

## Ocean deoxygenation and nutrient redistribution: subarctic Pacific perspective

FRANK A WHITNEY<sup>1\*</sup>, STEVEN BOGRAD<sup>2</sup> AND TSUNEO ONO<sup>3</sup>

<sup>1</sup> Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, B.C., Canada, whitneyf@shaw.ca (\* presenting author)

<sup>2</sup> Environmental Research Division, Southwest Fisheries Science Center, NOAA, Pacific Grove, CA, USA, steven.bograd@noaa.gov

<sup>3</sup> Subarctic Oceanography Division, Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro 085-0802, Japan, tonofra@fra.affrc.go.jp

### Abstract

Large regions of the global ocean are losing oxygen at rates dependent on processes governing their ventilation (gas exchange with the atmosphere). The most rapid losses are being observed in the Subarctic Pacific, a basin in which oxygen transport into its pycnocline (~100-500 m depth) occurs in localized regions undergoing changes in ice cover (Okhotsk Sea) or upper ocean stratification (Russian coast). Circulation of these waters brings them into contact with the atmosphere every few decades, then isolates them below a fresh surface layer where remineralization processes remove oxygen and regenerate nutrients.

Within the pycnocline, time-series measurements record nutrient increases matching oxygen losses. The enrichment of these waters immediately below the winter mixed layer appears to be counteracting an increasing buoyancy of surface waters, keeping nutrient supply stable over the past several decades. This trend has yet to be realized in models attempting to estimate impacts of global warming on ocean productivity.

Denitrification is a common sink for nitrate along continental margins throughout the North Pacific. As oxygen levels decline, an expansion of oxygen minimum zones (OMZ) is predicted to increase rates of nitrate loss and nitrous oxide production. In addition, warming oceans could release methane stored in frozen hydrates, placing new demands on oxygen.

### Some biological consequences

Primary productivity in the SAP has not been impacted by increased upper ocean stratification. Our initial understanding of processes allowing the pelagic community to adapt to change suggests a successful future adaptation to climate changes. However, increased storage of nutrients in the upper ocean comes at a cost. Presently, we can only suggest a reduced export either to the subtropics or deep ocean is occurring. Satellite chlorophyll indicates an expansion of the low chlorophyll biome northward, an expected outcome of changing wind patterns.

Also, expanding OMZs are predicted to compress habitat, making some species more vulnerable to predation. In coastal waters of the SAP, oxygen levels sharply define habitat for complex assemblages, placing pressure on fish communities including those presently harvested. Habitat loss will compound stresses on these fish and their habitat. Realistic projections of oxygen losses in coastal waters are needed to provide sensible management options.

## Mass dependent stable isotopic fractionation ( $\delta^{88/86}\text{Sr}$ ) during the precipitation of barite, Zodletone Spring, Oklahoma

WIDANAGAMAGE, I.H.<sup>1\*</sup>, SCHER, H.D.,<sup>2</sup> SENKO, J.M.<sup>3</sup> AND GRIFFITH, E.M.<sup>1</sup>

<sup>1</sup> Kent State University, Kent, U.S.A., [widanag@kent.edu](mailto:widanag@kent.edu), [egriff9@kent.edu](mailto:egriff9@kent.edu)

<sup>2</sup> University of South Carolina, Columbia, U.S.A. [hscher@geol.sc.edu](mailto:hscher@geol.sc.edu)

<sup>3</sup> The University of Akron, Akron, U.S.A. [senko@uakron.edu](mailto:senko@uakron.edu)

Barite precipitation in a continental setting occurs at Zodletone Spring, Slick Hills, southwestern Oklahoma and shows mass dependent stable  $\delta^{88/86}\text{Sr}$  isotopic fractionation, exhibiting lower values in the mineral barite relative to the solution from which it precipitated as expected. [1] The possibility of using stable Sr isotopic fractionation in barite as a bio-signature could be useful in understanding ancient and extraterrestrial samples. Zodletone Spring flows into a stream which merges into the southern bank of Saddle Mountain Creek. The precipitation of barite on the crust encircling the spring and along the stream is suggested to be microbially mediated. [2] Anaerobic, anoxygenic bacteria oxidize sulfide to sulfate in the system inducing barite precipitation in the barium-enriched water (Ba, 0.4-0.01 mM, Sr, 0.2-0.3 mM).  $^{87}\text{Sr}/^{86}\text{Sr}$  for the spring (0.7103) and the creek (0.7102) were identical in both barite and the waters. Thus barite records the value of the water in which it precipitated. These values are more radiogenic than the underlying carbonates suggesting a deep source of Sr to the spring (~1500 m) from an intrusive rhyolite. Barite is saturated in both the spring and creek. The saturation index of barite for the spring is 1.5 at 20.5°C and 1.9 in the creek at 33.6°C. Different morphologies of barite from the sites were seen. Barite crystals from the crust on the spring are 10-50  $\mu\text{m}$  in diameter and form rosettes which are likely biogenic barite. Rosettes and diamond shape barite at the end of the stream are 10-20  $\mu\text{m}$ , and probably have both biotic and abiotic origins. Barite crystals from the creek show rosettes, diamond and tabular shapes with diameters varying 5-30  $\mu\text{m}$ . This is also probably a mixture of biogenic and abiotic barite. Barite crystals precipitated at the left bank of the creek are 6-10  $\mu\text{m}$  and rosettes (~10%) and ellipsoidal crystals (~80%) indicating that the dominant type is likely abiotically precipitated barite (i.e. ellipsoidal). Preliminary data show the stable isotope fractionation during precipitation ( $\Delta^{88/86}\text{Sr}_{\text{barite-water}}$ ) ranges from -0.25‰ to -0.33‰ in the spring and the creek. Given the uncertainty of the isotopic measurements (approximately 0.05‰) the stable isotopic fractionation does not appear to be significantly affected by processes resulting in the varied morphologies (abiotic or biotic) at this site.

[1] Schauble and Griffith (2011) EOS Trans.AGU, PP41E-01.

[2] Senko et al (2004) Geochim.Cosmochim.Acta **68**, 773-780.