# Temporal and compositional heterogeneity in accessory minerals: Implications for magmatic differentiation and pluton emplacement processes

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The temporal sensitivity of an intrusion's crystallinity, mobilization and differentiation histories make geochronology indispensable to understanding magmatic processes. However, the observation of highly dispersed U-Pb dates in igneous rocks complicates the use of high-precision geochronological data in assessing the rates and mechanisms of magma genesis and emplacement. Our approach for relating dates to process employs (1) U-Pb TIMS-TEA geochronology+geochemistry of zircon, titanite and additional U-Pb phases, and (2) LA-ICPMS and EMP zircon trace element geochemistry, in order to quantify the chemical and temporal complexity of these same minerals at the handsample, single grain and sub-grain scales. These complementary techniques provide important constraints on the *in situ* geochemical stratigraphy generated by crystal zoning and the coupled geochronological-geochemical information retained within fragments of single crystals.

We apply this integrated methodology to a suite of accessory minerals from the Bergell Intrusion, N. Italy, a normally-zoned Alpine pluton preserving a ~10 km crustal transect. Zircon TIMS-TEA data traces magma differentiation at the handsample-, lithology- and pluton-scales over ca. 500 kyr, 1 Myr and 2 Myr timescales, respectively, which can be linked to whole-rock geochemical trends. "Microsampling" of individual grain fragments for TIMS-TEA following LA-ICPMS/EMP analysis produces single zircon growth intervals ranging $10^3$—$10^5$ years, with textural and geochemical controls demonstrating a combination of core-rim mixing and protracted magmatic growth in generating these crystallization durations. LA-ICPMS transects of CL-imaged zircons permit the assembly of composite trace element records for handsample populations as well as between samples, and corroborate compositional trends determined by TIMS-TEA. TIMS-TEA characterization of Bergell titanite and allanite allow reconstruction of the intrusion's thermal evolution and balancing of the system's trace element budget.