

Accelerated acidification in eastern boundary current systems

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Eastern Boundary Upwelling Systems (EBUS), such as the California Current System (CalCS), are particularly sensitive to ocean acidification: the pH of their surface waters is comparably low and their change in pH for a given uptake of anthropogenic CO₂ is particularly high. This effect is particularly strong in the Pacific Ocean, as evidenced by the dramatic shoaling of the aragonite saturation horizon off the U.S. West Coast to depth of less than 100 m (Feely *et al.*, 2008). We investigate this high vulnerability to ocean acidification of Eastern Boundary Current upwelling systems by conducting simulations with the ETH-UCLA Regional Oceanic Modeling System (ROMS) at eddy-resolving resolution for two of the four EBUS, namely the California, and the Canary Current Systems. Our simulations for the CalCS show that between pre-industrial times and present, the mean pH of the surface ocean has decreased by already about 0.1 pH units. As a result, the aragonite saturation horizon has shoaled by ~100 m and now reaches the euphotic zone in a few eddies and in near-shore environments during upwelling, in agreement with recent observations. Projections up to 2050 (IPCC SRES A2-scenario) suggest an additional drop of pH by ~0.2 units and a wide-spread and year-round shoaling of the saturation horizon into the euphotic zone. Transient simulations are currently underway to determine when critical thresholds are passed. We expect that the aragonite saturation horizon will be reaching up into the euphotic zone in nearshore environments throughout the upwelling season already during the next decade. The passing of certain thresholds will not be gradual, however. Due to the high temporal and spatial variability that characterizes EBUS, organisms are exposed to a wide range of pH (variations of up to 0.3 to 0.4 units) and saturation states, an effect that likely will increase in the future due to enhanced upwelling and lowered buffer capacity. As a result, the effect of ocean acidification in EBUS will consist of a simultaneous downward shift and a widening of the probability density function for pH and saturation state. Both effects will cause a rapid increase with time of the frequency, at which given thresholds will be passed. What this means for organisms can only be speculated about at present.

Volatile element variability in MORB: origins and consequences

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The abundances of H₂O, CO₂ and other volatiles in MORB can provide unique information on depths and extents of melting and lateral variations in mantle viscosity and melting temperature, but this information can also be obscured by degassing, fractionation and assimilation processes within the crust. Degassing begins at depths within the crust that depend on initial enrichment in CO₂, and depleted samples often show vapor saturation pressures consistent with the depths of axial magma chambers revealed by seismology. Magma transport times estimated from vapor supersaturation are generally faster on-axis than off-axis, and on-axis magmas generally show less assimilation (excess Cl). Assimilation tends to be stochastic in geographic distribution, such that uncontaminated magmas can be found both on- and off-axis, but contaminated magmas may become more frequent on-axis as magma supply and spreading rate decrease.

CO₂/Nb ratios decrease systematically with MgO, indicating concurrent degassing and fractional crystallization. An upper bound on CO₂/Nb (~400) appears to be a widespread feature of primitive depleted and normal MORB that have erupted quickly through the crust. A CO₂/Nb ratio of ~400 is also characteristic of vapor-undersaturated melt inclusions from the northern rift zone of Iceland, and place firm constraints on the flux of CO₂ and He from ocean ridges.

At Pacific ridges, ratios of H₂O/Ce, F/Nd and Cl/K in uncontaminated magmas show systematic co-variations with other trace element indices of enrichment (Th/La, Nb/La) that are correlated with Sr and Nd isotopes, indicating lateral variability in long-lived mantle source compositions in the upper mantle. The data are consistent with the entire spectrum of Pacific MORB (far from hotspots) being generated by melting of variable mixtures of only two sources, one highly depleted (D-MORB) and one enriched (E-MORB). Sparse stable isotope data are available from Pacific ridges and the MAR [1,2]; the data are permissive of enriched sources originating as “contamination” of the upper mantle by plumes, by recirculation of mantle-wedge peridotite from subduction zones, and by melts and residues of subducted oceanic crust, but not all of these origins are compatible with all the isotope, trace element and volatile data.

[1] leRoux *et al.* (2003) *Fall AGU #V51A-03*. [2] Cooper *et al.* (2004) *EPSL 220:297-316*.