B-5.2 Study on Sedimentation Flux of Particulate Carbon in the Ocean

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Abstract

Carbon in the settling particle conveys the net flux of carbon from the surface ocean to the deep. The settling process is the necessary knowledge to understand the global carbon cycles. In this program, sediment trap experiment to measure the net carbon flux in the pelagic ocean and the deep trench was planned. The degradation process of the settling particle in the deep sea, lateral transport of particulate having terrestrial origin were studied from chemical analysis. Samples collected by sediment traps moored in Japan Trench, where the bottom depth was 9200 m, were analyzed to asses the lateral flux of particulate matter from coastal area to the pelagic ocean through continental shelf. Adsorption of clay particle of terrestrial origin to larger biogenic particle and also scavenging of dissolved Mn and Cu with settling particle were observed. An *in situ* dissolution experiment of calcareous tests was done using the sediment trap mooring. The dissolution of calcitic tests increased with depth, which is consistent with the thermodynamic stability. However, the dissolution in the deep ocean was extremely slow compared with the results of laboratory experiment. To asses the lateral flux of organic carbon from coastal area to pelagic ocean through continental shelf, techniques for the estimation of the ages of the organic carbon in the trapped materials were developed. From ^{14}C measurement of surface sediment, suspended particle and settling particle, the transportation model of organic matter from continental shelf to the pelagic ocean, which consist of degradation of organic matter and scavenging of suspended particulate, was described.

Key Words ocean, sediment trap experiment, ocean particulate, organic carbon, flux

1. Introduction

The ocean exchanges a huge amount of CO_2 with the atmosphere, that is the greatest of the fluxes between global carbon reservoirs. The exchange flux of CO_2 between atmosphere and ocean is estimated as $100x10^{15}gC/y$, which is much larger than the anthropogenic emission rate of CO_2 ($6x10^{15}gC/y$). Therefore, the gas exchange effectively controls the atmospheric concentration of CO_2 over the long time scale. Since the atmosphere retains only one half of CO_2 emitted from burning fossil fuel, it is believed that the ocean absorbs a large portion of the other half. The absorption of CO_2 by the ocean is driven by physical gas exchange, ocean circulation and also surface photosynthetic activity. The net absorption flux of CO_2 by the ocean, determined by the difference between the absorption and release fluxes due to the gas exchange is quite small, which makes it difficult to measure the net flux from the analysis of ocean surface phenomena.

The carbon in the settling particle conveys the net flux from the surface water to the deep. Part of the carbon in the settling particle recycles with the decomposition during the sinking process. The settling process in the ocean is the necessary knowledge to understand the global carbon cycles. In this program, sediment trap experiment to measure the net carbon flux in the pelagic ocean, continental shelf and also the deep trench was planned, and degradation process of the settling particle in the deep sea, lateral transport of particulate having terrestrial origin were studied.

2. Sediment trap experiment

For the sampling of the settling particle, sediment trap experiment has been started in the Northwest Pacific. From this experiment, seasonally averaged data on the flux of particulate materials in the ocean can be obtained. In December 1990, three sediment trap systems were moored at tropical and subtropical regions in the North West Pacific. Each mooring system has two traps, one at 500 m above the bottom and the other at 1000 m depth from the surface.

Sediment trap experiment at the JT station in Izu–Ogasawara Trench has been continued since 1986 by cooperation with research institutes including the participants of this research project. This experiment deploys the deepest mooring system in the world ocean researches. In September 1992, we added two sediment trap systems at the southern part of Izu–Ogasawara Trench and at Mariana Trench with the support of this research fund.

3. Chemical nature of settling particulate

Samples collected by sediment traps moored in Japan Trench, where the bottom depth was 9200 m, were analyzed to asses the lateral flux of particulate material from coastal area to the pelagic ocean through continental shelf. The analyses of radioactive tracers and inorganic element give information of the formation mechanism and degradation process in the water column. The settling matter consists of particulate of different origins. Behavior of them can be categorized as follows; 1) Biogenic matter, consists of organics, calcium carbonate and silicic detritus are relatively large particulate, and usually accounts for largest proportion of the sedimentation flux. The vertical variation of the flux are small below 1000 m depth. 2) Clay particle of terrestrial origin is small particle, then the settling velocity is small. It adsorbs to the larger particle of biogenic origins and settles. 3) Manganese and copper in the water column are scavenged by the particulate of other origins. 4) Contribution of turbidite from the bottom sediments to the total sedimentation flux is sometimes important at the deeper layers.

4. Dissolution of calcareous tests in the deep ocean

The CO_2 absorption by the ocean is sustained by the reaction of CO_2 with $CaCO_3$. The surface ocean is supersaturated with respect to both aragonite and calcite, which are the two major forms of $CaCO_3$ produced as calcareous tests. The deep oceanic water is undersaturated with these calcareous. The settling calcareous test dissolutes with sinking in the water column.

An *in situ* dissolution experiment of calcareous tests was conducted during about 1 year using the Japan Trench sediment trap mooring. The results of the experiment are given in Table 1. The aragonitic tests dissolved completely below 1000m depth within the 1 year experimental period. Dissolution rate of calcitic tests increased with depth. The results are consistent with the thermodynamic stability of the calcareous tests. There found differences of dissolution with the laboratory study. The *in situ* experiment clearly shows that the dissolution occurs even at the degree of undersaturation less than 10 %. On the other hand, the dependency of rate of dissolution on the degree of undersaturation is much less than these of laboratory experiments, resulting in extremely slow dissolution rates at the higher degrees of undersaturation.

Table 1. Results of in situ dissolution experiment of foraminifera in seawater

depth (m)	initial weight mg C	initial weight mg A	after experiment mg C	after experiment mg A	weight loss % C	weight loss % A	rate of dissolution %/day C	rate of dissolution %/day A
1174	122.35	4.7	92.12	0	24.7	100	0.073	>0.3
3680	121.41	10.23	68.17	0	43.9	100	0.129	>0.3
5687	124.80	10.56	34.41	0	72.4	100	0.213	>0.3
8688	124.31	7.87	0	0	100	100	>0.294	>0.3

C: calcite, A: aragonite

5. Delta C^{14} analysis of organic carbon in particulate

To asses the lateral flux of organic carbon from coastal area to pelagic ocean through continental shelf, techniques for the estimation of the ages of the organic carbon in the trapped materials were developed. A new sample preparation method for C^{14} isotopic analysis with an accelerator mass spectrometer was developed. The carbon in organic materials in sediment trap sample are crystallized on metallic iron under hydrogen atmosphere to make a sample target for the mass spectrometric analysis. Stronger ion beam of C^{14} from the target improved the sensitivity. The sample amount required was reduced from 5 mg to 0.5 mg.

Figure 1 indicated the variation of organic carbon flux and C^{14} abundance from sediment trap samples at Hidaka Basin, off shore of Hokkaido, Japan. The C^{14} ratio represents the age of the photosynthesis of the organic materials. The winter minimum is attributed to the resuspension of coastal sediment, which contains fresh organic materials, by a storm. The C^{14} abundance observed through the sampling period was lower than that in suspended material (about +150 permil), which suggests the constant flux of organic carbon from coastal area to pelagic ocean.

The radio carbon date of organic matter in the settling particulate in the trench was extraordinary higher than that in the pelagic ocean. This indicates the accumulation of aged organic matter to the deeper part of the trench. However, the behavior of the accumulation is not simply described by the resuspension of the sediment at the continental shelf and slope. The transportation of the particulate organic matter has complicated mechanism. Surface sediments, suspended particles and sinking particles were collected from the mouth of Tokyo Bay, Sagami Bay and Japan Trench and adjacent areas. Their carbon isotope ratios of C^{13} and C^{14} were analyzed by mass spectrometric methods. The age of suspended particles in deep (>1000m) seawater was oldest (−500 to −720 permil). Processes of decomposition of the sinking particles and scavenging of the old suspended particles were observed in the areas. Figure 2 is the model description about the organic carbon sinking process occurs in the Izu−Ogasawara Trench mooring site.

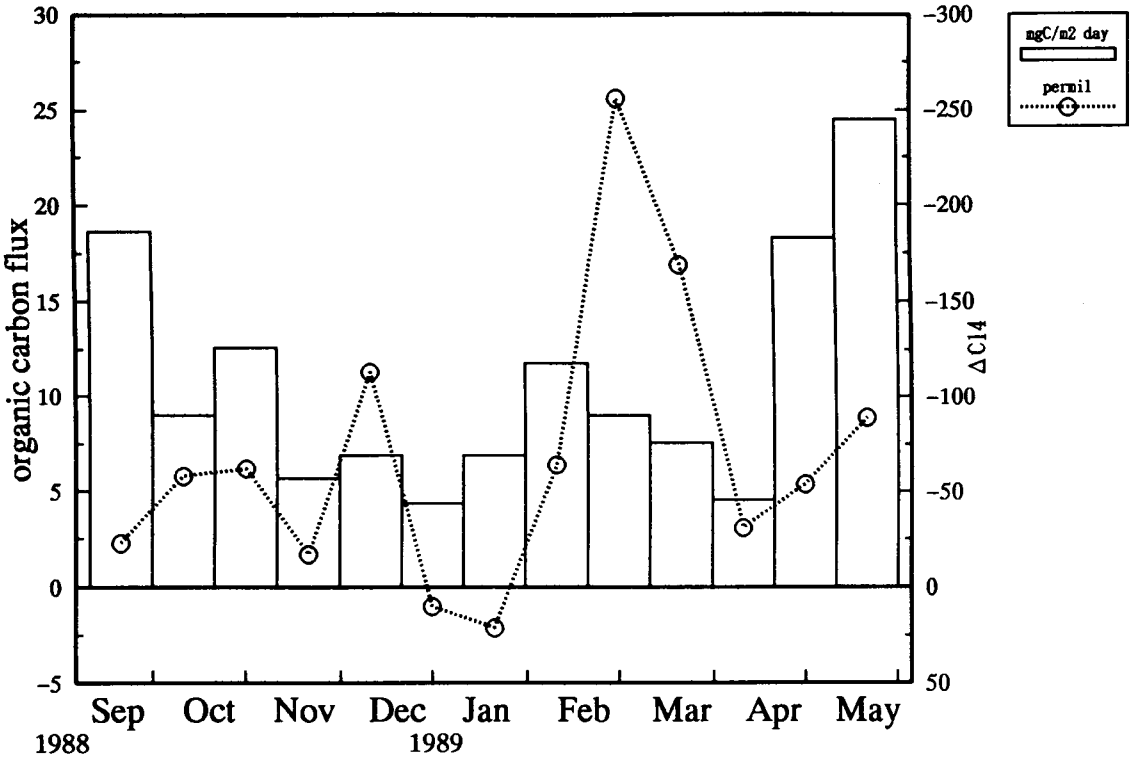

Fig. 1 Organic carbon flux and radio carbon analytical results from sediment trap experiment at Hidaka Basin, off shore of Hokkaido, Japan

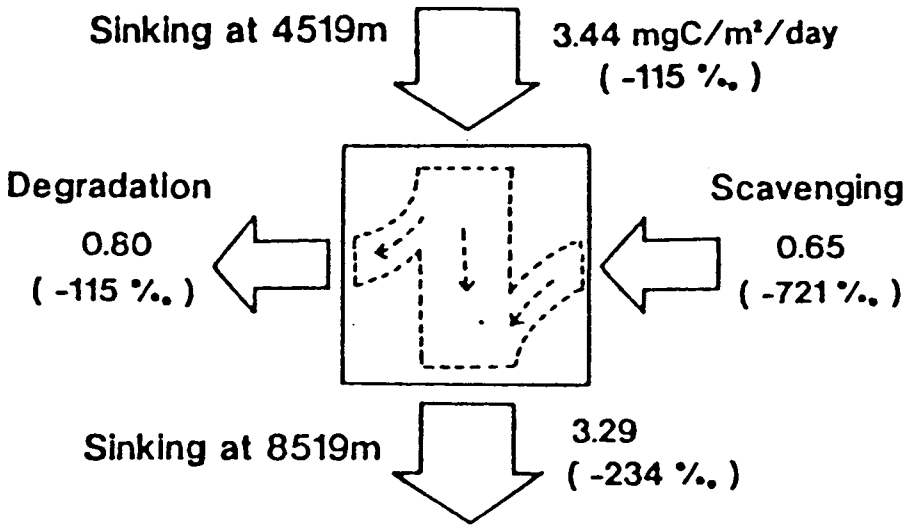

Fig. 2 Mass balance of organic carbon estimated from radio active carbon-14 at JT station located in the northern part of Izu-Ogasawara trench