Diffusion chronometry and seismology: insights into eruption precursors

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Timescales of magmatic processes are key to our understanding of active volcanic systems, yet remain one of the most poorly constrained variables. Today many active volcanoes are monitored through a combination of seismicity, ground deformation, gas emissions and geodetic methods. In some instances these methods can be used to track magma movement in the crust prior to eruption, but not every magma pulse of magma results in an eruption.

Petrological methods can interrogate the products of recent eruptions. Zoned volcanic crystals potentially perserve a record of magmatic processes during the lifetime of a crystal from nucleation to eruption. As the magma evolves, changes in the composition, water content, temperature or pressure will result in renewed growth of a different composition generating zoned crystals. In particular, diffusion chronology (relaxation of elements across compositional interfaces) enables us to calculate a time series, precisely dating the perturbations that occur in the magma chamber prior to eruption. These petrologically determined times series can be correlated with time series generated through geophysical techniques from the same eruption to ascertain links to pre-eruptive processes.

Mount St. Helens produced a series of well studied and characterised eruptions during 1980-86. Orthopyroxene is an ubiqitous crystal phase throughout the eruption sequence. Over 500 orthopyroxene crystals from nine of the eruptions have been investigated through a combination of back-scattered electron imaging and major element chemistry by electron probe microanalyser. This revealed multiple orthopyroxene crystal populations of both unzoned and zoned crystals. Zoned crystals populations were further sub-divided into: (1) normal zoned crystals (Fe-rich rims); (2) reversed zoned crystals (Mg-rich rims); (3) oscillatory zoned crystals. Diffusive chronometry of Mount St. Helens zoned orthopyroxene reveals that the majority of rim growth occurred within two years prior to eruption. Episodes of magma mixing identified in the petrological rocord are temporally correlated with the recorded seismicity indicating both tectonic and degassing driven seismic events occurred.

Molecular- and pore-scale response of uranium to advective geochemical gradients in heterogeneous sediments

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Experimental approach

Column experiments were devised to investigate the role of changing fluid composition on mobility of uranium through a sequence of geologic media. Fluids and media were chosen to be relevant to the ground water plume emanating from the former S-3 ponds at the Oak Ridge Integrated Field Research Challenge (ORIFC) site. Synthetic ground waters were pumped upwards at 0.05 mL/minute for 21 days through layers of quartz sand alternating with layers of uncontaminated soil, quartz sand mixed with illite, quartz sand coated with iron oxides, and another soil layer. Increases in pH or concentration of phosphate, bicarbonate, or acetate were imposed on the influent solutions after each 7 pore volumes while uranium (as uranyl) remained constant at 0.1mM. A control column maintained the original synthetic groundwater composition with 0.1mM U. Pore water solutions were extracted to assess U retention and release in relation to the advective ligand or pH gradients. Following the column experiments, subsamples from each layer were characterized using microbeam X-ray absorption spectroscopy (XANES) in conjunction with X-ray fluorescence mapping and compared to sediment core samples from the ORIFC, at SSRL Beam Line 2-3.

Results

U retention of 55 – 67 mg occurred in phosphate >pH >control >acetate >carbonate columns. The mass of U retained in the first-encountered quartz layer in all columns was highest and increased throughout the experiment. The rate of increase in acetate- and bicarbonate-bearing columns declined after ligand concentrations were raised. U also accumulated in the first soil layer; the pH-varied column retained most, followed by the increasing-bicarbonate column. The mass of U retained in the upper layers was far lower.

Speciation of U, interpreted from microbeam XANES spectra and XRF maps, varied within and among the columns. Evidence of minor reduction to U(IV) was observed in the first-encountered quartz layer in the phosphate, bicarbonate, and pH columns while only U(VI) was observed in the control and acetate columns. In the soil layer, the acetate and bicarbonate columns both indicate minor reduction to U(IV), but U(VI) predominated in all columns. In the ORIFC soils, U was consistently present as U(VI); sorption appears to be the main mechanism of association for U present with Fe and/or Mn, while U occurring with P appears in discrete particles consistent with a U mineral phase. U in soil locations with no other elemental associations shown by XRF are likely uranium oxide phases.