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Combined use of $\Delta^{14}C$ and $\delta^{13}C$ values to trace transportation and deposition processes of terrestrial particulate organic matter in coastal marine environments

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Abstract

Accelerator mass spectrometry was used to measure radiocarbons of riverine suspended particles and sediments from the estuary, continental shelf and slope off the coast of Tokachi River in Japan. The spatial distribution of $\Delta^{14}C$ and $\delta^{13}C$ values of sedimentary organic matter was divided into those of (1) estuary, (2) continental shelf, and (3) continental slope. For shelf sediments, respective maxima can be seen for $\Delta^{14}C$ value, C/N ratio and organic carbon content at a station near the river mouth. The mean grain size of surface sediments also exhibits a similar trend. The $\delta^{13}C$ values show a minimum near the river mouth. The shelf composition does not appear to be a simple mixture of terrestrial and marine origin. From the above data, it is considered that the spatial distribution of $\Delta^{14}C$ and $\delta^{13}C$ values may reflect variations in dispersion and deposition processes together with the size fractionation of riverine suspended particles, the resuspension of sediments, and differences in the contribution of marine organic matter.

Keywords: Particulate organic matter; $\Delta^{14}C$; $\delta^{13}C$; Surface sediments; Coastal areas; Terrestrial organic matter

1. Introduction

Global riverine discharge of dissolved and particulate terrestrial matter represents a substantial source of organic carbon to the ocean (Meybeck, 1993; Hedeges et al., 1997). Continental margins are recognized as the dominant reservoir for organic carbon burial in the marine environment. Total organic carbon comprises materials that are derived from both marine and terrestrial sources. An accurate inventory for terrestrial and marine organic carbon in continental margin sediments is important for quanti-

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tative understanding of biogeochemical cycles. A variety of geochemical approaches have been employed to define the mixing ratio of marine and terrestrial organic matter, including $\delta^{13}C$ and lignin biomarker analyses (e.g., Hedges and Parker, 1976; Hedges and Mann, 1979; Prahl et al., 1994).

The $\delta^{13}C$ tracer has proven to be simple and very useful for dissolved organic carbon (DOC) and particulate organic carbon (POC) in riverine, estuarine and marine environments (Hedges and Parker, 1976; Prahl et al., 1994). It has been utilized to estimate relative amounts of biological materials derived from terrestrial and marine sources. This method is based on a general enrichment of ^{12}C in terrestrial organic matter compared with marine materials. Nevertheless, a considerable overlap exists in the $\delta^{13}C$ values of several major sources of DOC and POC within these aquatic environments. For this reason, we require an additional tracer to determine the fate of organic matter and to estimate the contribution of terrestrial organic matter to continental margins. Radiocarbon abundances have become an additional indicator of terrestrial versus marine sources because nuclear weapons testing in the 1950s and 1960s injected large quantities of ^{14}C into the atmosphere. There are different $\Delta^{14}C$ signatures of contemporary marine dissolved inorganic carbon (DIC) and atmospheric CO_2 (Nydal and Lovseth, 1983). The $\Delta^{14}C$ values of organic matter in river suspended particles range from −980 to +75‰ (Kao and Liu, 1996; Raymond and Bauer, 2001), but plankton and particulate organic carbon in marine environments have enriched ^{14}C values ranging from −45 to +110‰ (Williams et al., 1992; Wang et al., 1998; Bauer et al., 2001). Therefore, the simultaneous use of $\Delta^{14}C$ and $\delta^{13}C$ values adds a second dimension to isotopic studies of carbon cycling in surface aquatic environments, especially to the study of the fate and geochemical behavior of particulate organic carbon at continental margins.

The $\Delta^{14}C$ values of dissolved and particulate organic matter have been measured by several authors using accelerator mass spectrometry to elucidate dynamics of organic carbon in river systems (e.g., Hedges et al., 1986; Raymond and Bauer, 2001; Nagao et al., 2004) and marine environments (e.g., Druffel and Williams, 1990; Wang et al., 1996; Megens et al., 2001). Radiocarbon of organic matter in sediment trap samples has also been used to study the lateral transport of materials derived from sea margins (e.g., Anderson et al., 1994; Nakatsuka et al., 1997; Honda et al., 2000). However, the application of this method to marine sediments is limited (e.g., Goni et al., 1997; Megens et al., 2002).

This study applies a combined use of $\Delta^{14}C$ and $\delta^{13}C$ to surface sediments from the river mouth, continental shelf, and slope off the coast of Hokkaido. This study is intended to test the utility of a combined $\Delta^{14}C$ and $\delta^{13}C$ approach to better understand the fate of terrestrial particulate organic matter that is released from the river to the coastal marine environment.

2. Materials and methods

2.1. Study area

The Tokachi River runs through southeastern Hokkaido, a large northern island in Japan. The 156-km-long river has a watershed of 9010 km^2. It originates at Mt. Tokachi-dake (2077 m) of the Taisetsu Mountain Range located in the middle of Hokkaido. It flows through the broad Tokachi Plain, which includes old and new alluvial fans and stream terraces. Geological features of the plain are mainly volcanic rocks with unconsolidated sediments along. The soil in this area consists mainly of ando soil and lowland soil (Otowa, 1985). Mean annual precipitation during the 22 years from 1979 to 2000 is recorded as 947 mm at the Urahoro observatory, which is located near the Moiwa sampling site (Japan Meteorological Agency, 2004).

The Tokachi River's mean annual water discharge is recorded as 220 m^3/s (129–330 m^3/s) at a water flow monitoring station at the Moiwa Bridge in 1970–1998 (Ministry of Land, Infrastructure, and Transport, 2004). Water discharge in the spring snow-melt season is up to four times greater than that of the winter season (Ministry of Land, Infrastructure, and Transport, 2004).

Fig. 1 depicts the offshore Tokachi area studied in this paper. The Oyashio current flows off the Hokkaido Island coast from northeast to southwest. The Oyashio region has high primary production (380–2500 mgC/m^2/day; Shiomoto et al., 1994; Kasai et al., 1998). Off the coast near the Tokachi River, a