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Geological and geochemical study of 3.2Ga BIFs in the Barberton Greenstone Belt, South Africa

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Banded iron-formations (BIFs) occur mostly through the Precambrian era. Because the formation of BIFs most likely requires oxidation of Fe by phototrophic activities (Konhauser et al., 2007), they may record evolutional history of life on the early Earth. However, previous researchers have questioned whether BIFs hosted in the Barberton Greenstone Belt (BGB) in South Africa (3.5 - 3.1 Ga) were deposited by the activity of either anoxygenic phototrophs (i.e., Fe-oxidizing bacteria), or oxygenic phototrophs (i.e.,cyanobacteria) (Beukes, 2004). Difficulty exists to determine which was the case for the Barberton BIFs, because depositional environments of the Barberton BIFs are not well constrained. Furthermore, information of original precipitates in BIFs was significantly altered by later diagenesis and metamorphism. Therefore, the objectives of this study were set to be to identify the primary Fe mineralogy and to constrain the depositional environments of BIFs in the BGB. We conducted (1) detailed outcrop survey of BIFs in the Fig Tree Group and Moodies Group in the BGB and their host rocks, and (2) petrographical and geochemical analyses of iron-bearing minerals in the BIFs. Outcrop samples were used in this study, which was useful to know the staratigraphical relationships among the samples. However, they were suffered by modern weathering. Therefore, fresh samples in the Moodies Group, obtained at an underground mine, were also analyzed for the comparison.
Results of the outcrop survey revealed that stratigraphy changed toward the top section in the following sequence: clay-rich zone, BIF zone (lower magnetite zone, jasper zone, upper magnetite zone), clay-rich zone, and sandstone zone. No indication of later hydrothermal activities was observed at the outcrop scale. The Fe content was highest in the lower magnetite zone. Mineralogical investigations of the outcrop samples at the Fig Tree Group showed that both hematite and magnetite were abundant in the BIFs. While magnetite in the lower magnetite zone was large (1 - 200 micro meter) subhedral grains, no euhedral hematite or siderite was observed. These observations suggest that magnetite in the lower magnetite zone was formed by a reaction between primary hematite and excess Fe^{2+}in hydrothermal plumes (Otake et al., 2007). On the other hand, magnetite in the jasper zone was not as large as that in the lower magnetite zones, and hematite in the jasper zone was fine grained (1 - 10 micro meter). Preservation of Mg-rich siderite in the jasper zone indicates that hematite in the jasper zone was not a product of modern oxidation, but a primary mineral. The upper magnetite zone also contained fine grains of hematite, which appeared to be primary in origin. Because of coexistence of siderite's psudomorph and magnetite in the zone, it can be interpreted that magnetite in the zone was formed by a reaction between primary hematite and siderite. Mineralogical observations of fresh samples obtained at the Moodeis Group were consistent with the interpretation. The result of study demonstrated that, hematite was primarily deposited in BIFs in the Fig Tree and Moodies groups in the BGB. The presence of primary hematite indicates that oxygenic phototrophs or anoxygenic Fe-oxidizing phototrophs existed in the 3.2 Ga ocean, implying that biological processes were responsible for the production of BIFs.