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Formation of graphite and diamond in carbonate-rich magmas

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Compositions of co-existing minerals from graphite bearing carbonatites were obtained by the EPMA analysis for beforsites from Chernigovsky complex (Ukraine), Pogranichnoe dolomite-rich carbonatites (Doroshkevich, Wall, and Ripp, 2007 Magmatic graphite in dolomite carbonatite at Pogranichnoe, North Transbaikalia, Russia. CMP 153, 339-353), Chagaday carbonatites, Uzbekistan, Khibina alkaline igneous complex, which includes carbonatites and graphite-bearing rocks (Kola Peninsula), and carbonatites of Gremyakha-Vyrmes magmatic complex (Kola Peninsula). In all cases graphite-bearing rocks contain magnetite. Sometimes late magnetite and graphite form intimate intergrowths. Thermodynamic analysis of equilibria between magnetite, silicate minerals, carbonates and graphite permitted to estimate temperatures and oxygen fugacities prevailing during the formation of the investigated rocks.

Chagaday graphite-bearing carbonatites, in which several grains of diamond were also reported, contain calcite, apatite, magnetite, clinopyroxene, albite and K-feldspar. Temperatures of equilibrium for mineral clinopyroxene+calcite+ titanomagnetite+titanite+graphite + albite + nepheline depending on titanomagnetite compositions were calculated using equilibrium constants of the following reaction:

4 $CaFeSi_2O_6$+3$CaCO_3$+7 Fe_2TiO_4+0.5$NaAlSiO_4$=7 $CaTiSiO_5$+6 Fe_3O_4+3C+0.5$NaAlSi_3O_8$

These calculations demonstrated that for a given magnetite composition decrease in temperature causes formation of graphite together with magnetite. Therefore, appearance of graphite in carbonatites may be caused by cooling, and graphite may crystallize from melt, it may form by solid-state reactions, or precipitate from cooling aqueous fluid.

fO_2 values were estimated from the equilibrium constant of the reaction

6$CaFeSi_2O_6$+6$CaCO_3$+12Fe_2TiO_4=12$CaTiSiO_5$+10Fe_3O_4+6C+O_2

Calculated fO_2 values are 0.5 to 1 log units below QMF buffer. Similar values of oxygen fugacities were estimated for other investigated graphite-bearing carbonatites.

Diamond forms in subcontinental lithosphere also due to the reductions of near-solidus carbonate-rich melts arriving from asthenosphere or from rising plume. This reduction is caused by interaction of these melts with the rocks of lower lithosphere, which are characterized by very low fO_2 values.