Taking the pulse of magma emplacement

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Understanding the rates of magma emplacement into the crust is important for building models for the interaction between deformation, magmatism and metmamorphism. Chemical abrasion (CA)-ID-TIMS U-Pb geochronology allows for the temporal resolution of magmatic processes at an unprecedented degree of detail, but requires further study into how zircon U-Pb dates reflect the processes we are interested in dating. The southern tip of the 43-32 Ma old Adamello batholith (NW Italy) is formed by gabbros, diorites, tonalites and grandiorites of the Re di Castello pluton, which were emplaced in the middle crust in ca. 2.5 million years. Magmas with gabbroic to dioritic compositions saturated and crystallized zircon in late stage, fluid-saturated residual melts. Such zircons yield emplacement ages at a subpermil uncertainty. All other dated lithologies contain antecrystic to autocrystic zircon recording 90 to 700 ka of zircon growth. U-Pb titanite dates, which record cooling of the rocks to c. 650°C, are equal to or slightly younger than zircon dates, suggesting the youngest zircon dates approximate magma emplacement and solidification.

Initial Hf isotopic ratios of dated zircon grains record a change from crust-dominated melts to juvenile compositions related to the 42 Ma old Blumone gabbroic suite and younger tonalites of the Listino area.

Our data demonstrate that the composite southern RdC pluton of the Adamello batholith was assembled by individual magma pulses over timescales of 2.5 Ma, with each magma batch of 10^{-1} to 10^{0} km^3 volume cooling to below the solidus before intrusion of the next one. The availability of such precise U-Pb ages from magmatic zircon with permil analytical uncertainties in $^{206}Pb/^{238}U$ age has shown that we can no longer sustain the notion of a concrete "age" for an intermediate to acid intrusive rock, simply because it records zircon crystallization over extended periods of time. However, our work in the Adamello batholith shows that given detailed geochronology using multiple accessory minerals combined with geochemical and isotopic tracers can lead to a more complete understanding of processes of magmatic differentiation and pluton assembly. Such studies will become increasingly important for generating accurate numerical models of crustal evolution during orogenesis.

Silicon isotope fractionation at high pressures and temperatures

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In this study we estimate potential stable-isotope signatures caused by dissolution of silicon into the Earth's core during planetary differentiation. First-principles lattice dynamics models of silicate and metal phases are used to estimate equilibrium $^{30}Si/^{28}Si$ fractionation factors between silicate melts and iron-rich metal alloys at temperatures up to 5000 K and pressures up to 135 GPa. Pressure effects on fractionation are approximated via quasiharmonic equations of state, coupled to a mixing model between tetrahedrally coordinated silicon (assumed to be analogous to ringwoodite) and octahedrally coordinated silicon (analogous to $MgSiO_3$-perovskite). The mixing model is designed to roughly match average silicon coordinations in high-pressure $MgSiO_3$ melts, observed in first-principles molecular dynamics models [1].

Calculated ringwoodite-metal, forsterite-metal and diopside-metal fractionations are all in reasonable agreement with recent low-pressure experimental calibrations (1.3-1.5‰ vs. 2‰ [2] at 2100 K), suggesting that the structural details of 4-coordinated silicate minerals and melts are of second-order importance. Perovskite-metal fractionations are only half as big at the same temperatures and pressures. Interestingly, pressure has little effect on calculated silicate melt–metal fractionations: pronounced increases in endmember ringwoodite–metal and perovskite–metal fractionations with increasing pressure are countered by the increased mixing ratio of the 6-coordinate component in high-pressure melts. These results suggest that silicon-isotope fractionation during planetary core formation is highly sensitve to temperature (scaling as T^{-2}) but not independently sensitive to pressure. Along an estimated proto-mantle liquidus, calculated silicate-metal fractionations decrease from about 1.5‰ at low pressures and 1900 K to 0.8‰ at 20 GPa, 2600 K and 0.5‰ at 50 GPa, 3500 K. These fractionations are large enough to have caused a measurable deviation from chondritic $^{30}Si/^{28}Si$ in the bulk silicate Earth, if several wt.% Si were incorporated into the core.

[1] Stixrude and Karki (2005) *Science* **310**, 297-299. [2] Shahar *et al*. (2008) *Eos* **89**(53), MR32A03.