Geochemical insights into one of the earliest marine habitats on Earth – the reliability of 3.5-billion-year-old jaspillites from the Dresser Fm., Australia

S. Viehmann[1], D. Krämer[2], C. Koeberl[3], S.V. Hohl[4], M.J. van Kranendonk[5]

[1]*University of Hannover, Institute of Mineralogy, Hannover, Germany*
[2]*Federal Institute of Geosciences and Natural Resources (BGR), Hannover, Germany*
[3]*University of Vienna, Deptartment of Lithospheric Research, Vienna, Austria*
[4]*State Key Laboratory of Marine Geology, Tongji University, Shanghai, P.R. China*
[5]*University of New South Wales Sydney, Australian Centre for Astrobiology, Sydney, Australia*
e-mail: s.viehmann@mineralogie.uni-hannover.de

The ca. 3.5 billion-year-old Dresser Formation in the Pilbara Craton, Western Australia, is famous for its traces of early life in the form of microfossil assemblages and stromatolites. These unique rock types provide fascinating windows into habitats of microbial life and the state of the ambient atmosphere-hydrosphere system. Among several pioneering studies targeting interdisciplinary fields of geo(micro)biology and geochemistry, trace elements in combination with Fe isotopes of jaspilites from different units within the Dresser Formation have recently been reported to reconstruct ancient paleo-environments (Johnson et al. 2022). This geochemical study targeted jaspillites, i.e., chemical sediments that are proposed to directly reflect ancient fluid chemistry from which the jaspillites formed, from four consecutive horizons of the Dresser Formation. They propose severe and fluctuating paleo-environmental changes during the deposition of these units in combination with changing nutrient availability and limitation during land-sea transitions based on Rare Earth's and yttrium (REY) and Fe isotope systematics. While this study provides a crucial milestone in understanding the earliest microbial habitats on Earth, the source of elements providing nutrients among other elements in the ancient Dresser aqueous environments remains still incompletely understood.

To determine the sources affecting water chemistry in the Dresser Formation, we obtained trace element and radiogenic Nd isotope compositions of high pressure-high temperature digestions of jaspilitic cherts directly overlying the famous "candelabra"-stromatolites from a terrestrial hot spring deposit (Djokic et al. 2017). The trace element data corroborate the endmembers (Johnson et al. 2022): endmember I shows seawater-like shale-normalized (subscript SN) REY_{SN} patterns with positive La_{SN}, Gd_{SN} anomalies, heavy REY_{SN} over light REY_{SN} enrichment, and super-chondritic Y/Ho ratios. In contrast, the endmember II is characterized by the lack of typical seawater-like anomalies, sub-chondritic Y/Ho ratios, and light REY_{SN} over heavy REY_{SN}. Positive Eu_{SN} anomalies representing REY contributions from high-temperature, hydrothermal fluids in the ancient Dresser depositional environment are present in both endmembers. Radiogenic Nd isotope compositions, commonly used to determine the local sources of REY in modern and ancient seawater due to the short residence time of Nd, show a significant impact of post-depositional alteration and a reset of the Sm-Nd isotope system in the Dresser Formation jaspillites. A best-fit isochron calculation yields a Sm-Nd age of 2260 Ga ± 180 Ma that overlaps with thermo-tectonic events in Pilbara Craton between 2430 to 2400 Ma and 2215 to 2145 Ma (Rasmussen et al. 2005), respectively, suggesting that Nd isotope of the Dresser Formation jaspillites are unreliable geochemical proxies to reconstruct sources in Dresser fluids 3.5 Ga ago. We – however- strongly emphasize that overall REY distributions and Fe isotope compositions must not necessarily be affected by these events, although the Nd isotope compositions in the Dresser jaspillites show significant disturbances.

Djokic T, Van Kranendonk1 MJ, Campbell KA, Walter MR, Ward CR (2017): Earliest signs of life on land preserved in ca. 3.5 Ga hot spring deposits. - Nat Comm 8, 15263

Johnson CM, Zheng X-Y, Djokic T, Van Kranendonk MJ, Czaja AD, Roden EE, Beard BL (2022): Early Archean biogeochemical iron cycling and nutrient availability: New insights from a 3.5 Ga land-sea transition. - Earth Sci Rev 103992

Rasmussen B, Fletcher IR, Sheppard S (2005): Isotopic dating of the migration of a low-grade metamorphic front during orogenesis. - Geology, 33, 773-776