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Phase Relations in the Basalt-CO₂ System at High Pressure and Temperature: Implication to the Carbon Recycling in the Earth's Interior

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ABSTRACT

The decarbonation reaction MgCO_3 (magnesite) + SiO_2 (stishovite) \rightarrow MgSiO_3 (perovskite) + CO_2 has been examined experimentally at 32 GPa and 2000–2300 K (corresponding to 870 km depth in the mantle) in a laser-heated diamond anvil cell. This reaction takes place as a candidate for decarbonation of the subducting mid ocean ridge basalts in the Earth's lower mantle. Release of CO_2 from the subducting slab into the mantle peridotite would form carbonates in the Earth's lower mantle.

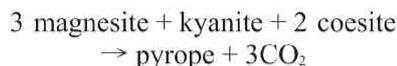
Keywords: High pressure, Magnesite, Recycling of carbon

INTRODUCTION

Carbon dioxide is known as an important greenhouse gas. One of the primary sources for this gas is the mantle. Carbonates play a fundamental role in the recycling of carbon into the Earth's interior via the subducted slab, producing one of the carbon budgets in the entire Earth system. Carbonation reactions for olivine-bearing ultramafic rocks up to 50 GPa have been studied extensively by several workers [e.g., 1–3]. In these assemblages, the carbonation reactions invariably involve olivine or pyroxene reacting with CO_2 to form carbonate without dissociation into a CO_2 -bearing assemblage. Contrary to this, in eclogite rocks, Luth [4] experimentally studied the following reaction;



Also, Knoche et al. [5] reported that the reaction



between 5 and 11 GPa in a multianvil apparatus.

However, these reactions may not give so large effects on the carbon cycle of the Earth's mantle because coesite is the minor phase in the subducting eclogite rocks. It is not known how this eclogite rocks-CO₂ system behaves at still higher pressures. Eclogite rocks transform into garnetite rocks (Irfune et al. [6]) whose essential mineral assemblage is majorite + stishovite.

Here, we report a phase relation of MgCO_3 (magnesite) + SiO_2 (stishovite) at the lower mantle condition in order to constrain the fate of carbonates carried on the subducted ocean floor.

EXPERIMENTAL

A powder mixture of α -quartz and natural magnesite was used as starting material (1 : 1 in mol). The sample was mixed with a small amount (<10 wt%) of platinum powder, which works as a laser-radiation absorber. The laser-heated diamond-anvil cell (LHDAC) experiments were carried out at 32 GPa and 2000–2300 K for 30 minutes. The sample was loaded into a 100 μm hole in a steel gasket and com-

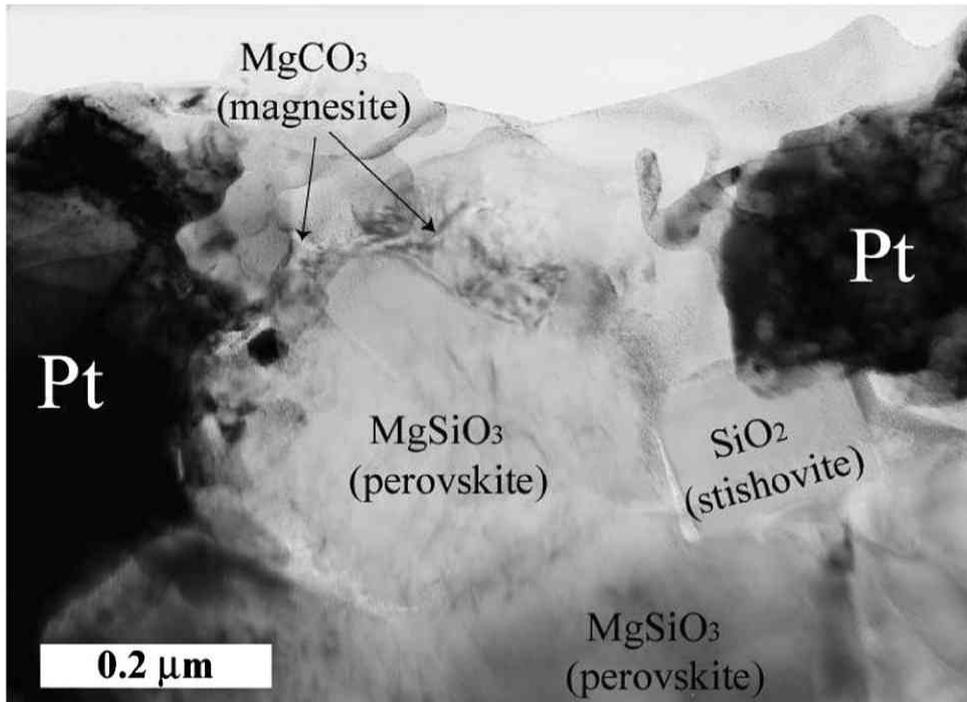


Fig. 1 A TEM image of MgSiO₃ perovskite, SiO₂ stishovite, MgCO₃ magnesite, and Pt platinum recovered from 32 GPa and 2300 K.

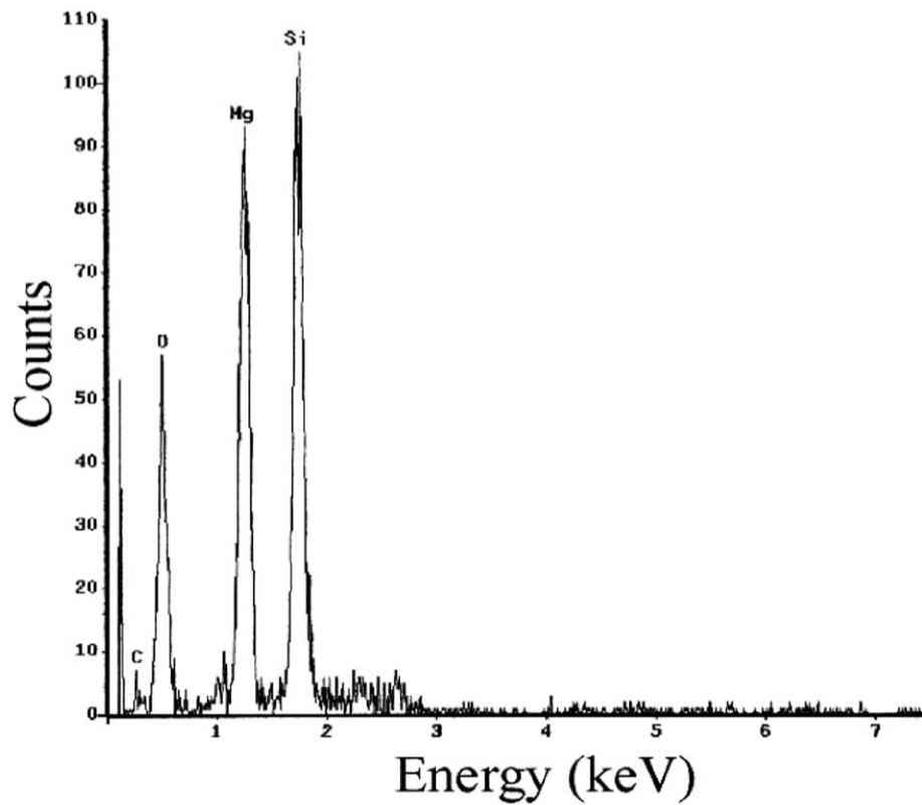


Fig. 2 EDS X-ray microanalysis of MgSiO₃ perovskite resulting from the decarbonation process $\text{MgCO}_3 + \text{SiO}_2 \rightarrow \text{MgSiO}_3 + \text{CO}_2$. Carbon comes from carbon deposition on the sample.

pressed by 350 μm culet diamond anvils. The sample was embedded between layers of NaCl in the hole in order to avoid a large axial temperature gradient. Heating was made with a focused TEM₀₁₀ YLF laser mode using a double-sided heating technique that minimizes both radial and axial temperature gradients, producing a heating spot size of ~ 30 μm in diameter. Temperature was monitored from one side using the spectroradiometric method. The spatial and temporal variations in temperature were within ± 150 K. Pressure was determined using ruby-fluorescence techniques after heating [7]. Present estimation of pressure did not include a correction for a thermal pressure.

Samples recovered from the LHDAC were Ar ion-thinned after trimming off the insulation layers and investigated with a JEOL-2010 Transmission Electron Microscope (TEM) operating at 200 kV. Chemical analyses were made using a NORAN Instruments energy dispersive spectroscope attached with TEM. Microanalysis was performed 0.06 μm sizes in diameter. Carbon was deposited on the sample due to avoid charging in the sample.

RESULTS AND DISCUSSION

At 30 GPa and 2000–2300 K (depths of ~ 800 km in the mantle), we found the following reaction: MgCO_3 magnesite + SiO_2 stishovite \rightarrow MgSiO_3 perovskite + CO_2 . Figure 1 shows an assemblage of the MgSiO_3 perovskite, SiO_2 stishovite, and magnesite grains. In consequence to the reaction, we observed MgSiO_3 perovskite grains as a new product in contact with magnesite and stishovite. Figure 2 shows an EDS X-ray analysis of the perovskite phase. Suppose oxygen number is 3, stoichiometry of the perovskite is $\text{Mg}_{0.98}\text{Si}_{0.99}\text{O}_3$. Carbon in Fig. 2 is caused by carbon deposition on the sample.

Release of CO_2 from the subducting slab into the mantle peridotite would form carbonate at sub-solidus conditions and produce a carbonate melt if temperatures are above the peridotite- CO_2 solidus, causing kimberlite or other carbonate-rich volcanism.

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REFERENCES

1. Canil, D. and Scarfe, C.M., 1990. Phase relations in Peridotite + CO_2 systems to 12 GPa: Implications for the origin of Kimberlite and carbonate stability in the Earth's upper mantle. *J. Geophys. Res.*, 95, 15, 805–15, 816.
2. Katsura, T. and Ito, E., 1990. Melting and subsolidus phase relations in the MgSiO_3 - MgCO_3 system at high pressures: implications to evolution of the Earth's atmosphere. *Earth Planet. Sci. Lett.*, 99, 110–117.
3. Biellmann, C., Gillet, P., Guyot, F., Peyronneau, J. and Reynard, B., 1993. Experimental evidence for carbonate stability in the Earth's lower mantle. *Earth Planet. Sci. Lett.*, 118, 31–41.
4. Luth, R.W., 1995. Experimental determination of the reaction dolomite + 2 coesite = diopside + 2 CO_2 to 6 GPa. *Contrib. Mineral. Petrol.*, 122, 152–158.
5. Knoche, R., Sweeney, R.J. and Luth, R.W., 1999. Carbonation and decarbonation of eclogites: the role of garnet. *Contrib. Mineral. Petrol.*, 135, 332–339.
6. Irifune, T., Ringwood, A.E. and Hibberson, W.O., 1986. The eclogite-garnet transformation at high pressure and some geophysical implications. *Earth Planet. Sci. Lett.*, 77, 245–256.
7. Mao, H.K., Bell, P.M., and Shaner, J., 1978. Measurements of Cu, Mo, Pd, and Ag and calibration of the ruby R1 fluorescence gauge from 0.06 to 1 Mbar. *J. Appl. Phys.*, 49, 3276–3283.