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Assessing the plausibility of directly constraining ancient atmospheric pCO_2 from halite fluid inclusions: Extending our record of ancient CO_2 beyond the ice cores.

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Our current methods for reconstructing ancient atmospheric CO_2 rely heavily on proxies for time periods prior to the ice-core record. Fluid inclusions in halite from surficial environments have recently gained attention for their ability to capture and preserve snapshots of ancient air, and by mechanical decrepitation these inclusion gases can be quantified via mass spectrometry. However, it has yet to be demonstrated that the CO_2 contents measured in halite accurately represents the overlying air at various pCO_2 levels. To address this, we precipitated halite in a sealed pressure vessel under various pCO_2 conditions (450 ppm, 3000 ppm, and 5000 ppm). The gas contents of the lab-grown halite (LGH) were measured with a quadrupole mass spectrometer. Observed CO_2 contents fall between expected values of air and air-saturated brine for the different pCO_2 conditions. By partitioning gas contributions from each phase[1], we observe atmospheric pCO_2 values closely matching the conditions under which the LGH precipitated. These findings demonstrate the ability of halite inclusions to faithfully entrap and preserve atmospheric CO_2, giving us confidence in applying our methods to new and existing analyses of both natural modern and ancient halite-inclusions. A major concern with natural and ancient inclusions is their propensity to trap organic matter and/or intact microbes, potentially leading to post entrapment alteration of the non-conservative species (i.e., CO_2 and O2). On natural samples from the modern we show that with appropriate partitioning we can exclude analyses showing evidence of such alteration, ensuring we only interpret unaltered atmospheric CO_2 contents. Finally, we present records of atmospheric CO_2 spanning from the modern to the Mesoproterozoic. Coupled with microthermometry data, we provide insight into Earth's long term climatic evolution that corroborates prior models and proxies. Bulk gas analysis of fluid inclusions in natural halite samples are clearly trapping the atmosphere during mineral formation. This is a promising method to reliably reconstruct atmospheric compositions through deep time and extend direct measurements of ancient pCO_2 well beyond the ice core record.

References:

[1] Park, J.G., and Schaller, M.F., (2025), GR, doi.org/10.1016/j.gr.2024.12.003