Carbon sources in granitoids of granulite complexes

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During high-grade metamorphism in the middle and lower crust, carbon can be recycled from the organic substance and carbonates dispersed in the pre-metamorphic sediments or supplied by fluids migrating through tectonic pathways or via magmas from various outer sources, including mantle. These sources can be recognized from the carbon isotope composition of fluids trapped in minerals or graphite and carbonates produced during the fluid-rock interaction.

We present results of the carbon isotope study of graphite and fluid inclusions in minerals from garnet-bearing trondhjemites from the Southern Marginal Zone (SMZ) of the Limpopo granulite belt, South Africa, and garnet-bearing plagiogranites from the Central Zone of the Lapland granulite belt, Russia. The granitoids were intruded during exhumation and thrusting of the granulite complexes over the adjacent cratons during the periods 2.67-2.68 Ga for the Limpopo rocks (Belyanin et al., 2014) and 1.90-1.91 Ga for the Lapland rocks (Mints et al., 2007; Kaulina et al., 2014). The Limpopo trondhjemites began to crystallize at T > 900°C and P = 8 – 8.5 kbar. Temperatures of crystallization of the Lapland plagiogranites were 840-860°C at 5.9-6 kbar.

Graphite in the studied samples of granitoids of both complexes is associated with the primary minerals. Following to x-ray and Raman data, ordered graphite from the Limpopo trondhjemites precipitated at temperatures >700-750°C. Average $\delta^{13}C$ values for graphite from three samples of the Limpopo trondhjemites are following: -6.52, -8.65 и -8.59 ‰. Dense CO_2 inclusions are ubiquitous in the trondhjemite minerals. Their $\delta^{13}C$ values are -4.10±1.2 ‰. Depletion of graphite in ^{13}C with respect to fluid serves as an

evidence for a genetic link between graphite and fluid in the trondhjemites. The carbon fractionation values (Polyakov, Kharlashina, 1995) correspond to temperatures > 900°C consistently with the mineral thermometry. The genetic link between graphite and fluid is supported by a presence of CH_4 and disordered graphite in the fluid inclusions assuming equilibrium $2C + 2H_2O = CO_2 + CH_4$. Thus, graphite from the Limpopo trondhjemites, apparently, was produced via reduction of the carbonic fluid during the interaction of the magma with country rocks.

The $\delta^{13}C$ values for graphite and fluid from the Limpopo trondhjemites lie within the range, which is specific for the deep-seated (mantle) carbon sources. These values strongly differ from the values $\delta^{13}C$ = -15.0…-12.5 ‰, which have been previously measured for graphite from the metapelites of the SMZ, but are close to the $\delta^{13}C$ values for graphite for graphite and garnet-bearing granite veins (Vennemann, Smith, 1992). Thus, the isotope data indicate that fluids associated with the trondhjemite magmas of the SMZ have originated from the outer source unrelated to the host metapelites (Safonov et al., 2014). The «heavy» isotope signatures of the Limpopo trondhjemites might be related to fluids, which have been produced during devolatilization of basic rocks (amphibolites) layered with hydrothermal carbonate veins (which usually show $\delta^{13}C$ >-9 ‰; e.g. Kerrich, 1989) in the granite-greenstone successions of the Kaapvaal craton buried under the SMZ granulites.

Graphite from the Lapland plagiogranites shows $\delta^{13}C$ = -20.19 … -20.21 ‰. The $\delta^{13}C$ values of low-density carbonic inclusions in the plagiogranites are -12.43±0.07 ‰ that is close to the signatures of the biogenic carbon. The fractionation values calculated from the above $\delta^{13}C$ data (Polyakov, Kharlashina, 1995) correspond to temperatures below 600°C. The $\delta^{13}C$ values are within the range $\delta^{13}C$ = -25…-20 ‰ for graphite from the shear-zones truncating the Lapland complex (Korja et al., 1996). Thus, graphite in the

plagiogranites seems to be re-deposited from the pre-metamorphic carbon during anataxis of peraluminous gneisses of the Lapland complex (Mints et al., 2007; Kaulina et al., 2014).

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