Modeling fluid flow in low-$\delta^{18}O$ skarns: insights from Empire Mountain, Mineral King, Sierra Nevada, California, USA

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The oxygen isotope composition of garnets from the Empire Mountain skarn in the Sierra Nevada batholith of California, USA reveal garnet growth in the presence of ^{18}O-depleted fluids at the beginning of skarn formation [1]. These results imply that surface waters penetrated through ~3.3 km of overlying crust to the paleo-depth of the intrusion without reaching oxygen isotope equilibrium with the surrounding rock. The infiltration of such fluids to skarn-forming depths requires that high-conductivity flow paths are maintained through the entire upper crust. However, brittle deformation, ductile deformation, and mineral reactions occurring during skarn formation will change the permeability and porosity of rocks through which fluids flow. Taking these processes into consideration, we present an alternative and simpler solution for the occurrence of negative $\delta^{18}O$ values at depth at the initiation of skarn formation.

We propose that given a normal crustal geotherm, pore fluids in isotopic equilibrium with surrounding metavolcanic rocks have negative $\delta^{18}O$ values prior to the emplacement of the pluton. Furthermore, these fluids comprise a large proportion of the overall budget. Negative $\delta^{18}O$ values account for ~43% of all subsurface pore fluid and ~82% of pore fluids in immediate contact with the magmatic body prior to skarn formation. Two dimensional numerical simulations of oxygen isotope transport during skarn formation confirm that these pore fluids can be drawn towards the magmatic body by hydrothermal convection during pressure-temperature conditions pertaining to garnet growth. The rate of fluid flow is greater than the rate of fluid-solid isotope exchange and thus pore fluids remain out of equilibrium with the surrounding rock. These findings provide an alternative explanation for the observed negative $\delta^{18}O$ values in garnets during the beginning of skarn formation.

[1] D'Errico et al., 2012, Geology, 40, 763-766