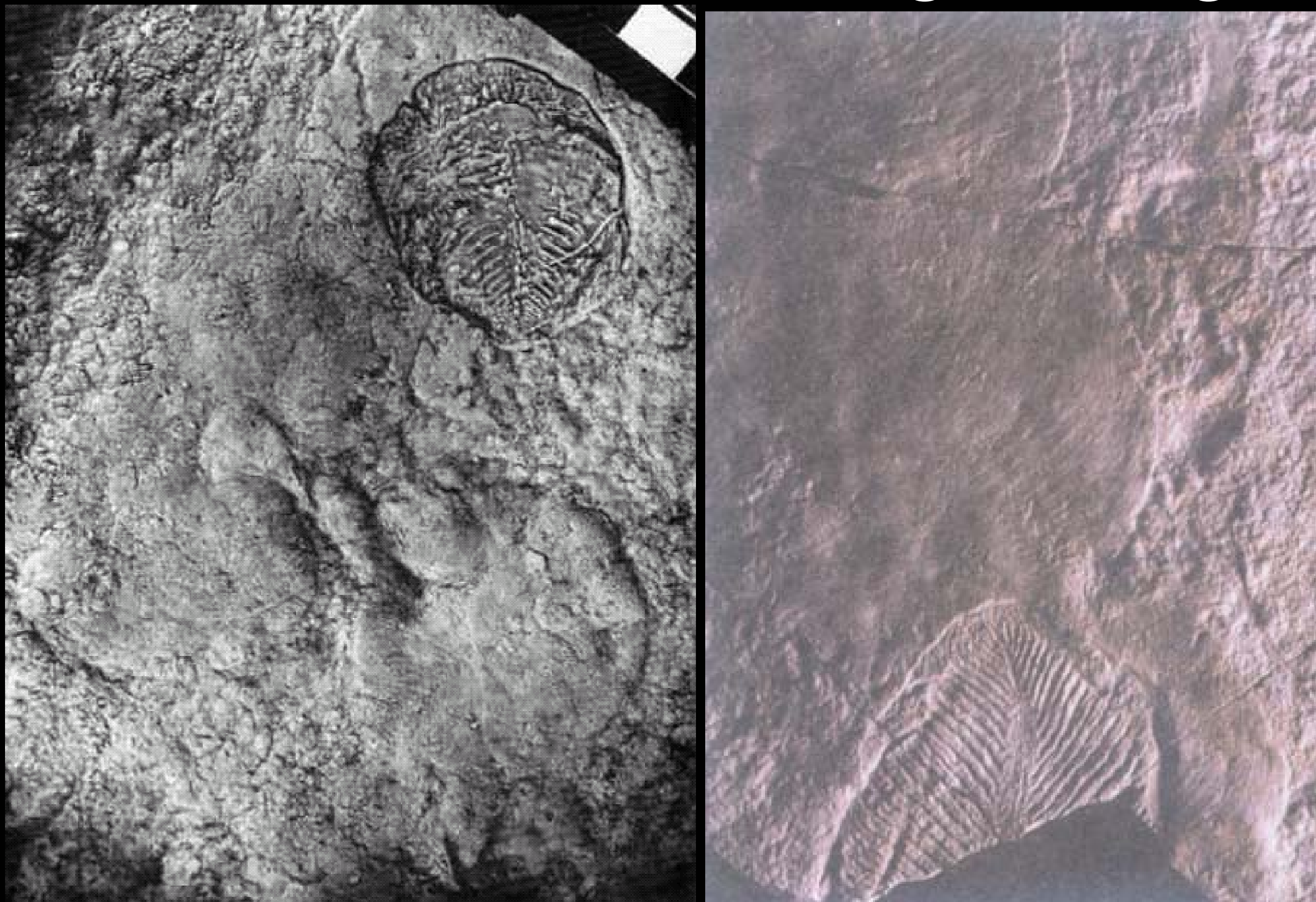
White Sea Assemblage: *Eoandromeda*



(Tang et al., 2008; Zhu et al., 2008)

- Each consists of eight clockwise spiral arms;
- Carbonaceous compress in uppermost Doushantuo shale; casts and molds in Ediacara sandstone;
- Diploblast-grade animals?

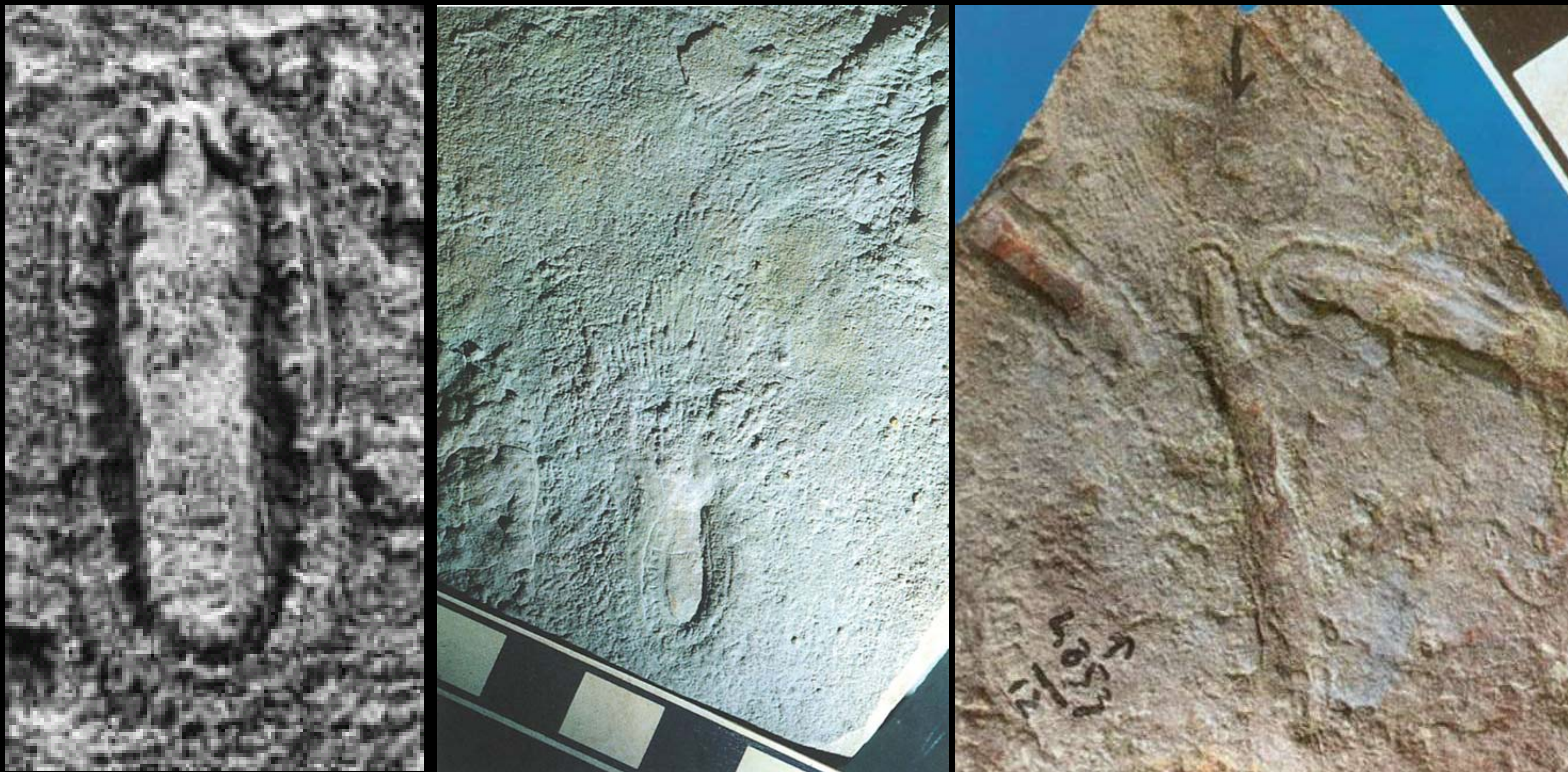
White Sea Assemblage: *Yorgia*



(Ivantsov and Malakhovskaya, 2002; Fedonkin, 2003)

- Intermittent (passive?) locomotion;
- Bilaterian animals?

White Sea Assemblage: *Kimberella*



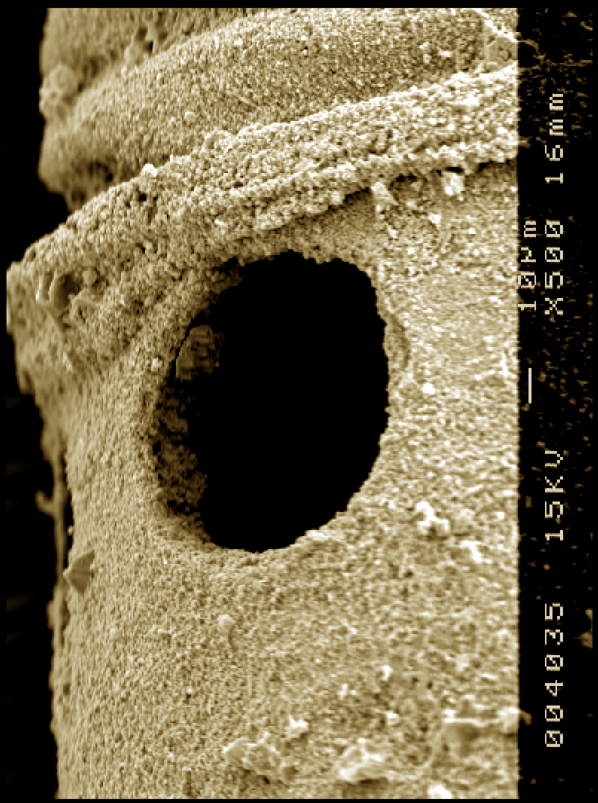
(Fedonkin, 2003; Fedonkin et al., 2007)

- Dorsal-ventral and anterior-posterior differentiation;
- Grazing activities;
- Self-powered, directional locomotion;
- Likely bilaterian animals;

White Sea and Nama: Trace Fossils

- The presence of Ediacaran bilaterian animals is also supported by trace fossils;

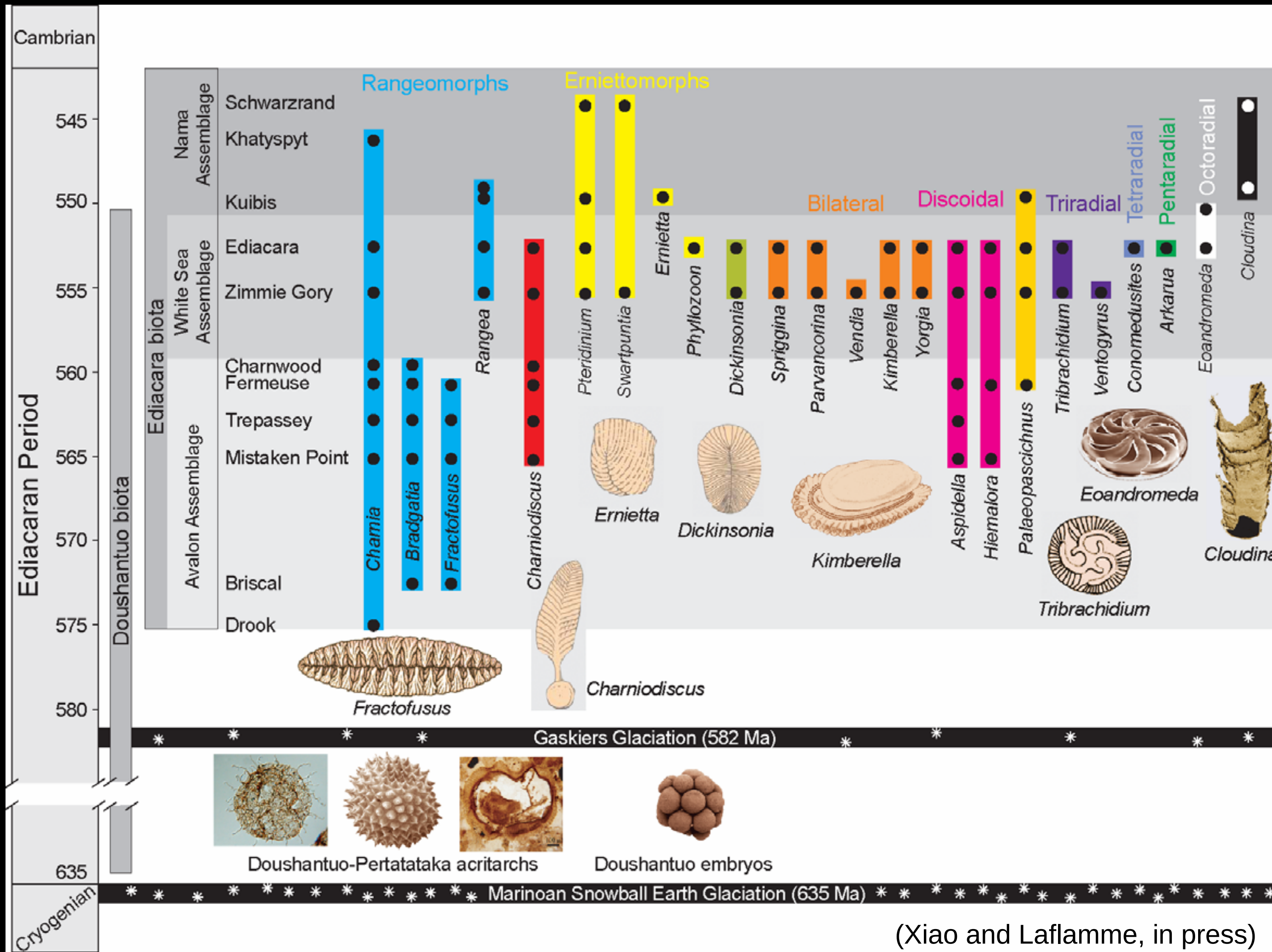
Nama assemblage:
Animal Biomineralization and Predation



(Hua et al., 2005)

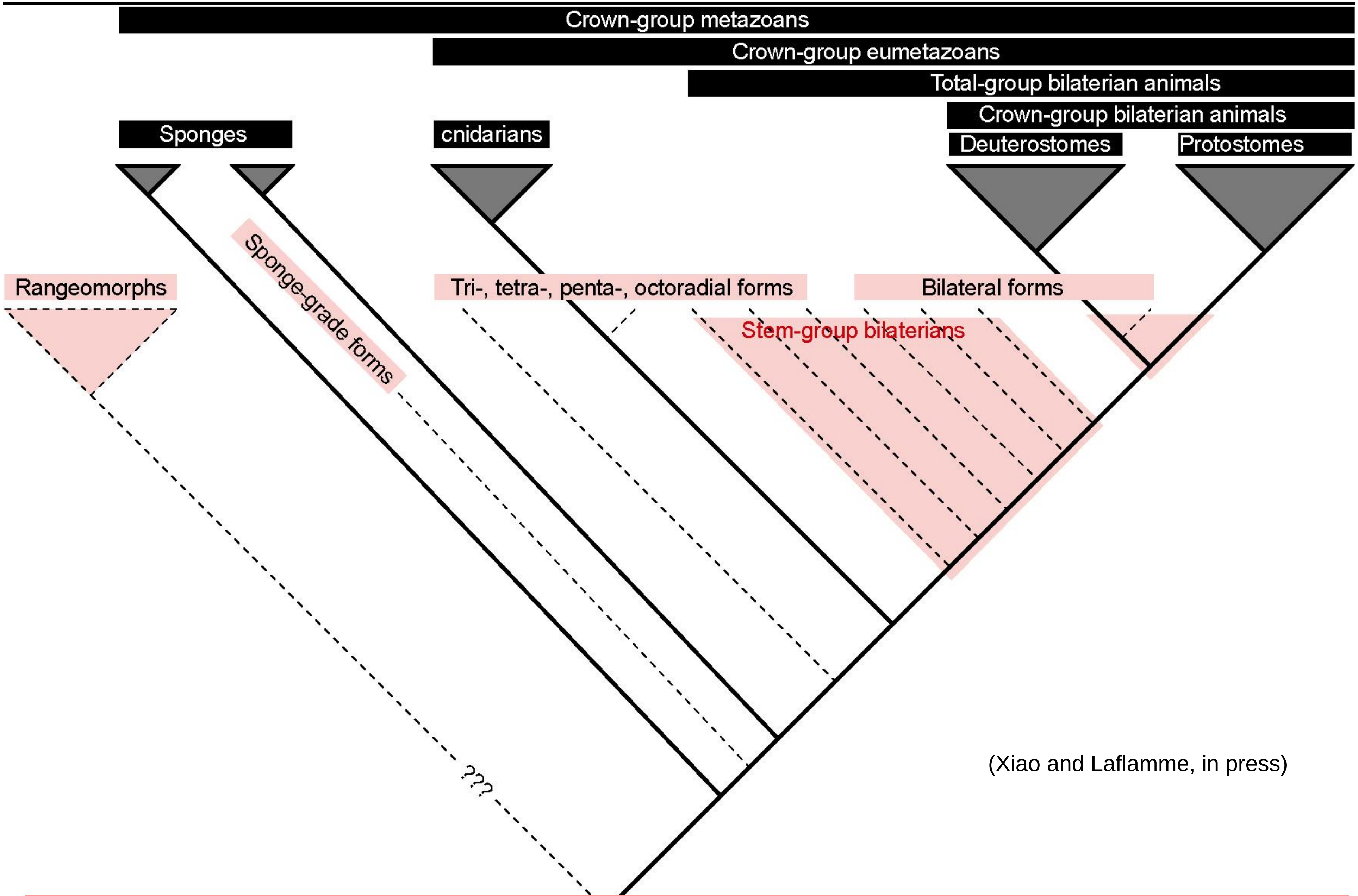
- *Cloudina*, the earliest biomineralizing animals;
- Drill holes may have been produced by predatory organisms?

Temporal Distribution of Ediacara Fossils



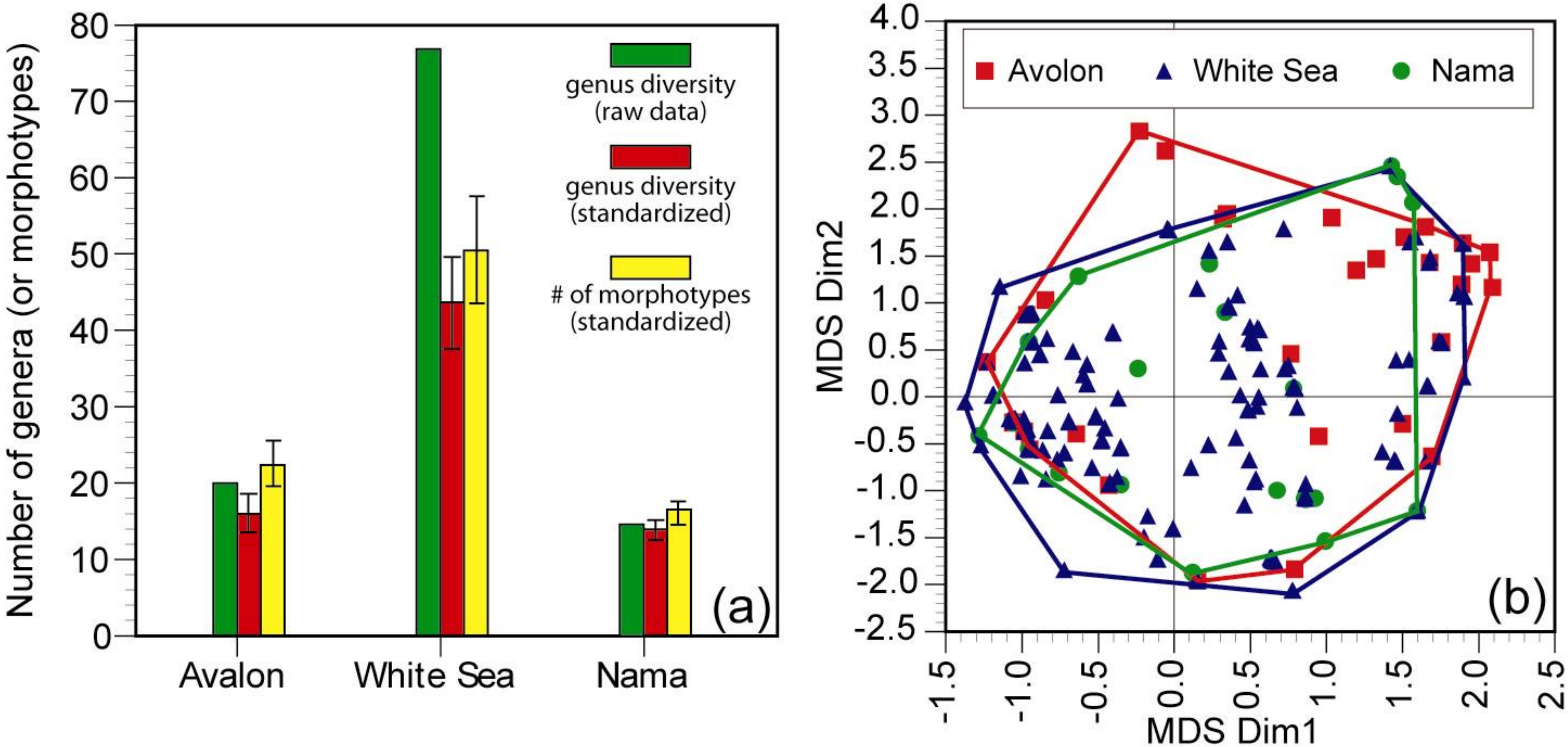
(Xiao and Laflamme, in press)

- Many have unusual bodyplans (triradial, tetraradial, pentaradial, octaradial);
- Diploblast-grade animals with a greater diversity of bodyplans in Ediacaran?



Ediacara fossils likely represent a paraphyletic group of organisms that scattered around the base of the animal tree.

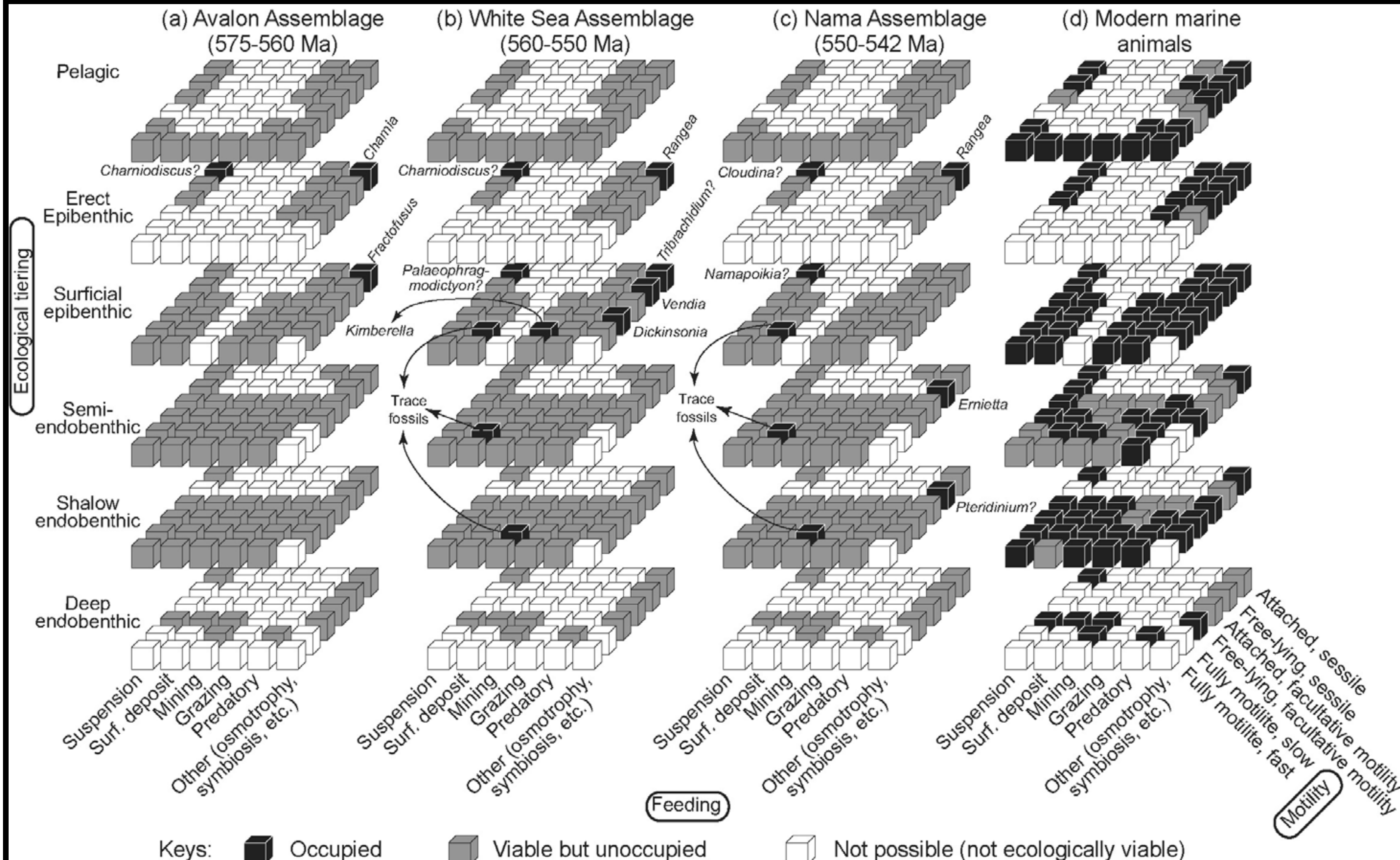
How many Ediacara fossils?



Taxonomic diversity vs. morphospace range (Shen et al., 2008)

- *White Sea has greater taxonomic diversity than Avalon or Nama*;
- But the three assemblages seem to occupy similar morphological range;

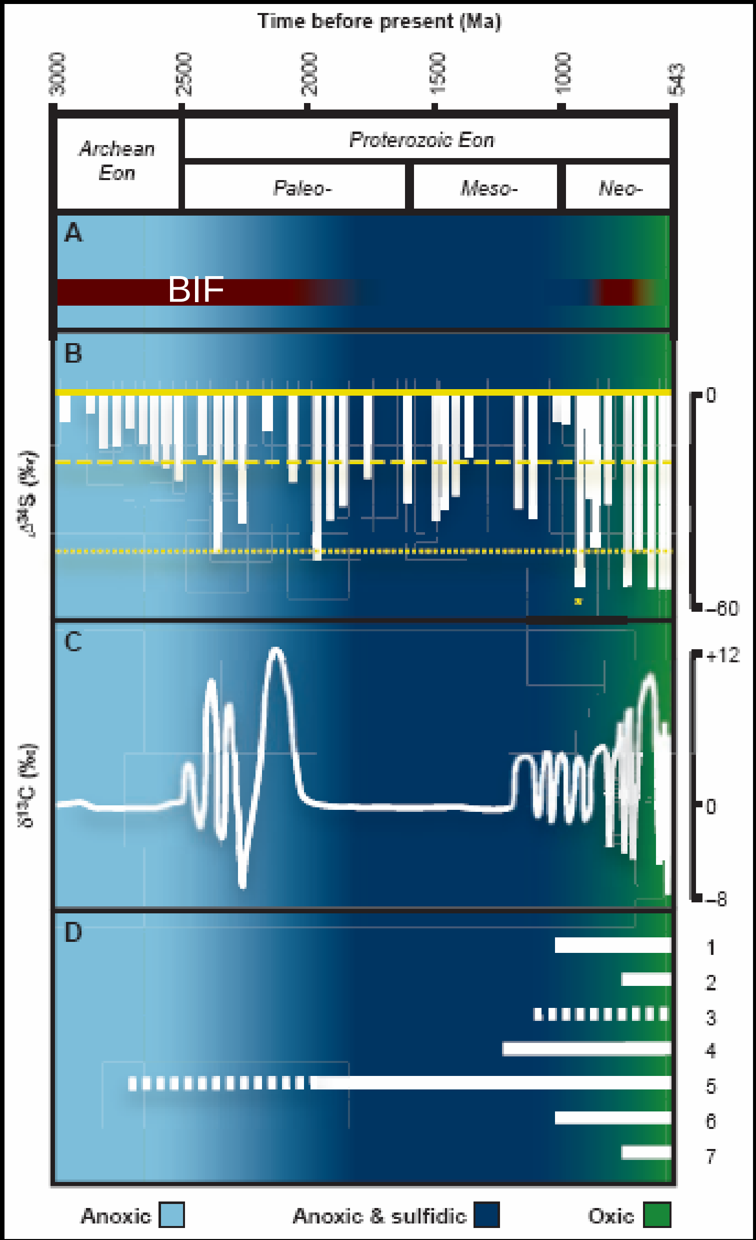
Ecospace Utilization by Ediacara Organisms



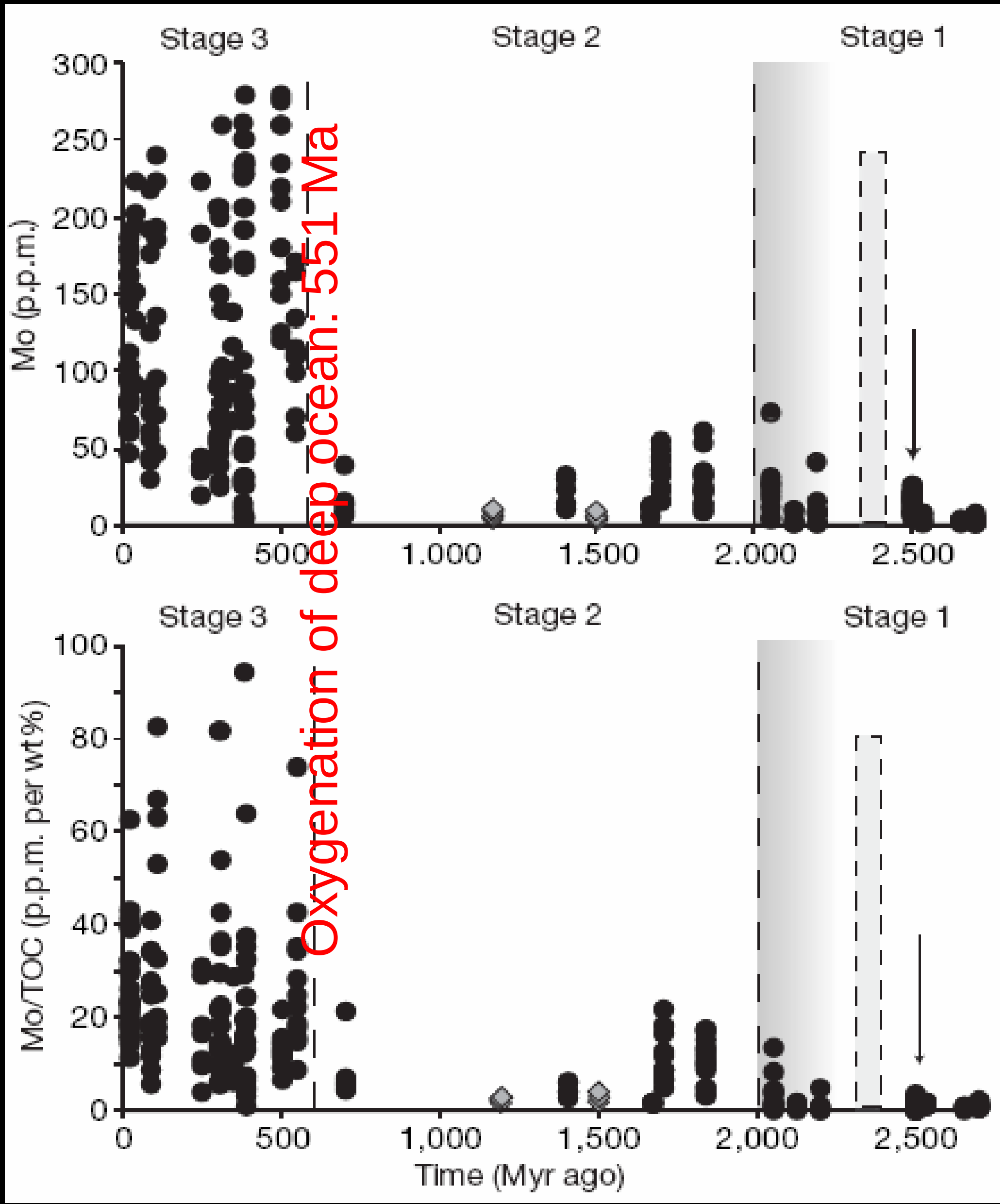
(Bambach et al., 2008)

- Ediacara ecospace occupation is sparse relative to modern marine animals;

Redox Evolution of Deep Ocean

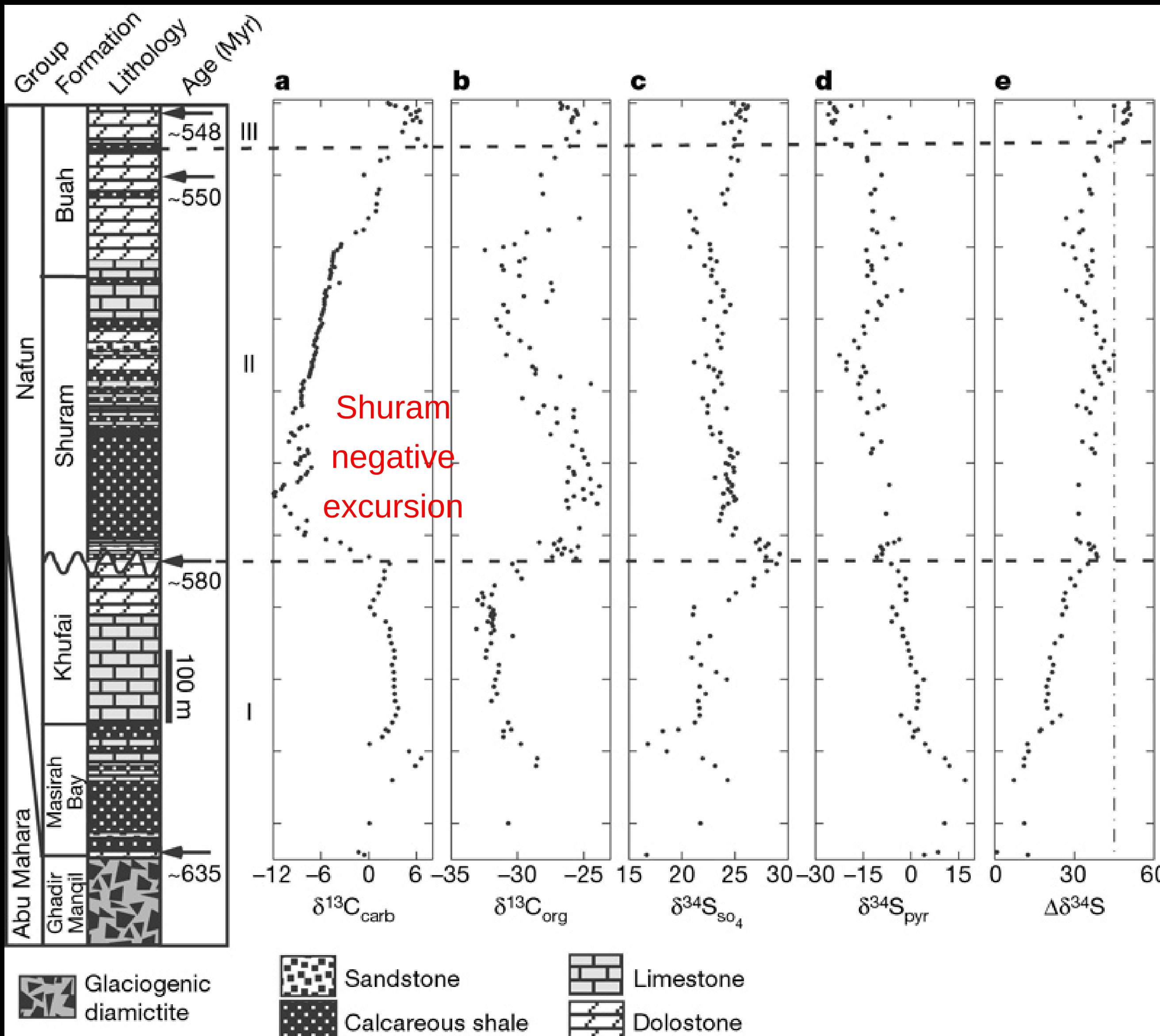


(Anbar and Knoll, 2002)



(Scott et al., 2008)

Ediacaran Oxygenation and DOC Remineralization: Oman



Stage 3c (550-540 Ma)

$\Delta\delta^{34}S$>46‰

oxidative sulfur cycle

Stage 3b (580-550 Ma)

$\delta^{13}C_{carb}$-$\delta^{13}C_{carb}$ decoupling

oxidation of large DOC reservoir in deep ocean

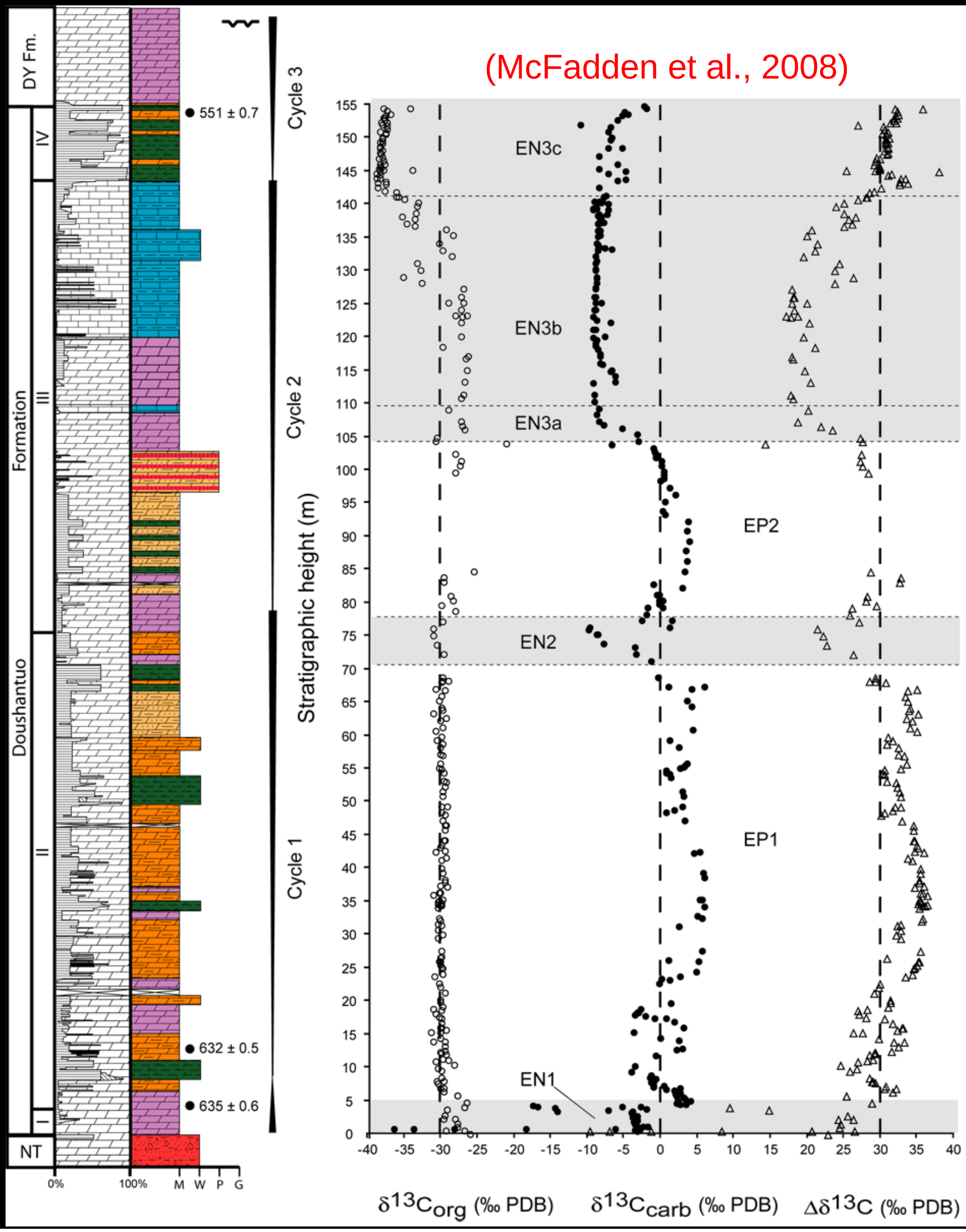
Stage 3a (635-580 Ma)

$\Delta\delta^{34}S$ from 1‰ to 35‰

$[SO_4^{2-}]$ from <200μM to <5mM

(Fike et al., 2006)

Doushantuo Carbon Isotope Data



Carbon Isotopes

EN3:

- Negative $\delta^{13}C_{carb}$ = -10‰
- DOC oxidation by sulfate input from weathering?
- $\delta^{13}C_{org}$ more variable;
- smaller DOC reservoir?

EP2:

- $\delta^{13}C_{carb}$ near +6‰

EN2:

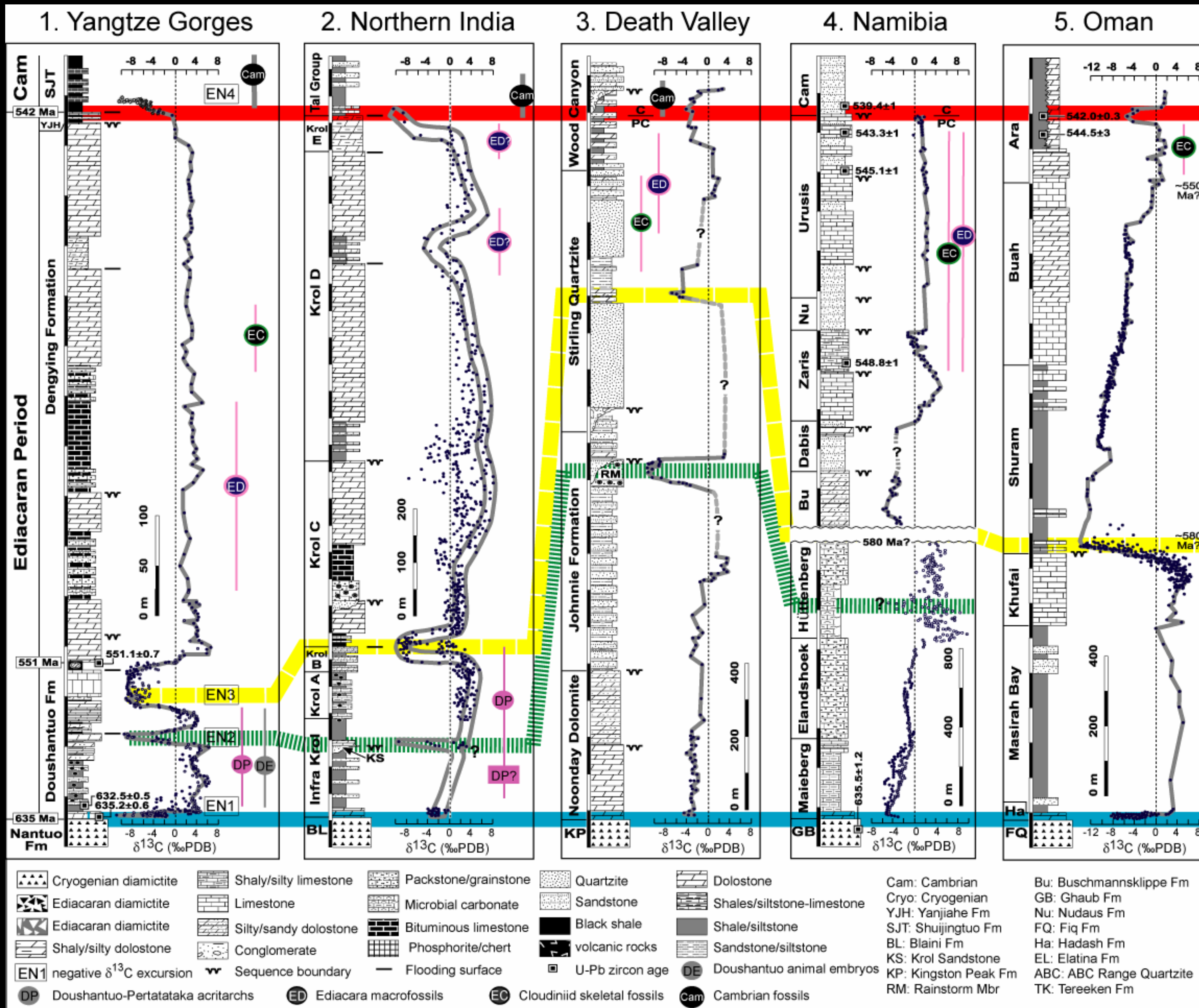
- $\delta^{13}C_{carb}$ near -9‰
- DOC oxidation?

EP1:

- $\delta^{13}C_{carb}$ near +6‰
- remarkably constant $\delta^{13}C_{org}$
- large, buffered DOC?

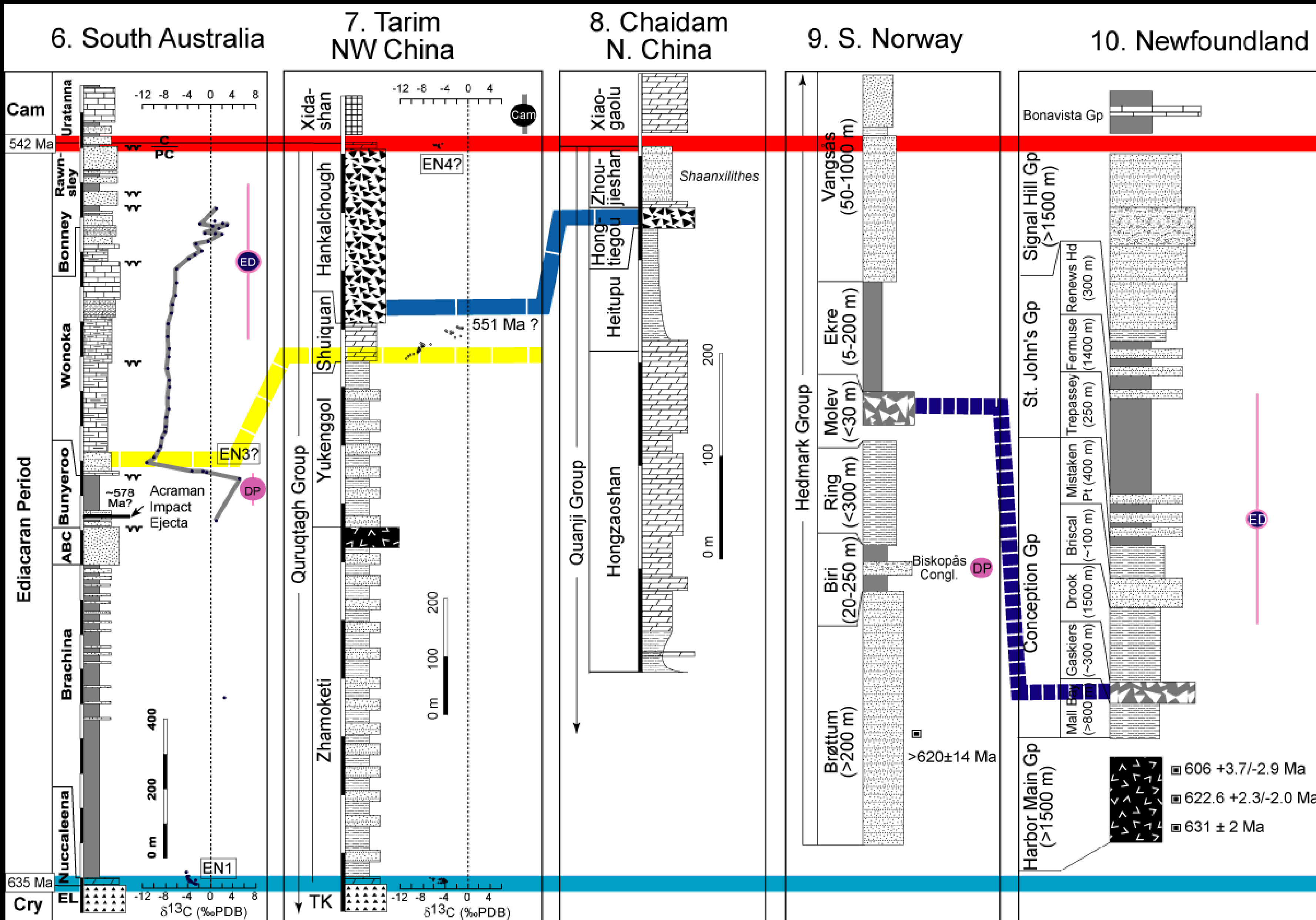
EN1: Cap carbonate negative anomaly ($\delta^{13}C_{carb}$ = -40‰)

Carbon Isotopes: Other Ediacaran successions



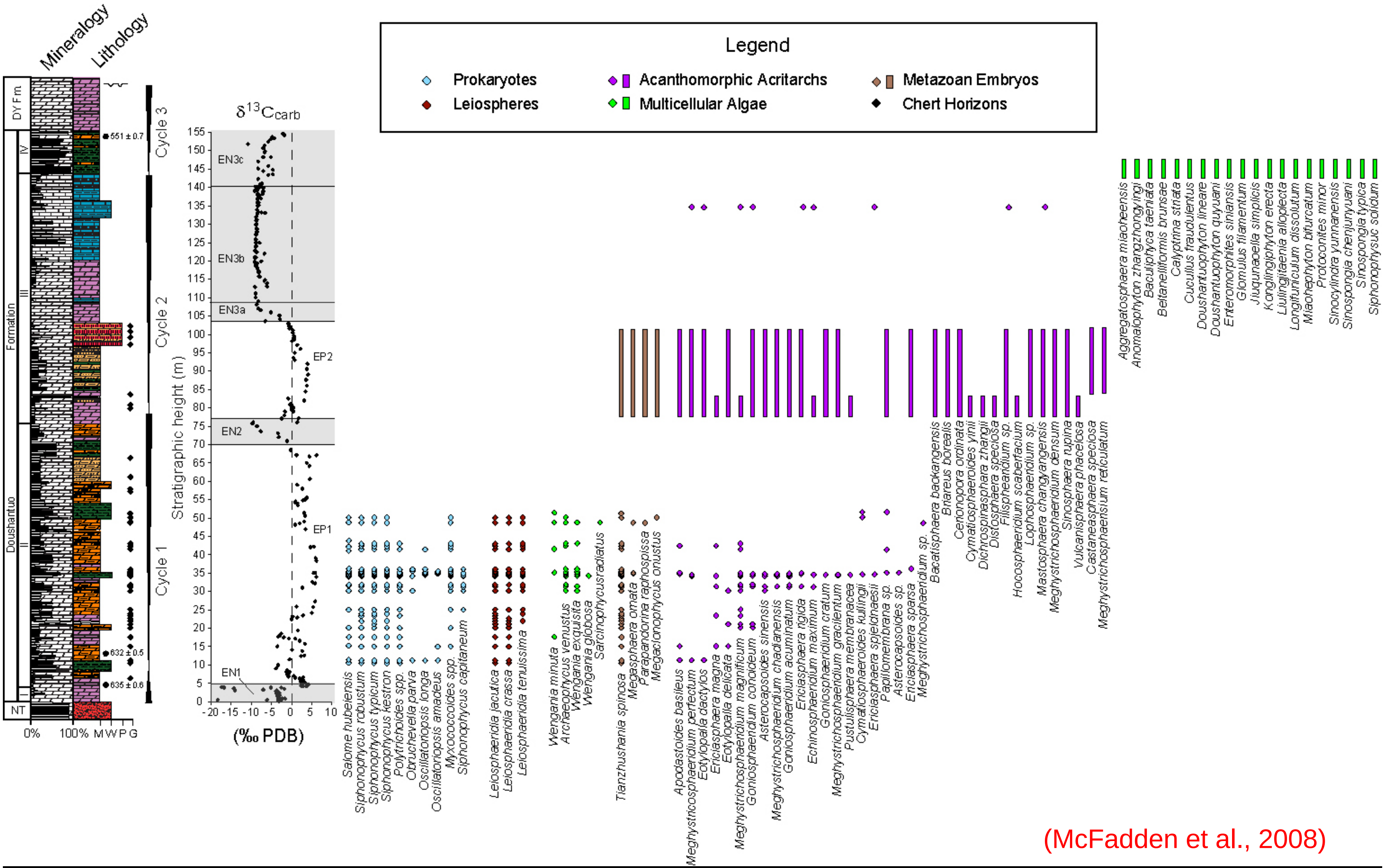
Sources: Halverson et al., 2005; Fike et al., 2006; Kaufman et al., 2006, 2007; Jiang et al., 2007; McFadden et al., 2008; Xiao, 2008

One or more Ediacaran glaciation(s)?



Modified from Jiang et al., 2007

Doushantuo Chemo- and Biostratigraphy



(McFadden et al., 2008)

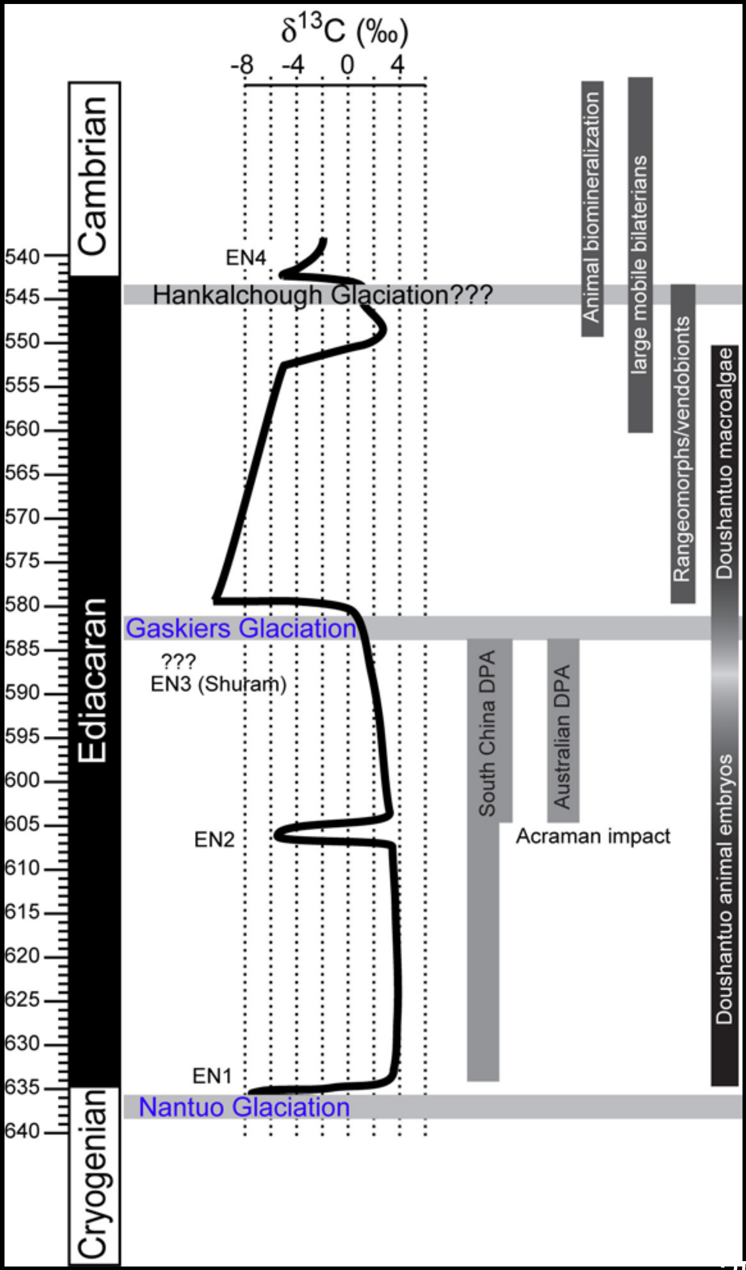
$\delta^{13}C_{carb}$ excursions and evolutionary events may be coupled;

Unresolved questions

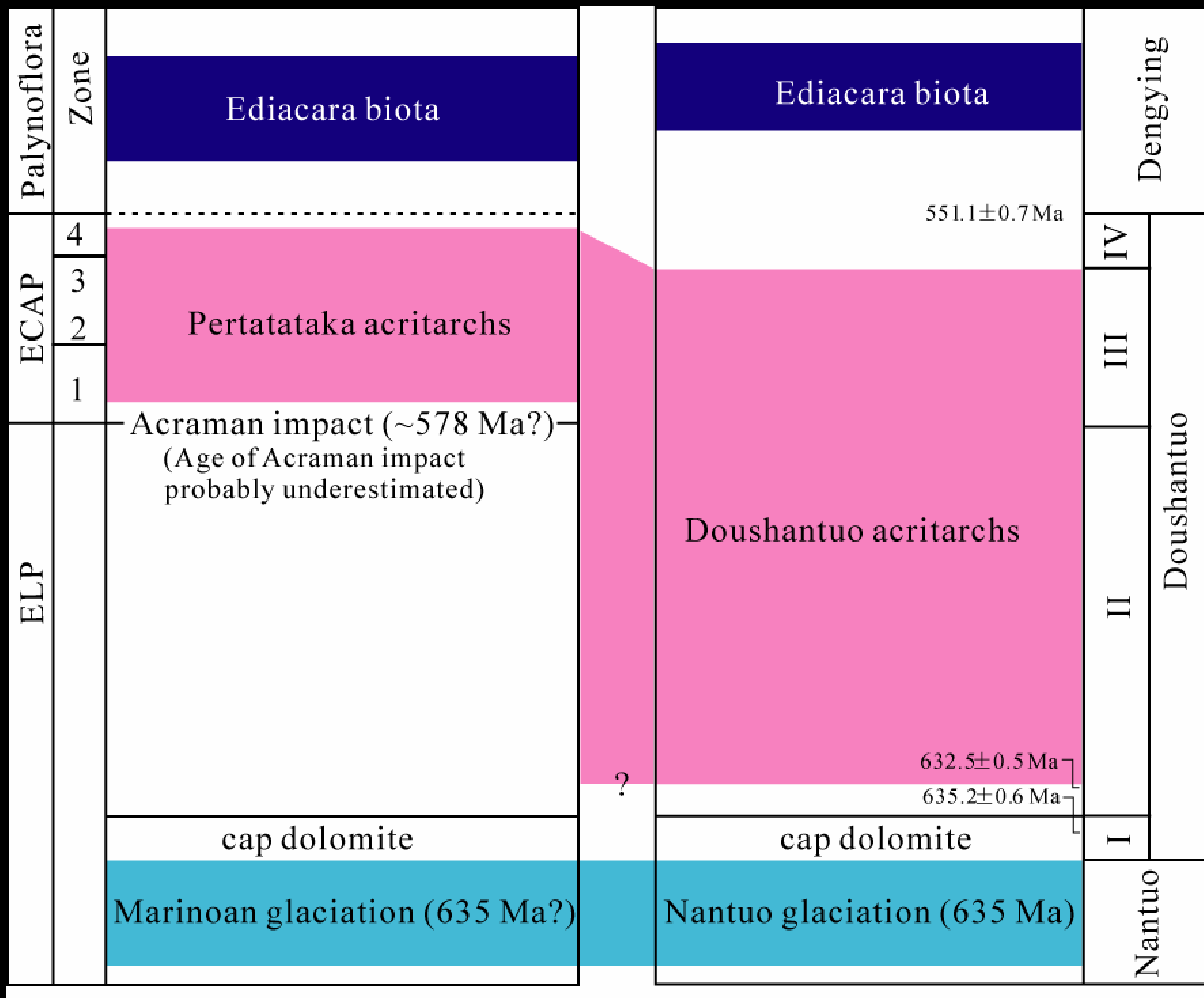
- Possible drivers for acritarch (and micrometazoan) diversification:
  - Termination of Nantuo/Marinoan glaciation?
  - Acraman impact?

- Possible drivers for acritarch extinction (and radiation of macrometazoans):
  - Gaskiers glaciation?
  - Rise of macrophagous animals?
  - Shuram event?
  - Oxygenation event?

- Possible drivers for Ediacara extinction:
  - Rise of macrobilaterians?
  - Glaciation?
  - Geochemical (redox) perturbation?



Ediacaran Acanthomorphic Acritarchs in Australia



The occurrences of Ediacaran acanthomorphic acritarchs in Australia post-date the Acraman impact event and may significantly post-date the Elatina glaciation;

Conclusions

- Two stages of biological evolution: acanthomorphic acritarchs followed by classical Ediacara fossils, including diploblastic eumetazoans and triploblastic bilaterians;
- Transition from a largely anoxic/euxinic to an oxic deep ocean;
- One (or more) Ediacaran glaciations;
- Emerging data indicate that Ediacaran biological, climatic, and redox evolution may be coupled;
- Correlation of Ediacaran successions remains poorly resolved;