EGU2020-2990
https://doi.org/10.5194/egusphere-egu2020-2990
EGU General Assembly 2020

Phase relations of Ca-Mg-carbonates and trace element partition coefficients between carbonates and dolomitic melt at 6 and 9 GPa

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Calcite ($CaCO_3$) and magnesite ($MgCO_3$) are among the most common carbonates on Earth. The presence of Ca□Mg□carbonates in the mantle affects the melting and phase relations of peridotites and eclogites and (partial) melting of carbonates liberates carbon from the mantle to shallower depths. The onset of melting and the incipient melt composition of carbonated peridotites and carbonated eclogites are influenced by the pure $CaCO_3$□$MgCO_3$□system. Thus, a deeper insight into the phase relations and melting behavior of the $CaCO_3$□$MgCO_3$□system is crucial to better understand the carbon cycle in the Earth's mantle.

We performed quenched multi-anvil experiments at 6 and 9 GPa to (a) examine the phase relations of the nominally anhydrous $CaCO_3$□$MgCO_3$□system and to (b) establish partition coefficients for Li, Na, K, Sr, Ba, Nb, Y and rare earth elements (REEs) between carbonates and dolomitic melt. We used a rotating multi-anvil press to overcome quenching problems as observed in previous studies. Rotation of the multi□anvil press is, additionally, indispensable to establish equilibrium between solid carbonates and dolomitic melt.

The melting temperature and phase relations of Ca□Mg□carbonates depend on the Mg/Ca□ratio. For instance, at 6 GPa 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 □. 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 □. Trace element distribution into Ca-Mg-carbonates depends on X_{Mg}, temperature and seems to follow lattice constraints for divalent cations. Partition coefficients of REEs between magnesite ($Ca_{0.11}Mg_{0.89}CO_3$) and dolomitic melt ($Ca_{0.5}Mg_{0.5}CO_3$) at 6 GPa and 1400 □ are uniform scattering marginal between 0.1□0.2. The partition coefficient of Lu (D=0.1) is unmodified to lower Ca-content in magnesite ($Ca_{0.04}Mg_{0.96}CO_3$) and higher temperature (1600 □), but the partition coefficients between such Ca-poor magnesite and dolomitic melt ($Ca_{0.2}Mg_{0.8}CO_3$) decrease continuously from heavy-REEs to light□REEs from 0.1 to 0.001, respectively.

Our findings have important implications for the cycle of carbon and trace elements in the mantle because Ca□Mg□carbonates will (partially) melt at 6 GPa and temperatures above ~1300 □ producing a dolomitic melt. Consequently, CO_2 will be liberated by partial melting of an upwelling carbonated mantle at a depth of ~200 km considering the thermal structure of the upper mantle.

The results also affirm that carbonates are stable in the subducting slab even for hot subduction zone geothermal gradients unless carbonate-bearing lithologies in the slab are infiltrated by aqueous fluids.