

Petrological analysis of Fe(III)-rich serpentine in the Central Indian Ridge serpentinites

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Aqueous fluids at serpentinite-hosted hydrothermal vent fields near mid-oceanic ridges are characterized by high concentrations of dissolved reducing chemical species, such as H₂, H₂S and hydrocarbons, and aid development of unusual chemosynthetic ecosystems. Petrological, geochemical and experimental works suggest that the cause of the H₂-rich fluids is oxidation of Fe during water-rock reactions in ultramafic lithosphere to form magnetite. However, a recent micro-XANES study of the Mid-Atlantic Ridge serpentinite indicates that serpentine can be a primary phase for Fe³⁺ prior to magnetite. In order to understand the role of Fe³⁺-rich serpentine in the H₂ production, we made petrological analyses of serpentinite exposed at the southern end of the Central Indian Ridge (CIR), very close to the Kairei Hydrothermal Field where high temperature, H₂- and Si-rich fluids are emitting. Serpentinite samples used in this study (dredged using Hakuho-maru from Yokoniwa Rise) include 11-13 modal % of bastite after Opx indicating that the protoliths are mantle peridotite with harzburgite compositions.

Base on microscopic observations and micro-Raman and EPMA analyses, we identified three types of serpentine after olivine. The most dominant one is characteristically brownish under microscope and optically isotropic. The Raman O-H bands are distinct from those of typical serpentine polymorphs but can be explained as composites of chrysotile and lizardite. Therefore, we call this type of occurrence as “brown serpentine aggregate”. It occupies about 70 vol % of the samples. Extensive replacement of olivine by brown serpentine (Stage I) was followed by formation of Fe-rich lizardite along pre-existing magnetite (Stage II), resulting in a mesh-like texture. During a later stage of hydrothermal alteration (Stage III), the mesh texture has been partly or fully overprinted by a vein-like texture consisting of Fe-poor well-crystalline lizardite and crack-filling chrysotile at its center. The microtextural evolution represents stepwise serpentinization probably during uplifting of the CIR mantle lithosphere.

Distribution and mineral chemistry of “brown serpentine” indicate that SiO₂ activity was a significant driving force of the formation. Total oxide compositions of “brown serpentine” are significantly lower than that of lizardite implying fine-grained aggregates with porous nature. They can be interpreted as a product of high reaction rate under high temperature conditions.

Preliminary micro-XANES analyses of “brown serpentine” at a mesh center revealed that about 70% of Fe in the serpentine is Fe³⁺. Assuming that this value is applicable to the whole sample and that the bulk Fe content is constant during serpentinization, we estimate that the contribution of “brown serpentine” in H₂ generation was as large as that of magnetite. Total H₂ produced by complete hydration of olivine 1kg is estimated to be 9.6L (the contribution of “brown serpentine” is 4.5L), which is equivalent to the amount of H₂ dissolved in 54kg of the Kairei hydrothermal fluid (8 mM H₂). Conversion of Fe³⁺-serpentine to Fe-poor serpentine + magnetite at shallower parts may cause a minor absorption of H₂ although we do not have sufficient data to quantify it. The maximum estimation of this study implies a high water/rock ratio in hydrothermal system beneath CIR.

Keywords: Mid-oceanic ridge, hydrothermal field, serpentinite, ferric iron, hydrogen