

The Neoproterozoic Oxygenation Event: its timing, magnitude and impact on the atmosphere/hydrosphere/biosphere

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The Neoproterozoic and encompassing Oxygenation Event represent the transition from the microbial to the animal worlds, and from Greenhouse to Icehouse back to Greenhouse periods. The Tonian and Ediacaran represent Greenhouse worlds bookending the Cryogenian with its extensive Snowball glaciations. Models suggest basic parameters of atmospheric (e.g., CO₂) drivers and concomitant air/water temperatures needed for these observational states (1). However, uncertainty persists due to the lack of direct evidence for environmental parameters.

Here we report the first environmental parameters (gas and liquid and solid) measured directly of fluid inclusions trapped within Tonian halite. The halite-bearing Browne Formation of the Officer Basin (Australia) based on strontium isotope age-dating against the Shaler Sequence (Canada), is about 836 to 821 Ma old (Fig. 1).

Based on previous studies the penecontemporaneous halite contains fluid-inclusion atmospheric O₂ ranging from 10.9% (2) to 1.5% (3) to 6.6% PAL (4). With a massively expanded database, the most stringent diagenetic screening process (Fig. 2) and modern day counterpart calibration, we determined atmospheric gas contents including greenhouse gases of carbon dioxide and methane for mid Tonian times. Microthermometry gives us air and water temperatures compatible with a Greenhouse world of the Tonian, which are agreement with equilibrium climate sensitivity calculations (5). In addition, seawater chemistry such as pH and redox are in-line with the other parameters measured for the Tonian atmosphere and hydrosphere. Furthermore, compatibility is further supported by the near equatorial position of Australia within the Rodinia Supercontinent.

This study provides some critical answers to the greenhouse and icehouse variation observed during the Neoproterozoic and a better understanding of the transition from the microbial world to one with great complexity of life in the sea and eventually on land. Generally, it also lends insight to a better understanding of the carbon cycle, oxygenation of ocean and atmosphere, and evolution of life.

(1) Pirrehumbert et al. 2011. *Annu. Rev. Earth Planet. Sci.* 39, 417-460
(2) Blamey et al. 2016. *Geology* 44, 651-654
(3) Yeung 2017. *Earth Planet. Sci. Lett.* 480, 66-74
(4) Park and Schaller 2025. *Gondwana Res.* 139, 204-215
(5) Cox et al. 2018. *Nature* 553, 319-322.

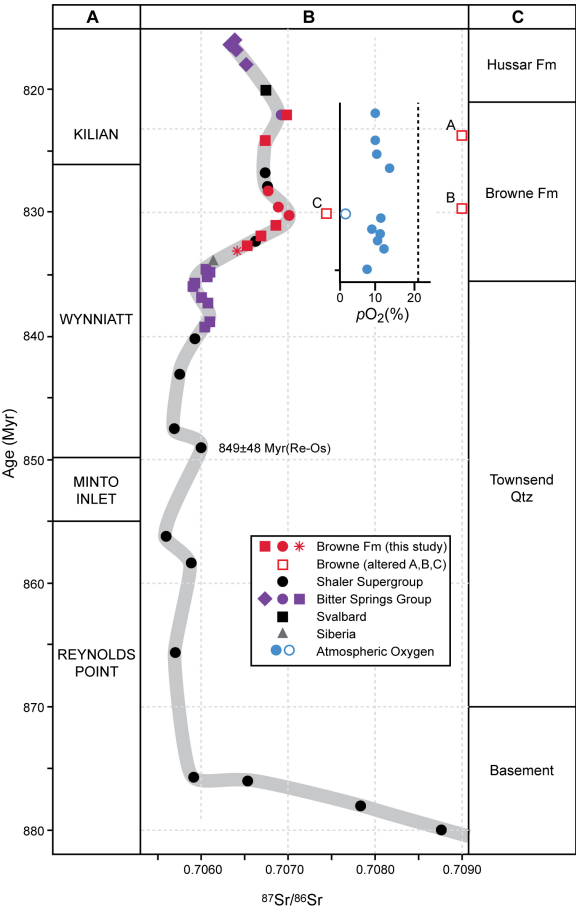


Fig. 1

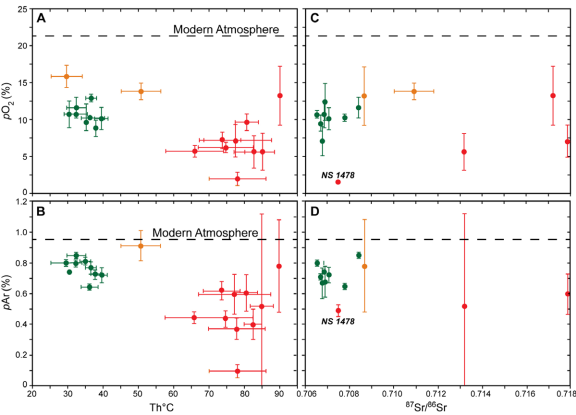


Fig. 2