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Granitic intrusions and UHT metamorphism in the South Marginal Zone of the Limpopo Complex, South Africa

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In the course of exhumation onto the Kaapvaal craton during the time period 2.72–2.66 Ga, the Southern Marginal Zone (SMZ) of the Limpopo Granulite Belt (LGB) has been invaded by trondhjemite–granodiorite melts [1,2], which are, probably, closely associated with the large diorite–granodiorite–quartz syenite Matok pluton [3]. These injections are usually closely associated with high-grade shear zones, which controlled exhumation of the SMZ [4,5]. Thermobarometry applied to the trondhjemites from the Petronella and Banderlierkop localities within the SMZ shows that average temperatures of the melts reached 1000°C. These hot magmas functioned as a heat source for the UHT event that affected metapelites at P ~7.5–8.5 kbar (23–25 km depth), resulting in localized dehydration melting of biotite-rich metapelites. This phenomenon is expressed by formation of spectacular K-feldspar-rich garnet–orthopyroxene patches. In addition, the trondhjemite melts heterogeneously assimilated metapelites producing trondhjemitic varieties containing garnet, sillimanite, spinel, and graphite. Various mineral assemblages from the garnet–sillimanite-bearing trondhjemites, garnet–orthopyroxene leucosome patches and surrounding metapelites indicate that the magma–rock system after being exhumed to a depth of 18–20 km (6.3–6.5 kbar) experienced sub-isobaric cooling from T ~900–1000°C to ~600°C (down to kyanite stability conditions).

Fluid inclusions in garnet and quartz from the trondhjemites at various localities show that the magma transported a CO_2 fluid, which dominated over the complex aqueous–salt (NaCl, KCl, $CaCl_2$) fluid. Similar CO_2 and aqueous–salt fluids were also detected in quartz from granodiorite and porphyritic quartz syenite of the Matok complex. The $\delta^{13}C$ of -6.52 to -8.65 $^{o}/_{oo}$ for graphite from some trondhjemites (at the Banderlierkop locality) are unrelated to the host metapelites and indicate a deep-seated source for both the fluids and, probably, also for trondhjemite melts. Graphite is supposed to have been formed via reduction of the CO_2 fluid during assimilation of the sulfide-rich country metapelitic material. During sub-isobaric cooling and solidification of the granitoid magmas, the CO_2-rich and aqueous brine fluids with water activities 0.5–0.3 provoked rehydration of a significant portion of the SMZ [4,5] accompanied by formation of various assemblages including late garnet, Na_2O-rich gedrite (locally coexisting with anthophyllite), biotite, sillimanite (kyanite), staurolite, and sodic plagioclase after cordierite in metapelites.

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