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Partition coefficients of trace elements between carbonates and melt and suprasolidus phase relation of Ca-Mg-carbonates at 6 GPa

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Abstract

The presence of Ca-Mg-carbonates affects the melting and phase relations of peridotites and eclogites in the mantle, and (partial) melting of carbonates liberates carbon from the mantle to shallower depths. The onset and composition of incipient melting of carbonated peridotites and carbonated eclogites are influenced by the pure $CaCO_3$-$MgCO_3$-system making the understanding of the phase relations of Ca-Mg-carbonates fundamental in assessing carbon fluxes in the mantle. By performing high-pressure and high-temperature experiments, this study clarifies the suprasolidus phase relations of the nominally anhydrous $CaCO_3$-$MgCO_3$-system at 6 GPa showing that Ca-Mg-carbonates will (partially) melt for temperatures above ~1300 °C. A comparison with data from thermodynamic modeling confirms the experimental results. Furthermore, partition coefficients for Li, Na, K, Sr, Ba, Nb, Y, and rare earth elements between calcite and dolomitic melt, Ca-magnesite and dolomitic melt, and magnesite and dolomitic melt are established.

Experiments were performed at 6 GPa and between 1350 to 1600 °C utilizing a rotating multi-anvil press. Rotation of the multi-anvil press is indispensable to establish equilibrium between solids and carbonate liquid. Major and trace elements were quantified with EPMA and LA-ICP-MS, respectively.

The melting temperature and phase relations of Ca-Mg-carbonates depend on the Mg/Ca-ratio. For instance, Ca-rich carbonates with a molar Mg/(Mg+Ca)-ratio (X_{Mg}) of 0.2 will transform into a dolomitic melt (X_{Mg} = 0.33–0.31) and calcite crystals (X_{Mg} = 0.19–0.14) at 1350–1440 °C. Partial melting of Mg-rich carbonates (X_{Mg} = 0.85) will produce a dolomitic melt (X_{Mg} = 0.5–0.8) and Ca-bearing magnesite (X_{Mg} = 0.89–0.96) at 1400–1600 °C. Trace element distribution into calcite and magnesite seems to follow lattice constraints for divalent cations. For instance, the compatibility of calcite (X_{Mg} = 0.14–0.19) for Sr and Ba decreases as the cation radii increases. Ca-Mg-carbonates are incompatible for rare earth elements (REEs), whereby the distribution between carbonates and dolomitic melt depends on the Mg/Ca ratio and temperature. For instance, at 1600 °C, partition coefficients between magnesite (X_{Mg} = 0.96) and dolomitic melt (X_{Mg} = 0.8) vary by two orders of magnitudes from 0.001 to 0.1 for light-REEs to heavy-REEs. In contrast, partition coefficients of REEs (and Sr, Ba, Nb, and Y) between magnesite (X_{Mg} = 0.89) and dolomitic melt (X_{Mg} = 0.5) are more uniform scattering marginal between ~0.1–0.2 at 1400 °C.

Keywords: Melt relations of carbonates at 6 GPa (~200 km), deep carbon cycle, trace-element partitioning, carbonate stability in the mantle