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The geochemistry and evolution of Palaeogene phonolites, central Namibia

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ABSTRACT

Phonolites of Palaeogene age occur at two different localities in central Namibia, occurring as clusters of eroded monogenetic lava domes. Six phonolites at Aris collectively exhibit a narrow compositional range and represent a single magma system of highly evolved phonolite with high concentrations of Na_2O, Rb, Th, Zr, Zn, Pb, and REE and very low abundances of MgO, P_2O_5, Sr and Ba. No mafic rocks are associated with the Aris phonolites and their ultimate petrogenetic origin remains obscure. The more abundant Staudhart phonolites exhibit more variable but scattered compositional variation consistent with fractional crystallization dominated by sanidine (and nepheline) and pyroxene. The behaviour of REE is decoupled from Zr, Nb, and Th in this suite indicating a controlling role for minor phases in their evolution. The least evolved phonolites have initial $^{87}Sr/^{86}Sr \approx 0.7043$, which is identical to a small occurrence of associated plagioclase-bearing nephelinite indicating a possible petrogenetic link. Higher isotopic ratios in more evolved phonolites suggest their evolution was accompanied by some crustal interaction. Comparisons of phonolites world-wide indicate that they all have similar trace element abundance patterns when normalized to associated and possibly parental mafic compositions, regardless of proposed petrogenetic origins (e.g. melting, fractional crystallization, AFC, etc.). These patterns of similar pronounced enrichments of Rb, Th, Zr, plus depletions in Ti and P, and $Yb_N > Gd_N$ (i.e. depletion of middle REE relative to heavy REE) confirm the suggestion that fractional crystallization is the dominant process by which phonolites evolve from mafic alkaline compositions. Despite similar published values of D_{Eu} for sanidine in silicic and phonolitic compositions, highly evolved phonolites develop only modest negative Eu anomalies compared to evolved silicic rocks. This might reflect differences in melt structure, fO_2, halogen complexing or fractionating mineral assemblages in phonolite and silicic liquids. Sparse data on Eu partition coefficients in phonolite bulk compositions does not provide insight into the role of these controls of Eu partitioning in phonolite.

1. Introduction

Trivial volumes of late-Cretaceous–Palaeogene alkaline volcanic rocks (hundreds of bodies with individual outcrop volumes generally <0.1 km^3 with a few larger occurrences approaching 1 km^3) are widespread throughout western southern Africa from Windhoek (in Namibia) southwards over a distance of 1500 km to the continental shelf offshore of Cape Agulhas, the southern tip of Africa. The alkaline rocks comprise alkaline basalts and basanites, nephelinites and melilitites, carbonatite, rocks of kimberlite affinity, and felsic trachytes and phonolites. Available ages range from 77 to 32 Ma but relatively few occurrences have been dated. There is no systematic spatial distribution with regard to age of volcanicity or petrological type. As in other continent-wide intraplate volcanic provinces (e.g. Cainozoic volcanism of eastern Australia (Johnson et al., 1989)) the origin of this southern African intraplate alkaline volcanicity remains poorly understood. Some authors have invoked mantle plumes (Hartnady and Le Roex, 1985; Le Roex, 1986; Reid et al., 1990), others a causal factor in broad epeirogenic uplift (Moore, 1976; Moore et al., 2008). Maps showing the distribution of these occurrences and compilations of available age data can be found in Jelsma et al. (2004) and Moore et al. (2008).

Felsic (i.e. trachyte and phonolite) members of this suite are concentrated in three localities: (a) on the Alphard Bank, SE of Cape Agulhas where trachytes and phonolitic trachytes dated at 58 ± 2.4 Ma (K/Ar age on sanidine) occur with alkaline basalt (Dingle and Gentle, 1972; Janney et al., 2002); (b) in the Klinghardt Mountains of southern Namibia where phonolites with an age of 46.0 ± 0.7 Ma ($^{40}Ar/^{39}Ar$ plateau age on sanidine — D. Phillips personal communication, 2002) have a spatial relationship with minor nephelinite (Lock and Marsh, 1981; Marsh, 1987); and (c) in the area between Windhoek and Rehoboth in central Namibia where phonolite and trachyte, possibly of different ages (see below), are again associated with minor alkaline mafic rocks. Phonolites from the latter occurrence are the subject of this paper.

2. Field relationships and previous work

In central Namibia phonolites occur in two distinct locations (Figs. 1, 2). About 6 individual phonolite bodies occur on either side of the National road at Aris (22°45.277' S; 17°08.013' E — WGS84

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