

Effect of water on carbonate-silicate liquid immiscibility in the system KAlSi_3O_8 - $\text{CaMgSi}_2\text{O}_6$ - $\text{NaAlSi}_2\text{O}_6$ - $\text{CaMg}(\text{CO}_3)_2$ at 6 GPa: Implications for diamond-forming melts

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ABSTRACT

To clarify the effect of water on carbonate-silicate liquid immiscibility in the diamond stability field, we performed experiments in the system KAlSi_3O_8 - $\text{CaMgSi}_2\text{O}_6$ - $\text{NaAlSi}_2\text{O}_6$ - $\text{CaMg}(\text{CO}_3)_2$ under nominally dry and hydrous conditions by adding 1.5 wt% H_2O at a pressure of 6 GPa and temperatures of 1000 to 1500 °C. Both systems start to melt at 1050–1100 °C. Under anhydrous condition the melting occurs via the following reaction: $6\text{KAlSi}_3\text{O}_8$ (K-feldspar) + $6\text{CaMg}(\text{CO}_3)_2$ (dolomite) = $2(\text{Ca}_n\text{Mg}_{1-n})_3\text{Al}_2\text{Si}_3\text{O}_{12}$ (garnet) + Al_2SiO_5 (kyanite) + 11SiO_2 (coesite) + $3\text{K}_2(\text{Ca}_{1-n}\text{Mg}_n)_2(\text{CO}_3)_3$ (carbonatitic melt) + 3CO_2 (fluid and/or liquid), where $n \sim 0.3$ – 0.4 . The carbonatitic melt has the following composition $38(\text{K}_{0.92}\text{Na}_{0.08})_2\text{CO}_3 \cdot 62\text{Ca}_{0.62}\text{Mg}_{0.38}\text{CO}_3$. A second immiscible silicic melt containing (in wt%, volatile free) $\text{SiO}_2 = 68.8$, $\text{Al}_2\text{O}_3 = 12.6$, $\text{CaO} = 3.7$, $\text{MgO} = 2.4$, $\text{Na}_2\text{O} = 1.1$, and $\text{K}_2\text{O} = 11.3$ appears at 1250 °C. Both melts remain stable up to 1500 °C and coexist with the clinopyroxene \pm garnet \pm coesite residue. In the presence of water stored away in phengite, the melting begins with silicic melt, which contains (in wt%, volatile free) $\text{SiO}_2 = 61.4$, $\text{Al}_2\text{O}_3 = 15.3$, $\text{CaO} = 4.8$, $\text{MgO} = 3.0$, $\text{Na}_2\text{O} = 2.2$, and $\text{K}_2\text{O} = 13.3$, and coexists with phengite, dolomite, clinopyroxene, and coesite. The phengite + dolomite assemblage remains to 1100 °C and disappears at 1200 °C producing two immiscible melts carbonatitic with approximate composition, $19(\text{K}_{0.89}\text{Na}_{0.11})_2\text{CO}_3 \cdot 81\text{Ca}_{0.57}\text{Mg}_{0.43}\text{CO}_3$, and silicic containing (in wt%, volatile free) $\text{SiO}_2 = 63.3$, $\text{Al}_2\text{O}_3 = 15.6$, $\text{CaO} = 4.5$, $\text{MgO} = 3.0$, $\text{Na}_2\text{O} = 2.0$, $\text{K}_2\text{O} = 11.6$. The present results imply that partial melting of continental material subducted to a depth of 200 km can yield simultaneous formation of two immiscible melts, K-dolomitic and K-aluminosilicate. Under dry conditions, carbonatitic melt appears earlier (at a lower temperature). Given the low density and high mobility of this melt, it must rapidly percolate upward, leaving a refractory eclogite-like residue and leaving no chance for the formation of a second aluminosilicate melt. However, under hydrous conditions silicate melt appears earlier than carbonatitic melt, leaving a phengite- and dolomite-bearing residue, which finally yields the formation of two immiscible silicic and carbonatitic melts. The compositions of these melts fall in the compositional range of carbonatitic and silicic high-density fluids (HDFs) in diamonds worldwide. Thus, we suggest that the presence of water is a necessary requirement for the formation of immiscible HDFs inclusions in diamonds, and this suggestion is strongly supported by natural data from HDFs.

Keywords: Carbonate-silicate liquid immiscibility, K-feldspar, phengite, carbonated pelites, high-density fluids, diamond formation, high-pressure experiment, Earth's upper mantle; New Advances in Subduction Zone Magma Genesis