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Characterising Earth's surface-to-mantle uranium flux from LA-ICP-MS imaging and bulk rock U isotope ratios of eclogites

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Chemical exchanges between the Earth's surface and its interior are a central feature of the Earth system. U, Th, and Pb, are time- and composition-sensitive tracers of multiple atmosphere-hydrosphere-crust–mantle processes owing to the redox sensitive low-temperature fractionation of $^{238}U/^{235}U$ and to the radioactive decay of ^{238}U to ^{206}Pb, ^{235}U to ^{207}Pb, ^{232}Th to ^{208}Pb.

Interpreting these data in terrestrial samples requires an accurate understanding of the open-system behaviour of these elements at the interface between terrestrial reservoirs, such as the alteration of oceanic crust (OC) by seawater and the dehydration of OC during its subduction into the mantle. First-order estimations of these fluxes can be made from bulk measurements of altered OC and from arc lavas compositions.

However, U uptake from seawater is complex, occurring through both reductive and oxidative processes, with contrasting isotopic fractionation, and resulting in highly heterogeneous concentrations in OC[1,2]. This complexity is likely to affect the loss of U relative to Pb and Th during subduction dehydration.

Obducted eclogites directly document subduction processing. Here we present bulk-rock $^{238}U/^{235}U$ ratios on eclogites from the Raspas Complex, SW Ecuador[3], as well as LA-ICP-MS (laser ablation mass spectrometry) trace elements maps at the mineral scale for the same samples (40 µm resolution).

U isotope results for eclogites are similar to OC, suggesting no significant U loss at shallower depths during subduction. U behaviour at greater depths is a function of the mineralogical hosts of the U and their P-T stability. LA-ICP-MS imaging reveal this distribution is complex, with U mineralogically decoupled from Pb, Th, and most large-ion lithophile elements.

We integrate our results to a model of U-Th-Pb budgets in the seawater-OC-mantle system.

[1]Andersen et al. 2024, *GCA, 382*

[2]Matsuno et al., 2025, *Chemical Geology*, 122651

[3]John et al., 2010, *Contributions to Mineralogy and Petrology*, *159*