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# Redox heterogeneities in the Archean mantle inferred from mineral inclusions in Siberian E-type diamonds: implications for volatile speciation and diamond formation

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The cycle of volatiles among Earth's reservoirs is related to the oxygen fugacity ($fo_2$) recorded by mantle rocks, which controls the mobility and composition of volatile-rich fluid/melt. Eclogites formed by the subduction of ancient oceanic crust (protolith) offer insight into the fate of early Earth's volatiles in depth. According to oxy-thermobarometric estimates, most eclogites fall into the diamond stability field equilibrated with $CH_4$-$H_2O$ dominated C-O-H fluids (Stagno and Aulbach 2021). However, the primary redox state of the subduction-modified eclogite source could be masked by interaction with (metasomatic) circulating fluids through time, which likely acted themselves as growth media for diamonds. Mineral inclusions trapped in eclogitic diamonds can provide pristine information on the redox conditions of the eclogite source.

We investigated nineteen eclogitic diamonds from Udachnaya (Russia) with both exposed (after polishing) and trapped paired garnet and clinopyroxene inclusions (three touching), and crystals extracted from the host rock of one diamond. We combined mineral chemistry (major elements and vanadium) with oxy-thermobarometric and $H_2O$ estimates, to reconstruct the nature of the inferred Archean protolith and redox evolution along subduction, with implications for fluid circulation and diamond formation. We employed EPMA for major elements and V concentration analysis, while $Fe^{3+}/\sum Fe$ was measured by synchrotron Mössbauer source spectroscopy. The $OH^-$ bands were detected in clinopyroxene by micro-FTIR supported by X-ray tomography to determine the water content.

Pressure and temperature of equilibrium are 4.9-7.6 GPa and 1080-1350 °C. The $Fe^{3+}/\sum Fe$ is up to 0.07 for garnet and 0.26 for clinopyroxene, while V concentration in the reconstructed bulk rock varies from ~150 to 450 ppm. The calculated $\log fo_2$ ranges from -4 to -0.4 log units (FMQ). Notably, we observed similar $\log fo_2$ and V bulk rock for inclusions in diamond and corresponding minerals in the host eclogite, indicating that (metasomatic) diamond formation did not affect $\log fo_2$, as proposed by Aulbach and Stachel (2022). Our findings show that inclusions recorded heterogeneous redox conditions, indicating that diamonds likely grew from diverse fluids/melts from $CH_4$-$H_2O$ to $CO_2$–$H_2O$ dominated.

Stagno and Aulbach (2021). In Magma Redox Geochemistry (eds R. Moretti and D.R. Neuville)

Aulbach and Stachel (2022). Nature Communications, 13(1), 1924