Calcium Carbonate Saturation States and pH in Orphan Knoll Region; Where the North Atlantic Subpolar and Subtropical Gyres Meet

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Introduction

Orphan Knoll is a bathymetric high located 550 km northeast of Newfoundland, Canada. It is a single peak rising to 1800m, and occupying the area about 75 km by 190 km. Bathymetric highs in the ocean, such as seamounts and knolls, provide important habitats for benthic communities with high biomass and biodiversity. Studies using a remote operated vehicle found a biologically rich and complex structure, including deep sea corals and sponges, in Orphan Knoll region. Consequently Orphan Knoll area (50°-51N, 45°-47W) is designated as Vulnerable Marine Ecosystem (VME) and closed for commercial fishing by Food and Agricultural Organization (FAO) of the United Nations and managed by Northwest Atlantic Fisheries Organization (NAFO).

Orphan Knoll is a boundary region of interaction and mixing of subtropical waters transported by the North Atlantic Current (NAC) (subtropical gyre) and fresh and cool waters of polar and sub-polar origin (subpolar gyre). Biological communities endemic to the region may be affected by changes in water mass properties and large scale circulation as well as regional oceanography specific to seamount/knoll. This study provides the first observation of the state of ocean acidification of the region.

Circulation

Complex topography, major frontal systems and recirculation contribute to convoluted circulation around Orphan Knoll region. Warm and saline North Atlantic Water (NAC), an extension of the Gulf Stream, flows from the south and turns sharply to the east near Orphan Knoll. Cold and less saline Arctic outflow (Labrador Current, LC) flows along the Labrador Shelf and Slope at the surface. Dense cold water from Nordic Seas (Denmark Strait Overflow Water, DSOW, and North East Atlantic Deep Water (NEADW) flows at depths. Together with some of the Labrador Sea Water (LSW), cold and fresher water formed locally in the Labrador Sea, they flow south as Deep Western Boundary Current (DWBC).

Water masses and Aragonite Saturation State ($\Omega_{\text{arg}}$)

The DSOW, NEADW and LSW are found deeper than 500m and showed low saturation states ($\Omega_{\text{arg}}$ < 1.5). For the surface layers, $\Omega_{\text{arg}}$ is higher for NAC ($\Omega_{\text{arg}}>2.0$), compared to the Arctic Outflow carried by Labrador Current (LC) ($\Omega_{\text{arg}}$ < 1.5). The Arctic outflow of the Pacific Water origin has higher DIC concentration than that of NAC, which reflects the observed $\Omega$ gradient (Azetsu-Scott et al., 2010). High values observed in surface waters are due to high biological uptake of CO$_2$ shown in MODIS satellite sea surface chlorophyll concentration during the cruise as well as super-saturation of dissolved oxygen.

$\Omega_{\text{arg}}$ and pH$_{\text{sat}}$ along section A and B

Aragonite saturation states at the plateau of Orphan Knoll were less than 1.2 with the average and standard deviation of 1.12 and 0.04, respectively, whereas the flanks deeper than 2100 m were undersaturated. Calcite saturation states were >1 throughout. The average and standard deviation of pH$_{\text{sat}}$ on the plateau of Orphan Knoll were 7.894 and 0.018, respectively. Saturation states and pH distribution in the study area are controlled by a large scale circulation. Local physical oceanographic processes caused by a topographic feature, such as upwelling/downwelling or Taylor Cap, weren’t evident, although weak anti-cycloic circulation were observed on Orphan Knoll. Due to the observed low aragonite saturation and pH$_{\text{sat}}$ on the plateau and flanks of Orphan Knoll, it is important to monitor carbonate chemistry and the response of the benthic community to future changes.