Mechanisms Controlling Archean Iron Formation Genesis in Shallow vs. Deep Water

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The mechanisms responsible for the deposition of Precambrian iron formations (IF) are still a point of contention amongst researchers, with even the original mineralogy being debated. Here we explore the geochemical differences between six deep and shallow water Archean IF located in the Superior Craton using bulk rock and laser ablation high resolution inductively coupled plasma mass spectrometry ((LA-)HR-ICP-MS). Both inter-formational and intra-layer geochemistry were evaluated to better understand their deposition and potential chemical contrasts in the shallow vs. deep Archean ocean.

Differences in REE+Y signatures normalized to Post Archean Australian Shale (PAAS) are apparent between shallow and deep water IF, the former marked by smaller Eu and Y anomalies and overall flatter patterns. Deep water IF patterns show LREE depletion and variable Y anomalies, but maintain a strong Eu anomaly (Eu/Eu*). The chondritic value of Y/Ho (28) and positive Eu/Eu* are both common in modern vent fluids, whereas subchondritic to slightly suprachondritic values of Y/Ho are associated with vent precipitates [1]. Y/Ho ratios in several deep water IF range from supra- to sub-chondritic (70 to 21) with Eu/Eu* values from 2 to 6. However, the studied IF deposited in shallow to intermediate water depths have Y/Ho ratios above 30 and up to almost 80 with no Eu/Eu* values greater than 3.

Trends between trace and redox sensitive elements (U, Cu, Mo, Cr, and V) within deep water IF are present, with positive relationships between U vs. Cu, U vs. V, and Cu vs. V. We see no relationships between Al and Ti in deep water IF, while there is a strong relationship between these immobile elements in the studied shallow IF and hydrothermal deposits. This implies a decoupling of Al and Ti sources from one another in the deep deposits, whereas a greater siliciclastic influx into the shallow water settings yields strong correlation. Interestingly, X-ray Fluorescence (XRF) scans of deep water IF show Al concentrating in iron-rich bands while Si-rich bands are much lower in Al, which might imply more rapid deposition. In summary, differences in geochemistry between shallow and deep water IF appear to reflect a combination of proximity to hydrothermal venting and distance from siliciclastic/freshwater sources.

[1] Bau, M. (1996). Controls on the fractionation of isovalent trace elements in magmatic and aqueous systems: evidence from Y/Ho, Zr/Hf, and lanthanide tetrad effect. Contributions to Mineralogy and Petrology, 123(3), 323–333.