Headless Placers and the Search for Buried Bodies

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Introduction

The durability of diamond enables survival through repeated sedimentary cycles. Consequently, detrital diamonds from sedimentary successions may have been transported considerable distances from their original kimberlite/lamproite volcanic source(s). Globally, there are numerous detrital diamond deposits with no clear links, or disputed links, to known primary kimberlitic sources – the so-called 'headless placers'. Examples include deposits along the West Coast of southern Africa; SE Asia (Burma, Thailand, Sumatra, Borneo); Kwango river, Angola; south-eastern Australia; Ural mountains, Russia; Parana basin, Brazil; Krishna river, India; Yuan region, China; and West Africa (Liberia, Sierra Leone, Guinea).

Recent work has suggested that source kimberlite eruption ages can be estimated from $^{40}Ar/^{39}Ar$ laser probe analyses of peridotitic or eclogitic clinopyroxene inclusions that have been extracted from their host diamonds (Phillips et al., 2004). This capability has significant implications for determining the age(s) of the source kimberlites that have contributed diamonds to detrital deposits, with concomitant application to diamond prospecting. However, this study also showed that, although some inclusions yield source eruption ages, others give older ages.

To test the applicability of the $^{40}Ar/^{39}Ar$ method to diamond provenance studies, Phillips and Harris (2008) analysed 50 eclogitic clinopyroxene inclusions from the ~93 Ma (Davis, 1977) Orapa kimberlite, Botswana. Low temperature steps produced anomalously old ages (up to 2.98 Ga), consistent with partial retention of pre-eruption ^{40}Ar in defect sites. Fusion steps yielded significantly younger ages, although only 35% are within error of the time of Orapa kimberlite eruption. However, 77% of results are within 50 Ma, and 92% within 100 Ma, of the Orapa emplacement age. These results mandate that individual inclusion ages be treated as maximum estimates of source kimberlite eruption ages. For multi-source diamond deposits, only the youngest detrital population, or populations separated by >100 Ma, will be resolvable. Subject to these limitations, Phillips and Harris (2008) concluded that the $^{40}Ar/^{39}Ar$ inclusion dating method can still be used to address key provenance questions.

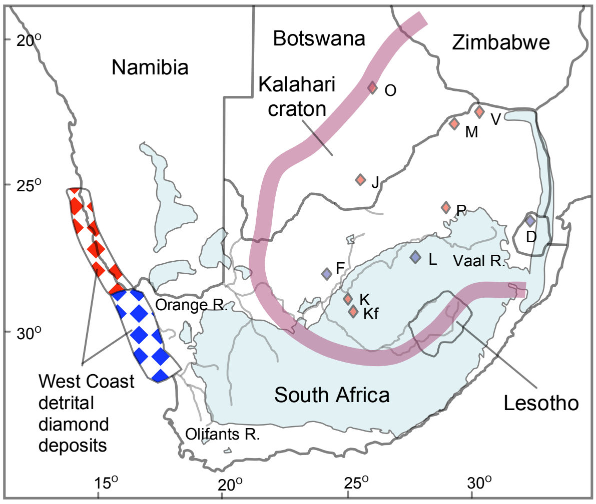

Fig. 1 Locality map showing the location of the West Coast detrital diamond deposits, Kalahari craton, Karoo outcrop (pale blue) and major diamondiferous Group I (red diamonds) and Group II (blue diamonds) kimberlites. (K = Kimberley, Kf = Koffiefontein, P = Premier, V = Venetia, M = Marnitz, J = Jwaneng, O = Orapa; F = Finsch, L = Lace, D = Dokolwayo).

In this study, we focus on the extensive detrital diamond deposits located along the West Coast of southern Africa. Although the interior of southern Africa hosts numerous diamond-bearing kimberlites, with emplacement ages from ~80 – 1200 Ma (e.g. Allsopp et al., 1989), considerable controversy exists as to the exact sources of the West Coast diamonds and the depositional history of these deposits. Some workers have suggested that the deposits along the west coast of South Africa (Namaqualand) resulted from transportation via the palaeo-'Karoo' river system, which eroded >115 Ma Group II kimberlites on the western Kaapvaal craton and entered the Atlantic ocean near the current outlet of the Olifants river (e.g. de Wit, 1993, 1999; Bluck et al., 2005). These authors also suggested that the Namibian detrital diamonds were transported by the younger Orange river drainage system, which eroded predominantly Cretaceous Group

I (~80 – 95 Ma) and Cretaceous/Jurrasic Group II kimberlites (~115 – 200 Ma). In contrast, other workers have argued that the majority of West Coast diamonds originated from recent erosion of Permo-Carboniferous Dwyka glacial deposits (~270 – 300 Ma), with their ultimate source being pre-Karoo kimberlites in the interior of the Kaapvaal craton (e.g. Maree, 1987, 1988; Moore and Moore, 2004). Resolution of these questions has implications for evolution of the Dwyka glaciation, erosion of the post-Gondwana landscape, post-Gondwana palaeo-drainage patterns, formation of detrital diamond deposits, and the timing and rates of these processes. These issues are also of economic importance, because demonstration of a pre-Dwyka origin for the West Coast diamond deposits would imply the existence of undiscovered older diamond-bearing kimberlites beneath Karoo cover rocks.

Samples and Results

To address the above controversy, clinopyroxene-bearing diamonds were collected from the West Coast of southern Africa for $^{40}Ar/^{39}Ar$ analyses, to provide constraints on the source(s) of these diamond deposits. Inclusions were extracted from a total of 116 diamonds, 68 from Namibia and 48 from Namaqualand, representing both eclogitic and peridotitic parageneses. Clinopyroxene inclusions from Namibian detrital diamonds yielded apparent ages ranging from 62 ± 30 Ma to 2304 ± 85 Ma (2σ) (Fig. 2). However, the majority of results (80%) are younger than 240 Ma. Eight samples (13%) produced ages within error of Cretaceous Group I kimberlites (~80 – 95 Ma), but distinctly younger than known diamondiferous Group II kimberlites (>115 Ma) on the Kaapvaal craton. These results provide compelling evidence for the presence of diamonds from Cretaceous Group I kimberlites in Namibian detrital deposits. Less than 10% of inclusions produced apparent ages older than 400 Ma.

Inclusions from Namaqualand detrital diamonds produced broadly similar results, although some subtle differences in age distributions are apparent (Fig. 3). The majority of apparent ages (84%) are younger than 300 Ma and <14% yielded ages older than 500 Ma. Although several inclusions produced apparent ages within error of 80- 95 Ma, these results are also within error of ~115 Ma.

Discussion and Conclusions

Compared to inclusions from Orapa diamonds (Phillips and Harris, 2008), the Namibian samples produced a higher proportion of apparent ages between ~150 and 200 Ma plus a small peak at ~300 Ma. If the Orapa results are generally representative, this would suggest that the Namibian detrital populations are dominated by diamonds from both Cretaceous Group I and Cretaceous/Jurrasic Group II kimberlites, in roughly

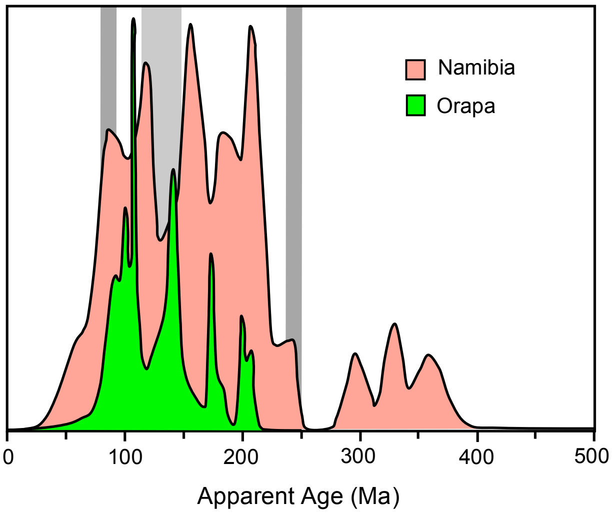

Fig. 2 Relative probablility plot showing the distributions of $^{40}Ar/^{39}Ar$ inclusion ages obtained from Namibian and Orapa diamonds

equal proportions. The small peak in ages at ~250 Ma could indicate a contribution from ~240 Ma kimberlites such as Jwaneng. However, as these are maximum ages, it is also feasible that these results reflect Group II kimberlite (~115 – 200 Ma) samples. A few inclusions yielded older ages (>300 Ma), suggesting that a small proportion of Namibian diamonds could be derived from pre-Karoo kimberlites. However, the previous study of Phillips et al. (2004) demonstrated that older apparent ages are also possible from clinopyroxene inclusions sourced from much younger (e.g. Cretaceous/Jurassic) kimberlites.

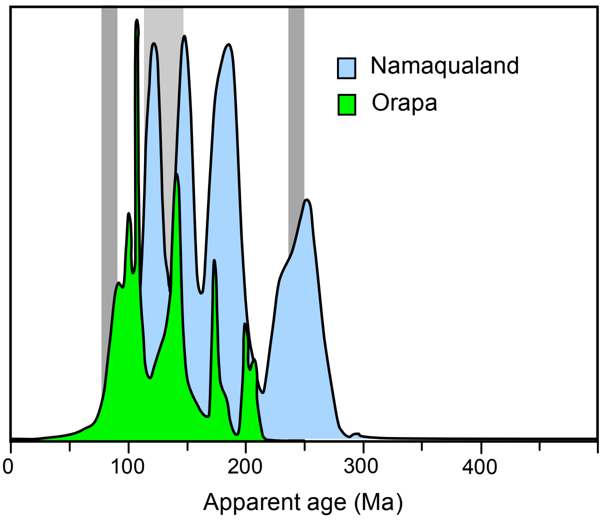

Fig. 3 Relative probablility plot showing the distributions of $^{40}Ar/^{39}Ar$ inclusion ages obtained from Namaqualand and Orapa diamonds

The Namaqualand results are broadly similar to the Namibian age distributions, although with fewer results younger than ~100 Ma. Therefore, in contrast to the Namibian samples, the presence of diamonds from Cretaceous Group I kimberlites remains equivocal for the Namaqualand deposits. As above, relatively few inclusions yielded apparent ages older than ~300 Ma, again suggesting limited (if any) input from pre-Karoo kimberlites.

In conclusion, the current results demonstrate that pre-Karoo kimberlite sources provided only minor or negligible quantities of diamonds to the West Coast deposits. Therefore, major contributions of diamonds from the Dwyka conglomerate are unlikely. Instead, the results support models advocating derivation of Namaqualand detrital diamonds from Group II kimberlites, with transportation by the paleao-'Karoo' river (e.g. de Wit, 1993, 1996, 1999; Bluck et al. (2005). At the same time, the data do not preclude the possibility that a significant proportion of Namaqualand diamonds originated from Group I kimberlites, and additional analyses are required to test this possibility. In contrast, the Namibian detrital deposits likely host diamonds from both Cretaceous Group I and Cretaceous/Jurassic Group II kimberlites.

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