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Raman spectroscopic study on CO2 inclusions in pyroxenite xenoliths from northwest Kyushu, SW Japan

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In the back arc region of southwest Japan, large amounts of basaltic magma have been erupted since late Cenozoic. The lavas often have lithosphere-derived ultramafic and mafic xenoliths, which present petrological and chemical information about deep crust and upper mantle. It is important to determine the depths where the xenoliths were trapped by host magma to make the best use of their information. It had been difficult to precisely determine the depths without garnet until Yamamoto et al.(2002) was published. Micro-Raman densimeter for CO_2 inclusions introduced by Yamamoto et al.(2002) enables precise determination of the original depths of xenoliths with arbitrary lithology. In this study, the Raman spectroscopic densimetry for CO_2 inclusions and chemical analyses of constituent minerals were performed for pyroxenite xenoliths occurred in an alkali basaltic lava at the Karatsu-Takashima, southwest Japan.

Ultramafic and mafic xenoliths occurred in the basaltic lava, erupted at ca. 3 Ma, chiefly consist of dunites, wehrlites, mafic granulites, and pyroxenites. In this study we concentrated on pyroxenites among these lithology. The mineral assemblages of the pyroxenite xenoliths were orthopyroxene (OPX) + clinopyroxene (CPX) +/- olivine +/- plagioclase +/- opaque minerals. Major element compositions of pyroxenes were analyzed by EPMA at Kobe University. OPX and CPX were respectively homogeneous in one xenolith. Mg#[=100Mg/(Mg+Fe)] and CaO content of OPX were 83-86.5 and 0.89-1.54wt%, respectively, and those of CPX were 83-87.7 and 19-22wt%, respectively. Equilibrium temperatures estimated by two-pyroxene geothermometer of Ishibashi and Ikeda (2005) varied in the range of 860-1060 degree C. Raman spectra of CO_2 inclusions observed in these constituent minerals were analyzed using micro-Raman analyzing system at Geochemical Laboratory, The University of Tokyo. Negative crystal-shaped inclusions were carefully selected for analyses. CO_2 densities in CO_2 inclusions were calculated from a correlation of the Fermi resonance splitting with CO_2 density determined by Kawakami et al.(2003). Densities in inclusions were almost identical in one xenolith. CO_2 densities in analyzed xenoliths varied only in the narrow range of 0.8-0.9g/cm^3. Residual pressures of CO_2 inclusions were calculated from their densities and equilibrium temperatures of xenoliths using an equation of state for CO_2 (Sterner and Pitzer, 1994). The obtained residual pressures were ca. 0.4-0.6 GPa, which corresponds to the middle crustal depth of 15-22 km.

The obtained P-T relations for the xenoliths were compared to theoretical geotherm. Temperatures of the xenoliths were ca. 500 degree C higher than those of theoretical geotherm at a given depth. These discrepancies cannot be responsible for post-entrapment alternation of CO_2 inclusions because a number of inclusions showed almost identical densities regardless of their host minerals in one xenolith. Error in temperature estimation cannot explain the discrepancies because the geothermometer is precise enough (Ishibashi and Ikeda, 2005) and also estimated pressure is less-dependent on temperature. The discrepancies should indicate an existence of hot region at the middle crustal depths at the time of the host basalt volcanism. We can interpret the hot region to be a slowly cooling magma chamber, and the pyroxenites correspond to magma-derived cumulates or crustal rocks heated by the magma.