The effect of hydrothermal alteration and seafloor weathering on the oceanic Si isotope cycle

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In partnership with Durham University

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Key Words	1. Ocean chemistry; 2. Silicon isotopes; 3. Sea-floor weathering; 4. Hydrothermal systems; 5. Seafloor alteration

Overview

Silicon is an important nutrient in the oceans – silica is essential for diatom growth (which represents ~40% of total ocean primary productivity) and is utilised by sponges and radiolaria. Ocean Si concentrations are also affected by long-term (glacial-interglacial) global climate change. The ocean Si cycle has thus benefitted from much research interest [1], primarily because it is strongly interlinked with the atmospheric C cycle, and the relevant sources and sinks are now broadly established (Fig. 1).

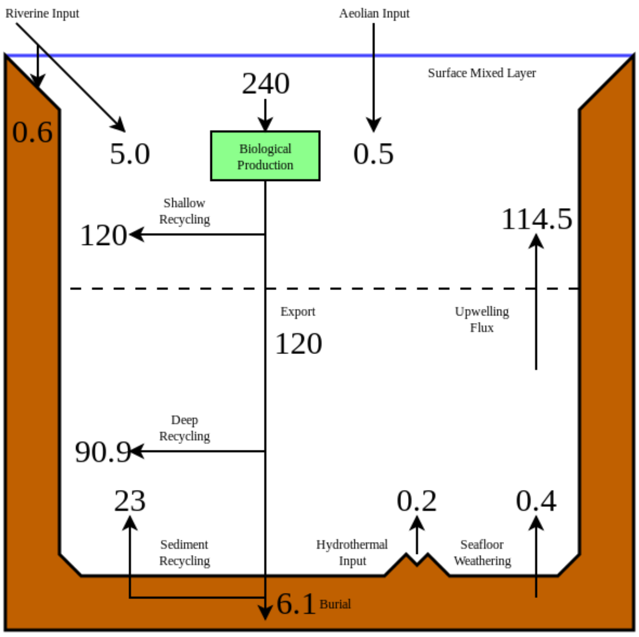

Figure 1. Box model of the oceanic Si cycle [see ref 1]

Silicon is a multi-isotope element and, in recent years with the development of new instrumentation and analytical techniques, the Si stable isotope variations of modern seawater and biogenic silica proxies are now reliably attainable, and can reveal powerful insights into current and past ocean conditions. For example, secular variations in Si isotopes in diatoms can be used as a proxy for diatom production [2], with obvious implications for constraining historic C uptake. As with all systems, for these insights to be reliable we need to know the isotopic composition of all sources and sinks of oceanic Si. Two glaring omissions in this respect are those of hydrothermal alteration and sea-floor weathering, which together comprise around 10% of the total Si flux to the oceans (Fig. 1).

Based on few data, made over a decade ago [3], the canonical view is that the Si isotope composition of ocean hydrothermal (and weathering) input is identical to that of fresh basalt [see ref. 4 for a recent review of oceanic Si isotope fluxes]. Now, however, there is good reason to think that this assumption is incorrect. First, the Si isotope compositions of secondary Si minerals (sinters, cherts, clays) are typically very distinct from basalt [4]. Secondly, in a recent study, fluids from the Geysir hydrothermal field, Iceland (Fig. 2), are shown to have Si isotope compositions much heavier (and again distinct) from basalt [5]. The potential impact of these large isotope variations on the ocean Si isotope system represents a serious gap in our knowledge, which this project will attempt to address. This has implications for both the whole ocean scale (in terms of modelling Si isotope cycling) and in interpreting local variations, i.e. where benthic Si isotope proxies may be affected by an isotopically distinct point source.

Methodology

The main aim of this project is to investigate the effects of hydrothermal alteration and seafloor weathering on Si isotopes – with an ultimate goal of placing robust constrains on the composition and variability of these sources to the oceanic Si isotope budget. This will be accomplished by measuring a broad range of hydrothermal fluids collected from wells on Iceland – this will involve field work visits to Iceland, working in collaboration with the Institute of the Earth Sciences, Iceland. The fluids will be characterised for temperature, pH and elemental composition, and their Si isotope composition analysed by high resolution multi-collector inductively coupled plasma mass spectrometry (MC-ICPMS).

A series of variable altered oceanic crust and mantle sampled from ophiolites (Ligurian Alps, Cyprus) which represent the counterpart to hydrothermal fluids will also be analysed. Furthermore, the data garnered from this second set of samples has potential implications for isotopic budgets during crustal recycling and arc volcanism.

Relevant fractionation factors will be established and new data included into whole ocean box models.

Figure 2. super-heated fluid erupting from Strokkur geysir, Iceland

Timeline

Year 1: Literature review and compilation of existing data for hydrothermal waters; training in water sampling characterisation techniques, elemental and stable isotope analysis; fieldwork in Iceland to collect waters and characterisation of said waters; selection and collection of altered oceanic crust samples; write and defend Year 1 Research Proposal.

Year 2: Characterisation of altered oceanic crust samples; continued Si stable isotope analysis of all samples; begin stable isotope modelling of data. Prepare fluid data for presentation/publication; attend Goldschmidt geochemistry conference.

Year 3-3.5: Completion oceanic crust isotope work and interpretation and modelling of data, writing up. Presentation of results at a national/international conferences; complete thesis.

Training & Skills

- Field sampling in various hydrothermal fields in Iceland; possible further sampling of European ophiolite sequences.
- Training in the measurement of Si stable isotopes using high precision MC-ICP-MS at St Andrews and Durham, as well as routine elemental sample characterisation.
- Interpretation and modelling of isotope and elemental data to place new constraints on the global Si isotope cycle.
- Participation and presentation of research at both national and international geochemistry conferences.

References & Further Reading

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[5] Geilert et al. (2015) Silicon isotope fractionation during silica precipitation from hot-spring waters: Evidence from the Geysir geothermal field, Iceland, Geochimica et Cosmochimica Acta 164, 403-427.

Further Information

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