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Oxygen fugacities determined from iron oxidation state in natural (Mg,Fe)O ferropericlase: new insights into lower mantle diamond formation

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Mineral inclusions in diamonds reflect the chemical composition and mineral assemblages of the two principal rock types occurring in the deep lithosphere, peridotite and eclogite. However, in the past two decades, the discovery of rare diamonds containing inclusions such as former Mg,Si-perovskite and (Mg,Fe)O ferropericlase led to the possibility that diamonds can form also at greater depths. (Mg,Fe)O ferropericlase is the most commonly found inclusion in lower mantle diamonds (more than 50% of the occurrences). Since the Fe^{3+} concentration in (Mg,Fe)O is sensitive to oxygen fugacity also at high pressures (Frost et al., 2004), the determination of $Fe^{3+}/\sum Fe$ in such inclusions provides a direct method for investigating lower mantle redox conditions during diamond formation. In the present study we explore whether variations in mantle oxygen fugacity exist as a function of chemical, physical and geographic parameters, by studying (Mg,Fe)O inclusions in lower mantle diamonds from a wide range of localities.

Eighteen (Mg,Fe)O ferropericlase inclusions from lower mantle diamonds selected worldwide were measured by the flank method using the calibration previously established for synthetic ferropericlase (Longo et al., in preparation). The $Fe^{3+}/\sum Fe$ measured in (Mg,Fe)O inclusions of the present work (Juina, Brazil, Machado River, Brazil and Orroroo, Australia) were compared to data already available for other inclusions of larger size previously measured by Mössbauer spectroscopy (McCammon et al. 1997, 2004). Oxygen fugacity was estimated for each specimen relative to two reference buffers such as the Fe-(Mg,Fe)O buffer (reducing conditions) and the Re-ReO_2 buffer (oxidizing conditions). Our results show a dependence on geographical location, and in particular, inclusions from the African province (Kankan Guinea) seem to record more reducing mantle conditions than the inclusions measured from the other provinces, which cover a larger range of fO_2 conditions.

It is noteworthy that a variation of oxygen fugacity was registered in multiple inclusions extracted from the same host diamonds. However, because the inclusions were removed from the host without textural control, information on the direction of any redox gradient that may have evolved, and possible correlation with diamond growth or anomalies in the variation of the redox conditions through time, were lost. These observations combined with the geographical correlation observed among all inclusions measured in the present work and from previous studies leads to the suggestion of other mechanisms than subducted slabs being involved in diamond formation. In order to provide insights on the mechanisms controlling the redox conditions at lower mantle depths and how such oxygen fugacities may affect the physical and chemical properties of the lower mantle, new measurements are planned to increase the data set on ferropericlase inclusions. Moreover, a multi disciplinary study involving cathodoluminescence studies and isotopic and optical studies is suggested for further work.

References

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