Uranium isotope fractionation in Saanich Inlet

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Theoretical studies have predicted [1], and measurements have confirmed [2, 3, 5], that U isotope fractionation occurs in low temperature aqueous and sedimentary environments. Surveys of both recent and ancient marine and marginal marine sediments indicates that light isotope enrichment characterizes U deposited in well-oxygenated environments, whereas heavy isotope enrichment characterizes U deposited in suboxic and anoxic environments. The results are consistent with isotopic fractionation being controlled by a nuclear field shift effect, whereby the insoluble reduced U(IV) species is heavier than the soluble oxidized U(VI) species.

To test these ideas further, we have initiated a U isotope study of the stratified waters and organic rich laminated sediments of the seasonally anoxic Saanich Inlet (a fjord-like basin). The U isotope measurements are being conducted by MC-ICPMS using $^{233}U/^{236}U$-double spike technique. The data are reported as $\delta^{238}U$ relative to NBL 112a with a $^{238}U/^{235}U$ ratio of 137.88 (2sd). External precision is better than 0.05 ‰ (2sd). Three analyses of seawater yielded $\delta^{238}U$ of –0.41±0.02 ‰ (2sd).

Measurements are ongoing, but the preliminary results show no U isotopic fractionation in the Saanich Inlet water column, either above or below the redoxcline. The deepest sample is 200m, well below sill depth where the bottom waters typically contain a small amount of H_2S year round. HF-HNO_3 digestions of the organic rich sediments gave $\delta^{238}U$ values 0.2‰ higher than the U in the overlying water column. This amount of ^{238}U enrichment is similar to findings in [3] for suboxic sediments, but also overlaps the known field of igneous rocks. Weak acid leaches of the sediment will be carried out in order to better characterize the $\delta^{238}U$ values of the hydrogenous and silicate U fractions. The results of these experiments will also be presented.

[1] Schauble (2007) *GCA* **71**, 2170-2189. [2] Stirling *et al.* (2007) *EPSL* **264**, 208-225. [3] Weyer *et al.* (2007) *GCA* **72**, 345-399. [4] Morford *et al.* (2001) *Marine Geology* **174**, 355-369. [5] Rademacher *et al.* (2006) *Environ. Sci. Technol.* **40**, 6943-6948.

Low heat flow inferred from >4 Ga zircons suggests Hadean plate boundary interactions

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Hadean detrital zircons from the Jack Hills of Western Australia can provide important constraints on the nature of terrestrial environments during the first ~500 Ma years of Earth history. We have surveyed over 400 Hadean igneous zircons and found the inclusion population to be dominated by muscovite and quartz, broadly restricting the host melts to have formed at *P-T* conditions of <750°C and >5 kbars. Most chemical analyses of muscovite inclusions large enough to measure by EMPA (i.e, >5 µm) cluster at a Si content (normalized to 11 O) of 3.12±0.01. Using celadonite-in-muscovite barometry coupled with Ti-in-zircon thermometry, we infer magmatic *P-T* conditions of 8±2 kbar and 700±50°C for concordant zircons ranging in age from 4.0-4.2 Ga. Assuming T_{surf}= 0°C and $\rho = 3$ g/cm^3, the average apparent geotherm to the site of zircon crystallization is ~28°C/km. While mechanisms associated with granitoid plutonism (e.g., crystallization following buoyant pluton ascent) and a >0°C Hadean T_{surf} would result in us overestimating the average geotherm to the site of melting, we have not identified a plausible mechanism that would have the opposite effect. For an average rock conductivity of 2.5 W/m-°C, ~28°C/km translates into a near surface (≤40 km) heat flow of ~70 mW/m^2 (i.e., lower than global heat flow today). This is substantially less than published estimates of global heat flow during both the Archean (150-200 mW/m^2) and Hadean (160-400 mW/m^2). Since radioactive heat generation was ~3 times greater at 4.1 Ga than present and the Earth is thought to have cooled by 50-100°C/Ga, Hadean global heat flow must have been at least 3 times higher than our ~70 mW/m^2 estimate. Today, the only magmatic environment characterized by heat flow that is one third of the global average is where subducting oceanic lithosphere refrigerates the overlying wedge as it descends into the mantle. Given that the inclusion mineralogy of ancient Jack Hills zircons points towards their origin from hydrous, SiO_2-saturated, meta- and peraluminous melts similar to the two distinctive type of convergent margin magmas observed today (i.e., arc-type andesites and Himalayan-type leucogranites), we interpret our result as evidence that petrogenesis of the magmas from which the Jack Hills Hadean zircons crystallized occurred in an underthrust environment, perhaps akin to modern subduction zones.