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Chemistry and Mineralogy of Earth's Mantle

Experimental determination of melting in the systems enstatite-magnesite and magnesite-calcite from 15 to 80 GPa†

Andrew R. Thomson[1,*], Michael J. Walter[1], Oliver T. Lord[1,2] and Simon C. Kohn[1]

[1]School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens's Road, Bristol, BS8 2HX, U.K.
[2]Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT, U.K.

Abstract

Pressure-temperature melting curves in two carbonate-bearing systems of relevance to Earth's mantle have been determined using the laser-heated diamond-anvil cell (LH-DAC). The solidus along the $MgSiO_3$-$MgCO_3$ join in the MgO-SiO_2-CO_2 system (MS-CO_2) was defined from 15 to 80 GPa using in situ melting criteria, reaching a maximum temperature of ~2340 K at 80 GPa. The occurrence of melting has been confirmed with ex-situ textural and chemical analysis of recovered samples. The melting curve has a negative dT/dP slope at pressures between ~15 and 23 GPa resulting from the subsolidus phase transition of ilmenite- to perovskite-structured $MgSiO_3$. The shallow slope of the melting curve at pressures higher than this transition indicate that for plausible mantle geotherms carbonate-bearing silicate lithologies will melt throughout the lower mantle. The solidus of a mixture along the $MgCO_3$-$CaCO_3$ join was determined as a proxy for alkali-free carbonate lithologies. Melting temperatures increase from 1860 K at 16 GPa to ~2100 K above 35 GPa, where the melting curve flattens. The melting reaction magnesite + post-aragonite (high-pressure $CaCO_3$) = melt was confirmed using an in situ experiment. We conclude that crystalline Mg and Ca carbonate mixtures are unstable with respect to molten carbonate at conditions of the convective lower mantle. The flat melting curves at high pressures in both systems suggests that subducted carbonates will undergo melting at lower mantle conditions, a process that may be important for superdeep diamond formation and carbon storage in the deep mantle.

Keywords: Deep carbon, diamond-anvil cell, magnesite, melting