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The ferric iron contents of lower mantle minerals and their use in the determination of deep diamond formation conditions

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Although rare, some inclusions in diamonds can be interpreted as being minerals from the deep or lower mantle, raising questions as to how diamonds may be formed under these conditions. Determining the oxygen fugacity at which diamonds have formed is one way to investigate the plausible diamond formation processes. This can be accomplished by measuring the ferric/ferrous ratios of such inclusions and experimentally calibrating equilibria through which to convert these ratios into oxygen fugacities. Following this methodology, we have developed thermodynamic models for both bridgmanite and ferropericlase that allow oxygen fugacities to calculated as a function of pressure, temperature and mineral composition. Ferropericlase inclusions in diamonds not only span a significant range in iron contents but some inclusions show evidence for exsolution of a magnetite-magnesioferrite phase. This implies that after entrapment, a change in P-T conditions led to the ferropericlase becoming saturated in ferric iron. To investigate this, we have determined the oxygen fugacity and ferric iron content of ferropericlase over a range of oxygen fugacities up to those where it coexists with magnetite-magnesioferrite, or higher-pressure ferric iron-bearing oxides. These experiments have been performed up to lower mantle conditions and include new measurements at 1 bar. The results show that once the oxygen fugacity rises above a certain threshold, all quenched samples contain nano-scale exsolutions of ferric-iron rich oxide, which makes it challenging to determine the original high temperature ferric iron content. Using results from Mössbauer and electron energy loss spectroscopy, we have developed a model that describes the ferric iron content of ferropericlase and can be used to calculate the oxygen fugacity at which inclusions of it formed and the conditions at which ferric-iron rich phases exsolved. This information can be used to interpret deep diamond formation conditions.