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Reduced volatile sources for Karelian diamonds linked to punctuated ultramafic magmatism

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Diamond xenocrysts and eclogite-hosted diamonds from the Lahtojoki kimberlite (Karelian craton, Finland) indicate metasomatism of the deep lithosphere by N-rich, relatively reduced fluids. P-T-fO₂ constraints show that all eclogites were derived from near the base of the lithospheric mantle (>5 GPa), but only the diamond-bearing samples are relatively reduced (ΔFMQ -3.5 vs. -1.7 for barren eclogites). The Lahtojoki diamonds show evidence of formation from reduced mantle-derived carbon, based on the restricted range of $\delta^{13}\text{C}$ values (-3 and -7.8 ‰; n = 67) that form a negatively-skewed distribution. This reduced CHO fluid was also anomalously N-rich, based on the diamond N contents that range up to 1830 at. ppm. While N-rich sources for eclogite-associated diamonds are often linked to recycled crustal materials, in this case we prefer derivation from K-rich cratonic mantle metasomes due to lack of firm crustal geochemical signatures in the eclogites ($\delta^{18}\text{O} = 5.7 - 5.9$ ‰), in addition to the magmatic history of the Karelian craton.

The Karelian craton has been periodically intruded by K-rich alkaline lamprophyres, Group-2 kimberlites and olivine lamproites from 1800 to 700 Ma. Such K-rich ultramafic alkaline magmatism is likely linked to phlogopite-rich metasomes, which may represent significant repositories of N (NH⁴⁺ substitution for K⁺). Because the Lahtojoki eclogites resided near the base of the lithospheric mantle, they would have been susceptible to interaction with ascending asthenosphere-derived C-bearing fluids/melts, which were reducing. Following ingress into and interaction with the K-rich metasomatised Karelian mantle lithosphere, the increasingly N-enriched, CH₄-bearing fluids precipitated diamond during interaction with relatively oxidized eclogite wall rock. In contrast to the prevalent oxidizing effects of mantle metasomatism as identified within cratonic lithosphere-derived samples from worldwide locations, the eclogite-hosted diamonds at Lahtojoki represent a natural example of metasomatic overprinting that was highly reducing.