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Isotopic equilibrium/disequilibrium in granites, metasedimentary rocks and migmatites (Damara orogen, Namibia)—a consequence of polymetamorphism and melting

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Abstract

The overwhelming part of the continental crust in the high-grade part of the Damara orogen of Namibia consists of S-type granites, metasedimentary rocks and migmatites. At Oetmoed (central Damara orogen) two different S-type granites occur. Their negative ε_{Nd} values (-3.3 to -5.9), moderately high initial $^{87}Sr/^{86}Sr$ ratios (0.714–0.731), moderately high $^{206}Pb/^{204}Pb$ (18.21–18.70) and $^{208}Pb/^{204}Pb$ (37.74–37.89) isotope ratios suggest that they originated by melting of mainly mid-Proterozoic metasedimentary material. Metasedimentary country rocks have initial ε_{Nd} of -4.2 to -5.6, initial $^{87}Sr/^{86}Sr$ of 0.718–0.725, $^{206}Pb/^{204}Pb$ ratios of 18.32–18.69 and $^{208}Pb/^{204}Pb$ ratios of 37.91–38.45 compatible with their variation in Rb/Sr, U/Pb and Th/Pb ratios. Some migmatites and residual metasedimentary xenoliths tend to have more variable ε_{Nd} values (initial ε_{Nd}: -4.2 to -7.1), initial Sr isotope ratios ($^{87}Sr/^{86}Sr$: 0.708–0.735) and less radiogenic $^{206}Pb/^{204}Pb$ (18.22–18.53) and $^{208}Pb/^{204}Pb$ (37.78–38.10) isotope compositions than the metasedimentary rocks. On a Rb–Sr isochron plot the metasedimentary rocks and various migmatites plot on a straight line that corresponds to an age of c. 550 Ma which is interpreted to indicate major fractionation of the Rb–Sr system at that time. However, initial $^{87}Sr/^{86}Sr$ ratios of the melanosomes of the stromatic migmatites (calculated for their U–Pb monazite and Sm–Nd garnet ages of c. 510 Ma) are more radiogenic ($^{87}Sr/^{86}Sr$: 0.725) than those obtained on their corresponding leucosomes ($^{87}Sr/^{86}Sr$: 0.718) implying disequilibrium conditions during migmatization that have not lead to complete homogenization of the Rb–Sr system. However, the leucosomes have similar Nd isotope characteristics than the inferred residues (melanosomes) indicating the robustness of the Sm–Nd isotope system during high-grade metamorphism and melting. On a Rb–Sr isochron plot residual metasedimentary xenoliths show residual slopes of c. 66 Ma (calculated for an U–Pb monazite age of 470 Ma) again indicating major fractionation of Rb/Sr at c. 540 Ma. However, at 540 Ma, these xenoliths have unradiogenic Sr isotope compositions of c. 0.7052, indicating depleted metasedimentary sources at depth. Based on the distinct Pb isotope composition of the metasedimentary rocks and S-type granites, metasedimentary rocks similar to the country rocks are unlikely sources for the S-type granites. Moreover, a combination of Sr, Nd, Pb and O isotopes favours a three-component mixing model (metasedimentary rocks, altered volcanogenic material, meta-igneous crust) that may explain the isotopic

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variabilty of the granites. The mid-crustal origin of the different types of granite emphasises the importance of recycling and reprocessing of pre-existing differentiated material and precludes a direct mantle contribution during the petrogenesis of the orogenic granites in the central Damara orogen of Namibia.

Keywords: S-type granite; A-type granite; Isotopes; Damara orogen

1. Introduction

The petrogenesis of granitic rocks sensu lato, being either intrusive or derived by in situ partial melting of high-grade metamorphic rocks, is of fundamental importance for an understanding of the growth and internal differentiation of the continental crust. The elucidation of granite petrogenesis is hampered by the great variety of petrological and geochemical types and the different tectonic setting in which granites are generated and emplaced. Furthermore, any given segment of the continental crust has generally resulted from a complex multi stage evolution and younger geological events have tended to obliterate any trace of the previous history. It is now well accepted (e.g., Chappell and Stephens, 1988; Chappell and White, 1992) that granites are formed by several processes mainly including differentiation of mantle derived mafic magmas and melting of pre-existing sedimentary (S-type granites) or igneous precursors (I-type granites). Another approach to solve the problem of diversity of crustally derived granitic melts is the study of migmatites that can represent initial stages of crustal anatexis. Despite the observation that many, but not all, regional-scale migmatite complexes in orogenic belts are spatially and temporally associated with intrusive rocks of mainly granitic composition, the relation between migmatites and granitic plutons is still unresolved. Migmatites may represent the link between high-grade metamorphism and larger-scale granitic bodies (e.g. Brown and D'Lemos, 1991) in which leucosomes did not coalesce to form large-scale bodies (e.g. Obata et al., 1994) or may result from contact effects induced by neighbouring plutons (e.g. Pattison and Harte, 1988). Alternatively, migmatites and granites may not be genetically related (e.g. White and Chappell, 1990). Therefore, a major difference between the various mechanisms proposed for the genesis of granites is the relative importance assigned to the mantle or to the crust in the melting events. Evaluation of such models are best based on detailed studies of the radiogenic and stable isotope geochemistry of such rocks because such studies may provide valuable constraints on the relative role of crustal recycling and new mantle additions to the continental crust during orogenic processes. The Oetmoed Granite Migmatite Complex (hereafter OGMC) has been studied in great detail (Jung et al., 1998b, 1999, 2001; Jung, 2000) and details about the field relationships, chronological events and major and trace element compositions of granites and country rocks are now available. Strontium, Nd, Pb and O isotope compositions of the post-tectonic A-type granites (Jung et al., 1998b) and some post-tectonic S-type leucogranites (Jung et al., 2001) have been published previously. Such data are lacking from the syn-tectonic granites, metasedimentary rocks, migmatites and residual xenoliths. Therefore, in this paper Sr, Nd whole rock and Pb isotope compositions from leached K-feldspar are presented and evaluated together with the existing isotope data. In the Damara belt, the nature of the lower crust is unconstrained and the relationship between orogenic granite magmatism and events deep within the crust cannot be directly investigated. Therefore, the isotopic data of granites are used to place limits on possible compositions of the unexposed sources of the granites and thus on the nature of the terranes through which the plutons ascended.

2. Geological setting and field relationships

The Damara orogen can be subdivided into a Northern, Central and Southern Zone (see inset to Fig. 1). In the Northern Zone, greenschist facies conditions with temperatures and pressures of 430–530 °C and 2–3 kbar are recorded (Miller, 1983). In the Southern