

Oxygen and carbon isotopic composition of planktonic foraminifera tests collected with sediment traps from the Japan Trench

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Abstract: Numerous specimens of eleven planktonic foraminiferal species were collected with sediment traps deployed at 4000 m and 9000 m water depths in the Japan Trench. The oxygen isotopic measurements of about 700 individual foraminiferal specimens indicate that each specimen is greatly affected by the water temperature rather than by the oxygen isotopic ratio of the sea water in which the foraminiferal specimen grew. The depth habitats of eleven planktonic foraminiferal species are estimated by comparing the oxygen isotopic ranges of these species and the seasonal change of the water temperature at the sediment trap site. The carbon isotopic values of these species are mostly controlled by the carbon isotopic ratios of the sea water. The present results provide fundamental information on the oxygen and carbon isotopic composition of individual specimens of living planktonic foraminifera. Carbon isotopic vertical profile in paleo-ocean was reconstructed by the oxygen and carbon isotopic measurements of individual specimens of surface, subsurface, deep-water dwelling species as well as benthic foraminiferal species collected from a horizon at 6000 years B.P. in a deep sea core near the sediment trap site.

Introduction

Sediment trap experiments are critical to evaluating the carbon fluxes in the present ocean as well as obtaining fundamental information for paleoceanographic studies. In the present study, the oxygen ($^{18}\text{O}/^{16}\text{O}$) and carbon ($^{13}\text{C}/^{12}\text{C}$) isotopic ratios of the planktonic foraminiferal tests collected in sediment traps were measured in order to obtain isotopic data on the ecology of individual specimens of living planktonic foraminifera. Sediment trap samples were recovered from 4000 m and 9000 m water depths in the Japan Trench (approximately $34^{\circ}10' \text{N}$, $141^{\circ}58' \text{E}$, water depth: about 9200 m). Samples were collected at intervals of about 20 days from August, 1986 to November, 1988 using time series traps of Mark six type by Drs. NOZAKI, HANDA, and HONJO. The oxygen and carbon isotopic ratios of about 700 specimens of eleven planktonic

foraminiferal species were measured individually by OBA and UOMOTO (1989) and UOMOTO (1990) with a Finnigan MAT 251 mass spectrometer possessing a small inlet system.

Results

The oxygen isotopic results of surface dwelling species, such as *Globigeinoides sacculifer* and *Globigerinoides conglobatus*, indicate a distinct seasonal change in the isotopic values. The light oxygen isotopic values are observed in the specimens living in the surface water during summer, while heavy values occur in specimens from the subsurface water during winter. The total range of the oxygen isotopic values of *Globigerinoides sacculifer* is between -4.1‰ and -1.1‰ vs PDB. Maximum 3 ‰ difference in the oxygen isotopic ratios occurred in the individual measurements of 185 specimens of *Globigerinoides sacculifer*. On the other hand, the oxygen isotopic values of subsurface species, such as *Globorotalia*

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truncatulinoides and *Globorotalia inflata*, remain in relatively narrow ranges, for example between -1.9‰ and $+0.2\text{‰}$ for *Globorotalia truncatulinoides* and between -1.2‰ and $+0.6\text{‰}$ for *Globorotalia inflata*. These two deep dwelling species secrete their tests mainly during winter and spring seasons, and in some cases during summer for *Globorotalia truncatulinoides*.

Since the oxygen isotopic ratio of foraminiferal tests is dependent on two factors, the temperature and the oxygen isotopic ratio of the sea water in which the foraminifera grew, the relative contributions of these two factors to the oxygen isotopic ratio of foraminiferal tests must be considered. The oxygen isotopic variation of the surface water at the sediment trap site is inferred from the seasonal change of the salinity, because a proportional relationship between the oxygen isotopic ratio and salinity of the surface water is observed in the Kuroshio region (OBA, 1990). The seasonal salinity change of the surface water is only 0.5‰ from 34.3‰ in summer to 34.8‰ in winter in this area at the present-day. It corresponds to an oxygen isotopic variation of 0.2‰ throughout the year. This suggests that the oxygen isotopic value of foraminiferal tests is mainly determined by the water temperature rather than the oxygen isotopic ratio of the sea water. Therefore, the depth habitat of each species can be estimated from the comparison between the oxygen isotopic range of each species and seasonal change of the water temperature at the sediment trap site. The estimated depth habitats of eleven planktonic foraminiferal species are as follows;

Species	Depth habitat
<i>Globigerinoides sacculifer</i>	0 - 200 m
<i>Globigerinoides ruber</i>	50 - 200 m
<i>Globigerinoides conglobatus</i>	50 - 200 m
<i>Orbulina universa</i>	50 - 200 m
<i>Globigerinella siphonifera</i>	50 - 400 m
<i>Neogloboquadrina dutertrei</i>	50 - 500 m
<i>Pulleniatina oblicuiloculata</i>	100 - 500 m
<i>Globolotalia truncatulinodes</i>	200 - 500 m
<i>Globolotalia inflata</i>	200 - 600 m
<i>Globolotalia hirsuta</i>	200 - 600 m
<i>Globolotalia scitula</i>	700 - 800 m

The carbon isotopic values of 700 individual specimens of eleven planktonic foraminiferal species also demonstrate the seasonal change. The heavy values are found in specimens living in the surface water during summer and the light values in subsurface and deep water specimens during winter season. It is assumed that the carbon isotopic ratio of the sea water becomes heavier during summer because of increased primary productivity in the surface waters after the spring bloom. During winter season, however, the carbon isotopic ratio consists of relatively light values because of low productivity and vigorous vertical mixing of the sea water which brings isotopically light carbon from the deep. When the carbon isotopic values of the 700 specimens of the eleven species are plotted versus their oxygen isotopic values, there is a trend showing heavy carbon isotopic ratios for the specimens having light oxygen isotopic values, corresponding to shallow water depth. Specimens which have light carbon isotopic ratios also have heavy oxygen isotopic values, indicating deep water depth. These observations suggest that the carbon isotopic ratio of foraminiferal tests is essentially controlled by the carbon isotopes of the sea water, i.e. carbon isotopic ratio of the bicarbonate ion in the sea water.

It is well known that the carbon isotopic profile of sea water is closely related to the dissolved oxygen content of sea water and that depleted carbon isotopic values are observed at the dissolved oxygen minimum layer under high biological productivity areas. Therefore, the carbon isotopic profile of paleo-ocean can be reconstructed by utilizing the oxygen and carbon isotopic measurements of individual specimens of foraminifera living in different water depths. In the present study, about 30 to 50 specimens of surface (*Globigerinoides sacculifer*), subsurface (*Globorotalia inflata*), and deep-water dwelling species (*Globorotalia scitula*) as well as two benthic foraminiferal species (*Uvigerina proboscidae* and *Bulimina aculeata*) were collected from a horizon at

6000 years B.P. in a deep sea core (KH-79-3, C-6) located near the sediment trap site. The resulting isotopic data was used to construct the carbon isotopic profile of sea water at 6000 years ago (OBA, 1990). Such a reconstruction of the carbon isotopic profile is very important for paleoceanographic investigations especially during the last glacial age when the atmospheric carbon dioxide content was 2/3 of the Holocene age.

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