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Isotope Characteristics of Carbon as Evidence of an External Source of High-Temperature Granitoids in Granulite Complexes

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Abstract—Data on the isotope composition of graphite and CO_2 from inclusions in quartz of granitoids of the Southern Marginal Zone (SMZ) of the Limpopo granulite belt, South Africa, are presented. The average values of $\delta^{13}C$ for graphite and CO_2 for fluid inclusions in quartz are found within the range that is typical of deep (mantle) carbon sources. The data are evidence of an external source of granitoid magmas. They are likely to be hybrid rocks that appeared during assimilation of host metapelites by trondhjemite magmas, while graphite in trondhjemites and granodiorites is a product of high-temperature (~900–1000°C) evolution of the CO_2-rich fluid phase of granitoid magmas when they intrude the rocks of the granulite complex and was formed during assimilation that led to reduction of CO_2 when sulfide-containing metapelite material fell into magma.

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Graphite is a widespread mineral of metamorphic rocks of the granulite metamorphic facies [1, 2]. It can be formed due to carbon from organic substances (OS) and carbonates dispersed in the sedimentary substrate and can precipitate from the CO_2-containing fluids of various genesis during their interaction with rocks [1–5]. Of special interest are the occurrences of graphite in connection with the processes of granulite anatexis and interaction with magmas. Graphite is known in granitoid leicosomes and dykes in granulite complexes [3, 5], indicating the carbon saturation of fluids that coexisted with crystallizing melts at >800°C. The carbon source is identified in these objects by the isotope characteristics of graphite. The $\delta^{13}C$ values vary from –20‰ and lower for graphite that formed from carbon of the host rocks [5], to –9...–6‰ for graphite recovered from fluids [3]. The last values correspond to the "mantle mark," signifying a possible mantle source of CO_2 in the fluids [3]. Since the value of the CO_2–graphite fractionation increases as the temperature of isotope exchange decreases [6], isotope-heavy graphite may also appear as a result of carbon isotope fractionation during crystallization of consecutive generations of graphite from the CO_2-rich fluid [4]. Thus, the comparison of the $\delta^{13}C$ values of graphite and the CO_2 inclusions in the coexistent minerals may provide relevant information both on the fluid source and the temperature evolution of the fluid–rock system [4].

We obtained new data on the isotope composition of graphite and fluid from quartz inclusions of leucocratic garnet- and sillimanite-containing granitoids associated with metapelites of the granulite facies of the Southern Marginal Zone (SMZ) of the Limpopo granulite belt, South Africa. The samples for studies were taken from the Bandelierkop quarry, which exposed a uniquely rich section of cordierite–orthopyroxene–biotite, cordierite–garnet–biotite, and garnet–orthopyroxene metapelites of the Bandelierkop formation [7], one of the main types of supracrustal associations of the SMZ. Granitoids that are associated with the rocks of the Bandelierkop formation are dated to 2.67–2.69 billion years ago and intruded the metapellites during exhumation and thrust of the SMZ granulites over the Kaapvaal craton [8].

Granitoids are medium- to coarse-grained rocks (Fig. 1) composed primarily of plagioclase (50–70 vol %) and quartz (25–45 vol.%). In trondhjemites, potassium feldspar is manifested only as dis-

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