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Frequent carbonate inclusions in sublithospheric diamonds suggest a genetic relationship at variable fO_2

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Carbonates are considered a rare inclusion in gem-quality diamond. Most known occurrences are found within sublithospheric diamonds, as indicated by their coexistence with ferropericlase or Ca-walstromite inclusions. This observation suggests carbonate stability, in some mantle assemblages, to uppermost lower mantle depths. Hence, these inclusions might provide new perspective on deep carbon recycling and diamond formation at great depths.

Investigation of sublithospheric diamonds from Collier-4 (Juina, n=8) and the C29/30 kimberlite (Candle Lake, Sask Craton, n=20), revealed that carbonates in these diamonds are frequent, being the third most common mineral inclusion after ferropericlase and Ca-walstromite (Juina)/ olivine (Candle Lake), with which they often coexist. The carbonate inclusions have diamond-imposed cubo-octahedral shape and small dimensions, ranging from ~5 to 40 µm. The small dimensions may have prevented their widespread recognition by previous studies.

Carbonate inclusions in Juina diamonds (n=5) have main Raman vibrational modes at 316-325 and 1091-1095 cm^{-1}, suggesting a lower and more variable Mg# with respect to the inclusions in the Candle Lake diamonds (n=5), which have Raman modes between 327-329 and 1095-1096 cm^{-1}.

This observation correlates with the Mg# of the ferropericlase inclusions, which is more variable at Juina and more restricted at Candle Lake, suggesting that ferropericlase formation may take place by decarbonation reactions of the type: $(Mg, Fe)CO_3 \rightarrow (Mg, Fe)O + CO_2$. At low oxygen fugacity, this process will generate diamond instead of CO_2. Alternatively, the different composition of the carbonate inclusions may relate to their equilibration with substrates being more Ca-rich at Juina and more mafic at Candle Lake.

The frequent occurrence of carbonate inclusions in the sublithospheric diamonds studied here suggests a genetic link between these mineral species under varying oxygen fugacity conditions. This may record the equilibration of a cool and relatively oxidized subducted slab with the warmer and more reduced sublithospheric ambient mantle.