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Phase relations on the K_2CO_3-$CaCO_3$-$MgCO_3$ join at 6 GPa and 900–1400 °C: Implications for incipient melting in carbonated mantle domains

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Abstract

To constrain the ternary K_2CO_3-$CaCO_3$-$MgCO_3$ *T-X* diagram at 6 GPa and to expand upon the known K-Mg, K-Ca, and Ca-Mg binary systems we have carried out multi-anvil experiments along the K_2CO_3-$Ca_{0.5}Mg_{0.5}CO_3$ join. The diagram has primary phase fields for K_2CO_3, $K_2Mg(CO_3)_2$, $K_2Ca_{0.1–0.5}Mg_{0.9–0.5}(CO_3)_2$, $K_4CaMg(CO_3)_4$, Ca-magnesite, and dolomite. The system has two liquidus minima near 1000 °C. At one minimum, a liquid with the composition of 36 K_2CO_3·64$(Ca_{0.65}Mg_{0.35})CO_3$ is in equilibrium with three phases: Ca-magnesite, $K_2Ca_{0.1–0.5}Mg_{0.9–0.5}(CO_3)_2$, and $K_6Ca_2(CO_3)_5$. The other minimum, a liquid with the composition of 62 K_2CO_3·38$Ca_{0.72}Mg_{0.28}CO_3$ is in equilibrium with K_2CO_3, $K_4CaMg(CO_3)_4$, and $K_6Ca_2(CO_3)_5$. At 900 °C, the ternary diagram contains two- and three-phase regions with Ca-magnesite, aragonite, $K_2Ca_3(CO_3)_4$, $K_2Ca(CO_3)_2$, $K_6Ca_2(CO_3)_5$, K_2CO_3, $K_2Ca_{0.1–0.5}Mg_{0.9–0.5}(CO_3)_2$ solid solution, $K_2Mg_{0.9}Ca_{0.1}(CO_3)_2$, and $K_4CaMg(CO_3)_4$. We also expect an existence of primary phase fields for $K_6Ca_2(CO_3)_5$, $K_2Ca_3(CO_3)_4$ and aragonite.

We suggest that extraction of K from silicate to carbonate components should decrease the minimum melting temperature of dry carbonated mantle rocks up to 1000 °C at 6 GPa and yield ultrapotassic Ca-rich dolomite melt containing more than 10 mol% K_2CO_3. As temperature increases above 1200 °C the melt evolves toward an alkali-poor, dolomitic liquid if the bulk molar CaO/MgO ratio >1, or toward K-Mg-rich carbonatite if bulk CaO/MgO < 1. The majority of compositions of carbonatite inclusions in diamonds from around the world fall within the magnesite primary field between the 1300 and 1400 °C isotherms. These melts could be formed by partial melting of magnesite-bearing peridotite or eclogite with bulk Ca/Mg <1 at temperatures ≤1400 °C. A few compositions revealed in the Ebelyakh and Udachnaya diamonds (Yakutia) fall within the dolomite primary field close to the 1200 °C isotherm. These melts could be formed by partial melting of dolomite-bearing rocks, such as carbonated pelite or eclogite with bulk Ca/Mg >1 at temperatures ≤1200 °C.

Keywords: Deep earth, high pressure, high temperature, melts, phase relations