

Excess ^{210}Pb and ^{210}Po in sediment from the Western North Pacific

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Introduction

Particles in most surficial marine sediments are mixed mostly by the biological activities on the sea floors and the mixing is called as bioturbation. Knowledge of the mechanisms and rates of the bioturbation is critical to understand rates of the recycling and burial of organic matter, biogenic silica, carbonate and manganese (Berner, 1980; Emerson, 1985; Aller, 1990).

To determine the rate of the bioturbation, excess ^{210}Pb , which was produced ultimately from ^{226}Ra and scavenged by settling or resuspended particles, has been widely used (e.g., Nozaki *et al.*, 1977; Peng *et al.*, 1979; DeMaster and Cochran, 1982).

The western North Pacific has relatively high biological activity in surface water compared to the eastern North Pacific. This means rain rate of organic carbon to the sea floor in the western North Pacific is high and high bioturbation rate is expected. To clarify the rate, ^{210}Pb profile in the sediment from the western North Pacific was determined.

Activity ratio of ^{210}Po to ^{210}Pb in particulate matter in water column is generally over unity (Harada and Tsunogai, 1986). This suggests that significant amount of ^{210}Po reaches to the sea floor and some part of the ^{210}Po exists in the sediment even though half-life of ^{210}Po is short, 138 days. To test this hypothesis, ^{210}Po in the sediment was also determined.

Methods

Coring and sample treatment on board of the ship

Station KNOT (Figure 1), which is a station for time series observations of Japanese JGOFS activity, is located at 44°N, 155°E in the western North Pacific. Sediment core samples were collected at Stn. KNOT twice in cruises of R/V Hakurei-Maru #2 in October 1998 and

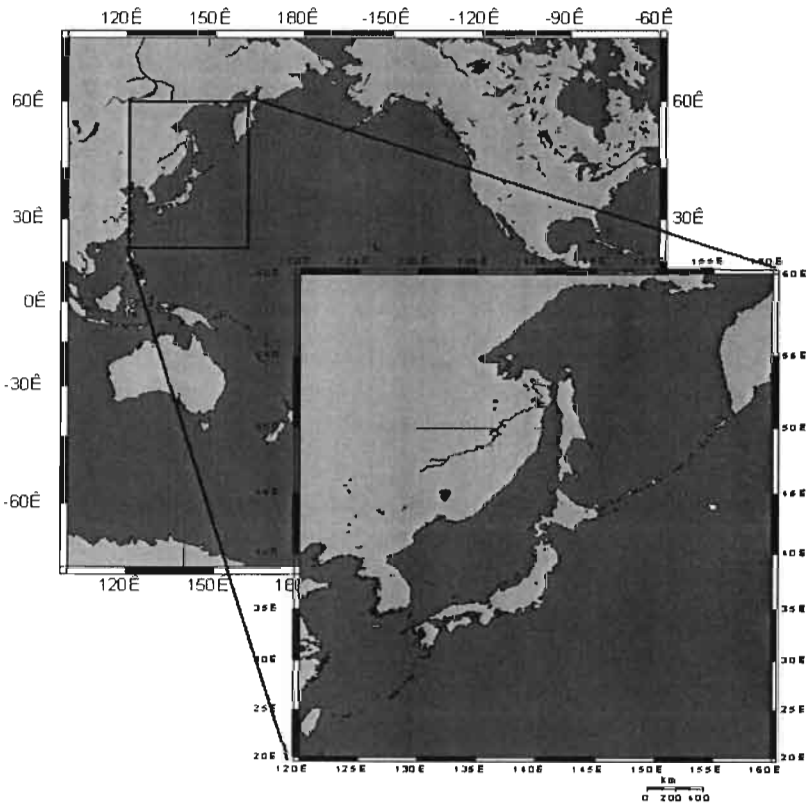


Figure 1
Map of the northwestern North Pacific showing a core location.

R/V Mirai in November 1998 using with a multiple corer (Figure 2). Immediately after recovery of the corer on the deck, the sediment core sample was sliced by 3 mm thickness for the top ten samples, by 6 mm thickness for the next 10 samples and by 12 mm thickness for the rest. The sliced samples were frozen and transferred to a land laboratory. In the laboratory, the samples were dried and powdered. Water content and porosity were calculated from weight loss after drying.

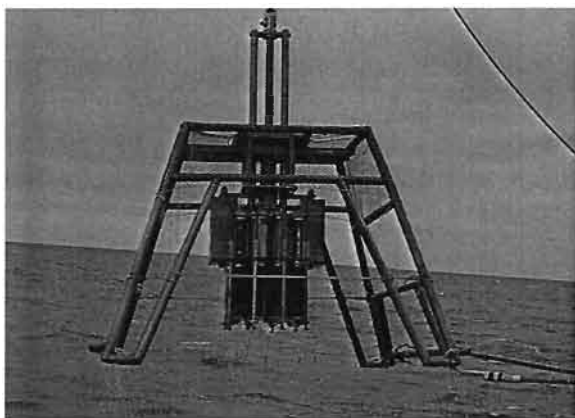


Figure 2
Picture of the Multiple Corer in the R/V Mirai cruise.

Radiochemical analyses

Radioactivities of ^{226}Ra and ^{210}Pb in the samples were determined by gamma spectrometry with a well-type intrinsic germanium detector. Efficiencies of the detector were calibrated by IAEA sediment standards.

Activity of ^{210}Po in the samples was determined by alpha spectrometry using ^{209}Po as a chemical yield monitor (Harada and Tsunogai, 1985). Aliquot amount of the sediment sample was leached in 6 M HCl solution and polonium was collected in hydroxide precipitate

from the leachate. Activities of ^{209}Po and ^{210}Po were determined by silicon surface barrier detectors after spontaneous deposition of polonium onto a silver disk from 0.1 M HCl that dissolved the precipitate.

Results and discussion

^{226}Ra and ^{210}Pb in the sediment at Stn. KNOT

Vertical distributions of ^{226}Ra and ^{210}Pb in the two sediment cores from Stn. KNOT were shown in Figure 3. Concentration of ^{210}Pb decreased rapidly from surface down to 1 cm depth, and then decreased gradually down to 6 cm depth. Below the depth, the concentration was almost constant, whereas there was a peak at 8 cm depth in the 1998 sample core. Contrastively, concentration of ^{226}Ra , which is a precursor of ^{210}Pb , was almost constant in the cores, ranging between 3.5 to 8.0 dpm.g⁻¹.

The vertical profiles of ^{226}Ra and ^{210}Pb showed that there was excess ^{210}Pb over its precursor ^{226}Ra from surface down to 6 cm depth. This excess ^{210}Pb must be supported by an input from outside of the sediment, which is an input of ^{210}Pb from the water column by settling particles.

Fluxes of ^{210}Pb from the bottom water to the sediment

Assuming a steady state condition, the ^{210}Pb flux from the overlying water column to the sediment can be calculated from inventories of ^{226}Ra and ^{210}Pb in the sediment from following relation,

$$F_i = \lambda_i I_i \quad (1)$$

where λ_i is a decay constant of nuclide i (day⁻¹) and I_i is an inventory in the sediment of the nuclide i (dpm.m⁻²).

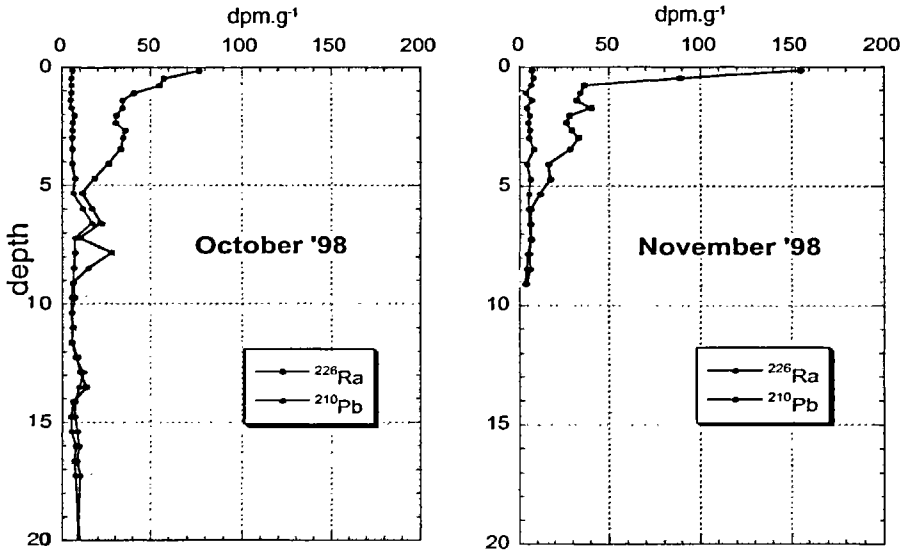


Figure 3
Vertical distributions of ^{226}Ra and ^{210}Pb
in the sediment core at Stn. KNOT.

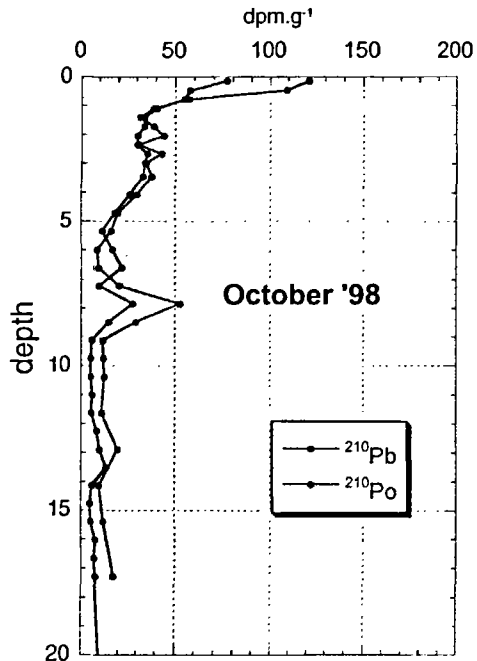
The flux of ^{210}Pb was calculated as 81.9 and 64.2 $\text{dpm}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ respectively from the October and November, 1998 profiles. This calculated flux can be compared with the flux observed by a sediment trap experiment. Unfortunately, ^{210}Pb in the sediment trap samples have not been determined so far, whereas the experiment at Stn. KNOT was carried out by the other group. Judging from previous papers, ^{210}Pb flux observed by the sediment trap in the North Pacific ranged from 20 to 100 $\text{dpm}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$. The calculated fluxes from the profiles in the sediment seem to be comparable with the fluxes observed by the sediment traps in the biologically productive area in the North Pacific.

^{210}Po in the sediment

Using the sediment samples collected in November 1998, ^{210}Po was also determined, which is a daughter nuclide of ^{210}Pb . The vertical

profile of ^{210}Po showed in Figure 4 with ^{210}Pb . Excess ^{210}Po over ^{210}Pb seems to exist in the top two sub-samples and between 7 and 10 cm depth. Generally speaking, the settling particles have high $^{210}\text{Po}/^{210}\text{Pb}$ ratio from 3 to 10 and this was explained by preferential scavenging of ^{210}Po from seawater to particulate matter. Although there still exist a possibility of calibration error of the counter because the excess ^{210}Po in the deeper samples is not explainable, the excess ^{210}Po in the core top seems to be caused by higher particulate flux of ^{210}Po from the water column than of ^{210}Pb . The ^{210}Po flux from the water column can be estimated from the inventory of the excess ^{210}Po in the sediment in the same method as ^{210}Pb flux mentioned above. The flux was calculated as $590 \text{ dpm}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ showing the estimated $^{210}\text{Po}/^{210}\text{Pb}$ ratio in the settling particle was 7, which is comparable or a little higher than the observed one in the North Pacific.

Figure 4
Vertical
distributions of
 ^{210}Pb and
 ^{210}Po in the
sediment core
collected in
October.



Estimation of bioturbation rate from the vertical profiles of ^{210}Pb and ^{210}Po

As shown above, excess ^{210}Pb and ^{210}Po were detected in the sub-surface layers of the sediment core from the western North Pacific. Even though the excesses were supplied from the overlying water column by the settling particles, there must be some mechanisms in which surface sediment particles was mixed with sub-surface one since accumulation rate of pelagic sediment is very slow, $<1 \text{ cm.kyr}^{-1}$, compared to the time scale of mean life of the nuclides. The particle mixing by organisms on sea floor, bioturbation, seems to be predominant although the mixing by bottom water current could be occur. If the nuclides is carried to the interior of the sediment only by the bioturbation, the concentration of the nuclides in the sediment can be expressed by the following equation,

$$\frac{dA}{dt} = D_B \frac{d^2A}{dz^2} + S \frac{dA}{dz} - \lambda A \quad 2$$

where A is a concentration of nuclide i in the sediment, D_B is a bioturbation rate constant, S is a sediment accumulation rate and λ_i is a decay constant of nuclide i . Since the second term in the right side in the Eq.(2) is negligible, the steady state concentration of the nuclide i can be expressed as follows;

$$A = C \cdot e^{-\sqrt{\frac{\lambda_i}{D_B}} \cdot z}$$

The concentrations of ^{210}Pb were plotted against depth semilogarithmically (Figure 5). Judging from the linearity, the sediments were separated into three layers, surface to 1 cm, 1 to 2.5 cm and 3 to 6 cm depth and the bioturbation coefficient in the layers was estimated to be 0.04, 0.4, 0.06 $\text{cm}^2.\text{yr}^{-1}$, respectively. It is very curious that the second layer has the largest coefficient, however, the reason is still unknown. Using the excess ^{210}Po profile, the coefficient was also calculated. The estimated value, 1.2 $\text{cm}^2.\text{yr}^{-1}$, is significantly larger than one obtained from the excess ^{210}Pb . To clarify the difference between the values from ^{210}Pb and ^{210}Po , further study is needed although the age dependent mixing of deep-sea sediments was reported (Smith *et al.*, 1993).

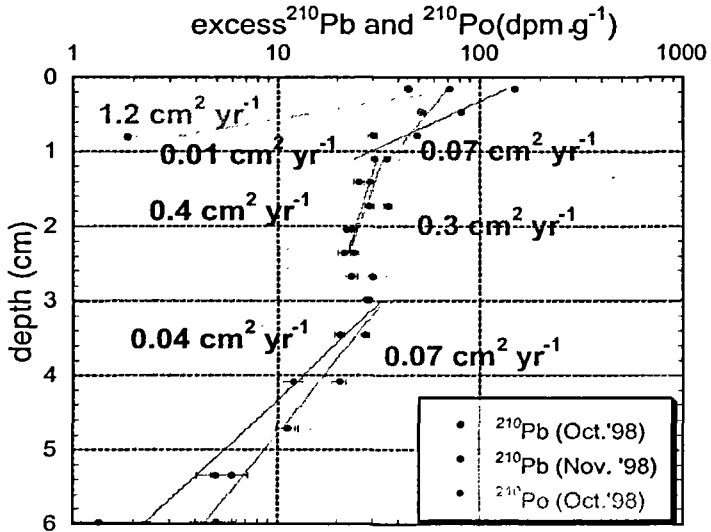


Figure 5
Semi logarithmic plots of ^{210}Pb and ^{210}Po
in the sediment and estimation of D_B .

Conclusion

In the sediment in the western North Pacific,

1. excess ^{210}Pb and excess ^{210}Po existed down to 6 and 1 cm depth, respectively,
2. particulate fluxes of ^{210}Pb and ^{210}Po from the overlying water were estimated as 70 and 590 dpm.g^{-1} , respectively,
3. bioturbation mixing coefficient in the sediment was estimated to be from 0.004 to $0.4 \text{ cm}^2.\text{yr}^{-1}$ and the highest value was observed in 1 – 2.5 cm layer.

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