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A multidisciplinary approach to quantifying atmospheric oxygen and environmental conditions in geologic time using evaporites

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Constraining past atmospheric oxygen levels and environmental temperatures has been a challenge to scientists because many geochemical approaches have lacked multidisciplinary analytical techniques. Many studies utilized a single analytical method, and use indirect analytical methods without calibration of modern proxies as well as materials derived from local basins with questionable links to the atmosphere. There is a clear need to develop a holistic and multidisciplinary approach where the conclusions are based on as many variables as possible and driven by direct analytical methods and corresponding results.

We use an approach based on halite and dolomite as the materials of choice, 1) both form in the shallow-marine environment and 2) precipitate at or near the brine-atmosphere interface. An 8-point screening protocol is applied that includes: macro- and micro-scale examination, fluid inclusion microthermometry, fluid inclusion gas analysis, trace element analysis, REE analysis with Ce*, $^{40}Ar/^{36}Ar$ analysis, and Sr-isotope analysis, and carbon and oxygen isotopes (where applicable) These methods combined together provide a more robust screening protocol (Blamey and Brand, 2019) and discriminate pristine marine and non-marine halite and marine dolomite from altered counterparts.

Results from the Neoproterozoic Browne halite (Blamey et al., 2016) confirm that the atmosphere at 835-825 Ma comprised 10-12 % pO_2 (~50% PAL) and temperatures ~35 °Celsius. Approaching the end-Ordovician mass extinction, atmospheric oxygen was 14-19 % pO_2 with temperatures 20-30 °Celsius; this refutes the hypothesis of euxinia causing the mass extinction. Halite from the Silurian Michigan Basin records a true Hothouse with temperatures of about 50 °Celsius. Throughout the Paleozoic, the atmosphere and shallow marine environments remained oxic, based on Ce* data.

Halite from the 2.0 Ga Onega Group of Russia confirms atmospheric oxygen levels ~16.3 % pO_2 (78 % PAL) whereas at 1.45 Ga, the Sibley Group of Canada confirms ~3.6 % pO_2 (17 % PAL). The increase of atmospheric oxygen at 2.0 Ga, then decrease by 1.45 Ga, provide a redox window and match metallogenic epochs for both U-unconformity and SEDEX Pb-Zn deposits.

Blamey et al., 2016. Geology, 44, 651-654.
Blamey and Brand, 2019. Gondwana Research, 69, 163-176.
Brand et al., 2021. Earth-Science Reviews, 216, 103560.