Carbonatite and silicate magmas at Dicker Willem, southern Namibia: their origin and source region characteristics

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The Dicker Willem complex consists mainly of calcio-carbonatite, but several varieties of silicate-bearing rock types also occur: ijolites and syenites occur as xenoliths within sövite; fenites are developed in the surrounding country rock; and trachyte forms peripheral dykes, sills and plugs. Many sövites are also silicate-bearing, and while a profound "silica gap" does exist between carbonatite and ijolite for example, some transitional rocks have been discovered that bridge these compositions, which we have termed nepheline sövites (Cooper and Reid, 1998a). The consanguinity of the silicate and carbonatite rocks at Dicker Willem has been investigated with radiogenic isotopes.

Such a test has been simplified by the homogeneous Sr, Nd and Pb isotope composition of the carbonatites (average $\epsilon_{Sr} = -17.3 \pm 1.9$, $\epsilon_{Nd} = 2.14 \pm 0.45$, Figs 1 and 2). Dispersion of present day Pb isotope ratios in the sövites and some ijolites is a function of *in situ* decay of U and a correction assuming an age of 49 Ma (Reid et al., 1990) causes all rock types (except for the fenites) to assume an average $^{206}Pb/^{204}Pb = 21.0 \pm 0.2$. Significantly the ijolites and the transitional nepheline sövites also have similar isotope compositions to the carbonatites, suggesting that the entire spectrum from carbonate to silicate are comagmatic. It is therefore possible to consider genetic models involving simple differentiation, whereby the suite can be derived from some common parent. While considerable debate has taken place concerning the generation of carbonatite melts by liquid immiscibility, the existence of the transitional nepheline sövites at Dicker Willem would seem to argue against such an explanation. However, recent experimental work (Lee and Wyllie, 1996; 1997) has shown that even at moderate pressure, the two liquid field in carbonate-silicate systems is reduced, and the observed field relations at Dicker Willem could be explained by the original existence of the nepheline sövite magma at depth, a component of which crystallized as a parent body. Degassing could give rise to depressurization and the onset of immiscibility, resulting in separate carbonate and silicate magmas, the latter crystallizing as the parent body to the ijolite suite, the latter being parental to the sövites and alvikites that build Dicker Willem.

Trachytes, syenite and especially fenites display wide variability in their respective isotopic compositions, but the observed patterns can be explained by mixing between crustal components, representing the affected country rock (granite gneisses of the Namaqua Province), and a magmatic component equated with a metasomatic fluid derived from the carbonatite (Figs 1 and 2). Syenites are arbitrarily distinguished from fenites as they are restricted to xenoliths within sövite, while the latter define the contact aureole. Trachyte is interpreted as the remobilized products of high grade potassic fenites at depth (Cooper and Reid, 1998b).

The radiogenic isotope signature of the Dicker Willem carbonatite provides an insight into the underlying mantle, and comparison is made between patterns derived from carbonatite, kimberlite and other mantle-derived magmas that traversed the Namibian lithosphere since the birth of the African plate in the Jurassic. Focussing initially on the isotope systematics of Dicker Willem, the Nd-Sr pattern (Fig. 3) closely resembles that already established for young carbonatites (< 200 Ma) worldwide (Nelson et al., 1988; Bell and Blenkinsop, 1989), plotting in the depleted quadrant, slightly below the oceanic mantle array. The radiogenic Pb isotope signature of Dicker Willem is typified in Fig. 4, where its composition extends the field obtained by Davies et al., (1991) for the alkaline rocks of southern Namibia. Thus Dicker Willem plots at the most Sr-depleted end of the Nd-Sr array and the most enriched end of the Pb isotope array. Addition of data from other alkaline silicate complexes from Namibia and South Africa (Marsh, J.S., unpublished data) confirm the spread in ϵ_{Sr} , but may reflect a crustal component, as some of the samples are highly fractionated phonolites (eg. Klinghardt and Rehoboth). This may be indicated by the high $^{207}Pb/^{204}Pb$ values observed in Fig. 4.

A more lucid comparison of isotopic signatures is achieved using initial Pb-Sr and Pb-Sr ratio plots (Figs 5 and 6), where the Namibian and adjacent South African alkaline silicate igneous suites are compared with mantle reservoirs, following the method of Milner and Le Roex (1996). Much of the data plot between the inferred composition of the Tristan plume source and the HIMU reservoir, the latter interpreted as plume-hosted recycled subducted oceanic crust. Samples with high ϵ_{Sr} appear to represent crustal contamination, while a few plot between Tristan and DMM (or MORB reservoir). Interestingly no data plot in the vicinity of the EM 1 reservoir, interpreted by Milner and Le Roex (1996) as ancient continental lithosphere, an important source for some of the lavas in the Etendeka flood basalt province in north-west Namibia. While it is not intended to specifically invoke the Tristan plume to explain the isotopic signatures of alkaline silicate and carbonatite magmas in southern Namibia and neighbouring South Africa, a mixed plume source, containing Tristan-type and HIMU mantle material would be a plausible candidate. Several other hotspot traces have been proposed for southern Namibia, including those now thought to be responsible for the Vema and Discovery seamounts in the South Atlantic (Hartnady and Le Roex, 1983; Reid et al., 1990; Davies et al., 1991). For magmas with compositions between Tristan and DMM, which include the Gibeon megacryst suite and some of the Namaqualand and Cape olivine melilitites, Davies et al., (1991) propose a model involving melts sourced in the subcontinental asthenosphere migrating into the overlying lithosphere, prior to incorporation into their respective parental magmas.

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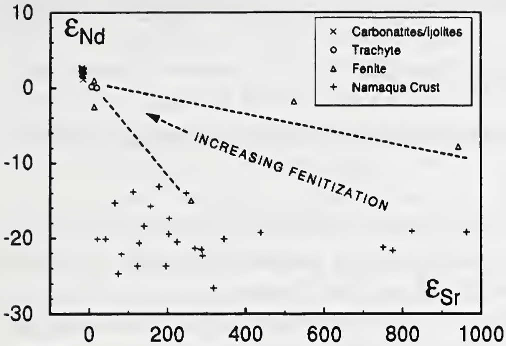

Figure 1. Plot of initial Sr-Nd ratios of the Dicker Willem carbonatite complex, compared with country rock gneisses (Namaqua Province data from various sources.

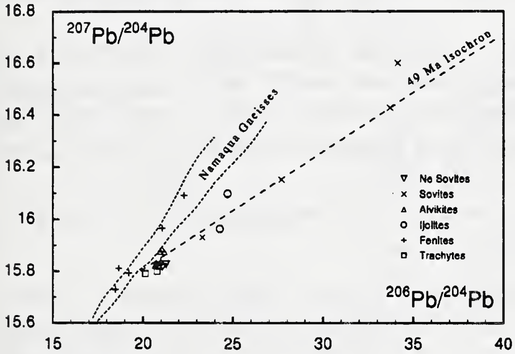

Figure 2. Plot of Pb isotope compositions of the Dicker Willem carbonatite complex. Field occupied by the country rocks is shown for comparison with the fenites (Namaqua data from various sources).

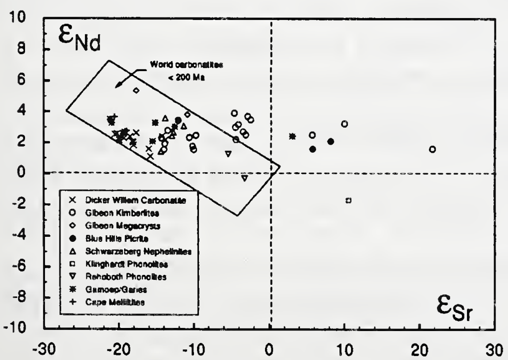

Figure 3. Plot of initial Sr-Nd ratios of the Dicker Willem complex, compared with data from other alkaline silicate intrusive suites from Namibia and South Africa (< 80 Ma). World carbonatite (< 200 Ma) field after Bell and Blenkinsop (1989).

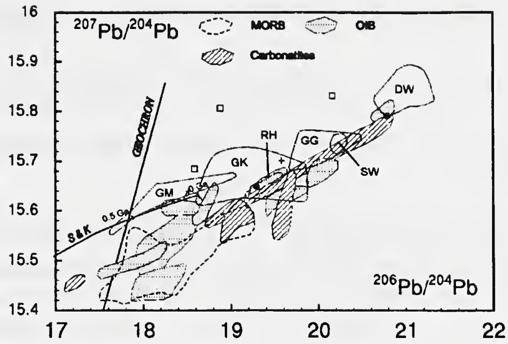

Figure 4. Plot of initial Pb isotope ratios of the various alkaline silicate and carbonatite suites (< 80 Ma) from southern Namibia and neighbouring South Africa. DW = Dicker Willem, SW = Shwarzeberg Nephelinites, GG = Gamoep/Garies olivine melilitites of Namaqualand, RH = Rehoboth phonolites, GK = Gibeon Kimberlites, GM = Gibeon Megacrysts; Open Squares = Klinghardt phonolites, + = Cape melilitites, ● = Blue Hills picrite. Shaded fields are modern oceanic basalts and < 200 Ma world carbonatites from Kwon et al., (1989).

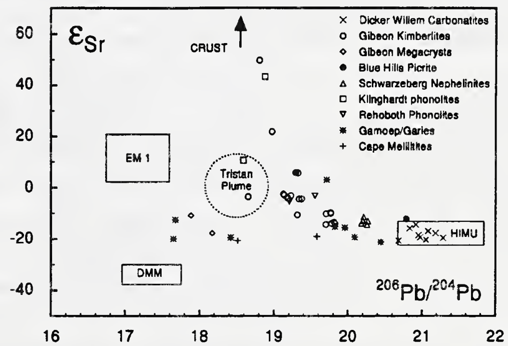

Figure 5. Comparison of initial Pb-Sr ratios with those inferred for mantle source regions under Namibia, after Milner and Le Roex (1996).

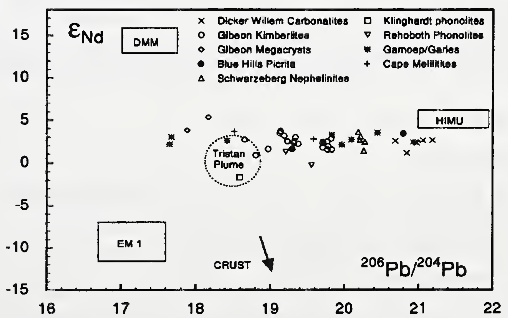

Figure 6. Comparison of initial Pb-Nd ratios with inferred mantle source regions under Namibia, after Milner and Le Roex (1996).