Reconstruction of a 3.5-billion-year-old marine environment: Evidence from trace element data of iron formation from the Daitari Greenstone Belt, Singhbhum Craton, India

S. Kienle[1], S. Viehmann[2], J. Jodder[3,4], A. Hofmann[4], T. Schulz[1], C. Koeberl[1]

[1]*Department of Lithospheric Research, University of Vienna, Austria*
[2]*Institute of Mineralogy, Leibniz University Hanover, Germany*
[3]*Evolutionary Studies Institute, University of the Witwatersrand, South Africa*
[4]*Department of Geology, University of Johannesburg, South Africa*
e-mail: a01616435@unet.univie.ac.at

Banded Iron Formations (BIF) are marine chemical sedimentary rocks common in Precambrian volcano-sedimentary sequences. BIFs serve as geochemical archive of the composition of Precambrian seawater, and their trace element composition aids to investigate the geochemical evolution of the early Earth.

The Daitari Greenstone Belt (DGB) in the Singhbhum Craton of India hosts a ca. 3.5–3.3 Ga old volcano-sedimentary sequence with BIFs preserved within the Tomka Formation (Jodder et al. 2023). The DGB has only experienced greenschist-facies metamorphic conditions (Hofmann et al. 2022) providing a unique record for marine chemical sediments from the early Archean. Here we studied the Tomka BIF, which might serve as an excellent geochemical archive to reconstruct physico-chemical conditions of the 3.5-billion-year-old marine environment in the Daitari area. It may provide unique insights into the state of Earth's oceans, continents, and atmosphere within this critical time window.

Trace element compositions of high pressure-high temperature digestions of individual chert-, Fe- and mixed Fe- and chert-microbands were determined via quadrupole ICP-MS following the protocol described in Viehmann et al. (2016). Trace element compositions of chemical sediments can be used to reconstruct the depositional environment and physico-chemical conditions of the ambient atmosphere and hydrosphere. The Tomka BIF samples have very low concentrations of incompatible elements such as Al, Hf, Th, and Zr. In addition, the concentrations of rare earth elements and yttrium (REY) show no correlations with fluid-mobile elements such as Sr. The chemical compositions thus highlight their usefulness as a geochemical archive of Paleoarchean seawater. Pure chert, Fe- and mixed layers of the Tomka BIF display typical REY distribution patterns of Archean seawater (e.g., Alexander et al., 2008) and shale-normalized (subscript SN) REY_{SN} patterns similar to modern seawater, i.e., enrichment of heavy to light REY_{SN} (Yb_{SN}/Pr_{SN}: 2.67-20.4), positive La_{SN} (La_{SN}/La_{SN}^*: 1.43-3.43) and Gd_{SN} (Gd_{SN}/Gd_{SN}^*: 1.12-1.64) anomalies and super-chondritic Y/Ho ratios (41.2-66.7). The presence of positive Eu_{SN} (Eu_{SN}/Eu^*_{SN}: 1.37-3.17) anomalies indicate REY contributions from high-temperature hydrothermal fluids in seawater of the Tomka depositional environment. The lack of negative Ce_{SN} (Ce_{SN}/Ce^*_{SN}: 0.67-1.37) anomalies suggests anoxic atmospheric-hydrospheric conditions during BIF deposition.

The presence or absence of Eu anomalies in chondrite-normalized (subscript CN) REY patterns of BIFs can be used to distinguish between Archean and Post-Archean chemical sedimentary rocks. REY data of pure BIFs show that Eu_{CN}/Eu^*_{CN} ratios of Precambrian seawater follow a general global evolution curve with BIFs displaying strong positive Eu_{CN} anomalies in the Eoarchean, followed by decreasing Eu_{CN}/Eu^*_{CN} ratios until the Neoarchean (Viehmann et al. 2015). Eu data from BIFs in the time frame around 3.5 Ga, however, are lacking to date. Eu_{CN}/Eu^*_{CN} ratios of the Tomka BIF that fall into this time window do not follow the global seawater Eu curve but show significantly lower Eu_{CN}/Eu^*_{CN} values than expected. These values may indicate a less pronounced flux of high-temperature hydrothermal REY to the Archean ocean 3.5 Ga ago.

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