Deep mantle melts recorded in superdeep diamonds and their mineral inclusions

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Sub-lithospheric, or 'superdeep', diamonds contain mineral inclusions indicating an origin in the deep upper mantle and transition zone, and even into the lower mantle [1]. Three of the most common superdeep inclusions are majoritic garnet, Ca(±Ti)-silicate, and ferropericlase. Barometric constraints based on mineral compositions indicate that the majority of these inclusions originated between ~ 300 and 500 km. Much rarer are inclusions with compositions indicating a deep transition zone or lower mantle origin (e.g. bridgmanite, CF-phase, NAL phase) [1] [2]. The major element composition of majorite garnet, Ca(±Ti)-silicate and ferropericlase are generally inconsistent with derivation as sub-solidus minerals in mantle peridotite or basaltic compositions. Extreme enrichments in lithophile trace element abundances in majorite garnet and Ca(±Ti)-silicates indicate equilibration with a low-degree melt that is depleted in large-ion lithophile elements relative to HFSE and REE, features consistent with derivation from subducted oceanic crust [3].

We have performed experiments to test a model whereby low-degree carbonated melts from subducted oceanic crust react with reducing mantle to crystallize diamonds and their mineral inclusions. Our results show a deep depression along the solidus of carbonated MOR basalt at depths of ~ 300 to 700 km, which effectively limits the transport of carbonate in subducted oceanic crust to the deep upper mantle and transition zone because the majority of slab geotherms intersect the solidus in this region. Low-degree partial melts at these depths are alkaline carbonatites, which are highly reactive with surrounding reduced mantle peridotite. Reaction experiments between alkaline carbonatite melt and reduced peridotite produce diamond, majorite, ringwoodite, Ca(±Ti)-silicate, and ferropericlase with compositions comparable to those observed in many superdeep diamonds. The solidus depression in carbonated basalt forms a barrier to carbon transport into the deepest mantle that may have operated since the onset of subduction.

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