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Intergranular fluid compositions in mantle xenoliths inferred from direct observation of crystal surfaces

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Recent geophysical observations of the Earth's interior indicate the presence of aqueous fluids in the uppermost mantle. However, direct observations of these fluids, apart from fluid inclusions observed in xenoliths and the phenocrysts of volcanic rocks, are rare; hence, the characteristics of intergranular fluids, such as volume fraction, chemical composition, and connectivity, are poorly understood. To calculate these parameters, we investigated the geometry of "dimples" (Watson and Brenan, 1987[1]) on the grain boundaries of mantle xenoliths. The dimples can be used to interpret the fossil pore fluid parameters since they retain the shape of the intergranular fluids. We estimated the compositions of intergranular fluids by analyzing the pore dihedral angles and combining them with the pressure (P) and temperature (T) conditions of the xenoliths.

We collected spinel peridotite xenolith samples from San Carlos (AZ, USA), Bullen-merri (Victoria, AU), Girona (Spain), Lanzarote Island (Canary Islands), and Ichinomegata (NE Japan) localities. Based on the relationship between the forsterite content of olivine and the chromium number of spinel, the samples from San Carlos, Bullen-merri, and Ichinomegata were classified as fertile peridotites, while the samples from Girona and Lanzarote were classified as depleted peridotites.

We observed dimples on the olivine surfaces of all the samples, and measured their three-dimensional shapes using a multi-angle SEM (Keyence VHX-1000). The lherzolite xenoliths from Bullen-merri, Lanzarote Island, and Ichinomegata contained plenty of dimples, while dimples were rare in the samples from San Carlos. The average dihedral angles of the intergranular fluids were 89^o, 68^o, and 82^o for the Bullen-merri, Lanzarote island, Ichinomegata samples, respectively. The equilibrium P-T conditions obtained on the basis of two-pyroxene thermobarometry (Putirka, 2008[2]) or two-pyroxene geothermometry (Wells, 1977[3]) were 12.3 kbar/1130^{o}C, 10.4 kbar/1020^{o}C, 7.6 kbar/1100^{o}C, 6-10 kbar/1113^{o}C, and 6.5 kbar/861^{o}C for the San Carlos, Bullen-merri, Girona, Lanzarote Island, and Ichinomegata samples, respectively. The obtained CO_2 mole fraction of the fluids was nearly zero (pure H_2O) for the Lanzarote and Ichinomegata samples, and 0.9 for the Bullen-merri sample.

The obtained P-T conditions of the lherzolite samples were hotter than the geothermal gradients of their respective areas and were located just below the solidus (Green et al., 2010[4]) in saturation with each fluid composition estimated from the dimple geometry. This suggests that these mantle xenoliths should not be sampled randomly from the conduit wall of the magma halfway between the mantle and surface, but from just above the partially molten region, which possibly has some genetic relation with the host basaltic magmas.

References

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