

Changing Sr content of seawater recorded in the Sr-isotope composition of the sheeted dike complex of ophiolites

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The latent and specific heat released during cooling of the oceanic crust provides an estimate of the upper limit of the heat available to drive hydrothermal circulation at mid-ocean ridges. Based on realistic models for the accretion and cooling of newly formed crust the majority of the hydrothermal circulation occurs within the upper (lavas and dikes) crust. The metamorphic mineralogy of the sheeted dike complex, along with vent fluid temperatures, provide insight into the maximum temperature most hydrothermal fluids attain within the crust (~450-500°C). The combination of the total available heat, the enthalpy of seawater at this temperature, and a model of crustal accretion allows the maximum possible fluid flux to be estimated. Using this maximum permissible fluid flux the Sr-isotopic shift observed in Cretaceous ophiolites (e.g., Oman, Troodos) cannot be explained based on the known $^{87}\text{Sr}/^{86}\text{Sr}$ of the ocean at that time unless Cretaceous seawater contained substantially more Sr than modern seawater does (>20 ppm). This is true irrespective of whether Sr exchange between seawater and crust occurred (as is the case today) or for complete removal of seawater Sr into the crust.

This suggestion that Cretaceous seawater was much more Sr-rich than modern seawater is consistent with the much greater extent of ^{87}Sr enrichment in these Cretaceous ophiolites than in modern oceanic crust recovered by drilling (ODP Hole 504B) and at tectonic windows (Hess and Pito Deeps). It is also consistent with indications that both the Sr/Ca and Ca contents of seawater were higher 50-100 Myrs ago. Because of the different major element composition of the oceans in the Cretaceous vent fluid compositions are expected to have been different than those observed today. Thus, high seawater Sr in the Cretaceous may in part be due to more extensive leaching of Sr from basaltic crust (generating high Sr vent fluids) at that time than occurs today.

If the concentration of Sr in seawater has changed substantially over the last 50-100 Myr then interpretations of the seawater Sr-isotope curve need to take this into account. For example, the lower modern day seawater Sr concentration means that smaller Sr fluxes would be needed to change the Sr-isotopic composition of the modern, than Cretaceous, ocean.

Lake sediments archive the history of metallurgy in the Andes

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The Andes represent the largest mineral wealth in the Americas and the birthplace of New World metallurgy. Despite a richly-documented history of metallurgy ensuing Hispanic conquest of the Inca, little is known concerning the loci and intensities of earlier metallurgical activities. The geochemical record preserved in lake sediments offer one strategy to interrogate this history, because the deposition of trace elements associated with smelting form a coherent archive that can be assessed in the context of regional archaeology. Here, we assess spatial and temporal patterns of metallurgy in the Andes by integrating lake-sediment records from four major pre-Columbian mining centers in Bolivia and Peru: Huancavelica, Morococha, the *Altiplano*, and Potosí. The earliest evidence for trace-metal enrichment from smelting occurs on the *Altiplano* ~400 AD, associated with early Tiwanaku culture. After ~1000 AD, trace-metal pollution decreased dramatically, coeval with collapse of the Tiwanaku Empire. In contrast, intensive metallurgy did not begin until ~1000-1200 AD at Huancavelica, Morococha and Potosí, suggesting lags associated the diaspora of Tiwanaku and Wari Empires. Following Inca conquest of the Andes, strong increases in trace-metals suggest an increase in silver production to meet Inca imperial demand. Following Hispanic conquest, Hg amalgamation replaced smelting as the primary silver extractive technique. Large increases in trace-metal and specifically Hg pollution are noted at Morococha, Potosí, and Huancavelica, apparently associated with adoption of Hg amalgamation. These results represent the first evidence for significant Colonial Hg pollution, and have ramifications for understanding human impacts on the global cycle of Hg. The sensitivity of lake-sediment geochemistry to pre-Colonial smelting activity has much potential for exploring the timing and magnitude of pre-industrial metallurgy in the New World.