

Changes in silicate utilization and upwelling intensity off Peru since the LGM – Insights from silicon and neodymium isotopes

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The Peruvian coastal upwelling area is characterized by one of the most pronounced Oxygen Minimum Zones in the world's ocean. Oxygen concentrations in the water column are controlled by consumption through decomposition of organic matter versus ventilation via ocean circulation. Surface bioproductivity which is dominated by diatoms building their frustules from dissolved silicic acid is a function of both nutrient supply and upwelling intensity. The utilization of silicic acid is reflected by its stable silicon isotope composition ($\delta^{30}\text{Si}$). The lighter isotopes are preferentially incorporated into the diatom frustules leaving the ambient seawater enriched in the heavier isotopes. Thus $\delta^{30}\text{Si}$ values directly mirror silicate availability and the amount of newly supplied silicate with upwelled waters.

Today, the upwelling is strongest near the coast between 10-15°S. There, fractionation is lowest ($\delta^{30}\text{Si} = 2\text{‰}$ for surface water and 1‰ for diatoms, respectively) because the permanent re-supply of nutrients prevents a high degree of fractionation. Outside the main upwelling zone fractionation is higher (up to 2.8‰ in the water and 1.8‰ in the diatoms) indicating slightly increased limitation of silicic acid.

A downcore record from 12°S documents that the main upwelling region has been highly dynamic since the LGM. Biogenic opal concentrations range from 2-31wt%. Accordingly the diatom $\delta^{30}\text{Si}$ data range from 0.4-1.6‰. During the deglacial and early Holocene the $\delta^{30}\text{Si}$ was overall lower than during the late Holocene but much more variable indicating a more dynamic regime. For the late Holocene the low range in $\delta^{30}\text{Si}$ indicate constant upwelling. Low $\delta^{30}\text{Si}$ during the early Holocene would require surface water with $\delta^{30}\text{Si} \sim 1.7\text{‰}$. Today, no surface waters in the area show such low values. Radiogenic Nd isotopes will be applied to address possible changes in source water, either freshwater runoff from the hinterland or enhanced contributions from the south.

For the entire record low $\delta^{30}\text{Si}$ values correspond to low biogenic opal concentrations. The opposite would be the case if silicic acid utilization had been the only driving factor of the $\delta^{30}\text{Si}$ variability. Instead, limitation by other nutrients, e.g. phosphate, during phases of low productivity is more likely.

Strontium and sulfur isotopes in celestite from Likak deposit, SW Iran

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Celestite mineralization in Likak deposit is hosted by Lower to Middle Miocene Gachsaran evaporitic formation. An epigenetic mode of formation via replacement of pre-existing gypsum and anhydrite by later celestite was previously proposed for mineralization [1].

In order to determine the origin of strontium and sulfur for celestite mineralization, 6 samples of the mineral from various outcrops of the orebody were collected for isotopic analyses (2 samples for strontium and 4 for sulfur isotopes). The isotopic analyses were performed by Actlabs (Activation Laboratories Ltd., Canada) using a Triton Multi-collector Mass Spectrometer for strontium, and a VG 602 Isotope Ratio Mass Spectrometer for sulfur isotopes.

Strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) are 0.708768 and 0.708829 for analyzed samples. These ratios match well with values reported by McArthur and Howarth [2] for Miocene seawater and indicate that Sr was originated from seawater. The celestite samples display $\delta^{34}\text{S}$ values falling in the range of 25.7–27.8. Sulfur isotopic ratios indicate higher $\delta^{34}\text{S}$ values in analyzed samples than those of Miocene seawater [3]. These higher values were probably resulted by bacterial reduction of sulfate [4–6].

Since celestite mineralization has an epigenetic origin, it can be suggested that precursors of the mineralizing fluids were probably produced by evaporation of seawater in a coastal marine setting. As these brines entered into underlying sediments, they leached considerable amounts of Sr from host sediments. Once these Sr-enriched fluids discharged back up into overlying beds containing gypsum and anhydrite, replacement of the beds by celestite were occurred [7].

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