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Protolith carbon isotope ratios in cordierite from metamorphic and igneous rocks

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Abstract

Cordierite commonly contains H_2O and CO_2 in the channels formed by its ring structure. In many studies cordierite has been shown to have volatile contents and carbon isotope ratios consistent with high-temperature equilibrium, suggesting preservation of protolith carbon isotope ratios and motivating this survey of carbon isotopes in cordierite CO_2. Cordierite CO_2 from pelitic country rocks in the Etive aureole have $\delta^{13}C$ values of –20.70 ± 1.27‰ (n = 10) that are unaffected by a ca. 150 °C thermal gradient and fluid-saturated and undersaturated regimes. These $\delta^{13}C$ values are consistent with expected carbon isotope ratios of organic carbon in protolith sediments. Similar lithologies from the Cooma and Huntly aureoles show more variable behavior in a more limited data set, with some rocks preserving organic carbon $\delta^{13}C$ values and others that may have been affected by externally derived fluids. In cordierite-gedrite gneisses, carbon isotopes of cordierite (Crd) are distinct from those of cordierite in pelites; when excluding one outlier new data plus those from the literature average $\delta^{13}C$(Crd) = –12.51 ± 2.45‰ (n = 17). These isotope ratios are higher than those of cordierite in typical metasedimentary protoliths and are similar to published carbon isotope ratios of trace carbonate in altered submarine volcanic rocks, which are likely analogs for protoliths of many cordierite-gedrite rocks. Igneous cordierite from granitic plutons have $\delta^{13}C$ = –23.61 ± 2.08‰ (n = 13), which is interpreted as reflecting a magmatic carbon budget dominated by organic carbon from sedimentary source rocks. In contrast, small pegmatites reported in the literature have $\delta^{13}C$(Crd) = –10.20 ± 3.06‰ (n = 6), which may indicate derivation from orthogneiss source materials. These new data show that carbon isotopes in cordierite can be used to help understand the protolith of even carbon-poor metamorphic rocks, and can also shed light on carbon in the sources of magmatic rocks. This latter approach has the potential for helping constrain the source rocks of peraluminous granitoids, which is controversial. Determining the extent to which organic carbon $\delta^{13}C$ is preserved in granitoids is important for understanding the deep carbon cycle, and could serve as an important constraint in the search for low-$\delta^{13}C$ graphite inclusions in Hadean detrital zircons, which have been reported as a potential biosignature for the early Earth.

Keywords: Stable isotopes, igneous petrology, metamorphic petrology, analysis, cordierite