The unusual nature of the Proterozoic biomarker record and the Mat-Seal hypothesis

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Petroleum and bitumens are concentrates of hydrocarbon fossils of biological lipids (biomarkers). These biomarkers often contain significant biological and environmental information and can remain stable over hundreds of millions of years. However, bitumens of pre-Ediacaran age (>635 Ma) are scarce in the geological record and frequently adulterated by younger contaminants [1].

In this study, we re-analysed most known pre-Ediacaran bituminous deposits and determined 10 basins that contain clearly indigenous biomarkers dating back to 1,640 Ma [2, 3]. After exclusion of allochthonous hydrocarbons, the molecular fossils detected in these Precambrian sequences are distinct from their Phanerozoic counterparts. The pre-Ediacaran bitumens show significantly higher concentrations of 'unresolved complex mixture' (UCM), low concentrations or absence of eukaryotic steranes, the presence of putative bacterial aromatic steroids, high relative concentrations of mono- and dimethyl alkanes, and a conspicuous carbon isotopic enrichment of straight-chain lipids relative to acyclic isoprenoids and total organic carbon. Here we propose that these unusual characteristics primarily derive from non-actualistic taphonomic processes based on the pervasive presence of microbial mats in the Precambrian. This 'mat-seal effect' was broken with the onset of bioturbation in the Ediacaran when the primary source of fossil biomarkers switched from the benthos to the plankton.

The disturbance of soft sediments and associated microbial mat cover by infaunal burrowing was one of the most important geobiological innovations in the Neoproterozoic-Phanerozoic transition. This "Cambrian substrate revolution" [3] had profound effects on contemporaneous ecology [4], sedimentology [5] and sulphur geochemistry [6]. We argue that it also fundamentally altered the way in which organic matter was incorporated and preserved in the sedimentary record, giving rise to typical Ediacaran and Phanerozoic petroleum reserves, and potentially contributing to increasing atmospheric oxygen levels.

[1] Brocks (2011) *GCA* **75**, 3196-3213. Brocks *et al.* (2008) *GCA* **72**, 871-888. [2] Brocks *et al.* (2005) *Nature* **437**, 866-870. Summons *et al.* (1988) *GCA* **52**, 1747-1763. [3] Indigenous hydrocarbons occur as far back as ~2,500 Ma (Brocks *et al.* (2003) *Org. Geochem.* **34**, 1161-1175). However, these bitumens exclusively consist of PAH and diamondoids with little biological information. [3] Bottjer *et al.* (2000) *GSA Today* **10**, 1-7. [4] Seilacher (1999) *PALAIOS* **14**, 86-93. [5] Droser *et al.* (2002) *PALAIOS* **17**, 3. [6] Canfield and Farquhar (2009) *PNAS* **106**, 8123-8127.

What cooled the Earth during the last 20 million years?

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Abstract

During the last 20 million years earth temperature decreased but the CO_2 content of the atmosphere appears to have remained constant. Further, large changes in the Mg to Ca ratio and in the isotopic content of lithium in sea water also took place during this time interval. Explaining the lack of a CO_2 change constitutes a dilemma.