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Silicon isotopes as a tracer for Silicate Utilization in the Peruvian Upwelling

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Natural stable isotopes are a powerful tool in marine sciences to investigate biological processes, such as present and past nutrient utilization. In this study we present the first dissolved silicon isotope data in the upwelling area off Peru, where one of the world's largest Oxygen Minimum Zones (OMZ) is located. Silicon is the most important component required for phytoplankton (diatom) growth, which dominates primary productivity in this region. Stable Si isotopes are fractionated during diatom growth in that the lighter Si isotopes are preferentially incorporated into diatoms with a fractionation factor of -1.1 ‰Ṫhe Si isotope composition of dissolved silicic acid of the corresponding surface waters is therefore left isotopically heavier. The Si isotope composition, 30Si/28Si, is expressed as δ30Si values, which stand for ‰ deviations from a given standard (NBS28).
Investigation of the dissolved seawater Si isotope composition thus provides a measure for the utilization and, combined with information on the Si isotope composition of the water masses upwelling off Peru, it is a measure for the supply pathways of Si to the coastal upwelling centres. Surface waters on the shelf off Peru are mainly fed by the Equatorial Undercurrent, which mainly consists of waters originating from the western and Central Pacific and which has a characteristic δ30Si of +1.5‰İn areas and during phases of intense upwelling the fractionation of Si isotopes was observed to be weaker due to upwelling-driven supply of less fractionated Si (δ30Si = 1.7‰, from water depths of around 100-150 m, whereas under weak upwelling conditions fractionation is higher (δ30Si $\sim$ 3 ‰ due to a more complete utilization of the available dissolved silicate. The distribution of dissolved δ30Si correlates strongly with particulate biogenic silicate (opal) concentrations in that highest opal concentrations in the surface waters show the lowest δ30Si values thus strongest upwelling intensity. The most extreme δ30Si values in surface waters (δ30Si = 4.5 ‰ are observed offshore where silicic acid concentrations are nearly zero. Furthermore we compare the δ30Si data with the dissolved nitrogen isotope distribution, which in addition to nitrate utilization is mainly influenced by denitrification and annamox processes in the OMZ. Combined silicon and nitrogen isotope compositions can thus help to disentangle different fractionation processes within the nitrogen cycle.