Crystal growth rates in plutonic systems via ID-TIMS U-Pb geochronology

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A growing body of work shows that models for magma generation, transport, storage, and eruptibility are dependent on the timescales of magma flux and composition, cooling rate and therefore crystallinity. Most time calibrations of these processes via geochronology and geospeedometry are from young volcanic systems, though a more comprehensive understanding of crustal evolution must include the complementary plutonic record.

We approach this problem using ID-TIMS U-Pb geochronology on zircon in two systems of contrasting depths: the shallow crustal Elba magmatic system, Italy (~ 7 Ma), and the Alpine Bergell instrusion (~30 Ma), which exposes an upper to lower crustal section. In Elba, zircon inclusions were separated and dated from cores and rims megacrystic K-feldspar, yielding crystallization rates that can be linked to rock petrogenesis via petrography and whole-rock and intracrystalline geochemistry combined with phase equilibrium modeling. We show that though zircon dates span 400 ka, one pulse of magma was emplaced and experienced crystal-mush lockup within 10s of ka. Thus, most of the zircons are antecrystic and imported to the ~ 5 km emplacement depth.

Tonalitic zircon from the Bergell intrusion also shows ~600 ka of growth in single hand samples, but can be shown to be autocrystic using a combined approach that links in situ trace element geochemistry with high-precision U-Pb dates and geochemistry of the same, microsampled, grains. These data can be used to calculate zircon growth rates and linked to magma evolution via whole-rock geochemistry, petrography and modeling of zircon saturation temperatures in evolving liquids. On a pluton scale, these data can be used to show that magma differentiation occurred both deeper in the crust and also in situ, with the latter decreasing in importance upward in the crust.

Though the techniques used are a step forward in linking dates to physical and chemical processes in magmatic systems, creative new approaches are needed that link both in situ and high-precision geochronology with intracrystalline- to crustal-scale geochemistry, petrography, and field relations.