

Magnesite-Bearing Inclusion Assemblage in Natural Diamond

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Abstract

A significant mineral assemblage has been found as an inclusion in a natural diamond from the Finsch kimberlite pipe of South Africa: a euhedral rhombohedron-shaped magnesite (MgCO_3) crystal ($d \sim 30 \mu\text{m}$) co-exists with several idiomorphic olivine [$(\text{Mg}_{1.86}\text{Fe}_{0.14})\text{SiO}_4$] grains ($d \sim 80 \mu\text{m}$). Many tiny anatase (TiO_2) particles ($d \sim 2\text{-}5 \mu\text{m}$) and microcrystallites ($d < 1 \mu\text{m}$) of diamond and disordered graphite are attached to the surface of the magnesite grain. Structural and compositional characterization of the inclusion phases was achieved by micro-Raman spectroscopy and electron microprobe analysis.

The occurrence of this syngenetic multiphase inclusion assemblage in a natural diamond provides unambiguous evidence for the existence in the Earth's mantle of magnesite, which has been proposed as a major carbon reservoir in most of the mantle. Both the formation and preservation aspects of the assemblage have been investigated. The mineralogy of the assemblage indicates that carbonated peridotite formed the surrounding petrologic environment. The inclusion assemblage suggests two reactions involving the decomposition of carbonates in mantle peridotite during decompression, which in part may explain the paucity of magnesite that has been found in other mantle rocks. The chemical inertness and low compressibility of the host diamond must have been critical to the preservation of this magnesite-bearing assemblage. The incorporation of a pure TiO_2 phase in a peridotitic diamond inclusion and its occurrence in the anatase structural form further emphasize the unusual conditions that allowed both the formation and preservation of this multiphase inclusion. The P-T- $f\text{O}_2$ conditions defined by the inclusion assemblage are represented by the intersection of the graphite-diamond transition curve and the enstatite-magnesite-olivine-diamond buffer. The oxygen fugacity range represented by the inclusion assemblage is below that of the quartz-fayalite-magnetite and C-CO-CO₂ buffers in the P-T range common to most diamonds. However, the coexistence of diamond, graphite, magnesite, olivine, and anatase in this inclusion assemblage represents the highest oxygen fugacity at which olivine could be stable in a C-O-bearing silicate mantle, i.e., the highest oxidation state under which a mantle diamond can be stabilized in a peridotite environment. The

diamond-carbonate-silicate coexistence wedge is relatively restricted in P-T-fO₂ space.

Therefore, the P-T-fO₂ conditions implied by this and other diamond inclusion assemblages lead to two significant implications for mantle petrology: 1) the conditions for diamond formation are very limited if carbonates are major carbon sources for diamonds; 2) given the low-fO₂ conditions inferred for portions of the earth's mantle, carbonates may rarely occur in peridotites, and much of the carbon in the mantle may be locked in reduced phases.