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Origins of chemical structures in Archean BIFs

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In this presentation, we consider the natures of chemical structures in the Archean banded iron formation (BIF) that we are now studying, by comparing with those in the other region BIFs (Katsuta et al., in press). Analytical samples are BIFs (2.9-2.8 Ga) exposed at the Bell Lake region of Yellowknife greenstone belt in the Slave Province, N.W.T., Canada. The Bell Lake BIF is characterized by centimeter-scale Fe-rich and Si-rich mesobands. The constituent minerals are recrystallized to metamorphic assemblages of the amphibolite facies. The metamorphic foliation locally cuts across the mesoband boundaries, indicating the mesobanding was formed prior to peak metamorphism.

EPMA analysis revealed that the Al_2O_3 content of Ca-amphibole in the Fe-rich mesobands (7.50 wt%) is markedly different from that of the Si-rich mesobands (0.54 wt%). Because Al is known to be a relatively immobile component during metamorphic and metasomatic processes, we suggest that initial differences in Al content in the different bands exerted a strong control on the type of Ca-amphibole. Therefore, compaction of the microbands due to silica transportation proposed by Trendall (1983) cannot explain the mesobanding in the Bell Lake BIF. A possible source of Al and Ca in the Fe-rich mesobands is mafic pyroclastic material related to submarine volcanic activity, given that the Bell Lake BIF was formed at a time of continental breakup and rifting (Mueller et al., 2005). The repeated Fe-rich mesobands may reflect the periodic supply of pyroclastic material (Morris, 1993) accompanied by the chemical precipitation of Fe^{2+} supplied by upwelling currents (Ohmoto et al., 2006).

The Si-rich mesobands are intercalated with least several of thin magnetite-rich layers of sub-millimetre thickness. Laminations on this scale, termed microbands, are commonly observed in BIFs throughout the world, including the Hamersley and Kuruman low-grade metamorphosed BIFs (Klein, 2005). Generally, the microbands are believed to record primary structures formed on the seafloor. Trendall (1983) considered that a couplet of Fe-rich and Fe-poor microbands represents a seasonal cycle of chemical precipitation, possibly related to the activity of iron-oxidizing microbes. This idea is supported by a recent laboratory experiment (Posth et al. 2008). In Bell Lake BIFs, however, the thickness and spacing of the original laminae could have changed due to metamorphic differentiation because of grain-boundary migration-recrystallized quartz.

SXAM imaging analyses revealed a symmetric chemical structure of the Fe-rich mesoband, characterized by high Ca contents in the central parts and high Mn contents in marginal parts. Some of the Proterozoic low-grade metamorphosed iron formations show chemical zoning with polarity (grading) in couplets of chert-rich and magnetite-rich bands. These asymmetric zonings have been explained by episodic storm currents (Pufahl & Fralick, 2004) and by settling of Fe-bearing materials in unconsolidated laminae during early diagenesis (Lescelles, 2006). In contrast, Matsunaga et al. (2000) reported a symmetric zonal structure for Hamersley BIF that Mn and Ti were concentrated in the upper and lower boundaries of Fe-rich mesobands in contact with Si-rich mesobands. Because Ti is relatively immobile during hydrothermal alteration, these boundary zones were interpreted as primary depositional structures that represent changes in ocean currents. In the case of the Bell Lake BIF, however, Mn is concentrated along the rims of Fe-rich mesobands, whereas Ti is homogeneously distributed within the mesobands. To explain the observed chemical structures, a mechanism is needed for chemical differentiation during the metamorphic stage.

Reference

Katsuta, N., Shimizu, I., Helmstaedt, H., Takano, M., Kawakami, S., and Kumazawa M. (in press), Major element distribution in Archean banded iron-formation (BIF): Influence of metamorphic differentiation. Journal of Metamorphic Geology.

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