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AMS RADIOCARBON DATES ON FORAMINIFERA FROM DEEP SEA SEDIMENTS

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ABSTRACT. ^{14}C ages were determined on samples of foraminifera separated from cores from three areas of the tropical Pacific (East Pacific Rise, Oontong Java Plateau, and South China Sea). Analyses were made on four planktonic species and on mixed benthics. The purpose of the multiple analysis on planktonic species is to assess the importance of artifacts resulting from the bioturbation-abundance change couple, from the bioturbation-partial dissolution couple and from redeposition by bottom currents. The goal is to use the benthic-planktonic age difference as a means of establishing changes in deep sea ventilation rate over the past 25,000 years. Results of a part of this work are presented in this paper.

INTRODUCTION

Much of what is known about ventilation rates of the deep sea was derived from ^{14}C data on ΣCO_2 ($CO_3^=$, HCO_3^- and dissolved CO_2) in sea water. Specifically, the CO_2 ventilation rate of the deep sea is a function of the ^{14}C concentration difference between warm surface water and mean deep ocean water. Observed changes of the atmospheric ^{14}C levels might partially originate from changes in ocean ventilation rate. A record of past changes of the CO_2 ventilation rate might be stored in the ^{14}C concentration differences between benthic (bottom dwelling) and planktonic (near-surface dwelling) foraminifera. As foraminifera build their shells from carbonates dissolved in the ambient waters, the ^{14}C level of the water is reflected in the shell's ^{14}C concentration. For convenience, the ^{14}C levels are expressed as conventional radiocarbon ages, which means that Libby's half-life has been used and that the results are normalized to a $\delta^{13}C$ value of $-25‰$ PDB. For a discussion of reservoir dependent effects one has to keep in mind that the ocean surface has a ^{14}C of $-50‰$, resulting in a ca +400 yr age shift for all oceanic ^{14}C ages relative to atmospheric conditions. Hence the best estimate of the age of the planktonic samples reported here is obtained by subtracting 400 years.

The foraminiferal record of surface-to-deep ocean ^{14}C age differences, however, is complicated by processes in the sediment that may mask the true record. Most disturbing are the effects of bioturbation coupled to abundance changes and carbonate dissolution (Broecker *et al,* 1984). Bioturbation describes the more-or-less homogeneous stirring of typically the top 8cm of the sediment by organisms. The disturbing effects become negligible if sedimentation rates are high. In this paper we present initial results from a high sedimentation rate core. More complete results, and a complete presentation of the data will be published elsewhere.

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RESULTS

The ^{14}C results presented here are from core V35-06, a piston core taken from the South China Sea (7° 13′ N, 112° 9′ E) at 2030m depth. This site is presently bathed by Pacific Deep Water, and has a surface-deep water ^{14}C age difference of 1585 ± 150 years (Broecker *et al*, in press). Two planktonic species, *Globigerinoides sacculifer* and *Pulleniatina obliquiloculata*, and mixed species of benthic foraminifera were analyzed from the top 100cm of core V35-06, covering the past ca 13,000 years. Each sample consists of ca 300 shells of the given species hand-picked from the bulk sediment. The results are listed in Table 1 and plotted in Figure 1.

The sedimentation rate was calculated from the benthic foraminiferal data. As the deep ocean is the larger oceanic carbon reservoir, it should be less sensitive to reservoir effects, and should give the best age model. The sedimentation rate is 11.5cm/kyr from 10 to 60cm depth in the core.

Extrapolation of the 10 to 60cm sedimentation rate to the core top yields estimated surface ages of ≈5500 years for the benthics, and ≈4000 years for the planktonics. A date on *G sacculifer* from 2 to 4cm of 3580 ± 80 years generally supports this extrapolation. The high core top age suggests that ca 30cm of sediment was lost from the piston-core top during coring. This speculation is confirmed by a date on *G sacculifer* from the companion trigger weight core (V35-06TW). The trigger-weight core top contains abundant opal, which is evidence that the sediment-water interface has been sampled. This date, 1170 ± 170 years from 1 to 7cm, is consistent with a sedimentation rate of 10cm/kyr, a bioturbated layer 8cm thick, and a surface water reservoir-age of ca 400 years ($^{14}C = -50‰$).

Between 68 and 82cm the ages remain approximately constant. Different explanations can be given for this observation:

– the sedimentation rate was extremely high for a brief period 10,000

TABLE 1
Results from sediment core V35-06

Depth (cm)	Species *G sacculifer*	*P obliquiloculata*	Benthics
1–7	1170 ± 170*		
2–4	3580 ± 80		
8–13	4860 ± 90	5140 ± 90	6420 ± 100
17–24	6040 ± 100	6060 ± 100	
18–20			7200 ± 110
22–28			7660 ± 130
27–34	6420 ± 100	6810 ± 100	
37–45	7890 ± 110	8030 ± 110	9210 ± 130
45–53	8780 ± 120	9020 ± 120	9760 ± 130
57–64	9550 ± 120	9630 ± 120	10,810 ± 150
68–72	10,130 ± 120	10,070 ± 120	11,290 ± 150
78–82	9740 ± 130	10,370 ± 130	11,180 ± 140
89–92	11,590 ± 140	11,820 ± 140	12,950 ± 160
98–102	12,540 ± 160	12,700 ± 160	13,550 ± 170

* This date of the accompanying trigger weight core (V35-06TW) supports a loss of core top in the piston core (compare date for 2 to 4cm depth).

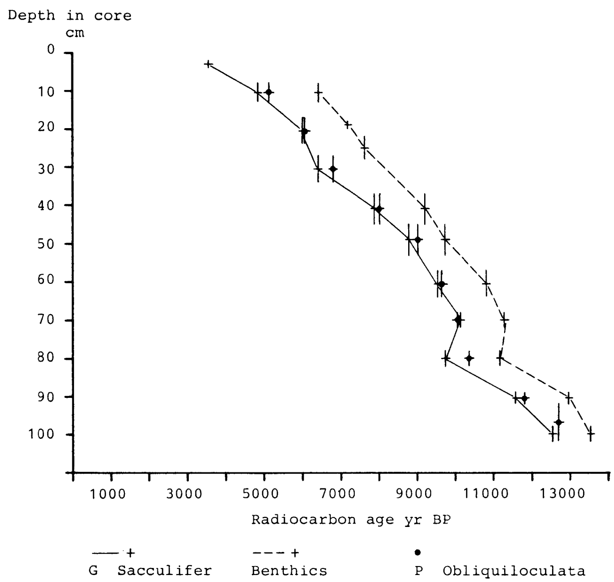

Fig 1. Ages of *G sacculifer, P obliquiloculata,* and mixed benthics *vs* depth obtained on piston core V35-06.

years ago, an effect that should also show up in the parallel core V35-05 (under investigation).

– the sediment contains a turbidite or other perturbation. Inspection of the core yielded no indication of such an event.

– the results reflect a perturbation in the ^{14}C production rate and/or the distribution within the ocean—atmosphere system. A point against this hypothesis is the benthic ages which follow *G sacculifer* unexpectedly well. Because of the 1000-year ventilation time one might expect short-term fluctuations in ^{14}C production to be buffered in the deep sea.

More work will have to be done before the significance of this feature can be properly assessed.

TABLE 2
Age differences between benthics and *G sacculifer* and benthics and *P obliquiloculata*

Depth (cm)	Age difference between benthics and *G sacculifer*	*P obliquiloculata*
8–13	1560 ± 140	1280 ± 140
17–24	1160 ± 150	1140 ± 150 (benthics 18–20cm)
27–34	1240 ± 160	850 ± 160 (benthics 22–28cm)
37–45	1320 ± 170	1180 ± 170
45–53	980 ± 180	740 ± 180
57–64	1260 ± 190	1180 ± 190
68–72	1160 ± 190	1220 ± 190
78–82	1440 ± 190	810 ± 190
89–92	1360 ± 210	1130 ± 210
98–102	1010 ± 230	850 ± 230 (Obliq 92–102cm)

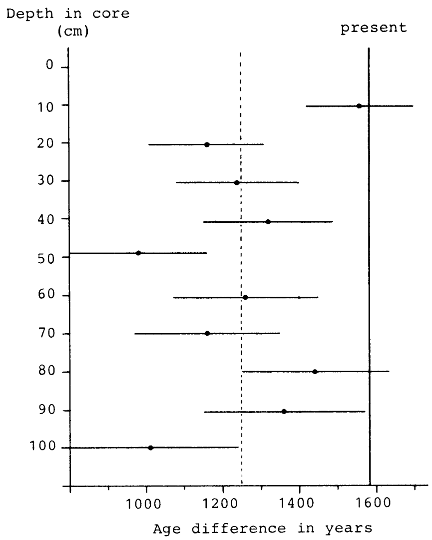

Fig 2. Deviation of the age of *G sacculifer* from the age of mixed benthics *vs* depth. The solid line marks the present age deviation. The dashed line indicates the mean value of the measured points.

The two planktonic species yield generally similar ages, but *G sacculifer* is on the average 210 ± 60 years younger than *P obliquiloculata.* This may reflect calcification of *P obliquiloculata* below the sea-surface mixed layer, which is ca 100m thick in the South China Sea. This interpretation is supported by oxygen isotope data, which indicate that *P obliquiloculata* calcifies at temperatures ca 3°C colder (and therefore deeper below the ocean's surface) than *G sacculifer* in the Western Equatorial Pacific (Berger, Killingley & Vincent, 1978). Whatever the reason for this small offset between planktonic species may be, this indicates that the best representation of the deep—surface ocean age difference will come from the benthic—*G sacculifer* age difference (see Table 2).

The results for benthic—*G sacculifer* age differences are plotted *vs* depth in Figure 2, and *vs* the age of *G sacculifer* in Figure 3. The mean age difference is 1250 ± 60 years, not significantly different from present conditions. Before more core top data are available, it cannot be decided whether the top sample (8 to 13cm) reflects a change in ventilation rate since ca 5000 BP or whether it just reflects statistical scatter of the data.

SUMMARY AND CONCLUSIONS

The sedimentation rate of core V35-06 is high (>10cm/kyr); therefore, the record of ^{14}C age differences between benthic and planktonic foraminifera is not seriously affected by bioturbation. The results show no significant change in ventilation rate for the past 12,000 years. A slightly increased ventilation rate compared with today may be indicated.

Tree-ring ^{14}C data covering the past 8000 years indicate that the atmospheric reservoir was more enriched in ^{14}C 8000 years ago (eg, Damon,

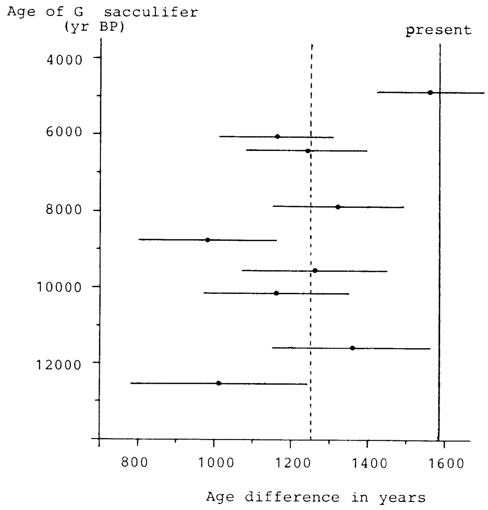

Fig 3. Deviation of the age of *G sacculifer* from the age of mixed benthics *vs* the age of *G sacculifer*. The solid line marks the present age deviation. The dashed line indicates the mean value of the measured points.

1982) and has been decreasing since. This has been interpreted as a higher ^{14}C production rate or slower deep-sea ventilation rate in the early Holocene. According to Siegenthaler, Heimann and Oeschger (1980), reduced ventilation would not change the ^{14}C content of the deep ocean, but markedly increase the ^{14}C content of the surface ocean and atmosphere. Under these conditions, the age differences between benthic and planktonic foraminifera should be larger than today. Our data do not show such a trend and exclude, if representative for the world's oceans, this second explanation for high atmospheric ^{14}C levels in the early Holocene. Further work is underway to study in detail the core top and to extend the record back to the glacial maximum, as well as to replicate these results at other core locations.

ACKNOWLEDGMENTS

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