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Determining holistic and integrated Tonian atmospheric, hydrospheric and climatic conditions

UWE BRAND[1], AUDREY K. MORRISON[2], NIGEL BLAMEY[3], PETER W. HAINES[4] AND CHRISTOPHE LÉCUYER[5]

[1]Brock University
[2]The University of Western Ontario
[3]University of Western Ontario
[4]Geological Survey of Western Australia
[5]UMR5276 LGL-TPE, Universite Claude Bernard Lyon1

In 1970, Fryer and Wagener presented the first results of atmospheric gas (whiffs of old air) trapped in inclusions of the Permian Zechstein halite. The difficulty is in obtaining robust results at the femto mole level, or with modelling of past atmospheric oxygen, carbon dioxide, and other gases with integrated relationships.

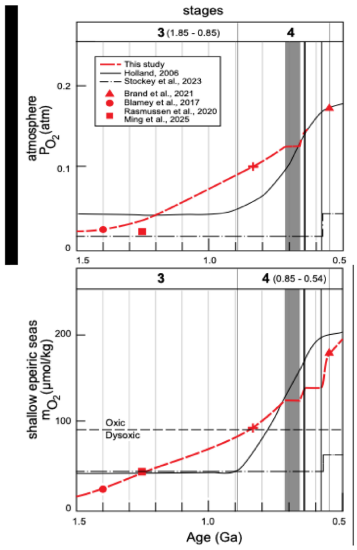
Another foray into the science of atmospheric gas trapped in anything older than ice cores came in 2016, when Blamey et al. announced that Tonian atmosphere contained about 10.9 % oxygen. This number was challenged immediately as being too 'high'. Later on it was realized that micro-organisms inhabiting the saline brine may have a profound effect on the gas compositions. Further advances were presented with the realization that atmospheric gas may reside in the 'dissolved' or microbubble state within halite-hosted fluid inclusions. The latter concepts necessitated a new approach to determining the 'original' and unaltered gas contents, fluid and solid chemistry of the hosts and 'guest' gases. Simply classifying material (gas, liquid, solid) as primary does not open the venue to a single approach of re-determining the ancient atmosphere.

We propose a holistic model that integrates *all* atmospheric components, as well as seawater temperature, dissolved oxygen and pH, and climatic conditions. Ancient atmosphere was determined by adding insight from microthermometry and climate sensitivity calculations and Henry's Law related parameters. Ultimately, the selection of the 'right stuff' of inclusions from either, a) trapped gas microbubbles, b) dissolved gas in fluids of inclusion, or c) combinations of a) and b) and possibly other still undefined factors for measuring the gas contents are related to the 'fixed' parameters of their respective N_2/Ar and O_2/Ar ratios.

We accomplished this holistic combination, and propose that the Tonian atmosphere appropriate for a greenhouse world consisted of 84.2, 9.99, 0.831, 0.951, 4.00 mol% N_2, O_2, Ar, CO_2 and H_2O, respectively, with global temperature ranging from 32 to 41°C (microthermometry and climate sensitivity calculations), and surface seawater (35°C) of 100 µmol/kg Dissolved Oxygen, and pH of 7.5 (Figures 1, 2).

Blamey et al., 2016. Geology, 44, 651-654.

Freyer, H.D., Wagener, H. 1970. Z. Naturforsch. 25, 1427-1430.



Brand et al. (2021), ESR, 216, 103560. Blamey et al. (2017), Goldschmidt 2017 Book of Abstracts, Paris. Holland (2006), PTRS,B, 361, 903. Meng et al. (2025), P3, 662, 112752. Rasmussen et al. (2020), Geology, 48, 44. Stockey et al. (2023), Nat. Geoscience, 17, 667.