The clumped isotope geochemistry of dolomite and calcite in contact metamorphic environments

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Studies of metamorphic processes commonly focus on greenschist- and higher grade rocks because conventional cation and isotopic exchange thermometers often fail to record heterogeneous equilibrium at lower grades. Carbonate `clumped' isotope thermometers often record homogeneous equilibrium at near-surface conditions, but undergo diffusion-limited solid-state reordering over geological timescales. In calcite, prior work indicates this re-ordering begins at temperatures above ~115 ˚C, and full re-equilibration occurs quickly (wks-yrs) above ~200 ˚C. We present new laboratory heating experiments that indicate dolomite is resistant to re-ordering below ~175 ˚C and reaches equilibrium quickly above ~350 ˚C. Within these intervals (115-200 ˚C for calcite and 175-350 ˚C for dolomite), clumped isotope compositions are sensitive to the details of the T-t path. For this reason, measurements of the Δ_{47} values of co-existing calcite and dolomite can place new constraints on thermal history over a large slice of the upper crust (from ~5 to ~15 km depth).

We studied the clumped isotope geochemistry of coexisting calcite and dolomite in marbles from the Notch Peak contact metamorphic aureole, Utah. Here, flat-lying limestones were intruded by a pluton, producing a regular, zoned metamorphic aureole. Calcite Δ_{47} temperatures are uniform, 140 ± 6 ˚C (1 s.e.), across rocks varying from high-grade marbles that exceeded 500C to nominally unmetamorphosed limestones >5 km from the intrusion. This result appears to require that the temperature far from the pluton was close to this value; an ambient temperature just 15 ˚C lower would not have permitted even partial re-equilibration, and should have preserved depositional or early diagenetic Δ_{47} values several km from the pluton. Combining this result with depth constraints from overlying strata suggests the country rock here had a regional geotherm of 21-24 ˚C/km from the Jurassic to the Tertiary.

Dolomite Δ_{47} in all samples above the talc+tremolite-in isograd record apparent equilibrium temperatures of 297 ± 11 C (1 s.e.), consistent with the blocking temperature we predict for cooling from peak contact metamorphic conditions. At greater distances, dolomite Δ_{47} records temperatures of peak (anchi)metamorphism or pre-metamorphic diagenetic conditions. The interface between these domains is the location of the 300 ˚C isotherm associated with intrusion.