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Spatial distribution of chromium enrichment in 3.2 Ga Moodies BIF, Barberton Greenstone Belt, South Africa

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Geochemical data for ferruginous chemical sedimentary rocks (e.g., Banded Iron Formation: BIF) have been used to understand surface environments on early Earth. For example, enrichment of Cr relative to Ti in BIFs that occurred ~2.48 billion years ago has been considered as a result of the chemical mobilization of Cr in acidic aqueous environments due to sulfide oxidation after the oxygenation of atmosphere. While the Archean sedimentary environments studied in most previous works are limited to deeper settings, the 3.2 Ga Moodies BIF in the Barberton Greenstone Belt, South Africa also indicated that Cr was enriched in the BIF and was therefore chemically mobile in a shallow marine environments. This finding could be significant because it may indicate the oxidation of, at least, some parts of the ocean and therefore, imply the emergence of oxygenic photosynthesis. However, spatial distribution of Cr enrichment in the BIF has not been well understood because the data were obtained from an outcrop and an underground mine. Therefore, the objective of this study is to investigate sedimentary environments and Cr enrichment of the Moodies BIF at another locality.

We conducted a geological survey of another outcrop of the Moodies BIF in the Eureka syncline located ~10 km northeast of Barberton. The section of the BIF exposed in the outcrop was underlain by a conglomeratic quartzite, which is stratigraphically correlated with the BIF at Moodies Hills block in the previous study. Whereas the BIF at Moodies Hills block are 22m in the thickness and overlain by 122m thick silty sandstone and sandstone, the BIF in this study has a thickness of 36m and is overlain by a 103m thick layer of greywacke and silty sandstone. Petrographic observation of the BIF samples shows that the reddish layers are composed of microcrystalline quartz and fine grains of hematite (~15μm), and that the black layers are composed of large grains of magnetite (~50μm). These observations indicate that they are typical oxide-type BIF and therefore were originally formed as precipitates from seawater. Although chromite, which is a host mineral for Cr, was found in both BIF and clastic sedimentary rock (e.g., silty sandstone) samples, chromite in the BIF was always overgrown by magnetite. This observation is also consistent with results from previous studies. The chemical compositions of the chromite determined by FE-EPMA were low Mg# (0.001~0.01) and high Cr# (0.76~0.89). No significant difference in chemistry was observed in chromite between BIF and clastic sedimentary rock samples. Bulk chemical compositions of the samples were also analyzed by XRF. The results show that the Cr/Ti ratio was not significantly different between BIF and clastic sedimentary rock samples. Therefore, Cr enrichment was not observed in the BIF in this study. The apparent contradiction to the previous study at Moodies Hills block can be explained by the difference in (1) analytical method used or (2) the sedimentary environment. The Ti contents of BIF at Moodies Hills block were determined by ICP-MS after acid decomposition, by which the detection limit is one order of magnitude lower than XRF used in this study. Therefore, the high detection limit in this study may lose the sensitivity for Cr enrichment in samples in which Ti content was low. Alternatively, the BIF in this study could have been deposited in a deeper setting than that at the Moodies Hills block. Therefore, the results may suggest that oxygenated seawater was only localized in very shallow parts.

Keywords: Banded Iron Formation, chromium, chromite, Barberton Greenstone Belt, surface environments on early Earth