# Origin of mantle-derived carbonate nodules from the Bultfontein kimberlite

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## Introduction

In order to account for $CO_2$-rich, Si-undersaturated magmas such as carbonatites and kimberlites, it has long been suggested that a carbonate-bearing peridotite mantle source must be present in the upper mantle. Experimental evidence suggests that if carbonate was present within kimberlite-derived mantle xenoliths, it would dissociate and degass and should not survive transport from the sub-continental lithospheric mantle (SCLM) to the surface (Canil, 1990). However, several studies have described the presence of fine-grained (10-20 µm) mantle-derived carbonate within xenoliths (e.g., Berg, 1986). This suggests that in some cases carbonate may survive rapid transport to the surface during kimberlite ascent. Here, we present textural descriptions along with major and trace element, O-C stable isotope, and Sr-Nd-Pb radiogenic isotope data for coarse (>1 cm) carbonate nodules from the Bultfontein kimberlite, South Africa.

**Figure 1.** Photograph of carbonate nodules within a hypabyssal kimberlite block from the Bultfontein kimberlite. Note the distinct green reaction margins. Scale is in cm.

## Results

The Bultfontein carbnate nodules (Figure 1) are polycrystalline calcite, coarse-grained (~4 mm), and are observed up to 10 cm (Figure 2). They are characterized by reaction margins with quench-related textures, including: radiating clusters of microlitic grains, a glass phase, and spherulites contained within the glass (Figure 2c). Furthermore, olivine grains spatially associated with the carbonate nodules are completely altered relative to the fresh grains away from the margins.

Six of the carbonate nodules were powdered and analysed for Sr-Nd-Pb-O-C isotopes and solution ICP-MS trace element analyses at the University of Cape Town. Strontium and Ba concentrations are 225-490 ppm and 1.4-17.7 ppm, repsectively. The REE are LREE enriched with relatively low concentraions 0.01 (HREE) to 1 (LREE) relative to chondrite (Figure 3). They have $\delta^{13}C$ and $\delta^{18}O$ of -6.0 to -6.3 ‰ and 15.7 to 16.9 ‰, respectively. The $(^{87}Sr/^{86}Sr)_i$ values have little variation with a range of 0.7047-0.7048 (Figure 4). In contrast, a large range in ƐNd was obsevered from -3 to -25 (Figure 4). Lead isotopes also show a large range with $^{208}Pb/^{204}Pb$ (36.5-38.5), $^{207}Pb/^{204}Pb$ (15.4-15.6), and $^{206}Pb/^{204}Pb$ (16.7-18.9).

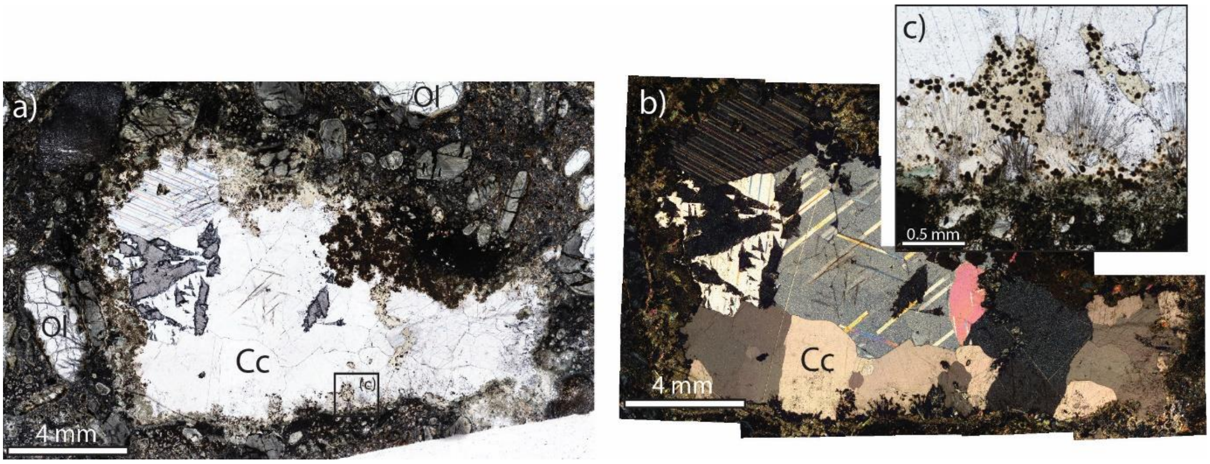


**Figure 2.** a) Plain polarized light (PPL) and b) cross-polarized light (XPL) photomicrographs illustrating the textures of a representative carbonate nodule from the Bultfontein kimberlite, South Africa. c) Inset: PPL image of the region marked in (a) illustrating the reaction textures surrounding carbonate nodules.

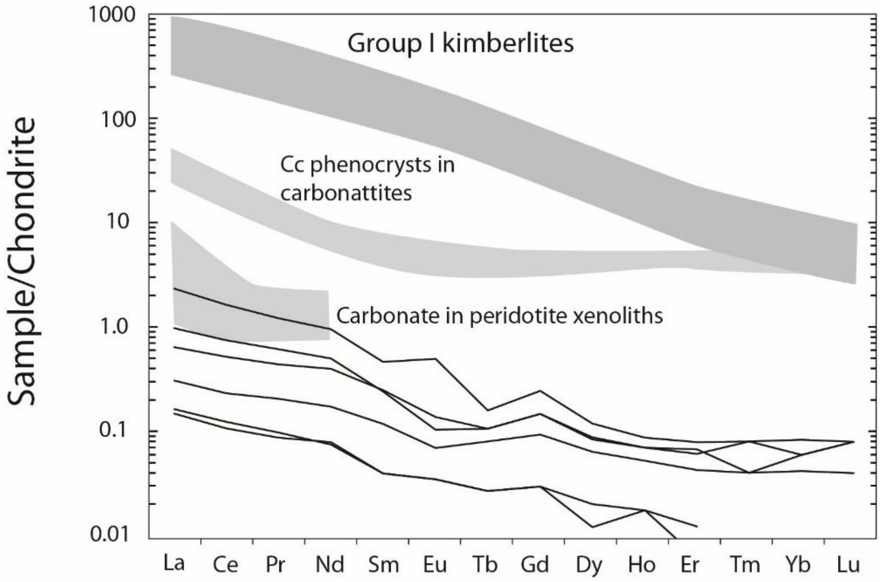


**Figure 3.** Chondrite normalized REE patterns for the Benfontein carbonate nodules. Field for Group I kimberlites is after Becker and le Roex (2006). The calcite (Cc) phenocryst field is after LREE enriched phenocrysts from the Spitskop carbonattites (Ionov and Harmer, 2002). The field for carboante in peridotite xenoliths is for mantle xenoliths in alkali basalts (Ionov, 1998).

**Discussion**

The distinct reaction margins and coarse-grained texture (relative to surrounding groundmass minerals) of the Bultfontein carbonate nodules indicate that they are not late-stage crystallization products but rather represent xenoliths entrained at some stage during kimberlite ascent from the SCLM. The $\delta^{13}C$ and $(^{87}Sr/^{86}Sr)_i$ and are consistent with formation within the mantle and not a crustal component. The REE concentrations are significanlty lower than typical kimberlites (Figure 3) suggesting that these carbonates do not represent late-stage residual carbonatitic melts associated with kimberlite melt evolution. The REE concentrations overlap with those reported for carbonates from peridotite mantle xenoliths recovered from alkali basalts (Figure 3). The very low $^{143}Nd/^{144}Nd$ ratios similarly suggest that these xenoliths are not related to the kimberlite magmas. Additionally the absence of correlation between $^{87}Sr/^{86}Sr$ with $^{143}Nd/^{144}Nd$ suggests that the very low ƐNd is not a result of crustal assimilation, but likely represents an ancient lithospheric mantle source.

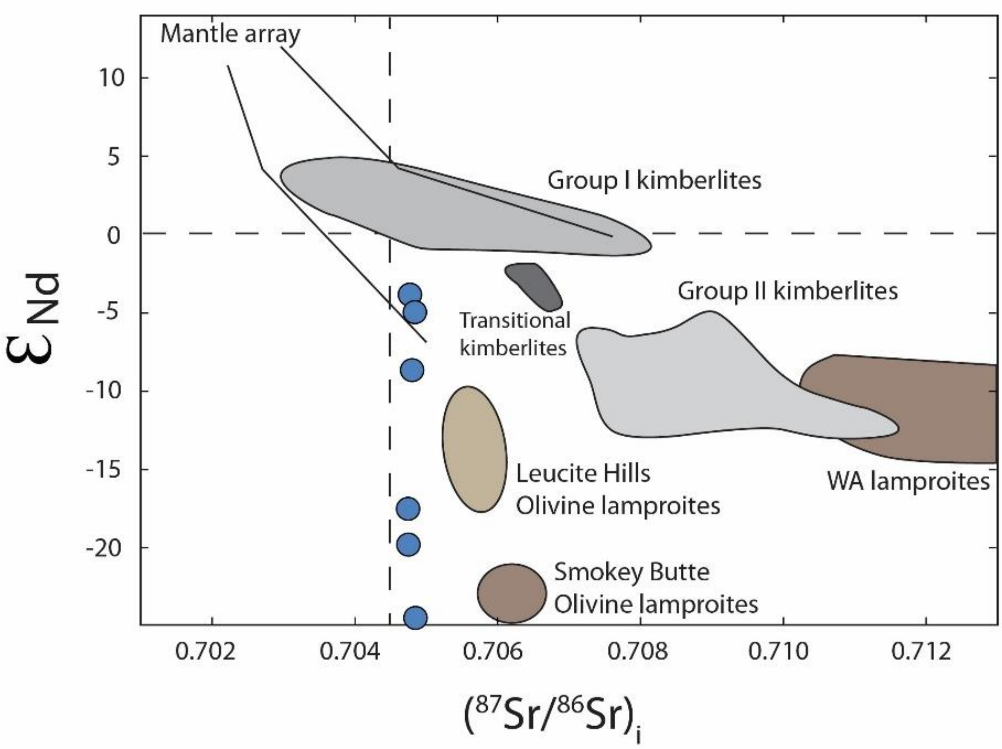


**Figure 3.** $(^{87}Sr/^{86}Sr)_i$ versus ƐNd for the Bultfontein carbonate nodules illustrating the large range in ƐNd at constant $(^{87}Sr/^{86}Sr)_i$. Group I and II kimberlite fields are after Nowell et al. (2004). Lamproite fields are after Fraser et al. (1985).

## Conclusions

Carbonate nodules from the Bultfontein kimberlite represent mantle xenoliths likely derived from an ancient lithospheric mantle source. They do not appear to be related to the host kimberlite. These types of xenoliths have not been previously identified in kimberlite magmas and may represent a distinct coarse-grained carbonate-rich mantle lithology wihtin the SCLM.

## References

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