Revision of the CaCO₃–MgCO₃ phase diagram at 3 and 6 GPa

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ABSTRACT

Subsolidus and melting relationships for the system CaCO₃–MgCO₃ have been reexamined using a Kawai-type multi-anvil apparatus at 3 and 6 GPa in graphite capsules. Phase boundaries were delineated according to the chemical composition of phases measured by electron microprobe in energy dispersive mode and identification of crystal phases by Raman spectroscopy.

At 3 GPa, the dolomite-magnesite solvus intersects the melting loop at about 1250 °C, and the isothermal three-phase line so produced represents the peritectic reaction: dolomite (Ca# 43) = magnesite (Ca# 13) + liquid (Ca# 48), where Ca# = 100·Ca/(Ca+Mg). The melting loop for the CaCO₃–MgCO₃ join extends from 1515 °C (CaCO₃) to 1515 °C (MgCO₃) through a liquidus minimum at 1230 °C (near 53 mol% CaCO₃). Starting from 1425 °C at ≤30 mol% CaCO₃ in the system, the liquid quenches to dendritic carbonate and periclase and contains rounded voids, indicating an incongruent melting reaction: MgCO₃ (magnesite) = MgO (in liquid) + CO₂ (fluid and/or liquid).

At 6 GPa, aragonite + magnesite assemblage is stable up to 1000 °C. The reaction aragonite + magnesite = dolomite locates between 1000 and 1050 °C. The presence of dolomite splits the system into two partial binaries: aragonite + dolomite and dolomite + magnesite. The dolomite-magnesite solvus intersects the melting loop between 1400 and 1450 °C, and the isotheermal three-phase line so produced represents the peritectic reaction: dolomite (Ca# 31) = magnesite (Ca# 21) + liquid (Ca# 57). The melting loop for the CaCO₃–MgCO₃ join extends from 1660 °C (CaCO₃) to 1780 °C (MgCO₃) through a liquidus minimum at 1400 °C and 62 mol% CaCO₃.

The compositions of carbonate crystals and melts from the experiments in the carbonated eclogite (Yaxley and Brey 2004) and peridotite (Dalton and Presnall 1998) systems are consistent with the geometry of the CaCO₃–MgCO₃ melting loop at 3 and 6 GPa: Ca-dolomite melt coexists with Mg-calcite in eclogite and peridotite at 3 GPa and dolomite melt coexists with magnesite in peridotite at 6 GPa.

Keywords: CaCO₃–MgCO₃, phase relations, high-pressure, magnesite, dolomite, calcite, aragonite, Earth’s mantle

INTRODUCTION

The (Ca,Mg)CO₃ carbonates are the most important carbon-bearing phases entering subduction zones and are believed to survive along most subduction P-T profiles through the island arc magma generation depths (Kerrick and Connolly 2001a, 2001b). The evidence for the deep subduction of carbonates arises from the findings of Ca-Mg carbonates associated with diamond in CO₂-bearing inclusions within xenoliths from a forearc magmatic rock in southwest Japan (Murakami et al. 2008). Another evidence originates from continental crust exhumed from mantle depths. The recovered ultrahigh-pressure (UHP) metamorphic rocks contain coesite and diamond with variable amounts of Ca-Mg carbonates as rock-forming minerals and/or as inclusions in high-pressure minerals (Sobolev and Shatsky 1990; Shatsky et al. 1995; Dobrzhinetskaya et al. 2006; Korsakov and Hermann 2006; Korsakov et al. 2009). Presence of Ca-Mg-carbonates at different levels of lithospheric mantle is apparent through the occurrence of calcite (Cal), dolomite (Dol), and magnesite (Mgs) in spinel peridotite xenoliths (Amundsen 1987; Ionov et al. 1993, 1996; Kogarko et al. 1995) and as inclusions in kimberlitic diamonds (Meyer and McCallum 1986; Bulanova and Pavlova 1987; Phillips and Harris 1995; Wang et al. 1996; Sobolev et al. 1997; Stachel et al. 1998; Shatsky et al. 2008; Zedgenizov et al. 2014).

High-pressure experiments revealed that Ca-Mg carbonates become stable at the solidus of carbonated peridotites, eclogites, and pelites at depths greater than 70–90 km (Wyllie and Huang 1975; Eggler 1978; Wallace and Green 1988; Dalton and Presnall 1998; Dasgupta et al. 2004; Yaxley and Brey 2004; Dasgupta and Hirschmann 2007; Thomsen and Schmidt 2008; Litasov and Ohtani 2009, 2010; Grassi and Schmidt 2011; Kiseeva et al. 2013; Thomson et al. 2016). Once carbonate becomes stable in the subsolidus, it plays a major role in the melting reaction, yielding essentially dolomitic liquid. Thus, phase relations in the CaCO₃–MgCO₃ system are important for understanding