Sediment Geochemistry In The Canadian Arctic

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Given the current threat of fast-paced global change, it has become urgent to understand the biogeochemical response of the Arctic environment to external forcing. The Canadian Arctic Shelf Exchange Study (CASES) is an interdisciplinary project put together by scientists from across Canada whose primary goal is to gain a better understanding of the Canadian Arctic environment. Objectives include evaluating issues such as the impact of climate change – extent of sea ice cover - on biological productivity and the carbon cycle. In order to predict the potential evolution of the complex Canadian Arctic system, the intricacies of its current dynamics must first be understood.

This study focuses on the geochemical characteristics of the sediments in the Canadian Arctic shelf. A series of sediment cores taken at various locations in the Beaufort Sea and Amundsen Gulf (fig. 1) were analyzed for reactive solid-phase manganese and iron oxides. These data were used to determine the redox zonation and availability of electron-acceptors within the sedimentary column. The abundance and vertical distribution of the metal oxides reflect a history of organic carbon delivery to the seafloor. Manganese and iron are the focus of this study because they contribute significantly to the oxidation of the organic matter (OM) reaching the seafloor and are abundant in the Earth's crust. By combining data on organic carbon content and dissolved manganese and iron, spatial correlations were established and the variations in sedimentary geochemical environments were interpreted across the study area.

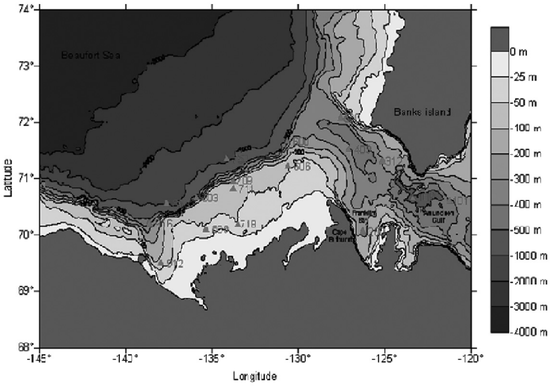

Figure 1. Location of the Beaufort Sea and Admunsen Gulf with respect to the Canadian Northwest Territories. Triangles represent sampling stations.

Laboratory work focused on sediment recovered from cores sub-sampled (at predetermined depth intervals) on-board the CCGS Amundsen in 2003-2004. The freeze-dried sediments were homogenized and the abundance as well as the vertical distribution of reactive iron and manganese minerals was determined according to methods described by Kostka and Luther (1994) and Leventhal and Taylor (1990), using buffered ascorbate- and HCl-extractable phases for their extraction. Manganese (Mn) and iron (Fe) dissolved by these reagents and the sediment porewaters were analyzed by atomic absorption spectroscopy using an air-acetylene flame.

The vertical distribution of solid and dissolved phases of Mn and Fe in the sediment is largely dependant on whether or not oxygen is present in the sediment and exactly how deep it can penetrate. The oxygen penetration depth (OPD) is mainly a function of bottom water oxygen concentration and OM input and reactivity. Oxygen oxidizes organic matter in reactions mediated by bacteria. The higher the input of OM and the more reactive it is, the more rapid

Key Terms

Forcing:
A persistent disturbance of a system (longer term than perturbation).

Redox zonation:
availability of electron-acceptors within the sedimentary column

Sedimentary column:
vertical section of sediment at a given location

Oxidizing conditions:
in the presence of oxygen

Reducing conditions:
in the absence of oxygen

Diagenesis:
any change undergone by sediment after deposition

is the consumption of oxygen. The more rapidly oxygen is consumed, the shallower the depth of oxygen penetration. The OM discussed here is derived from a combination of two sources: continental (i.e. Northwest Territories via the Mackenzie River) and the marine environment (i.e. Arctic surface waters). Typically, marine OM is more reactive than continental OM due to its lower carbon to nitrogen ratios.

The OPD is reflected in the distribution of Mn and Fe because these elements, delivered by settling particulate matter, are insoluble under oxidizing conditions and soluble under reducing conditions. The depth in the sediment that separates these two situations is called the redox boundary. For a given sediment sample the redox boundary and OPD occur at the same depth. A sharp increase in the concentrations of the dissolved, reduced forms characterizes the redox boundary (fig. 2). The elemental concentration gradients across this boundary drive a diffusive flux of soluble, reduced Mn and Fe upward. Upon encountering dissolved oxygen, soluble Mn and Fe precipitate as oxides and accumulate near the OPD. With time, as a result of continuous sedimentation, these oxides are buried below the redox boundary and are dissolved again via reduction. The net result is that Mn and Fe cycle across their respective redox boundaries. These boundaries are typically observed at depths varying between 5 and 25 cm in the Canadian Arctic.

The depth of the redox boundary is important because the closer it is to the sediment water interface, the higher the probability that dissolved metals may escape the sediment and get carried offshore by ocean currents, to be later deposited in the deep sea. In other words, the redox cycle is not necessarily confined to the sediment but may also include the water column.

The examination of several of these profiles has led to the conclusion that there are two distinct geochemical environments operating in the Canadian Arctic: The Admunsen Gulf/ Abyssal Plains of the Beaufort Sea, and the Mackenzie Shelf. The former is characterized by extremely high concentrations of reactive Fe and Mn, low sedimentation rates, low concentrations of poorly reactive organic carbon and a redox boundary located deep within the sediment (fig. 2). In contrast, the Mackenzie Shelf environment is characterized by low Fe and Mn concentrations, high sedimentation rates, elevated concentrations of highly reactive OM and a redox boundary close to the sediment-water interface. On the Mackenzie Shelf, diagenesis is fueled by a high influx of OM (sediment input from the continent), which brings the redox boundary for manganese and iron closer to the sediment-water interface.

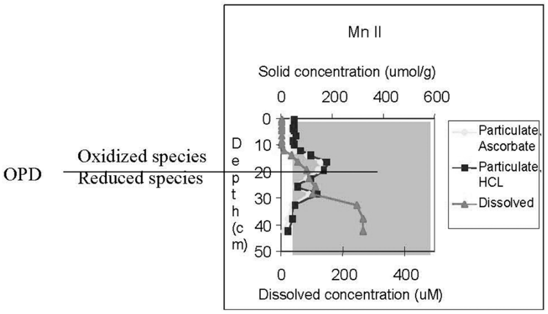

Figure 2. Sample Mn profile taken in the Beaufort Sea (Station 750) illustrating the position of the redox boundary.

This allows dissolved species to escape the sediment and to get carried offshore. Here, the dissolved species are re-oxidized in the water column and re-deposited in the Admunsen Gulf and Abyssal Plains of the Beaufort Sea.

The results in this study contribute to the advancement of CASES' objectives. From these results it can be speculated that increased global warming may increase precipitation over Canada, leading to higher weathering rates and greater sediment deposition onto the Mackenzie Shelf. Consequently, the redox boundary on the Mackenzie Shelf may thin even more, allowing a larger quantity of dissolved species to escape the water column and to be transported into the deep environment. In addition, the increased delivery of nutrients by the river and the decreasing ice cover may lead to greater primary production and the delivery of more reactive OM to the seafloor; once again thinning the oxidizing layer. It is generally believed that the Arctic is particularly fragile and sensitive to change, though this is still a hot topic for debate and has yet to be determined empirically.

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