

The oxygen fugacity of sublithospheric diamond formation and the conditions encountered during their ascent to the surface

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The rocks-salt structured Mg-Fe oxide, ferroperricite, is one of the more common minerals included in sub-lithospheric diamonds, where it appears in a wide range of Fe/(Fe+Mg) ratios. It is important to be able to understand the formation conditions of such inclusions as they provide some of the only direct evidence for the passage of carbon bearing fluids and melts in the deep mantle. In several TEM investigations, exsolution of Fe³⁺-rich phases, normally described as being part of the magnetite-magnesioferrite solid solution, have been identified within such ferroperricite inclusions. Their presence indicates changing conditions after entrapment and by understanding the exsolution processes we can potentially obtain information on the post entrapment conditions experienced by the diamonds. The ferric iron content of the entire inclusion before exsolution also provides information on the oxygen fugacity (fO_2) at which the diamond was formed and potentially the medium from which it formed.

To interpret this information, a model for the ferric iron content of ferroperricite as a function of MgO content, P, T and fO_2 conditions up to those where exsolution of Fe₂O₃-rich phases occurs, is required. In this work multianvil experiments were performed between 6–25 GPa and 1200–1800°C using a starting composition of (Mg₈₆Fe₁₄)O to (Mg₅Fe₉₅)O plus varying amounts of Fe₂O₃. Pt powder was added to act as a redox sensor and minor amounts of Ni, Cr, Mn and Na were also added. Samples were then analysed using scanning electron microscopy, electron microprobe, Mössbauer spectroscopy and X-ray diffraction.

In the recovered experiments, ferroperricite was found to coexist with magnetite-magnesioferrite solid solution up to 12 GPa and Mg₂Fe₂O₅-Fe₄O₅ solid solution at higher pressures. In all experiments the oxygen fugacities were determined from three different equilibria simultaneously, and in the calculation of the fO_2 a ferroperricite model in the FeO-Fe_{2/3}O-MgO system was employed and exchange of Mg-Fe²⁺ in magnetite, or the higher-pressure phase, was accounted for.

The results show that magnetite-magnesioferrite solid solution should not be in equilibrium with ferroperricite in the diamond stability field as the oxygen fugacity would be too high. Our results imply that the exsolution of Fe³⁺ rich phases observed in natural samples likely occurred at pressures corresponding to the transition zone or deeper.