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Partial melting of diverse crustal sources — Constraints from Sr–Nd–O isotope compositions of quartz diorite–granodiorite–leucogranite associations (Kaoko Belt, Namibia)

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ABSTRACT

The Torrabaai–Koigabmond Complex (southern Kaoko Belt, Namibia) consists of three main intrusive rock types including metaluminous hornblende- and titanite-bearing quartz diorites, metaluminous hornblende- and biotite-bearing granodiorites and peraluminous garnet- and muscovite-bearing leucogranites. Uranium–Pb zircon data obtained on the granodiorites and leucogranites indicate concordia upper intercept ages of 553 ± 40 Ma although $^{207}Pb/^{206}Pb$ ages of ca. 650 Ma in zircon from the granodiorites suggest some inheritance of older material. Uranium–Pb monazite data obtained on the leucogranites give concordant ages of 550 Ma ± 3 Ma. These ages are similar to the $^{87}Rb/^{86}Sr$ whole rock age of 584 ± 35 Ma obtained on the granodiorites and leucogranites although the Rb–Sr age seems to be biased towards older ages due to limited assimilation of older material. In contrast to other plutonic complexes from the Kaoko Belt, the quartz diorites, granodiorites and granites show a restricted range in their initial Nd, Sr and O isotope compositions (quartz diorites: $\varepsilon_{Nd\ (init.)}$: −5.4 to −6.7; $\delta^{18}O$: 8.3–9.4‰; $^{87}Sr/^{86}Sr$: 0.7081–0.7098; granodiorites: $\varepsilon_{Nd\ (init.)}$: −6.1 to −7.7; $\delta^{18}O$: 9.9–10.9‰; $^{87}Sr/^{86}Sr$: 0.7071–0.7105; leucogranites: $\varepsilon_{Nd\ (init)}$: −4.9 to −8.7; $\delta^{18}O$: 9.8–11.3‰; $^{87}Sr/^{86}Sr$: 0.7060–0.7125). Enclaves are found in the granodiorites and leucogranites but not in the quartz diorites. They have a granodioritic composition with quartz, plagioclase, K-feldspar and hornblende and some have additional garnet. Relative to the country rock gneisses (the so called Nk Formation), enclaves are depleted in SiO_2, Na_2O, K_2O, Sr, Ba and enriched in CaO, $FeO_{(total)}$, MgO, TiO_2, Sc, V, Cr, Ni, Rb and Y. Rare garnet-bearing enclaves are additionally depleted in LREE and enriched in HREE relative to the granodiorites. These features are qualitatively consistent with the hypothesis that these enclaves may represent moderately depleted melting residues of Nk Formation gneisses. In comparison with experimentally derived melts and based on low $Al_2O_3/(FeO+MgO+TiO_2)$ ratios and high $Al_2O_3+FeO+MgO+TiO_2$ values it is suggested that the quartz diorites are generated by dehydration melting of a mafic, amphibole- and plagioclase-bearing lower crustal source of Pan-African age. The granodiorites likely represent fractionation products of the quartz diorites. However, it is also possible that the granodiorites represent partial melting products of a mafic to intermediate lower crustal source but experienced likely slightly lower degrees of melting probably at water present conditions. The leucogranites display higher $Al_2O_3/(FeO+MgO+TiO_2)$ ratios but lower $Al_2O_3+FeO+MgO+TiO_2$ values and are most likely generated by biotite dehydration melting of felsic crustal sources. Major and trace element and isotope variations indicate that fractional crystallization with only limited crustal contamination was the major rock-forming mechanism. It is suggested that most of the isotope variation reflects pre-existing heterogeneities of the sources. Consequently, interpretation of geochemical and isotope data from the complex suggests that the Pan-African igneous activity in this part of the Damara–Kaoko Belt was not a major crust-forming episode and all rock types represent reprocessed crustal material.

1. Introduction

In the study of the histories of orogenic belts, synorogenic igneous rocks ranging in composition from gabbro-diorite to granite and even leucogranite are indispensable sources of information. Age

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relations and elemental and isotopic compositions provide evidence as to the dynamics of exhumed plate margins and give pivotal clues to the identity of unexposed basement terranes. As long as geochemical contrasts between source materials are clear, regional-scale geochemical mapping may illuminate basement-cover relations (Bennett and DePaolo, 1987; Ayuso and Bevier, 1991; Dorais and Paige, 2000). However, in areas such as the Kaoko Belt, where endmember source compositions are not precisely known, detailed studies of individual igneous complexes may be a more appropriate approach to provide the kind of information required. In the northern Kaoko Belt, the main exposed basement sources are Archaean to Proterozoic meta-igneous gneisses of granodioritic to granitic composition that exhibit some contrasts at least in their Nd isotopic signatures (Seth et al., 1998). In contrast, the nature of the basement beneath the southern Kaoko Belt is probably more diverse including various crustal reservoirs (meta-igneous and metasedimentary rocks) of dominantly Pan-African age (c. 500–550 Ma; van de Flierdt et al., 2003; Masberg et al., 2005). Therefore, our study of granite complexes in the southern Kaoko Belt is important because the magmas from which they crystallized potentially record

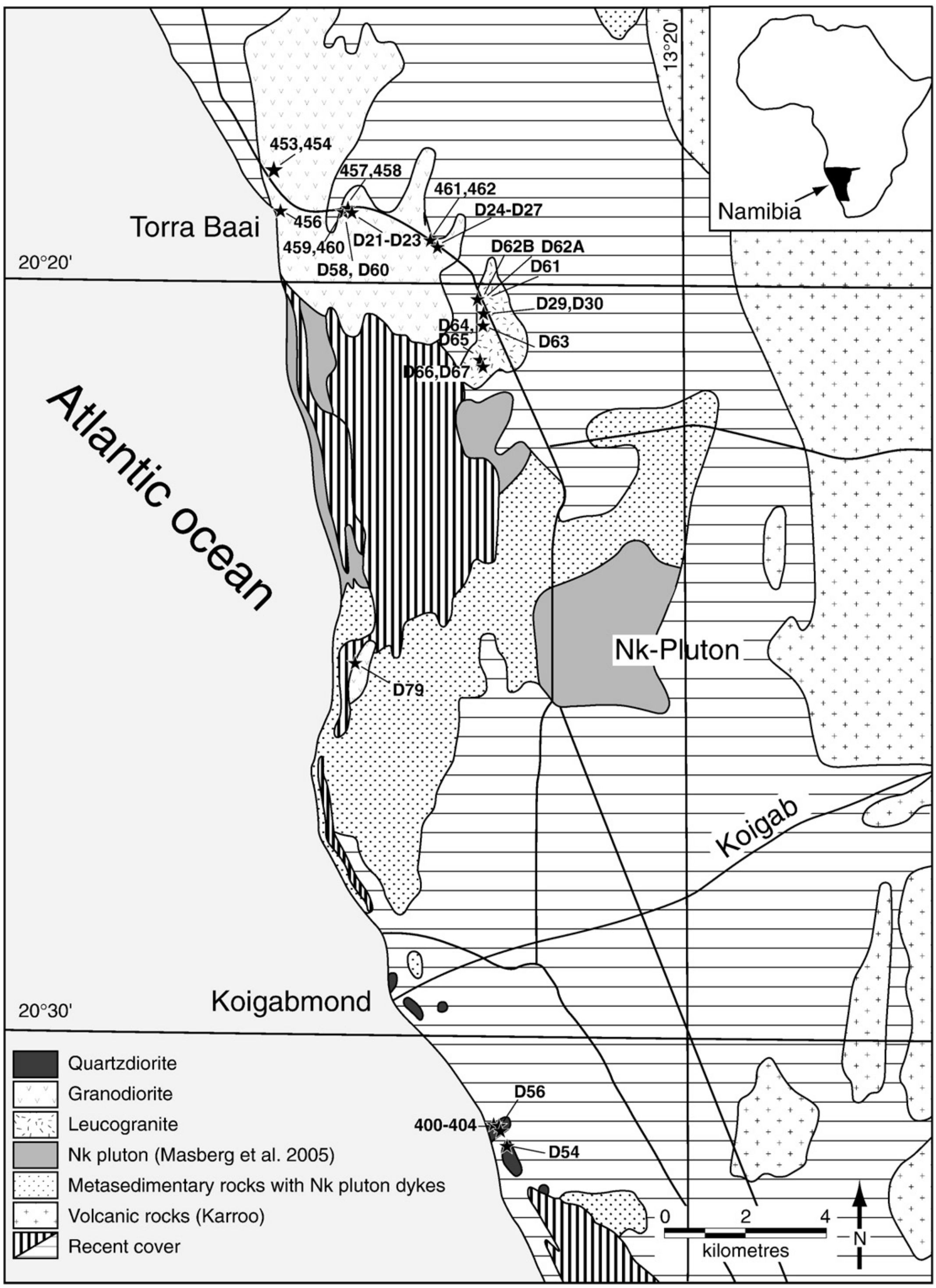

Fig. 1. Generalized geological map showing the study area within the southern part of the Kaoko Belt, Namibia.