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Preservation of C centres in Ib diamonds due to rapid tectonic exhumation following Gondwana assembly: Re-Os age constraints of West African diamonds

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Type Ib diamonds are rare diamonds (< 0.1% of natural diamonds) that still preserve unaggregated nitrogen as single atoms (C centres), rather than the more common nitrogen pairs (A centres) and nitrogen aggregates (B centres). Preservation of unaggregated nitrogen in cratonic Type Ib diamonds requires either extremely short mantle residency times of a few million years and/or storage of diamonds at cooler temperatures than diamonds containing A and B centres (T < 850 °C; [1]). For normal diamond formation scenarios both constraints create geological challenges.

The Zimmi alluvial locality on the West African craton is known for its steady supply of Type Ib diamonds [2] and sulphides contained within them provide the first ever opportunity to determine the age of these enigmatic diamonds. Here we present Re-Os age results from Zimmi sulphide inclusions combined with a new West African geotherm obtained using single clinopyroxene xenocrysts from the nearby Koidu kimberlite (146 Ma; [3]). The geotherm provides the minimum temperatures required for diamond stability in the West African lithospheric keel, which combined with the age results allow us to unravel the geodynamic setting for the preservation of unaggregated C centres in natural cratonic diamonds.

Ten eclogitic sulphides from 3 Zimmi Ib diamonds, have Re-Os isotopic compositions that fall along Pan-African age arrays (~650 Ma). Timing of Ib diamond formation correlates with the assembly of Gondwana that is recorded in the Rokelide orogen along the SW margin of the Man shield [4]. Initial $^{187}Os/^{188}Os$ obtained from age arrays are between 1.5 and 2.2, extremely radiogenic compared to chondritic composition mantle at 650 Ma ($^{187}Os/^{188}Os$ = 0.12387; [5]). These radiogenic $^{187}Os/^{188}Os$ can only evolve in a source with high Re/Os ratios (50 to 100): achieved though long-term isolation from the convecting mantle and typical in MORB [6]. This suggests the sulphides were derived from older eclogitic protoliths that have mafic oceanic crust precursors, possibly Archaean low-Mg eclogites from the nearby Koidu kimberlite [7]. The sulphides were then encapsulated during Pan-African diamond growth from carbon-bearing fluids remobilised during continental collision.

The single clinopyroxene geotherm we obtained for the West African craton indicates that diamonds are only stable above 850 ± 100 °C. Conversely, C centres in Zimmi diamonds require that they did not experience temperatures above 700 °C for any extended period. This suggests that after formation, these diamonds were rapidly exhumed to shallower depths in the lithosphere, likely through tectonic uplift following continent collision. Rapid tectonic exhumation is consistent with the presence of abundant deformation lines in Zimmi diamonds, which is also typical of most other natural Ib diamonds [8].

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