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Age and origin of peridotitic diamonds from Venetia, Limpopo Belt, Kaapvaal-Zimbabwe Craton

S.H. Richardson[1], P.F. Pöml[2], S.B. Shirey[3], and J.W. Harris[4]

[1]*Dept. of Geological Sciences, University of Cape Town, Rondebosch 7701, South Africa*

[2]*Institut für Mineralogie, Westfälische Wilhelms-Universität, 48149 Münster, Germany*

[3]*Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road NW, Washington DC 20015, USA*

[4]*Dept. of Geographical & Earth Sciences, University of Glasgow, Glasgow G12 8QQ, UK*

The age and origin of diamonds from the Venetia mine, Limpopo Belt, Kaapvaal-Zimbabwe Craton, have been investigated using the Sm-Nd and Rb-Sr isotope systems in peridotitic garnet inclusions and selected macrocrysts and the Re-Os system in sulfide inclusions. The 520 Ma Venetia kimberlite cluster is located in the Central Zone of the Limpopo Belt (Phillips et al., 1999; Seggie et al., 1999) where Archean crust has experienced at least two major tectonothermal events at ca. 2.6 and 2.0 Ga (Eglington & Armstrong, 2004; Boshoff et al., 2006). The first age may represent the time of amalgamation of the Kaapvaal and Zimbabwe cratonic nuclei by subduction-accretion processes some 2.7 – 2.5 Ga ago, while the second age overlaps the well-constrained 2.054 Ga emplacement age (Scoates & Friedman, 2007) of the Bushveld Complex.

Peridotitic garnet inclusions in Venetia diamonds are harzburgitic to lherzolitic in composition with low Ca and high Cr contents spanning the entire G10 garnet field. Garnet macrocrysts generally have less extreme Ca and Cr contents and represent the disaggregated mantle host rocks of at least some of the diamonds. Using Ca content as a proxy for Sm/Nd ratio, some 140 inclusions were combined into four Ca-Cr groups to obtain sufficient material for meaningful Sm-Nd and Sr isotope analysis. All the garnet inclusions and macrocrysts have negligible Rb contents. The garnets encapsulated in diamond have high Sr and Nd concentrations and low Sm/Nd inversely correlated with Ca. The garnet macrocrysts also show low but more scattered Sm/Nd and much more radiogenic Sr (up to 0.720).This suggests diffusive exchange of the unencapsulated garnet macrocrysts with their high Rb/Sr host rocks during storage in the mantle keel on a billion-year timescale.

Three out of the four inclusion groups give a nominal isochron age of 2.30 ± 0.04 Ga with an unradiogenic initial ($\varepsilon_{Nd} = -8$). However, initial $^{87}Sr/^{86}Sr$ is inversely correlated with reciprocal Sr and Nd concentration, indicating mixing between a low Ca, low Sm/Nd, harzburgitic endmember with radiogenic Sr (≤ 0.707) and a higher Ca, higher Sm/Nd, eclogitic endmember with less radiogenic Sr (< 0.705), which slightly but significantly raised the initial Nd isotope ratios of the inclusion groups in proportion to the degree of mixing. Therefore, 2.3 Ga is a maximum age for these diamonds. Even so, the initial Nd composition and the characteristics of the mixing array indicate a > 3 Ga continental mantle harzburgite precursor to which an eclogitic component was added at ca. 2 Ga, as also suggested by the Re-Os isotope systematics of single sulfide inclusions in Venetia diamonds (Richardson & Shirey, 2008).

One Venetia peridotitic sulfide inclusion has an unradiogenic Os isotope composition comparable to those of Venetia peridotite xenoliths with Archean Re depletion model ages (Carlson et al., 1999). Four Venetia eclogitic sulfide inclusions describe an approximately 2.05 Ga Re-Os array with elevated initial $^{187}Os/^{188}Os$, supporting the presence of old eclogitic SCLM components equilibrated at Bushveld time. This initial ratio is even more radiogenic than those of Bushveld PGE sulfide ore minerals (Hart & Kinloch, 1989; McCandless & Ruiz, 1991) that have previously been attributed to continental crustal contamination (e.g. McCandless & Ruiz, 1991; Schoenberg et al., 1999). The sulfide Re-Os data provide strong evidence that the main source of Bushveld PGE is the mantle rather than the crust (Richardson & Shirey, 2008). Combined sulfide Re-Os and silicate Sm-Nd and Rb-Sr isotope compositions suggest variable incorporation of harzburgitic and eclogitic SCLM components during genesis of both the diamonds and the Bushveld Complex (Richardson & Shirey, 2008).

In this scenario, the Venetia harzburgitic-to-lherzolitic diamonds crystallized (or recrystallized) at ca. 2 Ga, following emplacement of the Bushveld Complex. The Venetia garnet inclusions and macrocrysts show strong similarities to their harzburgitic-to-lherzolitic counterparts from the 1.2 Ga Premier kimberlite on the opposite side of the Bushveld Complex (Richardson et al., 1993), as well as the 370 Ma Udachnaya kimberlite, Siberian Craton, where both Archean and Proterozoic generations of peridotitic diamonds have previously been identified (Richardson & Harris, 1997; Pearson et al., 1999).

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