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Using Chromium in sulphide inclusion in diamonds as a proxy for mantle oxygen fugacity

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Oxygen fugacity (fO_2) exerts a major control on the partitioning of Cr^{2+} and Cr^{3+} between minerals and liquids. Cr^{2+}/Cr^{3+} in a mineral can then be used as a proxy of fO_2 prevailing while crystallizing. In endogenous rocks and magmas, Cr^{2+} and Cr^{3+} are in equal proportions at QFM-3.4 (i.e. near the IW buffer). At higher fO_2, Cr^{3+} dominates while Cr^{2+} becomes prevalent at lower fO_2[37]. For minerals inclusions in diamonds, in silicates (garnet, clinopyroxen, ferropericlase) or oxides (chromite), Cr^{3+} is always dominant.

For sulphides, no experimental calibration has yet been established to relate chromium (Cr) solubility to redox conditions. In this study, we conducted X-ray Absorption Near-Edge Structure (XANES) analyses on six sulphide recovered from peridotitic (n=2) and eclgotic diamonds (n=4), to investigate the redox state and coordination environment of Cr in mantle sulphides.

Reference materials with well-constrained Cr oxidation states were used, including both synthetic and natural solids and solid solutions. We also analyzed extraterrestrial sulphides containing trace to minor amounts of Cr—namely troilite (FeS) and alabandite ((Mn,Fe)S)—from the Canyon Diablo (IAB iron meteorite) and Pesyanoe (aubrite) meteorites, which are among the most reduced geological materials ever described.

Our results show that in peridotite sulphides, Cr is divalent implying very reducing conditions. This conclusion is supported by their spectra being similar to that of extraterrestrial sulphides that formed in conditions such as IW-6 < log $fO2$ < IW-2, suggesting that cratonic peridotites are more reduced than previously thought. In contrast eclogitic sulphides, dominated by Cr^{3+}, formed at more oxidizing conditions, possibly near or above QFM. Cr thus provides a more discriminant proxy for redox conditions in mantle rocks than other metals (e.g. Fe) revealing distinct oxygen fugacity ranges in diamond-bearing eclogite and peridotite, and challenging traditional distinctions in their formation environment.