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Primary structures in Archean metamorphosed BIF: the SXAM analyses

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Precambrian banded iron formations (BIFs) are characterized by alternating Fe-rich and Si-rich layers and have been assumed to preserve primary structures formed on seafloor; physical sedimentation and chemical precipitation from seawater or from submarine hydrothermal fluids, and microbial activity have been generally considered as genetic processes of BIFs. Banded structures in the BIFs exhibit several different scales, from sub-millimeters to several tens of meters. Some of these hierarchy structures have been considered to periodic phenomena in different time scales, corresponding to seasonal cycles, tidal or solar cycles, and Milankovitch cycles. However, most BIFs have undergone various grades of metamorphism. To decode environmental changes in the Precambrian era recorded in BIFs, it is necessary to distinguish primary structures from secondary ones (compositional banding), which were formed after burial of the BIFs. We analyze the banded structures in the BIF samples in the Yellowknife greenstone belt, NWT, Canada. In this study, we investigated the influence of metamorphic reactions on the banded structures in an Archean BIF (2.9-2.8 Ga) comprised in the Bell Lake Group.

In the Bell Lake BIF, there are centimeter-scale alternating Fe-rich and Si-rich bands. Under a microscope, this BIF is now completely recrystallized into medium-grained metamorphic minerals. The Fe-rich band is mainly composed of magnetite, green hornblende, and colorless Fe-Mg-amphibole (grunerite). The Si-rich band constitutes of quartz, magnetite, and a small amount of actinolite. The schistosity defined by orientation of amphiboles is almost parallel to the Fe-rich and Si-rich bands, but an intrafolial fold is locally developed, where the schistosity plane clearly intersects the banded structures. These observations indicate that the alternation of Fe-rich and Si-rich bands already existed at the time of metamorphism.

X-ray fluorescence (XRF) element mappings of the BIF samples were conducted with a Horiba XGT-2000V scanning X-ray analytical microscope (SXAM). The SXAM makes possible acquisition of XRF intensity maps of samples up to 20*20 cm2. The SXAM analyses found over the entire sequence that Ca concentrate at the middle parts of the Fe-rich bands and are sandwiched with Fe and Mg. These element distributions correspond that hornblende is observed at the center of Fe-rich band and is sandwiched with magnetite layers and Fe-Mg amphibole layers. As no exsolution lamellae are found in these co-existing amphiboles and the hornblendes have larger grain size compared with the Fe-Mg amphiboles, we consider that such sandwich structures were formed via nucleation-growth during prograde metamorphism. An incompatible element of Mn is considered to have diffused out to the margin of Fe-rich band and finally recrystallized as grunerite. On the other hand, Ti-spots are uniformly distributed in Fe-rich band. The SEM-EDS and XANES analyses appeared that Ti-spots are locally hosted in hornblende. Since titanium is generally known to be immobile in in metasomatic and metamorphic processes, primary structure of Fe-rich and Si-rich bands may be defined by the Ti-spots distribution.

The Si-rich bands are intercalated with thin magnetite-rich layers with the thickness of sub-millimeters, each of which contains several to tens of magnetite-rich layers. Laminations of this scale (microbands) are commonly observed in low-metamorphic grade Hamersley BIF (Western Australia). It is likely that these laminations record primary structures formed during the sedimentation and precipitation processes. In the Bell Lake BIFs, grain size of magnetite-rich layers is much larger than that in quartz-rich matrix, suggesting the role of Ostwald ripening in their development.

Keywords: banded iron formation, banded structure, metamorphic differentiation, primary structure, Scanning X-ray Analytical Microscope, element mapping