U-Pb age zoning in titanite by SIMS: New criteria for preservation

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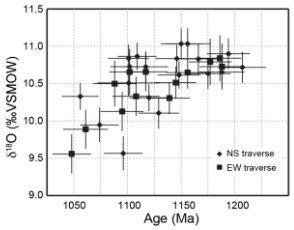
We report a set of thirty-two U-Pb SIMS ages measured in situ along two traverses of a single titanite porphyroclast from the Carthage-Colton mylonite zone in the Adirondack Mountains, New York, USA. Ages span ~140 m.y. from 1190 Ma to 1050 Ma and generally decrease from core to rim; however, ages within the interior of the grain fluctuate by as much as 50 m.y. over length scales < 100 μm. Electron microprobe element maps and Th/U spot analyses (SIMS) reveal distinct core and rim compositional domains. These do not correlate with the observed grain-interior age fluctuations and thus argue against trace element growth zoning as the source of U-Pb age variability. Light microscopy and EBSD mapping verify that the grain has not been recrystallized and show that more than 50% of the grain suffered deformation-related mechanical twinning. Ages in twinned areas of the grain are younger and more variable than ages in untwinned areas, suggesting that the presence of organized planar defects may have affected Pb mobility and abundance. SIMS $\delta^{18}O$ zoning along traverses parallel to U-Pb traverses, indicates volume diffusion of oxygen during cooling from peak T of 700°C. The strong positive correlation between $\delta^{18}O$ and U-Pb age (Figure) is consistent with the presence of first-order, core-to-rim age zonation similar in shape and extent to the zonation developed by diffusive exchange of oxygen, and it agrees with experimental studies that show similar diffusivities for oxygen and Pb in titanite over the temperature range 600-800°C.

We conclude that U-Pb age zoning within the Adirondack titanite grain reflects heterogeneous Pb redistribution by a combination of volume and intragrain fast-path diffusion. The oldest ages, preserved in untwinned areas, correlate with the 1164 ± 11 Ma intrusion age of the Diana metasyenite that hosts the grain. The youngest, ca. 1050 Ma ages near the grain rim are consistent with Pb loss and age resetting by volume diffusion during granulite-facies metamorphism accompanying the Ottawan phase (1090-1020 Ma) of the Grenville orogeny. We interpret the transitional and highly variable ages in twinned areas as reflecting segmentation of part of the grain into smaller diffusion domains between twin boundaries that behaved as diffusion fast paths. An integrated whole-grain age on this Adirondack grain would, at best, constrain the minimum age for syenite intrusion or the maximum age of high-T Ottawan metamorphism. Knowledge and careful characterization of the correlation between U-Pb age and $\delta^{18}O$ zoning in titanite will permit retrieval of more accurate ages for each event and may additionally allow for applications of coupled U-Pb-$\delta^{18}O$ titanite geospeedometry.



Microbial communities in low-permeability uranium mine tailings

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Uranium mine tailings management

The processing of uranium mine tailings at the Deilmann Tailings Management Facility (DTMF) at Key Lake was designed to stably co-precipitate ferrihydrite with various elements of concern (EOCs), such as As, Se, Ni, and Mo, present in the processed rock. During UO_2 extraction, tailings are milled to ≤100 μm diameter; on disposal in the DTMF, a saturated, diffusion-dominated matrix with restricted pore space (dry bulk density ~1.2 – 1.6 g/cm^3) results. The chemical stability of the DTMF relies upon maintenance of highly oxic, high pH conditions. However, microbes, given time and nutrients, have the potential to metabolically reduce the tailings which could result in the solubilization and subsequent mobilization of the EOCs. To date, the DTMF hasn't been studied from a microbiological perspective; it has been suggested that the high pH, radiation, and limiting nutrients in the DTMF would limit microbial growth and activity.

Characterization of the tailings microbial community

An in-depth analysis of microbial diversity, as well as their metabolic potential, within the tailings system has been undertaken using culture dependent and culture-independent analyses. A total of 60 tailings samples were obtained at 1 m intervals over a top 60 m of the tailings body and subjected to DNA extraction, as well as cultivation on a variety of microbiological media. A surprisingly high diversity (determined using 16s rRNA sequencing) of cultivatable bacteria under aerobic and anaerobic conditions were isolated over the tailings depth profile. These bacteria exhibited a range of characteristics reflective of being highly-adapated to life within the DTMF: of the 59 unique isolates, 69% were multiple metal resistant, 15% exhibited dual-metal hypertolerance, and a number were capable of reducing or oxidizing various metal elements.

Using extracted DNA from composited tailings samples from the upper, middle and lower 20 m layers of the DTMF profile, three *cpn60* clone libraries were assembled and sequenced. A total of 920, 952, and 693 sequences were generated for the upper, middle, and lower zones, respectively. Comparative phylogenetic analysis led to the classification of the different sequences from the three libraries into nine taxonomic groups: Gemmatimonadetes, Verrucomicrobia, Acidobacteria, Synergistetes, Planctomycetes, Actinobacteria, Bacteriodetes, Proteobacteria and Firmicutes. The prevalence of populations of metabolically-diverse, metal-resistant microorganisms capable of transforming metal elements suggests the potential for these organisms to influence the geochemical stability of the tailings. Integration of biological and geochemical data will aid in the construction of a predictive stability model that incorporates the role of organisms with unique metabolic activities.