Strontium isotope fractionation and its application in Earth system sciences

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Taking strontium (Sr) isotope fractionation into account allows the independent and simultaneous determination of paired Sr ratios ($^{87}Sr/^{86}Sr^*$, $\delta^{88/86}Sr$) in silicate and carbonate material. Following this approach the Sr isotope composition of seawater ($\delta^{88/86}Sr_{seawater}$: ~0.39 ‰) and marine carbonates ($\delta^{88/86}Sr_{carbonates}$: ~0.15 – 0.25 ‰) differ as a function of local environmental parameters and physiological processes which possibly qualifies Sr isotope fractionation as a new proxy in marine geochemistry. This approach extends the well-established application of the radiogenic Sr ($^{87}Sr/^{86}Sr$) by an additional dimension and also allows for simultaneous calculation of Sr input and output fluxes of the ocean using complete Sr isotope budget equations. In addition, Sr isotope fractionation is a new isotope tool for the study of organic and inorganic $CaCO_3$ precipitation mechanisms being sensitive to the precipitation rate at least for calcite.

Recent results indicate that the $\delta^{88/86}Sr$ value of seawater is controlled by the balance between input and output of shelf-carbonates. In periods of shelf carbonate exposure this input dominates that of Sr originating from silicate weathering. In this regard taking the long residence time (2.5 Ma) and Sr concentration in seawater into account it can be understood why modern and Quaternary corals show about the same $\delta^{88/86}Sr$ value in the order of ~0.2‰. Latter observation qualifies Sr isotope fractionation in marine carbonates as a temperature proxy tool as long as a solid and sensitive temperature-$\delta^{88/86}Sr$ calibrations can be established.

On Phanerocoic timescales $\delta^{88/86}Sr_{seawater}$ follows the general distribution of "calcite seas" and "aragonite seas", implying a control mechanism by $Mg/Ca_{seawater}$ ratios and further global spreading rates. On shorter timescales in the order of the residence time of Sr in the ocean we observe a strong relationship between the abundance of marine calcifiers and the $\delta^{88/86}Sr_{seawater}$ values providing the opportunity to study the disturbances of the ocean carbon budget during mass-extension events as shown for the Ordovician/Silurian and Permian/Triassic boundary, respectively.

Observational constraints on the water and volatile content of planet-forming regions of circumstellar disks

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Models of the protosolar nebula suggest that the Earth formed in an environment too hot for water or volatiles to exist in solid form. Because the Earth is known to possess these elements, investigators posit that they were delivered after the Earth formed by comets, asteroids, hydrated dust grains, or a combination of these mechanisms. Planets in habitable zones around other stars—of which we now have several examples—would require similar mechanisms for water and volatile delivery.

Understanding water delivery to the Earth is a crucial part of the story of our origins. Protoplanetary disks around young stars offer a window through which we can view processes that presumably occurred in our solar system billions of years ago. Study of these disks also illuminates the physical processes by which habitable planets may form elsewhere in the Galaxy.

Recent advances in spectroscopic capabilities both in space and on the ground enable probes of warm water vapor and volatile material across a range of excitation conditions. I will review observations of protoplanetary disks that reveal the spatial distribution, temperature, and column density of gas-phase water and volatile material in 'terrestrial' regions. The presence of these molecules in warm, inner disk regions implies transport from cooler regions at larger stellocentric radii, and presents observational constraints on models for water and volatile delivery to terrestrial planets.