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Two-stage serpentinization reactions: an example of Iwanai-dake ultramafic rocks, Kamuikotan belt, Hokkaido, Japan.

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The transformation of ultramafic rocks to serpentinites is an important process that influences geodynamic systems in subduction zones. Serpentinization changes physical properties of mantle peridotite. Furthermore, serpentinization in subduction zone affects water and material circulation and mantle dynamics. Despite this renewed interest in serpentinization, the underlying peridotite-water reactions are poorly understood. In recent years, a two stage model for serpentinization has been proposed. Serpentinization generally produces a large amount of magnetite, and petrography and magnetic properties of serpentinite show that magnetite is formed at the later stage of serpentinization. For example, Bach et al. (2006) proposed the formation of magnetite during the breakdown of brucite. On the other hand, Frost and Beard (2007) proposed the breakdown of ferroan serpentine under low silica activity condition. In addition to these, various reactions have been proposed. Although magnetite is an important factor that affects density or magnetic susceptibility of rocks, the previous studies didn't show enough petrographical evidence that support for the reactions proposed. In this study, serpentinization processes of Iwanai-dake peridotite, Kamuikotan belt, Hokkaido, have been investigated with petrological observations, chemical analyses, measurement of density and magnetic susceptibility. On the basis of these data, we discuss chemical processes that are responsible for magnetite formation.

The Iwanai-dake ultramafic body is located in the southern part of Kamuikotan belt, Hokkaido, Japan. A fresh peridotite body, which is about 1 km diameter, is located at the top of Mt. Iwanai-dake. It comprises harzburgite with a small amount of dunite. Ultramafic rocks surrounding peridotite are partly or completely serpentinized. Textures and mineral assemblages were identified by petrographic observation, and Raman spectroscopy. Mineral composition was determined by SEM-EDS. The serpentinite samples mainly consist of serpentine, brucite, and magnetite. Serpentine shows typical mesh textures. There are two kinds of mesh rim types in this area: Type A (Mg#97 serpentine and Mg#75 brucite) and, Type B (Mg#93 serpentine). Type B is associated with Mg#90 brucite vein in the central part. In harzburgite, with progress of serpentinization, mesh rim texture changes from Type A to TypeA+B, and Type B only. Type B is always associated with serpentinization of orthopyroxene. Type B and Mg#90 brucite vein are not observed in dunite. The magnetic susceptibility of harzburgite increases rapidly with increasing amount of serpentine, but that of dunite remains low. It is shown that magnetite appear only high-serpentinized harzburgite.

These observations show that the serpentinization proceeded as follows: First, Mg#95-97 serpentine and Mg#75 Brucite were formed by isochemical reaction of olivine-H2O. Second, Mg#93 serpentine (and Mg#90 Brucite vein) was formed. The second stage reaction was caused by addition of SiO2 rich fluid from serpentinization of orthopryroxene, as evidenced by no observation of the second stage reaction in dunite sample. Relation between magnetic susceptibility and density shows that magnetite was formed at the second-stage serpentinization. It is thought that the supply of SiO2 was the trigger of the formation of magnetite. The result differs from the proposal of Frost and Beard (2007). However, the textural classification in this study is inapplicable to the texture discussed by Bach et al. (2006). It is necessary to consider that serpentinization depends on tectonic setting, chemical component of fluid, or mineral assemblage of protolith.

References: Bach, W., H. Paulick, C. J. Garrido, B. Ildefonse, W. P. Meurer, and S. E. Humphris (2006), Geophys. Res. Lett., 33, L13306, doi:10.1029/2006GL025681. ; Frost, B. R. & Beard, J. S. (2007). On silica activity and serpentinization. Journal of Petrology 48, 1351-1368.