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 CaMgSi\textsubscript{2}O\textsubscript{6} + 2MgCO\textsubscript{3} (Di + 2Mgs), CaMgSi\textsubscript{2}O\textsubscript{6} + NaAlSi\textsubscript{2}O\textsubscript{6} + 2MgCO\textsubscript{3} (Di + Jd + 2Mgs), CaMgSi\textsubscript{2}O\textsubscript{6} + Na\textsubscript{2}Mg(CO\textsubscript{3})\textsubscript{2} + (Di + Na\textsubscript{2}Mg), and CaMgSi\textsubscript{2}O\textsubscript{6} + K\textsubscript{2}Mg(CO\textsubscript{3})\textsubscript{2} (Di + K\textsubscript{2}Mg) 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 CaMgSi\textsubscript{2}O\textsubscript{6} (clinopyroxene) + 2MgCO\textsubscript{3} (magnesite) = CaMg(CO\textsubscript{3})\textsubscript{2} (liquid) + Mg\textsubscript{2}Si\textsubscript{2}O\textsubscript{6} (orthopyroxene) leading to essentially carbonate liquid (L) with composition of Ca\textsubscript{0.56}Mg\textsubscript{0.44}CO\textsubscript{3} + 3.5 mol% SiO\textsubscript{2}. The initial melting in the Di + Jd + 2Mgs system occurs at 1350 °C via the reaction 2CaMgSi\textsubscript{2}O\textsubscript{6} (clinopyroxene) + 2NaAlSi\textsubscript{2}O\textsubscript{6} (clinopyroxene) + 8MgCO\textsubscript{3} (magnesite) = Mg\textsubscript{3}Al\textsubscript{2}Si\textsubscript{3}O\textsubscript{12} (garnet) + 5MgSiO\textsubscript{3} (clinopyroxene) + 2CaMg(CO\textsubscript{3})\textsubscript{2} (liquid) + Na\textsubscript{2}CO\textsubscript{3} (liquid) + 3CO\textsubscript{2} (liquid and/or fluid) yielding the carbonate liquid with approximate composition of 10Na\textsubscript{2}CO\textsubscript{3}: 90Ca\textsubscript{0.8}Mg\textsubscript{0.2}CO\textsubscript{3} + 2 mol% SiO\textsubscript{2}. The systems Di + Na\textsubscript{2}Mg and Di + K\textsubscript{2}Mg start to melt at 1100 and 1050 °C, respectively, via the reaction CaMgSi\textsubscript{2}O\textsubscript{6} (clinopyroxene) + 2(Na or K)\textsubscript{2}Mg(CO\textsubscript{3})\textsubscript{2} (solid) = Mg\textsubscript{2}Si\textsubscript{2}O\textsubscript{6} (orthopyroxene) + (Na or K)\textsubscript{4}CaMg(CO\textsubscript{3})\textsubscript{4} (liquid). The resulting melts have alkali-rich carbonate compositions of Na\textsubscript{2}Ca\textsubscript{0.6}Mg\textsubscript{0.4}(CO\textsubscript{3})\textsubscript{2} + 0.4 mol% SiO\textsubscript{2} and 43K\textsubscript{2}CO\textsubscript{3}:57Ca\textsubscript{0.8}Mg\textsubscript{0.6}CO\textsubscript{3} + 0.6 mol% SiO\textsubscript{2}. These melts do not undergo significant changes as temperature increases to 1400 °C retaining their calcium number, high Na\textsubscript{2}O, K\textsubscript{2}O and low SiO\textsubscript{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 K\textsubscript{2}Mg(CO\textsubscript{3})\textsubscript{2} compound. Such a decrease in solidus temperature has been observed previously in the K-rich carbonated lherzolite system. Although a presence of eitelite, Na\textsubscript{2}Mg(CO\textsubscript{3})\textsubscript{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 CaMgSi\textsubscript{2}O\textsubscript{6} + 2MgCO\textsubscript{3} (a), CaMgSi\textsubscript{2}O\textsubscript{6} + NaAlSi\textsubscript{2}O\textsubscript{6} + 2MgCO\textsubscript{3} (b), CaMgSi\textsubscript{2}O\textsubscript{6} + Na\textsubscript{2}Mg(CO\textsubscript{3})\textsubscript{2} (c), and CaMgSi\textsubscript{2}O\textsubscript{6} + K\textsubscript{2}Mg(CO\textsubscript{3})\textsubscript{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
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**Phase proportions (mol. %)**

**Temperature (°C)**

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**Diagram a:**
- **Di+2Mgs**
  - CaMgSi₂O₆ + 2MgCO₃
- **Phase proportions:**
  - Mgs, Cpx, Opx

**Diagram b:**
- **Di+Jd+2Mgs**
  - CaMgSi₂O₆ + NaAlSi₂O₆ + 2MgCO₃
  - Cpx, Mgs, CO₂, Grt

**Diagram c:**
- **Di+Na,Mg**
  - CaMgSi₂O₆ + Na₂Mg(CO₃)₂
- **Phase proportions:**
  - Na,Mg, Cpx, Opx

**Diagram d:**
- **Di+K,Mg**
  - CaMgSi₂O₆ + K₂Mg(CO₃)₂
- **Phase proportions:**
  - K₂Mg, Cpx, Mgs, Opx

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**Legend:**
- ▲ - Orthopyroxene (Opx)
- ▼ - Clinopyroxene (Cpx)
- ◆ - Garnet (Grt)
- ■ - Na₂Mg(CO₃)₂ (Na₂Mg)
- □ - K₂Mg(CO₃)₂ (K₂Mg)
- □ - Magnesite (Mgs)
- ○ - Liquid (L)

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