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New geobarometer applicable to mantle-derived xenolith

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If CO_2 is a dominant phase of fluid inclusion, the relationship between the intensity ratio and the frequency separation of the Fermi doublet components in the Raman spectra of CO_2 can be used for determinations of internal pressure of the fluid inclusions. The intensity ratio and the separation between the peaks thereby increase with pressure, and it may be able to use as a geobarometer.

Petrographical observation suggests that there are liquid inclusions in mantle xenoliths from far eastern Siberia. Because the liquid inclusions consist mostly of CO_2, a plot for CO_2 Fermi doublet by the Raman spectroscopic analyses can be applied to estimate the internal pressures of the CO_2 inclusions. As results of the analyses, the CO_2 inclusions in orthopyroxene may be suitable for the geobarometer.

Several kinds of species are usually found in fluid inclusions of minerals. However, if CO_2 is a dominant phase of the fluid, the relationship between the intensity ratio and the frequency separation of the Fermi doublet components in the Raman spectra of CO_2 can be used for determinations of internal pressure of the fluid inclusions. The intensity ratio and the separation between the peaks thereby increase with pressure, and it may be able to use as a geobarometer.

Petrographical observation suggests that there are liquid inclusions in mantle xenoliths from far eastern Siberia. Because the liquid inclusions consist mostly of CO_2, a plot for CO_2 Fermi doublet by the Raman spectroscopic analyses can be applied to estimate the internal pressures of the CO_2 inclusions.

As results of the Raman spectroscopic analyses, density of the CO_2 can be roughly separated into two groups; spinel-pyroxene area and olivine area. The CO_2 inclusions in oliviens have a density of the CO_2 lower than those of orthopyroxene by about 10%. The relatively low density of the CO_2 in olivine may be attributed to its selective deformation during ascent of the xenoliths to the Earth's surface. We have simulated the volume change of minerals caused by decompression and decrease in the temperature during the ascent based on difference in thermal expansion and bulk modulus from those of other minerals. During the ascent of xenoliths from the depth of 1 GPa, the constituent minerals expand by approximately 1vol%, and shrink by a few percent with the decrease in the temperature. This indicates that the volumes of inclusions (or densities of CO_2) are essentially the same (within a few percent) as those at the time of trapping. Furthermore, above simulation indicates that olivine is more shrinkable than the other minerals during the ascent and cooling of xenoliths. Thus the inclusions in olivine would be compressed more. Therefore, the difference in internal pressures among minerals may not be explained by such a process alone.

When host basalt entrains the xenoliths to around the Earth's surface, CO_2 inclusions can keep high pressure as those at the time of trapping. Thus, differential stress up to several kbar would have occured between the CO_2 inclusion and surrounding crystal lattice. Under the condition, olivine would be deformed by a strain rate of about 1E-8 (1/s). While, since the strain rate of orthopyroxene is several orders of magnitude lower than that of olivine, CO_2 inclusions in olivine would selevtively expand. If such a condition could have been kept for ten days, the CO_2 inclusions in olivine would expand by 10%. The time scales of ten days might be reasonable for annealing the xenoliths, because it is within the range of the time scales estimated by rate of decrease in dislocation density for olivine. Therefore, the CO_2 inclusions in orthopyroxene may be suitable for geobarometer.

Since the density was found to be ~1.0 g/cm3, the equation of state of CO_2 indicates that the pressure at the time of trapping of that specific inclusion was approximately 7 kbar if the temperature at the time of trapping was assumed as 1000C. Thus, these inclusions may have trapped a fluid at considerable depths. In order to estimate the exact pressure of the CO_2 inclusions, the density of the CO_2 is required to measure. The densities of the CO_2 were analyzed for the CO_2 inclusions in orthopyroxene, which was estimated to be 1.14 g/cm3. Adopting the density, the internal pressure was higher than 10 kbar at 1000C. Such a pressure corresponds approximately to 30 km in depth. Geophysical estimates indicate a relatively thin crustal thickness of ~30 km for far eastern Siberia and ~34 km for the southern part of far eastern Siberia. Therefore it may be reasonable that such a depth is roughly equivalent to the upper part of the mantle beneath the continental margin. Therefore, the xenoliths may have been derived from uppermost part of the mantle beneath the paleo-Siberia.