

Effect of alkalis on the reaction of clinopyroxene with Mg-carbonates at 6 GPa: Implications for partial melting of carbonated lherzolite

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The reaction between clinopyroxene and Mg-carbonate is supposed to define the solidus of carbonated lherzolite at pressures exceeding 5 GPa. To investigate the effect of alkalis on this reaction, subsolidus and melting phase relations in the systems $\text{CaMgSi}_2\text{O}_6 + 2\text{MgCO}_3$ (Di + 2Mgs), $\text{CaMgSi}_2\text{O}_6 + \text{NaAlSi}_2\text{O}_6 + 2\text{MgCO}_3$ (Di + Jd + 2Mgs), $\text{CaMgSi}_2\text{O}_6 + \text{Na}_2\text{Mg}(\text{CO}_3)_2$ (Di + Na_2Mg), and $\text{CaMgSi}_2\text{O}_6 + \text{K}_2\text{Mg}(\text{CO}_3)_2$ (Di + K_2Mg) have been examined at 6 GPa. The results are summarized in Fig. 1. The Di + 2Mgs system begins to melt at 1400 °C via the approximate reaction $\text{CaMgSi}_2\text{O}_6$ (clinopyroxene) + 2MgCO_3 (magnesite) = $\text{CaMg}(\text{CO}_3)_2$ (liquid) + $\text{Mg}_2\text{Si}_2\text{O}_6$ (orthopyroxene) leading to essentially carbonate liquid (L) with composition of $\text{Ca}_{0.56}\text{Mg}_{0.44}\text{CO}_3 + 3.5 \text{ mol\% SiO}_2$. The initial melting in the Di + Jd + 2Mgs system occurs at 1350 °C via the reaction $2\text{CaMgSi}_2\text{O}_6$ (clinopyroxene) + $2\text{NaAlSi}_2\text{O}_6$ (clinopyroxene) + 8MgCO_3 (magnesite) = $\text{Mg}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ (garnet) + 5MgSiO_3 (clinopyroxene) + $2\text{CaMg}(\text{CO}_3)_2$ (liquid) + Na_2CO_3 (liquid) + 3CO_2 (liquid and/or fluid) yielding the carbonate liquid with approximate composition of $10\text{Na}_2\text{CO}_3 \cdot 90\text{Ca}_{0.5}\text{Mg}_{0.5}\text{CO}_3 + 2 \text{ mol\% SiO}_2$. The systems Di + Na_2Mg and Di + K_2Mg start to melt at 1100 and 1050 °C, respectively, via the reaction $\text{CaMgSi}_2\text{O}_6$ (clinopyroxene) + $2(\text{Na or K})_2\text{Mg}(\text{CO}_3)_2$ (solid) = $\text{Mg}_2\text{Si}_2\text{O}_6$ (orthopyroxene) + $(\text{Na or K})_4\text{CaMg}(\text{CO}_3)_4$ (liquid). The resulting melts have alkali-rich carbonate compositions of $\text{Na}_2\text{Ca}_{0.4}\text{Mg}_{0.6}(\text{CO}_3)_2 + 0.4 \text{ mol\% SiO}_2$ and $43\text{K}_2\text{CO}_3 \cdot 57\text{Ca}_{0.4}\text{Mg}_{0.6}\text{CO}_3 + 0.6 \text{ mol\% SiO}_2$. These melts do not undergo significant changes as temperature increases to 1400 °C retaining their calcium number, high Na_2O , K_2O and low SiO_2 . We suggest that the clinopyroxene–Mg-carbonate reaction controlling the solidus of carbonated lherzolite is very sensitive to the carbonate composition and shifts from 1400 °C to 1050 °C at 6 GPa yielding K-rich carbonate melt if subsolidus assemblage contains $\text{K}_2\text{Mg}(\text{CO}_3)_2$ compound. Such a decrease in solidus temperature has been observed previously in the K-rich carbonated lherzolite system. Although a presence of eitelite, $\text{Na}_2\text{Mg}(\text{CO}_3)_2$, has a similar effect, this mineral cannot be considered as a potential host of Na in carbonated lherzolite as far as whole Na added into the system dissolves as jadeite component in clinopyroxene if bulk Al/Na 1. The presence of jadeite component in clinopyroxene has little impact on the temperature of the solidus reaction decreasing it to 1350 °C at 6 GPa.

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Fig. 1. Modal abundances of phases present as a function of temperature in the systems $\text{CaMgSi}_2\text{O}_6 + 2\text{MgCO}_3$ (a), $\text{CaMgSi}_2\text{O}_6 + \text{NaAlSi}_2\text{O}_6 + 2\text{MgCO}_3$ (b), $\text{CaMgSi}_2\text{O}_6 + \text{Na}_2\text{Mg}(\text{CO}_3)_2$ (c), and $\text{CaMgSi}_2\text{O}_6 + \text{K}_2\text{Mg}(\text{CO}_3)_2$ (d) at 6.0 GPa. Modes are in mol% were determined from the bulk compositions of starting mixtures and compositions of phases measured by electron microprobe.

Keywords: Alkalis, Clinopyroxene, Mg-carbonates, High pressure and temperature, solidus, phase relations

