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**BURIAL, REMINERALIZATION AND UTILIZATION OF ORGANIC MATTER AT
THE SEAFLOOR UNDER A STRONG WESTERN BOUNDARY CURRENT**

**Annual Progress Report
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ABSTRACT

The overall objectives of this project are to quantify the rates of organic carbon export from the southern mid-Atlantic Bight and to quantify the rates at which carbon is exchanged between the inorganic and organic pools within the bottom sediments. The strategy for achieving these goals is to quantify the rates of benthic exchange and burial of bioactive elements including oxidants (such as oxygen, nitrate, sulfate), micronutrients, and carbon system parameters on the continental shelf, slope and rise regions within and adjacent to the south portion of the mid-Atlantic Bight. This information, in conjunction with burial rates provided by others in this program, will be used to determine the locations and rates of export and oxidative loss of organic matter from the shelf. During this past funding period, three expeditions were completed to the study region, successfully conducting 6 *in situ* benthic flux chamber experiments. The results provide an initial assessment of the magnitude and location of organic matter export from the southern Middle Atlantic Bight shelf and of the importance of this region as a supplier of organic carbon to the North Atlantic Ocean Basin.

Progress to Date

The specific goals of this last year's effort were to conduct *in situ* benthic flux chamber experiments along the continental slope depocenter to determine what the rates of organic carbon oxidation and burial are in this region and determine whether these rates increase as the Cape Hatteras region is approached. Toward this goal, we have participated on three research expeditions to this region during the last 12 months. The first expedition was the DOE-sponsored cruise on the R/V Gyre in May 1993. I served as Co-Chief Scientist on this expedition. In addition, we participated on two NSF-funded cruises of opportunity to this region aboard the R/V Cape Hatteras in July and September, 1993. Our principle focus on these expeditions was to conduct *in situ* benthic flux chamber measurements on the continental slope and rise. In addition, however, we were able to test the new hydrostatically-damped multiple piston corer that was designed and constructed earlier in this project. The following is a brief summary of these activities.

Benthic fluxes were determined at the locations represented by the solid triangles in Figure 1. The northern most five locations (A-E) are within the continental slope depocenter at water depths of approximately 750m. The southern location (F) is on the continental rise at a depth of 3000m. Examples of the benthic flux chamber and pore water results for stations A and C are presented in Figure 2. A large and consistent decrease in oxygen concentration in the chambers is observed in both experiments. This decrease is caused by the consumption of oxygen by heterotrophic benthic organisms in the oxidation of organic matter to its inorganic components. The degradation of organic materials is verified by the concordant increase in chamber concentration during the incubation of the products of the remineralization processes such as titration alkalinity, ammonia and phosphate. In addition, the dissolution of biogenic hard parts is demonstrated by the increase of silicate in the chamber. Nitrate, which can be both consumed as an oxidant during remineralization in low oxygen conditions and released as a by product when oxygen is plentiful is observed to change only slightly during the incubation. The overall picture of intense remineralization at these sites is further indicated by the large increases observed in the pore water concentrations of titration alkalinity and ammonia

with increasing depth in the sediments.

The oxygen, titration alkalinity and (at sites B and D) total inorganic carbon results for the other four stations are displayed in Figure 3. As was observed at sites A and C, oxygen concentrations in the chamber decrease while T.A. and T.I.C. increase. The nutrient chamber and pore water results (not shown) are also similar suggesting that the overall pattern of intense organic matter remineralization driving pore water concentration gradients and benthic exchange rates occurs at all sites. Based on these results, the organic carbon remineralization rate and solute benthic exchange rates have been calculated.

Several important preliminary conclusions can be drawn from these results. First, the results clearly demonstrate that accurate benthic exchange rate estimates must be based on directly measured fluxes using benthic flux chambers rather than calculated from near surface pore water gradients. This is most clearly demonstrated by the results displayed in Figure 2. While the T.A. and ammonia pore water gradients are very similar between the two sites, the chamber T.A. and ammonia results are dramatically different. Benthic fluxes of these constituents are observed to vary by more than a factor of three whereas the exchange predicted from the pore water results would be indistinguishable.

Second, these results suggest that existing diagenetic models fail to explain the observed fluxes and that a fundamental improvement in our understanding and parameterization of benthic physical, chemical and biological processes will be required before the fate of inorganic carbon deposited on the sea floor can be quantified. The discrepancy between model predicted and measured T.A. fluxes is listed in Table 1.

This comparison demonstrates that in this region, the existing models consistently over-predict the observed T.A. flux. It is also important to note that the discrepancy varies significantly suggesting that a variety of parameters, such as small-scale patchiness in macrobenthic organism density and irrigation activities, which are presently not considered in diagenetic models must be included to reconcile the observed results.

Third, the results to date can be used to assess the overall importance of this continental margin system in the export of organic carbon to the deep North Atlantic basin. The organic carbon remineralization rate measured in this study are compared, as a function of water depth, with other estimates for the Atlantic seaboard reported by Martin and McCorkle (in press), Anderson et al. (in press) and Smith (1978) (Figure 4). Plotted in this manner, the magnitude of the fluxes observed within the slope depocenter (approximately 800m) relative to other regions is clearly apparent. However, to evaluate the overall importance of the margin system within the context of the entire Atlantic basin, we must normalize the fluxes to the area which they represent. The results are plotted vs distance from the shelf break (Figure 5) to provide a clearer representation of the areal extent to which the flux estimates apply. Plotted in this manner, it is clear that the high fluxes are found within the slope depocenter are restricted to a very narrow band and account for a small (<20%) portion of the total organic matter delivered to the sediments along the entire transect considered.

The distribution of fluxes perpendicular to the margin can best be interpreted by the

cumulative histogram presented in Figure 6. This compilation demonstrates that half of the organic carbon input to the deep seafloor occurs within 100 km of the shelf break and 2/3 of the total input occurs within 200 km. From this figure, it is clear that the margin system plays a dominant role in supplying organic carbon to the deep sea floor.

The importance of this margin system as a source of organic carbon for the entire deep North Atlantic can be evaluated by integrating the distribution displayed in Figure 5 along the approximately 1000 km long margin from Georges Bank to Cape Hatteras. This calculation suggests that the seafloor in this region remineralizes 1.2×10^{11} mol C/yr. Broecker et al. (1991) have reported that the total respiration rate for the deep North Atlantic is 10-12 μ mol O_2 /kg/century. Assuming a deep water volume of 237×10^6 km³, this rate corresponds to a remineralization of 1.1×10^{13} mol C/yr. Thus, seafloor respiration along the margin between Georges Bank and Cape Hatteras accounts for approximately 1% of the total deep water respiration. Since a significant amount of remineralization must also occur as particles settle through the deep water column, it is likely that this margin region accounts for more than 2% of the total North Atlantic remineralization. Omitting adjacent seas, there is a total of approximately 34,000 km of margin in the North Atlantic. If the rates in these other regions are similar to those observed along the Atlantic seaboard, margin account for at least 84% of the organic carbon input to the deep sea.

Future Plans

There are two more expeditions planned for the Cape Hatteras region in the summer of 1994. The first will be aboard the R/V Gyre in July. A tentative cruise track and deployment locations are displayed in Figure 7. The overall objectives of the benthic work are: to determine whether there is evidence of increased off-shelf export of organic matter associated with the Gulf Stream and slope sea return circulation and to provide a preliminary of benthic exchange rates and benthic primary production on the continental shelf. Toward these objectives, we propose to conduct three in situ benthic flux chamber deployments on the continental rise adjacent to Cape Hatteras. If waters advecting off of the continental shelf in this region are transporting significant amounts of dissolved or particulate organic material, some signature of increased inputs to the seafloor should be observable. In addition, we propose two preliminary, short-term chamber experiments on the continental shelf in approximately 20 m water depth. These experiments should provide a preliminary assessment of nutrient, oxidant and carbon exchange rates and, by comparing light and dark chambers, an initial determination of whether benthic primary production is a significant process in this region.

In August, we plan a short expedition on board the R/V Edwin Link equipped with the submersible Johnson Sea Link. Using this submersible, we will conduct benthic flux measurements on the steep continental slope in regions where the rough topography prevents routine deployments of free vehicle instruments from surface vessels.

References

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TABLE 1. Comparison of oxygen and titration alkalinity benthic fluxes and the percentage of the T.A. flux predicted from present-day diagenetic models and the measured oxygen flux that is actually observed.

LOCATION	Oxygen Flux (mol/m ² yr)	T.A. Flux (eq/m ² yr)	% of Model-Predicted T.A. Flux
A	1.60	1.58	59
B	2.50	1.69	40
C	1.65	0.38	14
D	1.46	0.65	27
E	3.00	1.60	32
F	0.48	0.47	58

Figure 1. Locations studied in 1993 (solid triangles).

Cape Hatteras Slope

Figure 2. Examples of results from the slope depocenter for sites A (open circles) and C (open squares).

Figure 3. Oxygen, T.A. and T.I.C. chamber results at sites B, D, E, and F.

Figure 4. Organic carbon benthic oxidation rate versus water depth; This study (▼), Smith, 1978 (●); Martin and McCorkle, in press (○); Anderson et al., in press (▽).

Figure 5. Organic carbon benthic oxidation rate versus distance from shelf break.

Figure 6. Cumulative histogram of the seafloor oxidation of organic carbon.

Figure 7. Planned ship track and station locations for the expedition scheduled for July 1994 on board the R/V Gyre. *In situ* benthic flux chamber deployments are planned for sites represented by the triangles.