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The timescale and carbon flux recorded by skarn andradite from Gangdese arc, southern Tibet

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Fluid-driven metamorphism in carbonate sequence gives rise to carbon release, of which the timescale is documented by the calc-silicate assemblages. In this study, we use andradite-grossular garnet to infer the timing and mass fluxes of decarbonation reactions in response to a 64 Ma granitoid emplacement in the Gangdese arc.

A garnet grain from the contact aureole shows distinctive dissolution-reprecipitation patterns. The host andradite crystal is crosscut by veins of porous garnet. These veins have lower TiO_2, lower MnO, and higher grossular components than the host andradite (Fig. 1). The host andradite includes abundant diopside, wollastonite and calcite, so we estimate a minimum temperature of 600 °C based on the phase relation at 2 kbar. We apply diffusion modeling to the sharp vein-host interface. For the Mg profiles, the best-fit sqrt(Dt) varies between 3.2 and 7.7 × 10^{-7} m (D–diffusion coefficient, t–time), with the spatial averaging by electron microprobe accounted. If we assume the same diffusion kinetics as almandine garnet, applying the diffusion model of Mg [1] yields 2-12 kyr at 600 °C (Fig. 2). This short timescale might still be significantly overestimated because the large unit-cell dimension and high water content of garnet accelerate diffusion by orders of magnitude. Notably, the fitted sqrt(Dt) of Al/(Al + Fe^{3+}) and Ti profiles are close to that of Mg, so the diffusion coefficients of Al-Fe^{3+} and Ti appear comparable to Mg. The diffusion of Ti and Al-Fe^{3+} in andradite-grossular garnet could be potential geospeedometers applicable to skarn deposits. Given the millennial duration, mass balance calculations applied to various lithologic units in this aureole yield a carbon flux of ~75 mol $year^{-1}$ m^{-2} for a 150 m reaction front. The areal carbon release scales to a carbon flux of ~2 Tmol/year of the whole Gangdese batholith. The vast carbon flux is of the same magnitude as the late Cretaceous global carbon flux contributed by contact metamorphism [2].

[1] Chu & Ague (2015), *Contributions to Mineralogy and Petrology* 170.

[2] Chu, Lee, Dasgupta & Cao (2019), *American Journal of Science* 319, 631–657.