Subcontinental mantle plume impact and kimberlite genesis

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The general concensus of recent theoretical and petrological studies is that the genesis of kimberlites and associated alkaline igneous rocks is related to the presence of anomalously high potential temperatures in the underlying convecting mantle (e.g. Le Roex, 1986; McKenzie, 1989; Haggerty, 1994; Gibson *et al.*, 1995a). The impact of a mantle plume on the base of the lithosphere is believed to affect a region up to 2500 km in diameter but the composition and location of the associated melts may vary according to the thickness of the overlying lithosphere. Anhydrous decompression melting of the plume head and the genesis of basaltic magmas will only occur beneath lithosphere of about <120 km. In regions of thicker lithosphere the plume may be volumetrically less significant as a melt source, but may be responsible for transferring heat by conduction or advection in very small-fraction melts. This may initiate melting of readily-fusible K-rich parts of the overlying lithospheric mantle. As a result, plume-related magmas emplaced in former mobile belts and cratons are often relatively small-volume and rich in K (e.g. kimberlites, lamproites, kamafugites and minettes).

The Lunda kimberlite province of NE Angola was emplaced near the southern margin of the Congo Craton. It is located at the NE end of a 1200 km linear magmatic belt of kimberlites and alkaline igneous complexes (including carbonatites and syenites). These appear to have been emplaced contemporaneously during the Early Cretaceous (~134 Ma: Davis, 1977; Torquato, 1970). Reconstructions of Gondwana show that at 134 Ma the Lunda kimberlite province was located near the postulated impact site of the starting head of the Tristan mantle plume (Fig. 1).

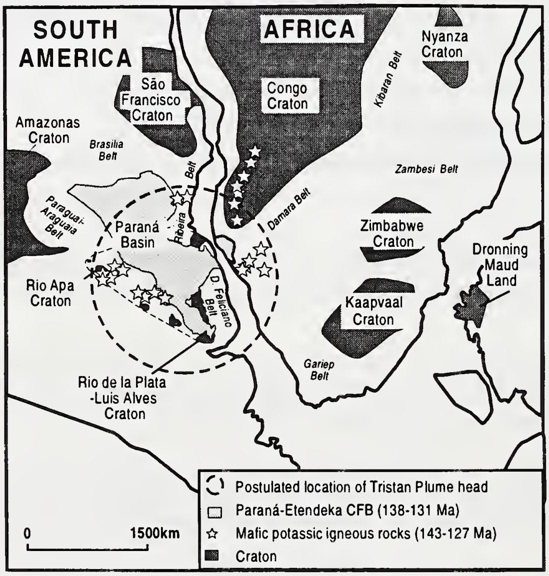

Fig. 1. Postulated location of the Early Cretaceous 'impact site' of the Tristan plume head. References for ages of magmatism and distribution of cratons and mobile belts are in Gibson *et al.* (1995b).

This thermal anomaly has also been linked with the genesis of: (i) the Paraná-Etendeka continental flood basalt province (White & McKenzie, 1989); (ii) mafic potassic magmatism in Namibia, southern Brazil and Paraguay (Gibson *et al.,* 1995b; Milner & Le Roex, 1996). A narrow (<250 km) linear chain of ocean islands and seamounts that constitute the Walvis Ridge forms a continuation of the NE/SW trending belt of Angolan magmatism. However, this shows a progressive decrease in age (from 113 Ma to 1 Ma; O'Connor & Le Roex, 1992) with distance from the continental margin and may represent the 'tail' of the steady-state Tristan mantle plume.

Despite the relatively high abundance and widespread occurrence of kimberlites in Angola, there are very few petrographic descriptions or whole-rock geochemical analyses available in the published literature. The Lunda province contains >40 richly diamondiferous kimberlite pipes that were emplaced into Archean/Early Proterozoic basement. All of the available samples have undergone hydrothermal alteration and most of the primary phases, with the exception of ilmenite macrocrysts, have been replaced by secondary minerals. Relict textures within the rocks suggest that they are from crater facies kimberlites.

The Lunda kimberlites have high contents of TiO_2 (4 to 5 wt.%) and also Nb (170 to 250 ppm). They are enriched in light rare-earth elements (LREE; La=65 to 193 ppm) and have low abundances of heavy REE (e.g. Lu=0.14 to 0.22 ppm). They have variable initial $^{87}Sr/^{86}Sr$ ratios (0.7029 to 0.7076) that reflect the hydrothermal alteration and variable contents of crustal xenoliths. The Lunda kimberlites have high εNd values (+4) and on a conventional Sr- Nd-isotope diagram plot in the field of ocean-island basalts, near Group I South African kimberlites (Fig. 2).

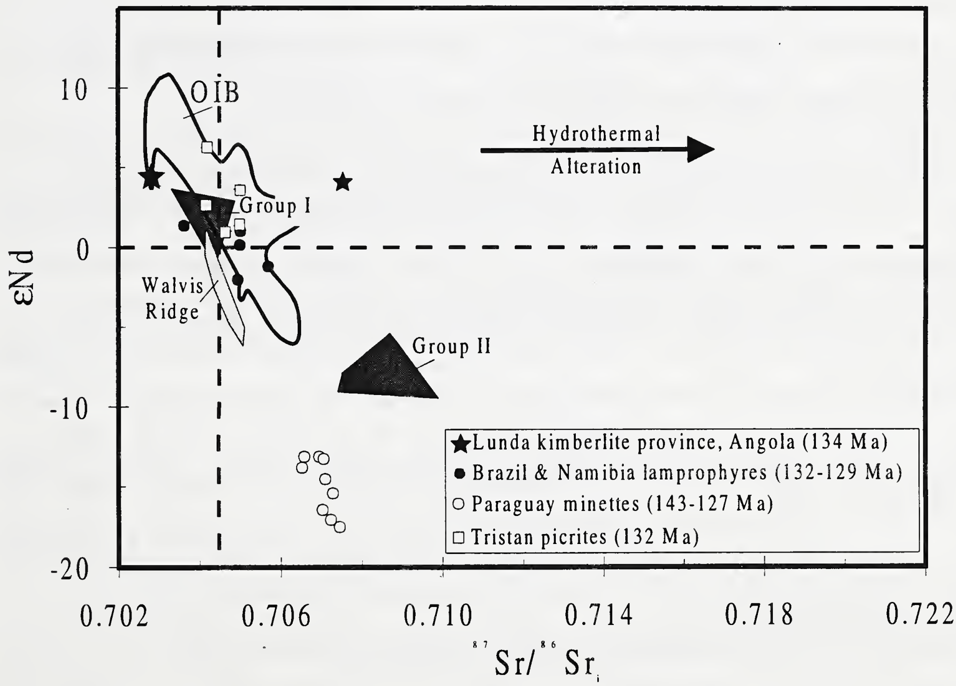

Fig. 2. Variation of $^{87}Sr/^{86}Sr_i$ ratios and εNd values in Tristan plume related magmas. References for data sources are in Gibson *et al.* (1995a and b).

The Sr- and Nd-isotopic ratios of the Lunda kimberlites are similar to those of 132 Ma picrites from the Paraná-Etendeka CFB province in NW Namibia (Fig.2). The picrites have normalised incompatible trace element patterns that are similar to those of ocean-island basalts and are believed to have been generated by melting of the Tristan mantle plume starting head (Gibson *et al.,* 1997). Inversion modelling of the REE abundances suggest that the picrites were generated over a depth range of 120-80 km, i.e beneath thinner lithosphere than the diamondiferous Angola kimberlites.

The Lunda kimberlites have slightly lower Sr- and higher Nd-isotopic ratios than the 132 to 129 Ma mafic potassic igneous rocks (lamprophyres) from the Damara Belt of NW Namibia and the Ribeira Belt of southern Brazil (Fig. 2). The latter are characterised by lower abundances of LREE and higher abundances of HREE (La/Yb=40 to 60) than the Angolan kimberlites (La/Yb=50 to 100). Mafic potassic magmas were also emplaced in the Rio Apa craton (Paraguay) between 143 and 127 Ma. These are characterised by intermediate REE ratios (La/Yb=40 to 80) but have low abundances of elements such as Nb, Ta and Ti and very low εNd values (-13 to -17; Gibson *et al.,* 1995b). These geochemical variations in the Early Cretaceous mafic potassic magmas presumably reflect: (i) the different evolutionary histories of the Rio Apa and Congo cratons; (ii) the thinner lithosphere of the surrounding Proterozoic mobile belts. Nevertheless, the spatial and temporal distribution of all of these mafic potassic magmas suggests that their genesis was associated with the impact of the Tristan mantle plume. The Angolan kimberlites appear to represent the deepest mantle melts to be associated with this thermal event. A plume-related origin for the Angolan kimberlites is consistent with entrained Cr-poor diopside megacrysts that are believed to have equilibrated at temperatures of 1300 -1400°C (Boyd & Danchin, 1980).

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