High-precision U-Pb zircon geochronology: Progress and Potential

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One emphasis of the EARTHTIME project (www.earthtime.org) is understanding the power and limitations of high-precision U-Pb geochronology towards sequencing earth history at high precision. This involves establishing absolute chronologies both for sequences of fossil-bearing rocks and for testing models for astronomical forcing of sedimentation. In the past decade, progress in imaging and microsampling of zircon domains prior to analysis, pre-treatment using the CA-TIMS method of Mattinson (2005), and the ability to make high-precision isotopic measurements on as little as 1-10 picograms of radiogenic Pb has revolutionized U-Pb geochronology.

With high precision and high spatial resolution has come recognition of previously underappreciated complexities that introduce both internal and systematic errors. These range from intermediate daughter product disequilibria, to distinguishing small amounts of Pb loss from protracted crystallization histories, to interlaboratory bias. For example, systematic error related to uncertainties in corrections for initial Th/U disequilibrium in zircon can be the largest source of uncertainty for absolute dating of rocks younger than about 10 Ma. Integration of U-Pb and ^{40}Ar/^{39}Ar geochronology is hindered by uncertainties in the ^{40}K and U decay constants, as well as issues associated with pre-eruptive residence time. Interlaboratory bias is currently at the 0.1-0.3% level, although distribution of the EARTHTIME U-Pb tracer should eliminate much of this discrepancy.

It is essential to understand these effects when calculating depositional ages for ash beds or "crystallization ages" for plutons using weighted means of dates. For most ash bed high precision data sets, between 10 and 20 analyses per sample and multiple samples of known stratigraphic order are necessary to address the above complexities. We are making progress in all these areas and the potential exists for determining the ages of volcanic rocks to the ±0.05% precison level.

References

Mattinson J. M. (2005), *Chem. Geol.* **220**(1-2), 47-66.

A high resolution time-sequential record of magmatic volatiles from apatite phenocrysts

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Understanding the time-dependent variation of volatile elements in magmatic systems is essential to the study of the generation, evolution, and eruption of magmas. The mineral apatite is capable of recording volatile variations, commonly incorporating H, F, and Cl as major components, with smaller amounts of C and S usually present. Unlike melt inclusions, which are often difficult to place in a relative temporal context, apatite crystals grow from core to rim (in the absence of resorption) providing a sequential record of volatile changes in the coexisting magma.

Using Secondary Ion Mass Spectrometry (SIMS), we have analyzed H, F, and Cl in several apatite phenocrysts from the Cerro Galan ignimbrite, Argentina. For each crystal, a traverse of individual spots was performed on polished sections in the C-axis direction. A 10nA, ~20µm O$^-$ primary beam was rastered ~20µm and used to sputter positive secondary ions: ^{1}H, ^{12}C, ^{19}F, ^{28}Si, ^{31}P, ^{37}Cl and ^{43}Ca. Ions with initial kinetic energies of 75±20 eV, originating from the central 8µm region, were allowed into the mass spectrometer.

Traverses of 40-60 spots at 4-7µm spacing were obtained on several crystals. Most apatite phenocrysts contain homogeneous OH-rich cores (~4000ppm), mantled with oscillatory but generally lower OH concentrations. Chlorine data describe apparently related patterns, with homogeneous cores (~5000ppm) and oscillatory rims (± up to 1500ppm), with similar patterns observed in several crystals. Fluorine variations are less well-resolved relative to analytical uncertainties, but are generally increasing towards the rim and inversely related to OH.

Relationships between OH, F, and Cl are most easily explained as parametric functions of relative time as defined by core-to-rim stratigraphy. Knowing volatiles as a function of time allows us to convert cryptic clouds of data into a history of the growth of this crystal, which give us clues as to the volatile evolution of the magma. Apatite core regions represent either growth in a stable magma chamber or residence in a stable magma chamber where any pre-existing volatile variations were homogenized. After this period of relative quiescence, these apatite crystals experienced cycles of magma mixing and or degassing – cycles which can only be differentiated from simple one-stage mixing by the addition of the time dimension to the composition data. These crystals appear to have shared a considerable portion of their growth histories, with similar cores and growth patterns – up until a point when they diverged greatly, suggesting that crystals in various parts of the magma system record different but related versions of the magmatic volatile story.