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The source of methane-bearing diamond fluids: C-N isotope and trace element constraints from Zimbabwe diamonds

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Mixed-habit diamonds are rare samples that contain two different, simultaneously-grown growth sectors, octahedral and cuboid. The faster-grown cuboid sectors often trap abundant fluid inclusions, in contrast to gem-quality octahedral sectors which, like gem-quality diamonds, rarely retain any direct samples of their source fluids. Mixed-habit diamonds from the Marange locality in the eastern Zimbabwe craton, that contain these co-crystallising inclusion-rich and gem-quality sectors in the same diamond, can potentially reveal source fluids for even gem-quality diamonds.

Marange diamonds contain abundant micro-inclusions of CH_4 within their cuboid sectors, the first direct occurrence of reduced CH_4-rich fluids that are thought to percolate through the lithospheric mantle. Detailed source composition modelling based on $\delta^{13}C$-$\delta^{15}N$-N content of the CH_4-bearing Marange diamonds, show that they did not precipitate through the traditional redox exchange concept of CH_4 oxidation [1]. Rather, we propose that they grew during non-redox growth from cooling CH_4-CO_2 hydrous fluids [2]. If so, then this growth mechanism must apply to both fluid-rich cuboid and gem-like octahedral sectors. Hence a non-redox model for diamond formation from mixed CH_4-CO_2 fluids may be applicable to a wider range of gem-quality lithospheric diamonds.

The positive $\delta^{15}N$ values suggest that these CH_4-bearing diamond source fluids were emplaced into the Zimbabwe cratonic lithosphere from subducted oceanic crust [1]. While there are no age constraints for Marange diamonds, slabs that were fluid sources could have been subducted during Archaean craton amalgamation [3] or during 2.1 - 1.8 Ga subduction along the western margin of the combined Kaapvaal and Zimbabwe cratons, recorded in the Magondi Belt [4,5].

Trace element analyses of the inclusion-rich cuboid sectors are on-going to evaluate the composition of these diamond source fluids. Previous studies of oxidised fluid inclusions common in fibrous diamonds reveal that the whole spectrum of observed fluids are derived from seawater-altered subducting slabs that variably interacted with either eclogite or peridotite to produce carbonatitic and silicic fluid compositions [6]. However, whether the fluids responsible for fibrous diamond growth can be applied to gem-quality diamond growth has never been firmly established. Trace element compositions of the CH_4-bearing subduction-derived fluids responsible for Marange mixed-habit growth may provide the link.

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