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Tatsuhiko Kawamoto, Tomohiro Inukai, Christian Nicollet, Kenneth T. Koga, Estelle F. Rose-Koga, Baptiste Debret

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Fluid inclusions of ophicarbonates in Oman and Western Alps ophiolite and carbonation experiments of mantle minerals

Kawamoto T., Inukai T., Nicollet C., Koga K.T., Rose-Koga E.F., Debret B.

Carbonated serpentinites, ophicarbonates, are exposed in ophiolites which can be remnants of oceanic lithosphere. Multiple generations of fluids for carbonation are recorded in fluid inclusions of ophicarbonates in the Oman and the Chenaillet and the Lago Nero ophiolites on the Franco-Italian border in the Western Alps. The Oman ophiolite records oceanic lithosphere in fast-spreading ridges and the Chenaillet and the Lago Nero ophiolites in slow-spreading ridges. The fluid inclusions of ophicarbonates are studied with Raman microscopy and microthermometry, revealing saline fluid inclusions commonly found in the carbonates. Their homogenization temperature ranges from 100 to 220 °C, suggesting they are hydrothermal origins. Three types of fluid inclusions are observed in the ophicarbonates studied in the Oman and the Western Alps: (1) fluid inclusions show a wide range of salinities from 0-11 wt. % NaCl eq., suggesting a mixing origin of brine and steam separated by seawater boiling in the ophicarbonate of the Chenaillet and Lago Nero ophiolites, (2) fluid inclusions with an average of 5 wt. % NaCl eq., a little higher than seawater, which may circulate beyond the Moho and form veins into the oceanic mantle harzburgite of the Oman ophiolite, (3) meteoric water during obduction processes in the Oman ophiolite with low salinities of 0–1 wt.% NaCl eq. during the obduction processes of the Oman. The role of slab-derived fluids in ophicarbonates can be understood by studying meta-ophicarbonates in the Queyras (France) and Monviso (Italy) regions of the Western Alps.

Carbonate ions are more soluble in saline fluids than in fresh water. It is reasonable to observe the saline fluids in carbonate minerals, though the fluid inclusions with low salinities as seen in the third type mentioned above are found. Not only salinity, but pH may have great effects on the carbonate solubility especially in shallow levels. To understand the conditions for carbonation of these serpentinites, experiments have been conducted in which mantle rocks have been reacted with H₂O-CO₂ fluids using hydrothermal apparatus under 300–400 °C at 180 MPa with NNO oxygen buffer. The starting materials (olivine, antigorite with/without diopside) are used. In addition to magnesite and talc, quartz is also found. Experiments with magnesium end components are largely consistent with previous work in the MgO-SiO₂-H₂O-CO₂ system [Johannes (1969) *American Journal of Science*, 267, 1083-1104]. Various reactions have been

observed in the olivine-diopside and serpentine-diopside systems. The experimental results show that the carbonation of serpentine is accompanied by a dehydration reaction. Under all experimental conditions, the volume of the solid phase increases during reactions. The addition of a carbon dioxide-containing fluids to serpentine causes both dehydration and an increase in solid volume. Carbonate veins are commonly found in serpentinite in nature. In most cases, calcite veins are formed, but in the present experiments, only magnesite or dolomite is formed, at least at temperatures above 300°C. We conclude that natural carbonation reaction in ophicarbonates occur at low temperatures below 300°C or the fluids carry Ca, which may come from sedimentary or mafic rocks.

Keywords: Serpentinization, Carbonation, Fluid inclusion, Microthermometry, Seawater, Meteoric water, Slab-derived fluids, Oman, Western Alps