

## Melting of Mantle Materials under Lower Mantle Conditions and Fractionation in Magma Ocean

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It is generally accepted that the Earth was covered by a deep magma ocean during early accretion. Cooling of the silicate magma ocean is likely to have resulted in fractional crystallization that would have produced large-scale chemical stratification in the mantle. To clarify the issue, melting relations and element partitioning among coexisting liquidus phases and melt in peridotitic materials have been studied extensively. Separation of majorite (Mj) (Kato et al., 1988), Mg-perovskite (Mg-Pv) (Ito and Takahashi, 1987; Kato et al., 1988), or both Mg-Pv and ferropericlase (Fp) (McFarlane and Drake, 1994) from a terrestrial magma ocean has been examined in terms of refractory and moderately refractory lithophile element ratios in the residual melt, under the assumption that the relative abundances of these elements in the bulk mantle are equal to those in CI-chondrite. Crystal fractionation have generally been unsuccessful in reproducing the element ratios observed in upper mantle peridotite or estimates of primitive mantle (i.e., the mantle before crust extraction).

Experimental pressure have been limited to ca. 26 GPa. Pressure, however, can have a considerable effect on liquidus phase relations, and experiments at higher pressures may provide new information regarding the plausibility of fractionation in a deep magma ocean. In this context, we have investigated melting of peridotite and a CI chondritic mantle material under lower mantle conditions, at pressures up to 35 GPa using a Kawai-type high-pressure apparatus equipped with sintered diamond anvils. The sample was kept at the prescribed pressure and at ca. 2500 C for 2 or 3 minutes. The recovered charge was examined by electron microscopy and then analyzed by EPMA.

In peridotite Fp is the first liquidus phase up to 30 GPa, which is successively followed by Mg-Pv and Ca-perovskite (Ca-Pv). The first liquidus phase changes from Fp to Mg-Pv at 31 GPa, and at 33 GPa liquidus Mg-Pv is successively followed by Fp and Ca-Pv within a small temperature range. Partition coefficients between Mg-Pv, Fp and melt for Si, Mg, Fe, and Ni do not show prominent pressure dependence. However, Al, Cr, and Ti tend to be incompatible in Mg-Pv at 33 GPa. It is evident that La supplied from the outer sleeve strongly prefer Ca-Pv rather than melt, presumably occupying part of Ca-site of the structure. Marked high concentrations of alkaline elements (K and Na) in Ca-Pv may be coupled with the substitution of La for Ca. Therefore it is inferred that Ca-Pv has a high capability to accommodate large univalent and trivalent cations, especially when both are combined. Melting experiments of CI chondritic mantle were carried out at 22, 28, and 35 GPa. At 22 GPa, the first liquidus phase is Mj which is successively followed by small amounts of Fp, Ca-Pv and wadsleyite or ringwoodite, in accordance with the previous studies (Ohtani et al., 1986; Ohtani and Sawamoto, 1987). At 28 GPa, however, Mj and Fp completely disappear, and the liquidus phase is Mg-Pv followed down temperature by Ca-Pv. Melting relations at 35 GPa are the same as those at 28 GPa.

Differentiation by crystal fractionation of Mg-Pv, Fp, and Ca-Pv in a deep magma ocean has been examined for a CI chondritic (Hart and Zindler, 1986) and two bulk silicate Earth models; 'pyrolite' (McDonough and Sun, 1995) and PRIMA (Allegre et al., 1995;). Mass balance indicates that subtraction of about 40% Mg-Pv and 2% Ca-Pv from a CI chondritic bulk silicate Earth yields a residual melt close to a model fertile upper mantle composition. A crystal layer composed of Mg- and Ca-Pv's would pile up to a depth ca. 1400 km, and may be characterized as an enriched and possibly heat-producing reservoir by the high capability of Ca-Pv to accommodate large cations such as La and alkaline elements. For peridotitic bulk silicate Earth models, fractionation would be quite limited, up to 10 wt % of Mg-Pv in addition to trace amount of Ca-Pv.