The growth of plutons: How precisely and accurately can we date incremental melt emplacement with zircon U-Pb (Adamello intrusion, Northern Italy)?

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Understanding the timescales and mechanisms relating to the injection, emplacement, and solidification of melts at upper crustal levels is important for generating models for the growth of continental crust. High-precision U-Pb geochronology can date zircon crystallization to better than 0.1% uncertainty of the age, and can therefore be used to deduce the timescales of melt crystallization of the whole melt batch. However, important for reconstructing the emplacement of single magma pulses is resolving post-crystallization lead loss in zircon from the effects of prolonged growth and inheritance of older grains. Thus, the lifetime of one magma batch can only be constrained by the dispersion of zircon ages using grains crystallized from one single melt.

We present the first results from an attempt to accurately quantify the timescales of magma emplacement and related processes in the Adamello batholith, a 43-33 Ma old intrusive body in northern Italy. Four of the southernmost intrusions (distinguished based on field relations) of the Re di Castello unit were emplaced over a time span of less than 2 m.y., between 42.6 Ma and 40.9 Ma. The youngest age clusters of each individual sample agree with the emplacement sequence deduced from field relationships. Age dispersion of up to several 100 kyrs in two intrusions may record prolonged zircon growth in the same magma whereas larger crystallization ranges of 700 kyr could be due to the incorporation of antecrystic zircon from the same magma system. Hf isotope analyses of dated zircons evidence coexistence of juvenile liquids with epsilon Hf of + 6 to + 8 with melts deduced from various sources at different degrees of hybridization, with epsilon Hf of -3 to +3.

These results provide a tight framework for future attempts to further refine the chronology and quantification of magmatic processes in the southern Adamello. These data also suggest that zircon ages combined with their geochemistry may be necessary to disentangle the complex interaction of melt transport, emplacement and crystallization.

Combining theory and experiment to calibrate stable isotope fractionations

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The development of precise techniques for stable isotope analysis of magnesium, silicon, iron and other heavy elements has created an opportunity to examine subtle fractionation processes occurring at high temperatures. One promising approach for calibrating high-temperature isotope fractionations combines reconnaissance theoretical modeling and high temperature/high pressure experiments with high-precision isotope ratio measurements [1]. The combination takes advantage of complementary strengths of theoretical and experimental methods. Thanks to advances in computational chemistry, it is possible and even routine to create reasonably accurate quantum-mechanical models of mineral phases, allowing rapid development of a framework for understanding what types of phases and reactions are likely to generate strong isotopic signatures. Examples include the prediction of strong redox-related fractionation of iron isotopes [2], coordination-number fractionation effects in magnesium, and a potential signature of metal-silicate fractionation of silicon isotopes during core formation [3]. While theoretical modeling is proving very useful for identifying important fractionating processes and phases, experiments can potentially constrain the magnitude of isotopic fractionation more precisely [4], and may correct potential systematic errors in quantum-mechanical calculations. Experiments can also probe complex and disordered phases that are difficult to model, extending calibrations from simple analogue phases to more realistic compositions. This is particularly important for understanding the behavior of fluids in mineral-melt and mineral-water systems.

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