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Boron isotope compositions establish the origin of marble from metamorphic complexes: Québec, New York, and Sri Lanka

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Abstract

The origin of an array of marble samples found in both the Grenville Province and southwestern Sri Lanka remains uncertain, whether magmatic, sedimentary, or mixed, due to their proximity to both carbonatite bodies and carbonate-rich metasedimentary rocks. This study reports boron and trace element abundances, in addition to carbon, oxygen, boron, and strontium isotopic compositions, to determine the petrogenesis of these carbonate-rich samples. Boron abundances for all of the samples are relatively high and variable (1.48–71.1 ppm) compared to those for carbonatites worldwide (≤1 ppm), and mostly overlap those documented for sedimentary sources (up to 54 ppm). The rare earth element (REE) abundances (0.5–1068 ppm) for the marbles studied are similar to those for local sedimentary units and thus contain, in general, lower REE contents than both the average worldwide calcio-carbonatite and respective neighboring carbonatite bodies. The $\delta^{13}C_{V\text{-}PDB}$ and $\delta^{18}O_{V\text{-}SMOW}$ compositions for all of the samples range between –2.9 to +3.2 ± 0.1‰ and +14.3 to +25.8 ± 0.2‰, respectively, and are considerably heavier than those reported for magmatic or metamorphosed carbonatites. The $^{87}Sr/^{86}Sr$ ratios reported here range from 0.70417 to 0.70672, which are more radiogenic than the average $^{87}Sr/^{86}Sr$ (~0.70345) reported for carbonatites included for comparison in this study. Importantly, the boron isotopic compositions ($\delta^{11}B$‰) for samples from the Grenville Province range from +7.5 to +15.7 ± 0.5‰, which are consistent with those reported for biogenic carbonate (+4.9 to +35.1‰). In contrast, $\delta^{11}B$ values for the samples of marble from Sri Lanka vary from –9.8 to –14.3 ± 0.5‰ overlapping with those estimated for average bulk continental crust (–9.1 ± 2.4‰). Together, the boron compositions, chemical data, stable (C, O), and radiogenic Sr isotopic data overwhelmingly point to a sedimentary origin for the marble samples examined here. Specifically, the samples from the Grenville Province represent marble formed during high-temperature regional metamorphism of limestone units. The Sri Lankan samples were formed from carbonate-rich and ^{11}B-poor fluids derived from a crustal source. The boron isotopic compositions for the samples studied here are also compared to those reported for mantle-derived carbonate (i.e., carbonatites) worldwide, along with their associated $\delta^{13}C_{V\text{-}PDB}$ and $^{87}Sr/^{86}Sr$ values. This comparison results in defining three isotopically distinct fields; mantle-derived carbonates, sedimentary carbonates derived from heterogeneous limestone protoliths, and carbonates derived from meteoric water interacting with crustal material. This work establishes the effective use of boron isotopic compositions in determining the origin of carbonate-rich rocks of contentious petrogenesis.

Keywords: Boron isotopes, Grenville Province, Sri Lanka, multi-colored marble, carbonatite; Lithium, Beryllium, and Boron: Quintessentially Crustal