Paradigm change: temperature-dependent strontium isotope variations

Strontium (Sr) is used widely to reconstruct the chemical and temperature history of the ocean on various time scales through measurement of the $^{87}Sr/^{86}Sr$ isotope ratio and the Sr/Ca elemental ratios in marine carbonates. Although Sr itself is not radioactive the isotope ^{87}Sr is supported by the radioactive beta decay of ^{87}Rb (Rb=Rubidium) which has a half-life of 48 billion years. The primary use of this isotope system in the geosciences is for rock and mineral dating. However, because Sr is enriched in the Earth´s mantle whereas Rb is enriched in the Earth´s crust, the $^{87}Sr/^{86}Sr$ ratio can also be used to distinguish the geological origin of minerals and rocks. Notably, the $^{87}Sr/^{86}Sr$ ratio of continental rocks and minerals tends to be higher than those originating from the Earth´s mantle. One major application of this element and isotope separation process in the marine sciences is to reconstruct changes in the chemical balance of Sr in the ocean and distinguish the relative contribution of Sr from marine hydrothermal sources to that delivered by continental weathering throughout Earth´s history. Such studies shed light on past rates of continental weathering and hence on a key process that controls atmospheric CO_2 levels on geological time scales.

Throughout decades of Sr isotope research it has been assumed that there are no additional isotope fractionation process which alter the $^{87}Sr/^{86}Sr$ ratio established by the radiogenic ingrowth of ^{87}Sr due to ^{87}Rb beta decay. In particular, this was assumed to hold true for the $^{88}Sr/^{86}Sr$ ratio, which is used in the calibration procedure for mass spectrometric measurement of $^{87}Sr/^{86}Sr$ ratios. However, recent high precision measurements at IFM-GEOMAR of $^{88}Sr/^{86}Sr$ (Fietzke and Eisenhauer, 2006) show that this ratio is not stable, but rather is variable and temperature dependent. The measurements also showed that the presently accepted $\delta^{88/86}Sr$-value for seawater ($\delta^{88/86}Sr_{seawater}=0$) is offset by about 0.4 ‰ from its true value (Fig. 1) which in turn implies that the true $^{87}Sr/^{86}Sr$ isotopic ratio in seawater is also significantly different (by about 0.2 ‰) from its presently-accepted value ($\delta^{87/86}Sr$ = 0.7091741(24)).

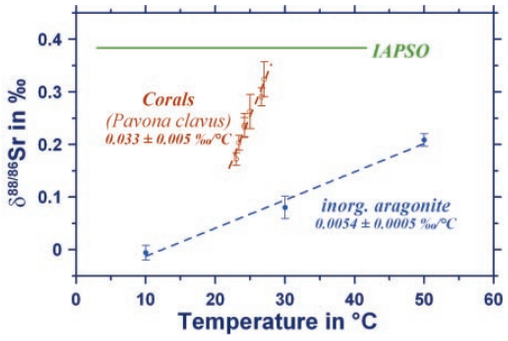

Figure 1: The $\delta^{88/86}Sr$ versus temperature data of inorganically precipitated aragonite and natural coral (Pavona clavus) samples. For comparison the $\delta^{88/86}Sr$ value of IAPSO seawater standard (0.381 ± 0.010% (2SEM)) is plotted as temperature-independent level.

The measurements also revealed, for the first time, that there is a temperature-dependent strontium isotope fractionation during calcium carbonate precipitation. This could be shown both for inorganically precipitated aragonite and for coral samples (Fig. 1). These results require further experimental confirmation but may point to a new tool for reconstructing past seawater temperature variations resulting from climate change. The isotopic ratio has the potential to be less sensitive to post depositional diagenetic alteration, water pressure effects and salinity variability than the traditional proxies for temperature reconstruction. Hence the results from these high-precision measurements both open a new door to past climate change but also, as a result of the insight into Sr-isotope fractionation, suggest that the history of continental weathering as deduced from the $^{87}Sr/^{86}Sr$-ratio of marine carbonate has to be reassessed. First, approximate calculations indicate that about 20 % of the Cenozoic $^{87}Sr/^{86}Sr$-variations might, in fact, be due to other sources of $^{88}Sr/^{86}Sr$-variability (e.g. temperature changes).

References:

Fietzke, J. and Eisenhauer, A., 2006: Determination of temperature-dependent stable strontium isotope ($^{88}Sr/^{86}Sr$) fractionation via bracketing standard MC-ICP-MS. *Geochmistry, Geophysics, Geosystems* **7**(8), doi:10.1029/2006GC001243.

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