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Mg-Fe oxide Inclusions in Diamonds and Mantle Dynamics

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Mg-Fe oxide is an expected mineral phase in the lower mantle, but Mg-Fe oxide inclusions in diamonds are sometimes associated with upper mantle mineral inclusions, rather than ones belonging to the lower mantle. It is suggested that in all cases the Mg-Fe oxides have originated within the lower mantle (protolith conditions of formation). Occurrences of Mg-Fe oxide with upper mantle minerals are believed to suggest conditions of encapsulation in diamond in the upper mantle, but the material may still have originated within the lower mantle and been transported upwards by mantle dynamics.

Mg-Fe oxide minerals, commonly Mg-rich and therefore ferropericlase, are increasingly being found as inclusions in natural diamonds. Ferropericlase is particularly expected to occur in the Earth`s lower mantle, where common ultrabasic (pyrolitic) compositions should contain MgSi-perovskite (Mg,Fe)SiO3 and ferropericlase (Mg,Fe)O, in place of the (Mg,Fe)2SiO4 minerals which occur in the upper mantle. Excluding concerns about how material from the lower mantle may be erupted at the Earth`s surface, it has been suggested by several workers that the ferropericlase inclusions have been derived from the lower mantle (e.g. Scott-Smith et al., 1984, Harte and Harris, 1994). The purpose of this paper is to consider aspects of this interpretation, and to particularly draw attention to distinguishing the circumstances of origin of material (protolith conditions) from those of the place of recrystallisation and encapsulation in diamond (metamorphic conditions).

Unfortunately many of the ferropericlase inclusions found in diamonds occur as single inclusions unaccompanied by other minerals, and there is therefore no information on mineral assemblage, which can be used to infer temperature and pressure conditions of formation (metamorphic or mineral facies of formation). In some cases the same diamonds that contain ferropericlase inclusions may contain other, but usually separate, inclusions of other minerals. On this basis the occurrence of (Mg,Fe)O with (Mg,Fe)SiO3 inclusions has been used to infer a lower mantle origin (even though the inclusions no longer necessarily possess lower mantle crystal structures). In the case of inclusions from Sao Luiz, there is a relatively large suite of inclusions where (Mg,Fe)O, (Mg,Fe)SiO3, CaSiO3 and an aluminous phase are all associated, and formation in the uppermost part of the lower mantle has been postulated (Harte and Harris, 1994; Harte et al., in press). In this case it is important to note that these postulated conditions of formation are those of encapsulation in diamonds (metamorphic conditions), and do not imply that the material of the inclusions necessarily originated in the uppermost lower mantle. Some material may be derived from the crust ot lowermost mantle.

Recently ferropericlase inclusions have been recorded as part of inclusion suites which are strongly dominated by minerals expected in the upper part of the upper mantle. One interpretation of such inclusions is that they show formation of ferropericlase under special conditions outside of the lower mantle. The author concurs with this interpretation in the sense that the inclusions became encapsulated in diamond at upper mantle conditions (metamorphic conditions); but does not believe this implies that the ferropericlase did not originate in a lower mantle protolith. The convective circulation in the mantle including plumes, which potentially travel from the lowermost lower mantle to the lithosphere, clearly allows for the possibility of mixing material from different locations in the mantle. It is therefore possible that an upwelling mantle plume may carry lower mantle material into the upper mantle. If such convective transport carries with it small domains of lower mantle material with (Mg,Fe)O slightly in excess of that required to combine with (Mg,Fe)SiO3 to form (Mg,Fe)2SiO4, then small amounts of ferropericlase may remain stable in the upper mantle. It is suggested that ferropericlase within the upper mantle is of this origin, and provides exciting evidence of mantle dynamics rather than uncertain or unknown circumstances of formation.