The biogeochemistry of the suboxic and anoxic zones in the cariaco basin

Biogeoquímica de las zonas subóxica y anóxica en la fosa de cariaco

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ABSTRACT

A decade-long study of the Cariaco Basin has demonstrated that the suboxic interface in this system is temporally and spatially variable and that it is the home for a diverse and active microbial community. The thickness and structure of the suboxic zone appears to be primarily controlled by the physics of the basin, with oxygen containing intrusions occurring from both eastern and western sills. The microbial populations, which include both heterotrophic and chemoautotrophic micro-organisms, are actively growing at rates which cannot be supported by vertical transport of oxidants or reductants. Our studies suggest that the microbial loop depends on cycling of intermediate oxidation state sulfur species (sulfite, thiosulfate and elemental S) possibly coupled with cycling of metal oxides. Production of these species is maintained by the active intrusion process and by transport from land of iron and metal oxides during rain events.

Keywords: Chemoautotrophy, sulfur, temporal variability, microbial loop.

RESUMEN

Los estudios realizados en la Fosa de Cariaco durante una década han demostrado que la interfaz sub-óxica en este sistema posee una variabilidad temporal y espacial, siendo el hábitat de una comunidad microbiana diversa y activa. La circulación en la cuenca, caracterizada por intrusiones ricas en oxígeno desde los umbrales oriental y occidental, controla aparentemente el espesor y la estructura de la zona sub-óxica. Las poblaciones microbianas,
INTRODUCTION

The Cariaco Basin has a large but temporarily variable suboxic zone (waters with less than 1 µmol L⁻¹ oxygen and sulfide) overlying the world’s largest marine anoxic basin. In this system, the suboxic zone is a site of diverse and active microbial communities with high rates of heterotrophic metabolism and chemosynthetic production rates which can approach (or on occasion even exceed) surface primary production (Taylor et al. 2001). However, the presence of these active populations, which has been noted elsewhere, has been perplexing as fluxes calculated from vertical diffusion of oxidants and reductants are completely inadequate to support the observed microbial activity at the interface.

As a part of the decade long CARIACO (Carbon Retention in a Colored Ocean) Time Series Program, we have been examining the factors which control the microbial communities living within and near the suboxic interface. Our results suggest that lateral transport of oxidant (in the form of oxygen, intermediate oxidation state sulfur compounds such as thiosulfate, sulfite and elemental sulfur, and iron and manganese oxides) and of reductant (in the form of sulfur species including the intermediate oxidation state compounds as well as hydrogen sulfide) to the suboxic zone is likely to be key in maintaining the suboxic-zone populations. Another important factor is spatial heterogeneity in primary production, driven by regional upwelling, which results in variable carbon flux to depth in this coastal environment. Our sampling site, located in the deepest part of the eastern basin of the Cariaco, is probably not the location where the maximum carbon flux reaches the bottom, and thus vertical flux models only poorly reflect elemental and energy budgets.

MATERIALS AND METHODS

Over the more than 10 years of the CARIACO Time Series, most of our samples have been taken at a site located at 10°30’N - 64°40’W in the deepest part of the eastern basin. Recently we have begun to explore the spatial distribution of the suboxic zone, sampling in the deep western basin, on the sill to the NW of the CARIACO station and in the Margarita basin to the NE of the CARIACO site. All samples for chemical and microbial analyses have been collected using 8-L Niskin bottles on a rosette equipped with a Seabird CTD system, an oxygen electrode and beam attenuation and fluorescence sensors. Sampling and analytical details for most parameters have been described elsewhere (Scranton et al. 2006, Taylor et al. 2006, Hayes et al. 2006, Lin et al. 2006). Most importantly all samples are drawn from the Niskin bottles under a nitrogen headspace and all incubations are done without headspace at in situ temperature in the dark. Trace metal samples were collected in as clean a manner as we could manage but due to the likelihood of contamination, we do not discuss data from above the oxic/anoxic transition zone. We have recently added analyses for elemental S using the method of Ramsing et al. (1996) as modified by R. Trowburst (personal communication) and for iron and manganese using atomic absorption spectroscopy as described by Percy (2006).

RESULTS

Results of biogeochemical studies of the Cariaco Basin over the past decade have confirmed that the suboxic water column is a site of intense biological activity and that this activity is strongly influenced by the chemistry of the water column (Scranton et al. 2001, Taylor et al. 2001). Suboxic zone thickness (defined as the zone where oxygen and sulfide concentrations are both below 1 µM) has varied from less than 10m (Jan 2005) to more than 75 m (May 2002) as shown in Fig. 1. However microbial activity always seems to be most intense at the base of the suboxic layer. In fact we have found the most successful way to optimize our sampling is to center our samples on the small beam attenuation (light scattering) maximum found at or slightly above the depth where hydrogen sulfide concentrations are about 1 µM.
Intermediate oxidation state sulfur species have been measured across the suboxic interface on four occasions and at four stations. Profiles for thiosulfate, sulfite, and elemental sulfur (together with oxygen and sulfide concentrations) are shown in Fig. 2. A strong minimum is seen in thiosulfate and sulfite in the lower part of the suboxic zone, while elemental sulfur is at a maximum in this depth range. In Fig. 3, we plot results for chemoautotrophic carbon fixation for the same stations and in Fig. 4, the effect of addition of thiosulfate on both cell growth rates and dark carbon fixation. Rates of both CO$_2$ fixation and stimulation of rates by added thiosulfate are at a maximum in the suboxic zone and seem to reflect the chemical distributions, particularly that of elemental sulfur.
Figure 2: Oxygen, sulfide, thiosulfate, sulfite and elemental S at three stations in the Cariaco Basin for Jan 2006. Station A is the CARIACO site, Station B is near the eastern sill, and Station C is in the deep portion of the western basin.

Figure 3: Dark carbon fixation for Jan 2006 as for Fig. 2

Figure 4: Effect of addition of thiosulfate on bacterial growth and chemoautotrophic production for samples
collected in Jan 2006.

**DISCUSSION**

As reported previously, our data from the Cariaco Basin suggest that the active microbial loop present in the suboxic zone is dependent on external supply of oxidant for its livelihood. Our present data strongly suggest that there are several primary sources for this oxidant, including intrusion of oxygenated water through both the eastern and western sills to the Cariaco Basin (Astor et al. 2003) and input of terrestrial materials during rain events along the northern coast of Venezuela (Lorenzoni 2005, Percy, in prep.). Evidence for terrestrial input will be presented at the meeting, although there is not room enough to show it here. Specifically we have seen increases in deep iron and manganese concentrations and elevated abundances of α-proteobacteria (thought to be freshwater organisms) as a major component of the bacterioplankton during a period of elevated rainfall along the northern coast of Venezuela. Lorenzoni (2005) has shown that runoff from a number of small rivers can produce plumes of elevated light scattering at the southern boundary of the Cariaco Basin, and low surface salinities typically co-occur with elevated surface silicate levels.

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**REFERENCES**


