A new proxy to constrain Cambrian sea temperatures

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1. Background

The earliest known fossils of most of the modern animal phyla are found in rocks of Cambrian age, 541–485 Ma (e.g. Erwin et al., 2011). Their appearance in the fossil record is known as the Cambrian metazoan adaptive radiation, or 'Cambrian explosion'. However, marine environments during this important interval of Earth's biological history remain poorly constrained. The Cambrian is the only Phanerozoic period lacking ocean temperature proxy data (Fig. 1).

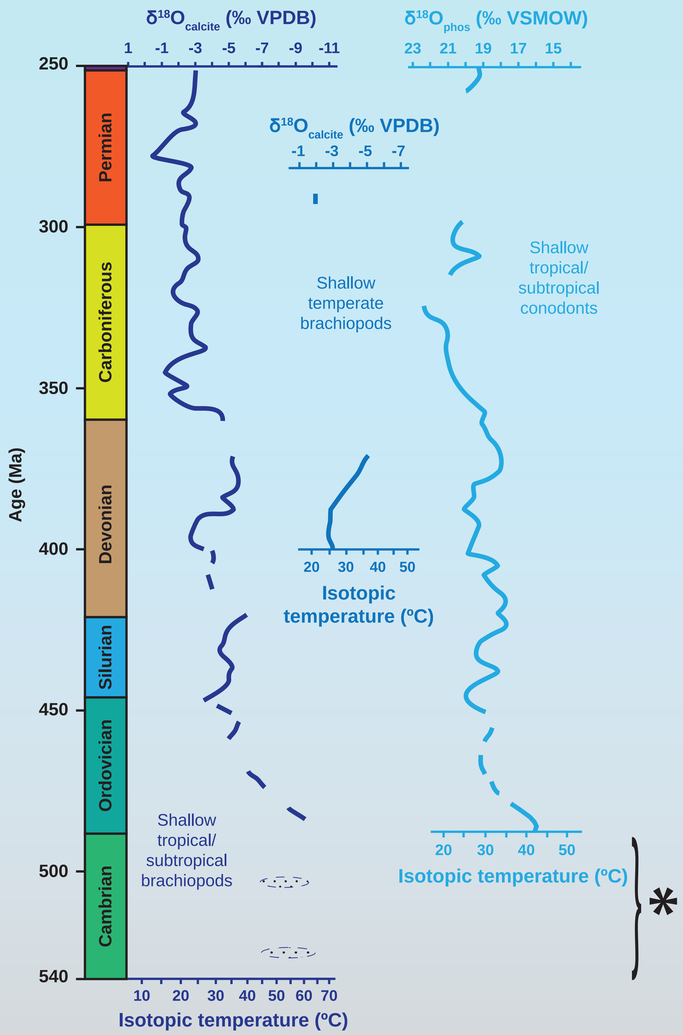

Fig.1. Oxygen isotope data and isotopic temperatures for the Palaeozoic Era. *Note the dearth of data through the ~55 million year Cambrian Period. Simplified after Grossman (2012).

2. Research Questions

1. Do phosphatic 'small shelly fossils' of the Comley Limestone (Fig.2), from the lower Cambrian of Shropshire, preserve original biogeochemical signals, including $\delta^{18}O_{phos}$?

2. Can a palaeotemperature signal be deconvolved from this $\delta^{18}O_{phos}$ data?

3. Could a wider range of phosphatic microfossils now be used to quantitatively investigate past climates?

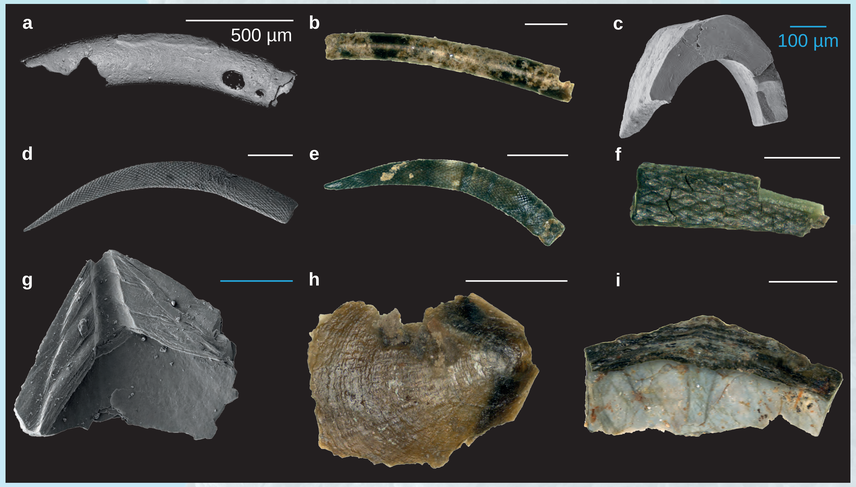

Fig.2. SSFs from the recently dated Comley Limestone (Harvey et al., 2011), lower Cambrian of Shropshire, include: the tubular forms *Hyolithellus* (a, b) and *Torellella* (c); the enigmatic spinous genus *Rhombocorniculum* (d-f); alongside various lingulid brachiopods (g-i). Greyscale images from SEM, colour images from optical microscopy.

3. Small Shelly Fossil (SSF) Preservation

A subset of phosphatic SSFs from the Comley Limestone have well-preserved biological ultrastructure (Fig.3) and have not undergone crude geochemical alteration (Fig.4).

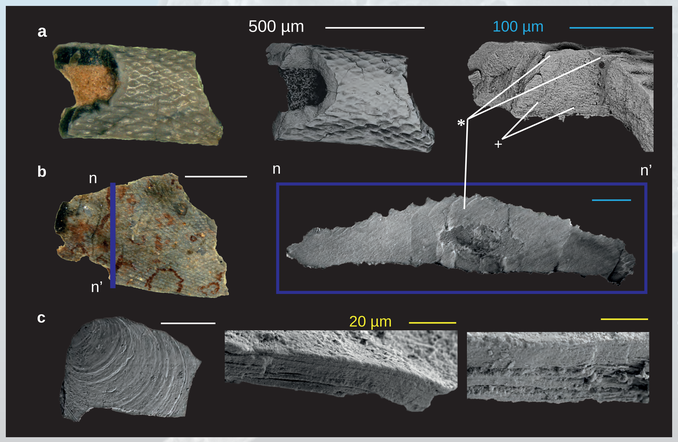

Fig.3. (a, b) *Rhombocorniculum* colour distinguishes between biogenic (dark, prismatic, +) and recrystallised (light, massive, *) phosphate. (c) biogenic compact and bacculate laminae are preserved in lingulid brachiopods.

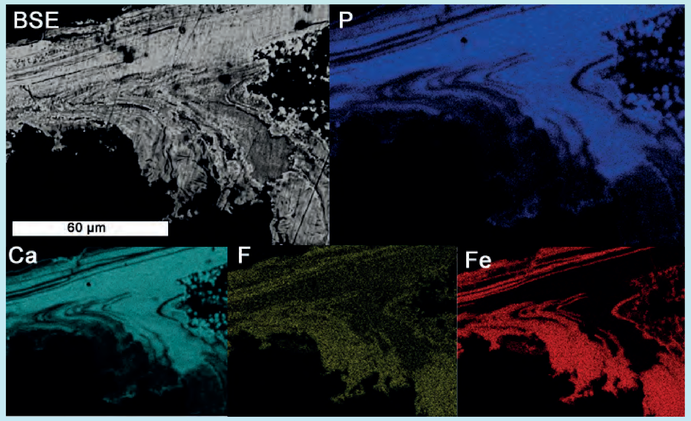

Fig.4. SEM-EDX analyses of a polished cross section of the hinge region of a lingulid brachiopod from the Comley Limestone. BSE = back-scattered electron image; P = phosphorous EDX map; Ca = calcium EDX map; F = fluorine EDX map; Fe = iron EDX map. Ca and P concentrated in the compact laminae, F and Fe concentrated in the more porous bacculate laminae.

5. Conclusions

SSFs from the Comley Limestone preserve biogenic ultrastructure and, to first order, chemistry. Higher resolution chemical data is currently being collected, inline with a newly developed protocol for determining phosphate diagensis. These microfossils will be targeted to determine the first quantitative constraints on Cambrian ocean temperatures.

SSFs have a global distribution in the lower Cambrian and include taxa from at least 6 animal phyla (e.g. Kouchinsky et al., 2012). Small phosphatic fossils are known throughout the Cambrian Period and have the potential to be used in palaeoclimate studies, much as conodonts are throughout the rest of the Palaeozoic Era.

Acknowledgements

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Background image: *Lapworthella* from the Comley Limestone , ~450 µm long.
Right: Thomas Hearing at Mistaken Point, Newfoundland.

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