

Experimental study of Group-I kimberlite: evidences for carbonatite primary melt and implication to mantle plumes

LITASOV, Konstantin^{1*} ; SHARYGIN, Igor² ; SHATSKIY, Anton² ; OHTANI, Eiji³

¹Novosibirsk State University, Novosibirsk, Russia, ²V.S. Sobolev Institute of Geology and Mineralogy SB RAS, Novosibirsk, Russia, ³Department of Earth and Planetary Materials Science, Tohoku University, Sendai, Japan

The experiments on the origin of Udachnaya-East kimberlite (UEK) have been performed using a Kawai-type multianvil apparatus at 2-6.5 GPa and 900-1500 °C. The studied composition represented exceptionally fresh Group-I kimberlite containing (wt.%): SiO₂ = 25.9, TiO₂ = 1.8, Al₂O₃ = 2.8, FeO = 9.0, MgO = 30.1, CaO = 12.7, Na₂O = 3.4, K₂O = 1.3, P₂O₅ = 1.0, Cl = 0.9, CO₂ = 9.9, and H₂O = 0.5. Super-solidus assemblage consists of olivine (Ol), Ca-rich garnet (Gt), Al-spinel (Sp), perovskite (Pv), CaCO₃ (calcite or aragonite), and apatite at 4-6.5 GPa with an addition of clinopyroxene at 3-4 GPa and Na-Ca carbonate with molar ratio of (Na+K)/Ca ~ 0.44 at 6.5 GPa and 900 °C. The apparent solidus was established between 900 and 1000 °C at 6.5 GPa. In the studied P-T range, melt has Ca-carbonatite composition (Ca/(Ca+Mg) = 0.6-0.8) with high alkali and Cl contents (2.8-6.7 wt.% K₂O, 7.3-11.6 wt.% Na₂O, 1.2-3.7 wt.% Cl). The K, Na and Cl contents and Ca/(Ca+Mg) value decrease with temperature. It is argued, that the primary kimberlite melt at depth >200 km was essentially carbonatitic (<5 wt.% SiO₂), however, evolved toward carbonate-silicate composition (with 15-20 wt.% SiO₂) during ascent. The absence of orthopyroxene among the run products indicates that xenogenic orthopyroxene was preferentially dissolved into kimberlite melt. The obtained subliquidus phase assemblage (Ol + Gt + Sp + Pv) at P-T condition of UEK source region differs from lherzolite lithology of this source. Both petrological observations and experiments indicate that kimberlite magma lost substantial amount of CO₂ at shallow depths.

Our study combined with earlier experiments on carbonate-silicate systems at pressures to 30 GPa implies that liquid phase of thermo-chemical plume generated at the core-mantle boundary is represented by alkali-carbonatite melt. This conclusion has broad geodynamic implication providing insight into fluid regime of mantle melting under hotspots along margins of African large low-shear-wave-velocity province. We conclude that the long term activity of rising hot mantle plume and associated carbonatite melt (i.e. proto-kimberlite melt) causes thermo-mechanical erosion of the subcontinental lithosphere mantle (SCLM) roots and creates hot, oxidized, and deformed metasomatic layer at lower parts of initially depleted SCLM, which corresponds to depths constrained from the sheared Gt-lherzolites. The sheared Gt-lherzolites undoubtedly represent the samples from this layer.

Keywords: mantle, kimberlite, carbonatite, plume, melting