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Melting experiments on the Udachnaya kimberlite at 6.3-7.5 GPa: implications for the role of H_2O in magma generation and formation of hydrous olivine

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Melting experiments on kimberlite from the Udachnaya pipe have been performed at 6.3-7.5 GPa and 1300-1600˚C using a split-sphere multianvil apparatus. The water content in kimberlite varied from 2.5 to 11.6 wt.% and the CO_2/(CO_2+H_2O) molar ratio was from 0.61 to 0.23. The samples were placed in a graphite container inside a Pt capsule. The oxygen fugacity during the experiment was close to the EMOG/D equilibrium. An olivine + garnet + clinopyroxene assemblage was present at about 100-150˚C below the liquidus of the Udachnaya kimberlite, with 2.5-6 wt.% at the pressure 6.3-7.5 GPa and 8-10 wt.% H_2O at 7.5 GPa. Orthopyroxene did not form at any temperature and pressure of the experiments. The presence of clinopyroxene near the liquidus was due to the calcic nature and a high degree of silica undersaturation in the Udachnaya kimberlite. At the supra-solidus conditions, garnet and clinopyroxene, crystallized in equilibrium with low-H_2O carbonated melt, are compositionally distinct from minerals of the megacryst/macrocryst suite. Near the liquidus of high-H_2O kimberlite, the stable olivine composition was from Fo_{91} to Fo_{97}. The garnet (CaO 8-15 wt.%, TiO_2 0.7-1.5 wt.% and Cr_2O_3 up to 2.2 wt.%) and clinopyroxene compositions were an analogues of garnet and clinopyroxene megacrysts in kimberlite. Infrared absorption measurements showed that crystallized olivines contained water in the form of Ti-clinohumite-like and OH-clinohumite-like defects. The predominant role of these types of hydroxyl defects in water storage of liquidus olivine was demonstrated in a special series of experiments performed at 6.3 GPa and 1400˚C with the systems Mg_2SiO_4-Fe_2SiO_4-H_2O-C, Mg_2SiO_4-TiO_2-H_2O-C, Mg_2SiO_4-$MgCO_3$-H_2O-C, Mg_2SiO_4-$MgCO_3$-TiO_2-KCl-H_2O-C.

The H_2O content of olivine formed in melting experiments on the Udachnaya kimberlite was found to depend mainly on water content in kimberlite melt and pressure. Olivine with 120-170 ppm H_2O crystallized at 6.3 GPa in equilibrium with the melt compositionally close to the archetypical kimberlite rather than a carbonate one, and water as high as 6 wt.%. Olivine with 270-300 ppm H_2O crystallized near kimberlite liquidus only at 7.5 GPa and 9.5-10.1 wt.% H_2O. The experimental results imply that hydrous olivine, which is typical to kimberlites, including the Udachnaya pipe, very unlikely can crystallize from anhydrous carbonated magma. Judging by the conditions for multiphase saturation of the Udachnaya kimberlite melt, its generation was possible by partial melting of carbonated garnet wehrlite at pressures from 6 to 7.5 GPa and temperatures within 1450-1600˚C in the presence of aqueous fluids. Thus, water must have been a trigger for generation of the primary kimberlite magma. This study was supported by the Russian Foundation for Basic Research (No. 11-05-00429).