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Phase relations in the system $FeCO_3$-$CaCO_3$ at 6 GPa and 900–1700 °C and its relation to the system $CaCO_3$-$FeCO_3$-$MgCO_3$

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Abstract

The subsolidus and melting phase relations in the $CaCO_3$-siderite system have been studied in multi-anvil experiments using graphite capsules at pressure of 6 GPa and temperatures of 900–1700 °C. At low temperatures, the presence of ankerite splits the system into two partial binaries: siderite + ankerite at 900 °C and ankerite + aragonite up to 1000 °C. Extrapolated solvus curves intersect near 50 mol% just below 900 °C. At 1100 and 1200 °C, the components appear to form single-phase solid solutions with space group symmetry $R\bar{3}c$, while $CaCO_3$ maintains aragonite structure up to 1600 °C and 6 GPa. The $FeCO_3$ solubility in aragonite does not exceed 1.0 and 3.5 mol% at 900–1000 and 1600 °C, respectively. An increase of $FeCO_3$ content above the solubility limit at $T > 1000$ °C, leads to composition-induced phase transition in $CaCO_3$ from aragonite, *Pmcn*, to calcite, $R\bar{3}c$, structure, i.e., the presence of $FeCO_3$ widens the calcite stability field down to the *P-T* conditions of sub-cratonic mantle. The siderite-$CaCO_3$ diagram resembles a minimum type of solid solutions. The melting loop for the $FeCO_3$-$CaCO_3$ join extends from 1580 °C ($FeCO_3$) to 1670 °C ($CaCO_3$) through a liquidus minimum near 1280 ± 20 °C and 56 ± 3 mol% $CaCO_3$. At $X(Ca)$ = 0–30 mol%, 6 GPa and 1500–1700 °C, siderite melts and dissolves incongruently according to the reaction: siderite = liquid + fluid. The apparent temperature and $X(Ca)$ range of siderite incongruent dissolution would be determined by the solubility of molecular CO_2 in $(Fe,Ca)CO_3$ melt.

The compositions of carbonate crystals and melts from the experiments in the low-alkali carbonated eclogite (Hammouda 2003; Yaxley and Brey 2004) and peridotite (Dasgupta and Hirschmann 2007; Brey et al. 2008) systems are broadly consistent with the topology of the melting loop in the $CaCO_3$-$MgCO_3$-$FeCO_3$ system at 6 GPa pressure: a Ca-rich dolomite-ankerite melt coexists with Mg-Fe-calcite in eclogites at CaO/MgO > 1 and Mg-dolomite melt coexists with magnesite in peridotites at CaO/MgO < 1. However, in fact, the compositions of near solidus peridotite-derived melts and carbonates are more magnesian than predicted from the $(Ca,Mg,Fe)CO_3$ phase relations.

Keywords: Siderite, $FeCO_3$, aragonite, ankerite, phase relations, Raman, high pressure, Earth's mantle