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Novel reconstructions of seawater trace element concentrations and redox chemistry from halite fluid inclusions

ESZTER SENDULA[1], DR. HANA JURIKOVA[2], ROBERT J. BODNAR[3], MATTHEW D. DUMONT[2], ROBERT C. J. STEELE[2], DAVID EVANS[4], TIM K. LOWENSTEIN[5], MEBRAHTU F. WELDEGHEBRIEL[6], JAVIER GARCÍA-VEIGAS[7] AND JAMES W. B. RAE[2]

[1]Supervisory Authority for Regulatory Affairs, Geological Survey
[2]University of St Andrews
[3]Virginia Tech
[4]University of Southampton
[5]Binghamton University
[6]Princeton University
[7]University of Barcelona

Fluid inclusions entrapped within marine evaporites represent a unique and direct archive of paleo-seawater chemistry, offering valuable constraints on fundamental aspects of the Earth System, including ancient climates, supercontinent assembly and breakup, continental weathering, and seafloor spreading. Despite their considerable potential, reconstruction of seawater chemistry from fluid inclusions remains challenging. These challenges arise from analytical limitations inherent to single fluid inclusion measurements, as well as from an incomplete understanding of trace element fractionation during progressive seawater evaporation, evaporite mineral crystallization, and potential local biogeochemical modification. As a result, our understanding of past trends in elemental concentrations in seawater remains incomplete, and uncertainties persist regarding the accuracy and interpretation of fluid inclusion geochemical data.

To address these knowledge gaps, we present new elemental data from modern and ancient halite samples, complemented by halite grown during seawater evaporation experiments under controlled laboratory settings. Single fluid inclusions were analyzed using state-of-the-art laser ablation inductively coupled plasma mass spectrometry system (LA-ICP-MS). First, we integrate natural and experimental sample datasets to evaluate trace element behavior during progressive evaporation of seawater and evaporite mineral precipitation, identifying systematic fractionation trends, and assessing the extent of preservation of primary seawater signatures in halite-hosted inclusions. Second, we present a case study from the Polish Zechstein Basin, where reconstructed Fe, Mn, Mo, U, and V concentrations record a transition from oxidizing to reducing conditions in the Zechstein epicontinental sea during the Late Permian, documenting oxygen loss during the warming that led up to the Permian-Triassic mass extinction (Sendula et al., 2022). Collectively, our results contribute to refining the interpretation of halite fluid inclusion records and provide improved constraints on past changes in seawater chemistry.

Reference: Sendula et al. (2022) Redox conditions in Late Permian seawater based on trace metal ratios in fluid inclusions in halite from the Polish Zechstein Basin. *Chemical Geology*, 596, 120794.