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# 28. PLIOCENE OXYGEN ISOTOPE STRATIGRAPHY OF HOLE 709C[1]

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## ABSTRACT

A closely spaced (5-cm interval) oxygen isotope stratigraphy of planktonic foraminifers from Hole 709C was completed for most of the Pliocene and lowermost Pleistocene (around 4.6–1.4 Ma). This will contribute data to the future testing of the Matthews and Poore model of 1980, in which it was assumed that low-latitude sea-surface temperature has remained virtually constant as global climate evolved.

Spectral analyses of the record by means of biostratigraphic time controls show a distinct peak at a period near 40 ka that is probably associated with the orbital obliquity cycle. Visual inspection of the record shows that intervals containing distinct 40-ka cycles are present in both lower and upper parts of the Pliocene even though a regular cycle cannot be followed throughout the entire 4-m.y. investigated.

## INTRODUCTION

Oxygen isotope analysis was first successfully applied in low-latitude sequences of planktonic foraminifers from the Caribbean and equatorial Atlantic (Emiliani, 1955). More recently, the focus has shifted toward analyses of benthic foraminifers so that, although there are now several benthic data sets available for the Pliocene that enable us to build up a picture of the history of deep-water formation processes (Shackleton and Opdyke, 1977; Keigwin, 1982; Hodell et al., 1985; Loubere and Moss, 1986; Loubere, 1987; Raymo et al, 1989; Shackleton and Hall, in press), there are fewer low-latitude planktonic records (Keigwin, 1982; Prell, 1985).

We analyzed Hole 709C with the objective of obtaining a high-resolution planktonic oxygen isotope record for the low-latitude Indian Ocean in an area unaffected by upwelling. The concept of temperature stability in such areas (Matthews and Poore, 1980) requires testing with the aid of detailed oxygen isotope records from the warmest low-latitude regions where, according to their model, temperature should have had a minimal influence on isotopic variations. In addition, we hope that such a record will enhance the value of high-quality records from upwelling areas (such as Prell's [1985] from the central equatorial Pacific, and those that may be anticipated from Ocean Drilling Program [ODP] Leg 116) by providing a nonupwelling reference.

## METHODS

Samples were taken at 5-cm intervals for this part of a multi-institutional investigation. This proves to be equivalent to a coarsest temporal interval of 10,000 yr in the lower Pleistocene and to a best temporal interval of under 3,000 yr in the lower Pliocene. Samples were washed over a 63-$\mu$m sieve after dispersing in distilled water overnight on an orbital shaker. Half splits of the coarse fraction were transferred to Norwich for geochemical and other studies. Foraminifers for isotopic analysis were selected from the 300–355-$\mu$m fraction to minimize noise arising from isotopic change during ontogeny (Berger et al., 1978). Samples were analyzed isotopically in a VG Isogas SIRA 9 triple collector mass spectrometer using standard methods.

Initially, about 30 specimens of *Globigerinoides ruber* were picked from each sample, but unfortunately this species became too rare in the lower part of the sequence. We were obliged, therefore, to select *Globigerinoides sacculifer* instead. To mitigate the disadvantage of this switch, two short sections were analyzed for both species. The mean $\delta^{18}O$ difference is about 0.25‰, similar to the figure observed by Shackleton and Hall (1983) in Deep Sea Drilling Project (DSDP) Site 504 from the east Pacific.

Preliminary time-series analysis was performed using the standard methods of Jenkins and Watts (1968). The programs are in the ARAND package, as used by Hays et al. (1976), and were set up in Cambridge by N. Pisias.

## RESULTS

All isotopic results are given in Table 1, with reference to the PDB standard. Figures 1 and 2 show the data for *G. ruber* and *G. sacculifer* separately. Figure 3 shows the whole data set as a function of depth below seafloor (mbsf), after making an adjustment of 0.25‰ to the *G. ruber* measurements to make them approximately comparable with the *G. sacculifer* data. Also on Figure 3 are the positions of biostratigraphic control points (Table 2) that may be used to obtain a provisional time series.

## DISCUSSION

The planktonic oxygen isotope record shown in Figures 3 and 4 is surprisingly featureless in comparison with benthic oxygen isotope records covering the same time interval. The very marked change in character that is observed in published benthic $\delta^{18}O$ records at about 2.4 Ma (Shackleton and Opdyke, 1977; Shackleton et al., 1984) is not obvious in this record. This implies that the marked change in the character of the benthic oxygen isotope record about 2.4 Ma may, in part, reflect an increase in deep-water temperature variability. However, before any conclusions are reached regarding the climatic significance of that transition, it is essential that benthic species are analyzed in Hole 709C to confirm that the record is complete across the 2.4-Ma transition.

In Figure 4, the data are plotted on an approximate time scale obtained by linear interpolation between the biostratigraphic datum levels in Table 2. To facilitate the discussion of the whole record, an adjustment of 0.25‰ was again made to the *G. ruber* measurements to "correct" them to an equivalent value for *G. sacculifer*.

The high-frequency variability in Figure 4 appears to be around 1‰ from peak to peak throughout the entire interval de-

[1] Duncan, R. A., Backman, J., Peterson, L. C., et al., 1990. *Proc. ODP, Sci. Results*, 115: College Station, TX (Ocean Drilling Program).

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**Table 1. Stable isotope data for Hole 709C.**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| S 88/1641 | 13.35 | *G. ruber* | 300–355 | −0.92 | 1.17 |
| S 88/1642 | 13.40 | *G. ruber* | 300–355 | −1.08 | 1.19 |
| S 88/1643 | 13.45 | *G. ruber* | 300–355 | −0.95 | 1.41 |
| S 88/1644 | 13.50 | *G. ruber* | 300–355 | −1.15 | 1.40 |
| S 88/1645 | 13.55 | *G. ruber* | 300–355 | −0.96 | 1.50 |
| S 88/1646 | 13.60 | *G. ruber* | 300–355 | −1.10 | 1.30 |
| S 88/1647 | 13.65 | *G. ruber* | 300–355 | −1.34 | 1.48 |
| S 88/1648 | 13.70 | *G. ruber* | 300–355 | −1.30 | 1.44 |
| S 88/1649 | 13.75 | *G. ruber* | 300–355 | −1.26 | 1.45 |
| S 88/1650 | 13.80 | *G. ruber* | 300–355 | −1.09 | 1.20 |
| S 88/2411 | 13.85 | *G. ruber* | 300–355 | −0.97 | 1.14 |
| S 88/2412 | 13.90 | *G. ruber* | 300–355 | −0.88 | 1.08 |
| S 88/2413 | 13.95 | *G. ruber* | 300–355 | −1.01 | 1.29 |
| S 88/3321 | 13.95 | *G. ruber* | 300–355 | −0.95 | 1.19 |
| S 88/2414 | 14.00 | *G. ruber* | 300–355 | −0.52 | 1.30 |
| S 88/3322 | 14.00 | *G. ruber* | 300–355 | −0.78 | 1.19 |
| S 88/2415 | 14.05 | *G. ruber* | 300–355 | −1.10 | 1.23 |
| S 88/2416 | 14.10 | *G. ruber* | 300–355 | −1.33 | 1.32 |
| S 88/2417 | 14.15 | *G. ruber* | 300–355 | −1.61 | 1.62 |
| S 88/2418 | 14.20 | *G. ruber* | 300–355 | −1.35 | 1.30 |
| S 88/2419 | 14.25 | *G. ruber* | 300–355 | −1.48 | 1.61 |
| S 88/2420 | 14.30 | *G. ruber* | 300–355 | −1.33 | 1.36 |
| S 88/2421 | 14.35 | *G. ruber* | 300–355 | −1.48 | 1.05 |
| S 88/2422 | 14.40 | *G. ruber* | 300–355 | −1.34 | 0.92 |
| S 88/2423 | 14.45 | *G. ruber* | 300–355 | −0.97 | 1.02 |
| S 88/2424 | 14.50 | *G. ruber* | 300–355 | −0.94 | 1.16 |
| S 88/2425 | 14.55 | *G. ruber* | 300–355 | −1.39 | 0.76 |
| S 88/3323 | 14.55 | *G. ruber* | 300–355 | −1.32 | 1.14 |
| S 88/2426 | 14.60 | *G. ruber* | 300–355 | −1.03 | 1.47 |
| S 88/2427 | 14.65 | *G. ruber* | 300–355 | −1.28 | 1.59 |
| S 88/2428 | 14.70 | *G. ruber* | 300–355 | −1.38 | 1.58 |
| S 88/3324 | 14.75 | *G. ruber* | 300–355 | −1.13 | 1.47 |
| S 88/2429 | 14.85 | *G. ruber* | 300–355 | −1.29 | 1.70 |
| S 88/2430 | 14.90 | *G. ruber* | 300–355 | −1.03 | 1.51 |
| S 88/2431 | 14.95 | *G. ruber* | 300–355 | −0.99 | 1.34 |
| S 88/2432 | 15.00 | *G. ruber* | 300–355 | −0.83 | 1.35 |
| S 88/2433 | 15.05 | *G. ruber* | 300–355 | −0.97 | 1.40 |
| S 88/2434 | 15.10 | *G. ruber* | 300–355 | −0.86 | 1.51 |
| S 88/2435 | 15.15 | *G. ruber* | 300–355 | −1.08 | 1.44 |
| S 88/2436 | 15.25 | *G. ruber* | 300–355 | −1.00 | 1.13 |
| S 88/2809 | 15.29 | *G. ruber* | 300–355 | −1.11 | 1.34 |
| S 88/2437 | 15.45 | *G. ruber* | 300–355 | −1.08 | 1.32 |
| S 88/2438 | 15.50 | *G. ruber* | 300–355 | −0.80 | 1.07 |
| S 88/2439 | 15.55 | *G. ruber* | 300–355 | −0.83 | 1.01 |
| S 88/2440 | 15.60 | *G. ruber* | 300–355 | −0.88 | 1.11 |
| S 88/2441 | 15.65 | *G. ruber* | 300–355 | −0.89 | 0.89 |
| S 88/2442 | 15.70 | *G. ruber* | 300–355 | −1.01 | 1.09 |
| S 88/2443 | 15.75 | *G. ruber* | 300–355 | −1.15 | 1.05 |
| S 88/2444 | 15.80 | *G. ruber* | 300–355 | −1.22 | 1.04 |
| S 88/2445 | 15.85 | *G. ruber* | 300–355 | −1.27 | 1.05 |
| S 88/2446 | 15.90 | *G. ruber* | 300–355 | −1.27 | 1.01 |
| S 88/2447 | 15.95 | *G. ruber* | 300–355 | −1.13 | 0.92 |
| S 88/2448 | 16.00 | *G. ruber* | 300–355 | −1.05 | 0.84 |
| S 88/2449 | 16.05 | *G. ruber* | 300–355 | −0.96 | 1.09 |
| S 88/2450 | 16.10 | *G. ruber* | 300–355 | −1.25 | 1.10 |
| S 88/2901 | 16.15 | *G. ruber* | 300–355 | −1.09 | 1.23 |
| S 88/2902 | 16.20 | *G. ruber* | 300–355 | −0.97 | 1.23 |
| A 89/15 | 16.25 | *G. ruber* | 300–355 | −1.07 | 1.02 |
| S 88/2904 | 16.30 | *G. ruber* | 300–355 | −1.01 | 1.37 |
| S 88/2905 | 16.35 | *G. ruber* | 300–355 | −1.09 | 1.28 |
| S 88/2476 | 16.40 | *G. ruber* | 300–355 | −0.89 | 0.89 |
| S 88/2477 | 16.45 | *G. ruber* | 300–355 | −1.08 | 1.26 |
| S 88/2478 | 16.50 | *G. ruber* | 300–355 | −1.12 | 1.17 |
| S 88/2479 | 16.55 | *G. ruber* | 300–355 | −0.98 | 1.29 |
| S 88/2907 | 16.60 | *G. ruber* | 300–355 | −1.19 | 1.37 |
| S 88/2581 | 16.65 | *G. ruber* | | −0.95 | 1.46 |
| S 88/2906 | 16.70 | *G. ruber* | 300–355 | −1.19 | 1.29 |
| S 88/2583 | 16.75 | *G. ruber* | | −1.04 | 1.31 |
| S 88/2584 | 16.80 | *G. ruber* | | −1.11 | 1.10 |
| S 88/2585 | 16.85 | *G. ruber* | | −0.76 | 0.92 |
| S 88/2586 | 16.95 | *G. ruber* | | −0.94 | 1.54 |
| S 88/2587 | 17.00 | *G. ruber* | | −1.31 | 1.46 |
| S 88/2588 | 17.05 | *G. ruber* | | −1.16 | 1.41 |
| S 88/2589 | 17.10 | *G. ruber* | | −1.38 | 1.45 |
| S 88/2590 | 17.15 | *G. ruber* | | −1.37 | 1.19 |
| S 88/2591 | 17.20 | *G. ruber* | | −1.15 | 1.07 |
| S 88/2592 | 17.25 | *G. ruber* | | −1.26 | 1.31 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| S 88/2593 | 17.30 | *G. ruber* | | −1.46 | 1.50 |
| S 88/2594 | 17.35 | *G. ruber* | | −1.33 | 1.53 |
| S 88/2595 | 17.40 | *G. ruber* | | −1.06 | 1.52 |
| S 88/2596 | 17.45 | *G. ruber* | | −1.11 | 1.53 |
| S 88/2597 | 17.50 | *G. ruber* | | −1.21 | 1.46 |
| S 88/2598 | 17.55 | *G. ruber* | | −1.07 | 1.38 |
| S 88/2599 | 17.60 | *G. ruber* | | −1.09 | 1.41 |
| S 88/2600 | 17.65 | *G. ruber* | | −1.15 | 1.49 |
| S 88/2801 | 17.70 | *G. ruber* | 300–355 | −1.00 | 1.33 |
| S 88/2802 | 17.75 | *G. ruber* | 300–355 | −0.86 | 1.14 |
| S 88/2803 | 17.80 | *G. ruber* | 300–355 | −0.77 | 1.19 |
| S 88/2804 | 17.85 | *G. ruber* | 300–355 | −0.77 | 1.20 |
| S 88/2805 | 17.90 | *G. ruber* | 300–355 | −0.90 | 1.45 |
| S 88/2806 | 17.95 | *G. ruber* | 300–355 | −0.99 | 1.46 |
| S 88/2807 | 18.00 | *G. ruber* | 300–355 | −1.13 | 1.32 |
| S 88/2808 | 18.05 | *G. ruber* | 300–355 | −1.25 | 1.43 |
| S 88/2810 | 18.10 | *G. ruber* | 300–355 | −1.26 | 1.17 |
| S 88/2811 | 18.15 | *G. ruber* | 300–355 | −1.11 | 1.22 |
| S 88/2812 | 18.20 | *G. ruber* | 300–355 | −0.99 | 1.56 |
| S 88/2813 | 18.25 | *G. ruber* | 300–355 | −1.06 | 1.50 |
| S 88/2814 | 18.30 | *G. ruber* | 300–355 | −1.03 | 1.51 |
| S 88/2815 | 18.35 | *G. ruber* | 300–355 | −0.97 | 1.25 |
| S 88/2816 | 18.45 | *G. ruber* | 300–355 | −1.16 | 1.48 |
| S 88/2817 | 18.50 | *G. ruber* | 300–355 | −1.28 | 1.60 |
| S 88/2818 | 18.55 | *G. ruber* | 300–355 | −1.14 | 1.62 |
| S 88/2819 | 18.60 | *G. ruber* | 300–355 | −0.89 | 1.50 |
| S 88/2820 | 18.65 | *G. ruber* | 300–355 | −0.96 | 1.44 |
| A 89/9 | 18.70 | *G. ruber* | 300–355 | −0.95 | 1.39 |
| A 89/10 | 18.75 | *G. ruber* | 300–355 | −1.02 | 1.27 |
| S 88/2910 | 18.80 | *G. ruber* | 300–355 | −0.89 | 1.36 |
| A 89/11 | 18.85 | *G. ruber* | 300–355 | −0.96 | 1.27 |
| S 88/2912 | 18.90 | *G. ruber* | 300–355 | −0.75 | 1.24 |
| S 88/2913 | 18.95 | *G. ruber* | 300–355 | −0.86 | 1.21 |
| A 89/12 | 19.00 | *G. ruber* | 300–355 | −0.70 | 1.22 |
| S 88/2915 | 19.05 | *G. ruber* | 300–355 | −1.07 | 1.26 |
| S 88/2916 | 19.10 | *G. ruber* | 300–355 | −1.15 | 1.37 |
| S 88/2917 | 19.15 | *G. ruber* | 300–355 | −1.13 | 1.39 |
| A 89/13 | 19.20 | *G. ruber* | 300–355 | −1.42 | 1.27 |
| S 88/2919 | 19.25 | *G. ruber* | 300–355 | −1.24 | 1.23 |
| A 89/14 | 19.30 | *G. ruber* | 300–355 | −0.93 | 1.26 |
| S 88/2941 | 19.35 | *G. ruber* | 300–355 | −1.10 | 1.45 |
| S 88/2942 | 19.40 | *G. ruber* | 300–355 | −1.13 | 1.10 |
| S 88/2943 | 19.45 | *G. ruber* | 300–355 | −0.80 | 1.17 |
| S 88/2944 | 19.50 | *G. ruber* | 300–355 | −0.50 | 1.16 |
| S 88/2945 | 19.55 | *G. ruber* | 300–355 | −0.68 | 1.00 |
| S 88/2946 | 19.60 | *G. ruber* | 300–355 | −0.97 | 1.19 |
| S 88/2947 | 19.65 | *G. ruber* | 300–355 | −1.03 | 1.29 |
| S 88/2948 | 19.70 | *G. ruber* | 300–355 | −1.16 | 1.40 |
| S 88/2949 | 19.75 | *G. ruber* | 300–355 | −1.21 | 1.33 |
| S 88/2950 | 19.80 | *G. ruber* | 300–355 | −1.19 | 1.55 |
| S 88/2951 | 19.85 | *G. ruber* | 300–355 | −1.40 | 1.67 |
| A 89/593 | 19.95 | *G. ruber* | 300–355 | −1.37 | 1.52 |
| S 88/2952 | 20.00 | *G. ruber* | 300–355 | −1.38 | 1.40 |
| S 88/2953 | 20.05 | *G. ruber* | 300–355 | −1.25 | 1.37 |
| S 88/2954 | 20.10 | *G. ruber* | 300–355 | −1.16 | 1.40 |
| S 88/2955 | 20.15 | *G. ruber* | 300–355 | −1.05 | 1.41 |
| S 88/2956 | 20.15 | *G. ruber* | 300–355 | −0.97 | 1.40 |
| S 88/2957 | 20.20 | *G. ruber* | 300–355 | −1.04 | 1.39 |
| S 88/2958 | 20.25 | *G. ruber* | 300–355 | −1.25 | 1.43 |
| S 88/2959 | 20.30 | *G. ruber* | 300–355 | −1.33 | 1.38 |
| S 88/2960 | 20.35 | *G. ruber* | 300–355 | −1.73 | 1.40 |
| S 88/2981 | 20.40 | *G. ruber* | 300–355 | −1.30 | 1.38 |
| S 88/2982 | 20.45 | *G. ruber* | 300–355 | −1.30 | 1.32 |
| S 88/2983 | 20.50 | *G. ruber* | 300–355 | −1.55 | 1.41 |
| S 88/2984 | 20.55 | *G. ruber* | 300–355 | −1.50 | 1.17 |
| S 88/2985 | 20.60 | *G. ruber* | 300–355 | −1.59 | 1.21 |
| S 88/2986 | 20.65 | *G. ruber* | 300–355 | −1.28 | 1.12 |
| A 89/16 | 20.70 | *G. ruber* | 300–355 | −1.07 | 1.01 |
| S 88/2988 | 20.75 | *G. ruber* | 300–355 | −1.31 | 1.29 |
| S 88/2989 | 20.80 | *G. ruber* | 300–355 | −1.51 | 1.44 |
| S 88/2990 | 20.85 | *G. ruber* | 300–355 | −1.46 | 1.38 |
| S 88/3011 | 20.90 | *G. ruber* | 300–355 | −1.52 | 1.42 |
| S 88/3012 | 20.95 | *G. ruber* | 300–355 | −1.40 | 1.32 |
| S 88/3013 | 21.00 | *G. ruber* | 300–355 | −1.46 | 1.30 |
| S 88/3014 | 21.05 | *G. ruber* | 300–355 | −1.45 | 1.33 |
| S 88/3015 | 21.10 | *G. ruber* | 300–355 | −1.28 | 1.10 |
| S 88/3016 | 21.15 | *G. ruber* | 300–355 | −1.07 | 1.40 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| S 88/3017 | 21.20 | *G. ruber* | 300–355 | −1.14 | 1.41 |
| S 88/3018 | 21.25 | *G. ruber* | 300–355 | −1.27 | 1.46 |
| S 88/3019 | 21.30 | *G. ruber* | 300–355 | −1.69 | 1.38 |
| S 88/3020 | 21.35 | *G. ruber* | 300–355 | −1.69 | 1.58 |
| S 88/3325 | 21.45 | *G. ruber* | 300–355 | −1.14 | 1.27 |
| S 88/3326 | 21.50 | *G. ruber* | 300–355 | −1.09 | 1.33 |
| S 88/3327 | 21.55 | *G. ruber* | 300–355 | −1.15 | 1.41 |
| S 88/3328 | 21.60 | *G. ruber* | 300–355 | −1.17 | 1.43 |
| S 88/3329 | 21.65 | *G. ruber* | 300–355 | −0.84 | 1.52 |
| S 88/3330 | 21.70 | *G. ruber* | 300–355 | −1.14 | 1.38 |
| S 88/3331 | 21.75 | *G. ruber* | 300–355 | −1.39 | 1.48 |
| S 88/3332 | 21.80 | *G. ruber* | 300–355 | −1.47 | 1.63 |
| S 88/3333 | 21.85 | *G. ruber* | 300–355 | −1.02 | 1.63 |
| S 88/3334 | 21.90 | *G. ruber* | 300–355 | −0.96 | 1.47 |
| S 88/3335 | 21.95 | *G. ruber* | 300–355 | −0.95 | 1.37 |
| S 88/3336 | 22.00 | *G. ruber* | 300–355 | −0.89 | 1.48 |
| S 88/3337 | 22.05 | *G. ruber* | 300–355 | −0.73 | 1.73 |
| S 88/3338 | 22.10 | *G. ruber* | 300–355 | −0.72 | 1.77 |
| S 88/3339 | 22.15 | *G. ruber* | 300–355 | −0.93 | 1.68 |
| S 88/3340 | 22.20 | *G. ruber* | 300–355 | −0.92 | 1.88 |
| S 88/3561 | 22.25 | *G. ruber* | 300–355 | −0.99 | 1.73 |
| S 88/3562 | 22.30 | *G. ruber* | 300–355 | −1.00 | 1.74 |
| S 88/3563 | 22.35 | *G. ruber* | 300–355 | −0.92 | 1.90 |
| S 88/3564 | 22.40 | *G. ruber* | 300–355 | −0.96 | 1.72 |
| S 88/3565 | 22.45 | *G. ruber* | 300–355 | −0.95 | 1.75 |
| S 88/3566 | 22.50 | *G. ruber* | 300–355 | −1.05 | 1.70 |
| S 88/3567 | 22.55 | *G. ruber* | 300–355 | −1.05 | 1.70 |
| S 88/3568 | 22.60 | *G. ruber* | 300–355 | −1.17 | 1.77 |
| S 88/3569 | 22.65 | *G. ruber* | 300–355 | −1.02 | 1.55 |
| S 88/3570 | 22.70 | *G. ruber* | 300–355 | −1.13 | 1.58 |
| S 88/3411 | 22.75 | *G. ruber* | 300–355 | −0.91 | 1.33 |
| S 88/3412 | 22.80 | *G. ruber* | 300–355 | −0.89 | 1.33 |
| S 88/3413 | 22.85 | *G. ruber* | 300–355 | −0.83 | 1.22 |
| S 88/3414 | 22.95 | *G. ruber* | 300–355 | −0.85 | 1.28 |
| S 88/3415 | 23.00 | *G. ruber* | 300–355 | −0.83 | 1.38 |
| S 88/3416 | 23.05 | *G. ruber* | 300–355 | −0.83 | 1.27 |
| S 88/3417 | 23.10 | *G. ruber* | 300–355 | −1.03 | 1.52 |
| S 88/3418 | 23.15 | *G. ruber* | 300–355 | −1.17 | 1.44 |
| S 88/3419 | 23.20 | *G. ruber* | 300–355 | −1.26 | 1.56 |
| S 88/3420 | 23.25 | *G. ruber* | 300–355 | −1.18 | 1.55 |
| S 88/3421 | 23.30 | *G. ruber* | 300–355 | −1.20 | 1.55 |
| S 88/3422 | 23.35 | *G. ruber* | 300–355 | −1.31 | 1.35 |
| S 88/3423 | 23.40 | *G. ruber* | 300–355 | −1.17 | 1.29 |
| S 88/3424 | 23.45 | *G. ruber* | 300–355 | −1.11 | 1.14 |
| S 88/3425 | 23.50 | *G. ruber* | 300–355 | −1.05 | 1.04 |
| S 88/3426 | 23.55 | *G. ruber* | 300–355 | −0.74 | 0.94 |
| S 88/3427 | 23.60 | *G. ruber* | 300–355 | −0.51 | 1.12 |
| S 88/3428 | 23.65 | *G. ruber* | 300–355 | −1.03 | 1.33 |
| S 88/3429 | 23.70 | *G. ruber* | 300–355 | −1.22 | 1.30 |
| S 88/3430 | 23.75 | *G. ruber* | 300–355 | −1.21 | 1.16 |
| S 88/3431 | 23.80 | *G. ruber* | 300–355 | −1.21 | 1.23 |
| S 88/3432 | 23.85 | *G. ruber* | 300–355 | −1.05 | 1.03 |
| S 88/3433 | 23.90 | *G. ruber* | 300–355 | −0.90 | 0.88 |
| S 88/3434 | 23.95 | *G. ruber* | 300–355 | −0.90 | 0.95 |
| S 88/3435 | 24.00 | *G. ruber* | 300–355 | −1.06 | 1.00 |
| S 88/3436 | 24.05 | *G. ruber* | 300–355 | −0.81 | 0.98 |
| S 88/3437 | 24.10 | *G. ruber* | 300–355 | −1.05 | 1.08 |
| S 88/3438 | 24.15 | *G. ruber* | 300–355 | −1.18 | 1.14 |
| S 88/3439 | 24.20 | *G. ruber* | 300–355 | −1.22 | 1.15 |
| S 88/3440 | 24.25 | *G. ruber* | 300–355 | −1.38 | 1.51 |
| S 88/3441 | 24.30 | *G. ruber* | 300–355 | −1.35 | 1.55 |
| S 88/3442 | 24.35 | *G. ruber* | 300–355 | −1.20 | 1.50 |
| S 88/3443 | 24.45 | *G. ruber* | 300–355 | −1.15 | 1.55 |
| S 88/3444 | 24.50 | *G. ruber* | 300–355 | −1.03 | 1.56 |
| S 88/3445 | 24.55 | *G. ruber* | 300–355 | −1.14 | 1.57 |
| S 88/3446 | 24.60 | *G. ruber* | 300–355 | −1.05 | 1.56 |
| S 88/3447 | 24.70 | *G. ruber* | 300–355 | −1.11 | 1.51 |
| S 88/3448 | 24.75 | *G. ruber* | 300–355 | −1.35 | 1.40 |
| S 88/3449 | 24.80 | *G. ruber* | 300–355 | −1.18 | 1.57 |
| S 88/3450 | 24.85 | *G. ruber* | 300–355 | −1.37 | 1.35 |
| S 88/3451 | 24.90 | *G. ruber* | 300–355 | −1.27 | 1.21 |
| S 88/3452 | 25.15 | *G. ruber* | 300–355 | −1.39 | 1.37 |
| S 88/3453 | 25.20 | *G. ruber* | 300–355 | −1.15 | 1.23 |
| S 88/3454 | 25.25 | *G. ruber* | 300–355 | −0.82 | 1.38 |
| S 88/3455 | 25.30 | *G. ruber* | 300–355 | −0.82 | 1.40 |
| S 88/3456 | 25.35 | *G. ruber* | 300–355 | −0.98 | 1.35 |
| S 88/3457 | 25.40 | *G. ruber* | 300–355 | −1.04 | 1.38 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| S 88/3458 | 25.45 | *G. ruber* | 300–355 | −1.18 | 1.36 |
| S 88/3459 | 25.50 | *G. ruber* | 300–355 | −1.11 | 1.24 |
| S 88/3460 | 25.55 | *G. ruber* | 300–355 | −1.30 | 1.30 |
| S 88/3461 | 25.60 | *G. ruber* | 300–355 | −1.20 | 1.38 |
| S 88/3462 | 25.65 | *G. ruber* | 300–355 | −1.38 | 1.46 |
| S 88/3463 | 25.70 | *G. ruber* | 300–355 | −1.25 | 1.71 |
| S 88/3464 | 25.75 | *G. ruber* | 300–355 | −1.32 | 1.63 |
| S 88/3465 | 25.80 | *G. ruber* | 300–355 | −1.25 | 1.68 |
| S 88/3466 | 25.85 | *G. ruber* | 300–355 | −1.44 | 1.50 |
| S 88/3467 | 25.90 | *G. ruber* | 300–355 | −1.47 | 1.46 |
| S 88/3468 | 25.95 | *G. ruber* | 300–355 | −1.32 | 1.46 |
| S 88/3469 | 26.00 | *G. ruber* | 300–355 | −1.21 | 1.48 |
| S 88/3470 | 26.05 | *G. ruber* | 300–355 | −1.32 | 1.55 |
| S 88/3471 | 26.10 | *G. ruber* | 300–355 | −1.27 | 1.70 |
| S 88/3472 | 26.15 | *G. ruber* | 300–355 | −1.37 | 1.70 |
| S 88/3473 | 26.20 | *G. ruber* | 300–355 | −1.12 | 1.78 |
| S 88/3474 | 26.25 | *G. ruber* | 300–355 | −1.33 | 1.67 |
| A 89/899 | 26.30 | *G. sacculifer* | 300–355 | −0.79 | 1.36 |
| S 88/3475 | 26.30 | *G. ruber* | 300–355 | −0.96 | 1.39 |
| A 89/17 | 26.35 | *G. ruber* | 300–355 | −1.34 | 1.46 |
| A 89/900 | 26.35 | *G. sacculifer* | 300–355 | −0.79 | 1.50 |
| S 88/3476 | 26.35 | *G. ruber* | 300–355 | −0.34* | 0.99 |
| A 89/971 | 26.40 | *G. sacculifer* | 300–355 | −0.69 | 1.56 |
| S 88/3477 | 26.40 | *G. ruber* | 300–355 | −1.14 | 1.68 |
| A 89/972 | 26.45 | *G. sacculifer* | 300–355 | −0.59 | 1.33 |
| S 88/3478 | 26.45 | *G. ruber* | 300–355 | −1.12 | 1.58 |
| A 89/973 | 26.50 | *G. sacculifer* | 300–355 | −1.01 | 1.58 |
| S 88/3479 | 26.50 | *G. ruber* | 300–355 | −1.22 | 1.63 |
| A 89/18 | 26.55 | *G. ruber* | 300–355 | −1.34 | 1.82 |
| A 89/974 | 26.55 | *G. sacculifer* | 300–355 | −0.62 | 1.68 |
| S 88/3480 | 26.55 | *G. ruber* | 300–355 | 0.40* | 0.77 |
| A 89/975 | 26.65 | *G. sacculifer* | 300–355 | −0.90 | 1.50 |
| S 88/3481 | 26.65 | *G. ruber* | 300–355 | −0.93 | 1.68 |
| A 89/976 | 26.70 | *G. sacculifer* | 300–355 | −0.64 | 1.52 |
| S 88/3482 | 26.70 | *G. ruber* | 300–355 | −0.60 | 1.41 |
| A 88/2136 | 26.75 | *G. ruber* | 300–425 | −1.31 | 1.63 |
| A 89/977 | 26.75 | *G. sacculifer* | 300–355 | −0.71 | 1.46 |
| A 89/978 | 26.80 | *G. sacculifer* | 300–355 | 0.61 | 1.56 |
| S 88/3483 | 26.80 | *G. ruber* | 300–355 | −0.60 | 1.42 |
| A 89/979 | 26.85 | *G. sacculifer* | 300–355 | −0.75 | 1.64 |
| S 88/3484 | 26.85 | *G. ruber* | 300–355 | −1.08 | 1.73 |
| A 89/980 | 26.90 | *G. sacculifer* | 300–355 | −0.89 | 1.50 |
| S 88/3485 | 26.90 | *G. ruber* | 300–355 | −1.12 | 1.68 |
| A 89/981 | 26.95 | *G. sacculifer* | 300–355 | −0.54 | 1.53 |
| S 88/3486 | 26.95 | *G. ruber* | 300–355 | −1.18 | 1.49 |
| A 89/19 | 27.00 | *G. ruber* | 300–355 | −1.25 | 1.62 |
| A 89/982 | 27.00 | *G. sacculifer* | 300–355 | −0.60 | 1.52 |
| S 88/3487 | 27.00 | *G. ruber* | 300–355 | 0.42* | 0.63 |
| A 89/983 | 27.05 | *G. sacculifer* | 300–355 | −0.53 | 1.57 |
| S 88/3488 | 27.05 | *G. ruber* | 300–355 | −0.67 | 1.64 |
| A 89/984 | 27.10 | *G. sacculifer* | 300–355 | −0.71 | 1.55 |
| S 88/3489 | 27.10 | *G. ruber* | 300–355 | −0.99 | 1.54 |
| A 89/985 | 27.15 | *G. sacculifer* | 300–355 | −0.96 | 1.52 |
| S 88/3490 | 27.15 | *G. ruber* | 300–355 | −1.05 | 1.49 |
| A 89/986 | 27.20 | *G. sacculifer* | 300–355 | −0.82 | 1.53 |
| S 88/3491 | 27.20 | *G. ruber* | 300–355 | −1.07 | 1.67 |
| A 89/987 | 27.25 | *G. sacculifer* | 300–355 | −0.89 | 1.48 |
| S 88/3492 | 27.25 | *G. ruber* | 300–355 | −0.99 | 1.35 |
| A 89/988 | 27.30 | *G. sacculifer* | 300–355 | −0.86 | 1.54 |
| S 88/3493 | 27.30 | *G. ruber* | 300–355 | −0.66 | 1.19 |
| A 89/989 | 27.35 | *G. sacculifer* | 300–355 | −0.89 | 1.31 |
| S 88/3494 | 27.35 | *G. ruber* | 300–355 | −1.15 | 1.33 |
| A 89/990 | 27.40 | *G. sacculifer* | 300–355 | −0.70 | 1.29 |
| S 88/3495 | 27.40 | *G. ruber* | 300–355 | −1.03 | 1.22 |
| A 89/991 | 27.45 | *G. sacculifer* | 300–355 | −0.86 | 1.44 |
| S 88/3496 | 27.45 | *G. ruber* | 300–355 | −1.03 | 1.21 |
| A 89/992 | 27.50 | *G. sacculifer* | 300–355 | −0.80 | 1.32 |
| S 88/3497 | 27.50 | *G. ruber* | 300–355 | −1.05 | 1.33 |
| A 88/2137 | 27.55 | *G. ruber* | 300–425 | −1.29 | 1.48 |
| S 88/3498 | 27.60 | *G. ruber* | 300–355 | −1.59 | 1.67 |
| S 88/3499 | 27.65 | *G. ruber* | 300–355 | −1.56 | 1.49 |
| S 88/3500 | 27.70 | *G. ruber* | 300–355 | −1.32 | 1.57 |
| S 88/3571 | 27.75 | *G. ruber* | 300–355 | −1.41 | 1.62 |
| S 88/3572 | 27.80 | *G. ruber* | 300–355 | −1.42 | 1.68 |
| S 88/3573 | 27.85 | *G. ruber* | 300–355 | −1.54 | 1.56 |
| S 88/3574 | 27.90 | *G. ruber* | 300–355 | −1.28 | 1.37 |
| S 88/3575 | 27.95 | *G. ruber* | 300–355 | −1.40 | 1.51 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| S 88/3576 | 28.00 | *G. ruber* | 300–355 | −1.42 | 1.54 |
| A 89/20 | 28.05 | *G. ruber* | 300–355 | −1.54 | 1.52 |
| S 88/3578 | 28.15 | *G. ruber* | 300–355 | −1.60 | 1.28 |
| S 88/3579 | 28.20 | *G. ruber* | 300–355 | −1.20 | 1.26 |
| S 88/3580 | 28.25 | *G. ruber* | 300–355 | −1.21 | 1.48 |
| A 88/2138 | 28.30 | *G. ruber* | 300–355 | −1.37 | 1.46 |
| A 88/2139 | 28.35 | *G. ruber* | 300–355 | −1.43 | 1.51 |
| A 88/2140 | 28.40 | *G. ruber* | 300–355 | −1.34 | 1.57 |
| A 88/2229 | 28.45 | *G. ruber* | 300–355 | −1.32 | 1.34 |
| A 88/2231 | 28.55 | *G. ruber* | 300–355 | −0.85 | 0.83 |
| A 88/2232 | 28.60 | *G. ruber* | 300–355 | −1.50 | 1.30 |
| A 88/2233 | 28.65 | *G. ruber* | 300–355 | −1.44 | 1.21 |
| A 88/2234 | 28.70 | *G. ruber* | 300–355 | −1.42 | 1.56 |
| A 88/2235 | 28.75 | *G. ruber* | 300–355 | −1.34 | 1.30 |
| A 88/2236 | 28.80 | *G. ruber* | 300–355 | −1.63 | 1.40 |
| A 88/2237 | 28.85 | *G. ruber* | 300–355 | −1.22 | 1.67 |
| A 88/2238 | 28.90 | *G. ruber* | 300–355 | −1.33 | 1.46 |
| A 88/2239 | 28.95 | *G. ruber* | 300–355 | −1.31 | 1.42 |
| A 88/2240 | 29.00 | *G. ruber* | 300–355 | −0.85 | 1.63 |
| A 88/2241 | 29.05 | *G. ruber* | 300–355 | −0.96 | 0.81 |
| A 88/2243 | 29.15 | *G. ruber* | 300–355 | −1.17 | 1.31 |
| A 88/2242 | 29.20 | *G. ruber* | 300–355 | −0.78 | 1.38 |
| A 88/2244 | 29.20 | *G. ruber* | 300–355 | −0.66 | 1.45 |
| A 88/2245 | 29.25 | *G. ruber* | 300–355 | −1.53 | 1.35 |
| A 88/2246 | 29.30 | *G. ruber* | 300–355 | −0.86 | 1.21 |
| A 88/2247 | 29.35 | *G. ruber* | 300–355 | −1.01 | 1.05 |
| A 88/2248 | 29.40 | *G. ruber* | 300–355 | −0.98 | 1.25 |
| A 88/2249 | 29.45 | *G. ruber* | 300–355 | −1.14 | 1.35 |
| A 88/2250 | 29.50 | *G. ruber* | 300–355 | −1.27 | 1.17 |
| A 88/2251 | 29.55 | *G. ruber* | 300–355 | −1.00 | 1.32 |
| A 88/2252 | 29.65 | *G. ruber* | 300–355 | −0.30 | 1.42 |
| A 88/2253 | 29.70 | *G. ruber* | 300–355 | −0.84 | 1.34 |
| A 88/2254 | 29.75 | *G. ruber* | 300–355 | −1.23 | 1.24 |
| A 88/2255 | 29.80 | *G. ruber* | 300–355 | −1.47 | 1.33 |
| A 88/2256 | 29.85 | *G. ruber* | 300–355 | −1.44 | 1.46 |
| A 88/2258 | 29.95 | *G. ruber* | 300–355 | −1.39 | 1.40 |
| A 88/2259 | 30.00 | *G. ruber* | 300–355 | −1.12 | 1.53 |
| A 88/2260 | 30.05 | *G. ruber* | 300–355 | −1.34 | 1.41 |
| A 88/2262 | 30.15 | *G. ruber* | 300–355 | −1.38 | 1.51 |
| A 88/2263 | 30.20 | *G. ruber* | 300–355 | −1.46 | 1.65 |
| A 88/2264 | 30.25 | *G. ruber* | 300–355 | −1.38 | 1.57 |
| A 88/2266 | 30.35 | *G. ruber* | 300–355 | −1.42 | 1.69 |
| A 88/2267 | 30.40 | *G. ruber* | 300–355 | −1.45 | 1.72 |
| A 88/2268 | 30.45 | *G. ruber* | 300–355 | −1.30 | 1.40 |
| A 88/2269 | 30.50 | *G. ruber* | 300–355 | −0.88 | 1.73 |
| A 88/2270 | 30.55 | *G. ruber* | 300–355 | −1.21 | 1.60 |
| A 88/2271 | 30.60 | *G. ruber* | 300–355 | −1.28 | 1.50 |
| A 88/2272 | 30.65 | *G. ruber* | 300–355 | −1.45 | 1.25 |
| A 88/2273 | 30.70 | *G. ruber* | 300–355 | −1.24 | 1.40 |
| A 88/2274 | 30.75 | *G. ruber* | 300–355 | −1.17 | 1.64 |
| A 88/2647 | 30.80 | *G. ruber* | 300–355 | −1.24 | 1.39 |
| A 88/2275 | 30.85 | *G. ruber* | 300–355 | −0.86 | 0.75 |
| A 88/2276 | 30.90 | *G. ruber* | 300–355 | −1.12 | 1.45 |
| A 88/2277 | 30.95 | *G. ruber* | 300–355 | −1.17 | 1.20 |
| A 88/2278 | 31.00 | *G. ruber* | 300–355 | −1.20 | 1.15 |
| A 88/2280 | 31.15 | *G. ruber* | 300–355 | −1.03 | 1.21 |
| A 88/2281 | 31.20 | *G. ruber* | 300–355 | −1.05 | 1.12 |
| A 88/2283 | 31.30 | *G. ruber* | 300–355 | −1.43 | 1.24 |
| A 88/2284 | 31.35 | *G. ruber* | 300–355 | −1.18 | 1.23 |
| A 88/2285 | 31.40 | *G. ruber* | 300–355 | −1.49 | 1.22 |
| A 88/2286 | 31.45 | *G. ruber* | 300–355 | −1.44 | 1.32 |
| A 88/2287 | 31.50 | *G. ruber* | 300–355 | −1.36 | 0.98 |
| A 88/2288 | 31.55 | *G. ruber* | 300–355 | −1.50 | 1.22 |
| A 88/2290 | 31.65 | *G. ruber* | 300–355 | −1.30 | 1.59 |
| A 88/2291 | 31.70 | *G. ruber* | 300–355 | −1.41 | 1.15 |
| A 88/2293 | 31.80 | *G. ruber* | 300–355 | −1.21 | 1.45 |
| A 88/2322 | 31.90 | *G. ruber* | 300–355 | −1.36 | 1.09 |
| A 88/2323 | 31.95 | *G. ruber* | 300–355 | −1.46 | 1.19 |
| A 88/2324 | 32.00 | *G. ruber* | 300–355 | −1.29 | 1.00 |
| A 88/2325 | 32.05 | *G. ruber* | 300–355 | −1.17 | 1.03 |
| A 88/2326 | 32.10 | *G. ruber* | 300–355 | −0.97 | 1.41 |
| A 88/2327 | 32.15 | *G. ruber* | 300–355 | −1.05 | 1.18 |
| A 88/2329 | 32.30 | *G. ruber* | 300–355 | −1.28 | 1.13 |
| A 88/2330 | 32.35 | *G. ruber* | 300–355 | −1.66 | 1.39 |
| A 88/2332 | 32.40 | *G. ruber* | 300–355 | −1.47 | 1.23 |
| A 88/2333 | 32.45 | *G. ruber* | 300–355 | −1.76 | 1.12 |
| A 88/2335 | 32.50 | *G. ruber* | 300–355 | −1.45 | 1.30 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| A 88/2336 | 32.55 | *G. ruber* | 300–355 | −1.54 | 1.17 |
| A 89/208 | 32.70 | *G. ruber* | 300–355 | −1.73 | 1.31 |
| A 88/2337 | 32.75 | *G. ruber* | 300–355 | −1.39 | 1.48 |
| A 88/2338 | 32.80 | *G. ruber* | 300–355 | −2.06 | 1.21 |
| A 88/2339 | 32.85 | *G. ruber* | 300–355 | −1.64 | 1.62 |
| A 88/2340 | 32.90 | *G. ruber* | 300–355 | −1.97 | 1.23 |
| A 88/2648 | 32.95 | *G. ruber* | 300–355 | −1.77 | 1.49 |
| A 88/2649 | 33.00 | *G. ruber* | 300–355 | −1.62 | 1.49 |
| A 88/2650 | 33.05 | *G. ruber* | 300–355 | −1.60 | 1.29 |
| A 89/1 | 33.10 | *G. ruber* | 300–355 | −1.60 | 1.42 |
| A 89/2 | 33.15 | *G. ruber* | 300–355 | −1.53 | 1.26 |
| A 89/3 | 33.20 | *G. ruber* | 300–355 | −1.56 | 1.29 |
| A 89/4 | 33.25 | *G. ruber* | 300–355 | −0.45 | 1.39 |
| A 89/5 | 33.30 | *G. ruber* | 300–355 | −1.33 | 1.57 |
| A 89/6 | 33.35 | *G. ruber* | 300–355 | −1.55 | 1.79 |
| A 89/7 | 33.40 | *G. ruber* | 300–355 | −1.32 | 1.58 |
| A 89/8 | 33.45 | *G. ruber* | 300–355 | −1.20 | 1.63 |
| A 89/214 | 33.50 | *G. ruber* | 300–355 | −1.31 | 1.73 |
| A 89/595 | 33.50 | *G. sacculifer* | 300–355 | −0.93 | 1.70 |
| A 89/22 | 33.55 | *G. ruber* | 300–355 | −1.29 | 1.54 |
| A 89/23 | 33.60 | *G. ruber* | 300–355 | −1.03 | 1.77 |
| A 89/24 | 33.65 | *G. ruber* | 300–355 | −1.25 | 1.72 |
| A 89/25 | 33.70 | *G. ruber* | 300–355 | −1.31 | 1.59 |
| A 89/213 | 33.75 | *G. ruber* | 300–355 | −1.33 | 1.76 |
| A 89/594 | 33.75 | *G. ruber* | 300–355 | −1.41 | 1.62 |
| A 89/27 | 33.80 | *G. ruber* | 300–355 | −1.19 | 1.56 |
| A 89/28 | 33.85 | *G. ruber* | 300–355 | −1.46 | 1.48 |
| A 89/29 | 33.90 | *G. ruber* | 300–355 | −1.46 | 1.32 |
| A 89/30 | 33.95 | *G. ruber* | 300–355 | −1.29 | 1.44 |
| A 89/31 | 34.00 | *G. ruber* | 300–355 | −1.43 | 1.27 |
| A 89/32 | 34.05 | *G. ruber* | 300–355 | −1.15 | 1.44 |
| A 89/33 | 34.15 | *G. ruber* | 300–355 | −1.41 | 1.59 |
| A 89/34 | 34.20 | *G. ruber* | 300–355 | −1.18 | 1.79 |
| A 89/35 | 34.30 | *G. ruber* | 300–355 | −1.49 | 1.63 |
| A 89/36 | 34.35 | *G. ruber* | 300–355 | −1.71 | 1.71 |
| A 89/37 | 34.40 | *G. ruber* | 300–355 | −1.18 | 1.60 |
| A 89/38 | 34.40 | *G. ruber* | 300–355 | −1.07 | 1.70 |
| A 89/39 | 34.45 | *G. ruber* | 300–355 | −1.18 | 1.56 |
| A 89/40 | 34.50 | *G. ruber* | 300–355 | −1.42 | 1.49 |
| A 89/41 | 34.55 | *G. ruber* | 300–355 | −1.11 | 1.50 |
| A 89/42 | 34.60 | *G. ruber* | 300–355 | −1.19 | 1.41 |
| A 89/43 | 34.65 | *G. ruber* | 300–355 | −1.27 | 1.42 |
| A 89/44 | 34.70 | *G. ruber* | 300–355 | −1.21 | 1.47 |
| A 89/48 | 34.75 | *G. ruber* | 300–355 | −0.84 | 1.19 |
| A 89/49 | 34.80 | *G. ruber* | 300–355 | −1.19 | 1.40 |
| A 89/50 | 34.85 | *G. ruber* | 300–355 | −1.14 | 1.47 |
| A 89/51 | 34.90 | *G. ruber* | 300–355 | −1.29 | 1.51 |
| A 89/45 | 34.92 | *G. ruber* | 300–355 | −1.30 | 1.47 |
| A 89/52 | 34.95 | *G. ruber* | 300–355 | −1.37 | 1.48 |
| A 89/46 | 34.97 | *G. ruber* | 300–355 | −1.14 | 1.45 |
| A 89/53 | 35.00 | *G. ruber* | 300–355 | −1.32 | 1.45 |
| A 89/47 | 35.02 | *G. ruber* | 300–355 | −1.17 | 1.62 |
| A 89/54 | 35.05 | *G. ruber* | 300–355 | −1.01 | 1.48 |
| A 89/55 | 35.10 | *G. ruber* | 300–355 | −0.86 | 1.30 |
| A 89/56 | 35.15 | *G. ruber* | 300–355 | −0.94 | 1.48 |
| A 89/57 | 35.20 | *G. ruber* | 300–355 | −0.91 | 1.40 |
| A 89/58 | 35.25 | *G. ruber* | 300–355 | −1.10 | 1.33 |
| A 89/59 | 35.30 | *G. ruber* | 300–355 | −1.24 | 1.36 |
| A 89/60 | 35.35 | *G. ruber* | 300–355 | −1.21 | 1.35 |
| A 89/158 | 35.40 | *G. ruber* | 300–355 | −1.32 | 1.62 |
| A 89/159 | 35.45 | *G. ruber* | 300–355 | −0.98 | 1.57 |
| A 89/160 | 35.50 | *G. ruber* | 300–355 | −1.12 | 1.36 |
| A 89/161 | 35.55 | *G. ruber* | 300–355 | −1.31 | 1.59 |
| A 89/596 | 35.60 | *G. sacculifer* | 300–355 | −1.23 | 1.42 |
| A 89/163 | 35.65 | *G. ruber* | 300–355 | −1.12 | 1.24 |
| A 89/993 | 35.65 | *G. sacculifer* | 300–355 | −1.18 | 1.32 |
| A 89/597 | 35.70 | *G. sacculifer* | 300–355 | −1.21 | 1.40 |
| A 89/994 | 35.70 | *G. sacculifer* | 300–355 | −1.12 | 1.35 |
| A 89/165 | 35.75 | *G. ruber* | 300–355 | −1.28 | 1.43 |
| A 89/995 | 35.75 | *G. sacculifer* | 300–355 | −0.84 | 1.47 |
| A 89/166 | 35.80 | *G. ruber* | 300–355 | −1.02 | 1.33 |
| A 89/996 | 35.80 | *G. sacculifer* | 300–355 | −0.93 | 1.39 |
| A 89/167 | 35.85 | *G. ruber* | 300–355 | −1.06 | 1.57 |
| A 89/997 | 35.85 | *G. sacculifer* | 300–355 | −1.11 | 1.36 |
| A 89/998 | 35.90 | *G. sacculifer* | 300–355 | −1.20 | 1.25 |
| A 89/169 | 35.95 | *G. ruber* | 300–355 | −3.37* | 0.50 |
| A 89/999 | 35.95 | *G. sacculifer* | 300–355 | −1.35 | 1.07 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| A 89/1010 | 35.95 | *G. ruber* | 300–355 | −1.52 | 1.05 |
| A 89/170 | 36.00 | *G. ruber* | 300–355 | −1.77 | 1.04 |
| A 89/1000 | 36.00 | *G. sacculifer* | 300–355 | −1.58 | 1.10 |
| A 89/205 | 36.05 | *G. ruber* | 300–355 | −1.34 | 1.05 |
| A 89/1001 | 36.05 | *G. sacculifer* | 300–355 | −1.55 | 1.23 |
| A 89/206 | 36.10 | *G. ruber* | 300–355 | −1.75 | 1.34 |
| A 89/1002 | 36.10 | *G. sacculifer* | 300–355 | −1.05 | 1.17 |
| A 89/207 | 36.15 | *G. ruber* | 300–355 | −1.63 | 1.61 |
| A 89/1003 | 36.15 | *G. sacculifer* | 300–355 | −1.14 | 1.16 |
| A 89/209 | 36.25 | *G. ruber* | 300–355 | −1.74 | 1.27 |
| A 89/1004 | 36.25 | *G. sacculifer* | 300–355 | −1.49 | 1.40 |
| A 89/210 | 36.30 | *G. ruber* | 300–355 | −1.67 | 1.75 |
| A 89/1005 | 36.30 | *G. sacculifer* | 300–355 | −1.41 | 1.39 |
| A 89/211 | 36.35 | *G. ruber* | 300–355 | −1.71 | 1.25 |
| A 89/1006 | 36.35 | *G. sacculifer* | 300–355 | −1.26 | 1.40 |
| A 89/212 | 36.40 | *G. ruber* | 300–355 | −1.76 | 1.28 |
| A 89/1007 | 36.40 | *G. sacculifer* | 300–355 | −1.15 | 1.42 |
| A 89/215 | 36.45 | *G. ruber* | 300–355 | −1.43 | 1.22 |
| A 89/1008 | 36.45 | *G. sacculifer* | 300–355 | −1.27 | 1.37 |
| A 89/216 | 36.50 | *G. ruber* | 300–355 | −1.38 | 1.22 |
| A 89/1009 | 36.50 | *G. sacculifer* | 300–355 | −1.41 | 1.38 |
| A 89/217 | 36.55 | *G. sacculifer* | 300–355 | −1.27 | 1.28 |
| A 89/218 | 36.60 | *G. sacculifer* | 300–355 | −1.01 | 1.12 |
| A 89/219 | 36.65 | *G. sacculifer* | 300–355 | −1.03 | 1.26 |
| A 89/220 | 36.70 | *G. sacculifer* | 300–355 | −0.99 | 1.33 |
| A 89/228 | 36.75 | *G. sacculifer* | 300–355 | −0.86 | 1.51 |
| A 89/229 | 36.85 | *G. sacculifer* | 300–355 | −0.68 | 1.35 |
| A 89/230 | 36.90 | *G. sacculifer* | 300–355 | −1.08 | 1.40 |
| A 89/231 | 36.95 | *G. sacculifer* | 300–355 | −1.20 | 1.19 |
| A 89/232 | 37.00 | *G. sacculifer* | 300–355 | −1.09 | 1.19 |
| A 89/233 | 37.05 | *G. sacculifer* | 300–355 | −1.10 | 1.15 |
| A 89/234 | 37.10 | *G. sacculifer* | 300–355 | −0.78 | 1.03 |
| A 89/235 | 37.15 | *G. sacculifer* | 300–355 | −1.07 | 1.22 |
| A 89/236 | 37.20 | *G. sacculifer* | 300–355 | −1.12 | 1.25 |
| A 89/237 | 37.25 | *G. sacculifer* | 300–355 | −1.23 | 1.13 |
| A 89/238 | 37.30 | *G. sacculifer* | 300–355 | −0.89 | 1.27 |
| A 89/239 | 37.35 | *G. sacculifer* | 300–355 | −0.97 | 1.17 |
| A 89/598 | 37.40 | *G. sacculifer* | 300–355 | −1.09 | 1.35 |
| A 89/241 | 37.45 | *G. sacculifer* | 300–355 | −1.04 | 1.21 |
| A 89/242 | 37.50 | *G. sacculifer* | 300–355 | −0.77 | 1.32 |
| A 89/243 | 37.55 | *G. sacculifer* | 300–355 | −0.65 | 1.43 |
| A 89/244 | 37.60 | *G. sacculifer* | 300–355 | −0.82 | 1.58 |
| A 89/245 | 37.65 | *G. sacculifer* | 300–355 | −0.95 | 1.20 |
| A 89/246 | 37.75 | *G. sacculifer* | 300–355 | −0.87 | 1.28 |
| A 89/247 | 37.80 | *G. sacculifer* | 300–355 | −0.55 | 1.46 |
| A 89/248 | 37.85 | *G. sacculifer* | 300–355 | −0.77 | 1.29 |
| A 89/249 | 37.90 | *G. sacculifer* | 300–355 | −0.46 | 1.14 |
| A 89/250 | 37.95 | *G. sacculifer* | 300–355 | −0.94 | 1.27 |
| A 89/251 | 38.00 | *G. sacculifer* | 300–355 | −0.67 | 1.33 |
| A 89/252 | 38.05 | *G. sacculifer* | 300–355 | −0.71 | 1.44 |
| A 89/253 | 38.10 | *G. sacculifer* | 300–355 | −0.87 | 1.26 |
| A 89/254 | 38.15 | *G. sacculifer* | 300–355 | −0.72 | 1.45 |
| A 89/255 | 38.20 | *G. sacculifer* | 300–355 | −0.71 | 1.48 |
| A 89/256 | 38.25 | *G. sacculifer* | 300–355 | −0.83 | 1.42 |
| A 89/257 | 38.30 | *G. sacculifer* | 300–355 | −0.81 | 1.29 |
| A 89/258 | 38.35 | *G. sacculifer* | 300–355 | −0.91 | 1.28 |
| A 89/259 | 38.40 | *G. sacculifer* | 300–355 | −0.69 | 1.54 |
| A 89/260 | 38.45 | *G. sacculifer* | 300–355 | −0.73 | 1.52 |
| A 89/292 | 38.50 | *G. sacculifer* | 300–355 | −0.74 | 1.46 |
| A 89/293 | 38.55 | *G. sacculifer* | 300–355 | −0.95 | 1.55 |
| A 89/294 | 38.60 | *G. sacculifer* | 300–355 | −0.77 | 1.58 |
| A 89/295 | 38.65 | *G. sacculifer* | 300–355 | −0.62 | 1.58 |
| A 89/296 | 38.70 | *G. sacculifer* | 300–355 | −0.79 | 1.57 |
| A 89/599 | 38.75 | *G. sacculifer* | 300–355 | −0.87 | 1.42 |
| A 89/298 | 38.80 | *G. sacculifer* | 300–355 | −0.71 | 1.54 |
| A 89/299 | 38.85 | *G. sacculifer* | 300–355 | −0.86 | 1.50 |
| A 89/300 | 38.90 | *G. sacculifer* | 300–355 | −0.82 | 1.27 |
| A 89/301 | 38.95 | *G. sacculifer* | 300–355 | −0.75 | 1.57 |
| A 89/302 | 39.00 | *G. sacculifer* | 300–355 | −0.90 | 1.46 |
| A 89/303 | 39.05 | *G. sacculifer* | 300–355 | −1.01 | 1.42 |
| A 89/304 | 39.10 | *G. sacculifer* | 300–355 | −0.99 | 1.48 |
| A 89/305 | 39.15 | *G. sacculifer* | 300–355 | −1.05 | 1.41 |
| A 89/306 | 39.25 | *G. sacculifer* | 300–355 | −0.95 | 1.60 |
| A 89/307 | 39.30 | *G. sacculifer* | 300–355 | −1.18 | 1.50 |
| A 89/600 | 39.35 | *G. sacculifer* | 300–355 | −0.96 | 1.36 |
| A 89/601 | 39.40 | *G. sacculifer* | 300–355 | −1.00 | 1.65 |
| A 89/310 | 39.45 | *G. sacculifer* | 300–355 | −0.68 | 1.50 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| A 89/311 | 39.50 | *G. sacculifer* | 300–355 | −0.86 | 1.58 |
| A 89/312 | 39.55 | *G. sacculifer* | 300–355 | −0.82 | 1.76 |
| A 89/313 | 39.60 | *G. sacculifer* | 300–355 | −0.90 | 1.37 |
| A 89/314 | 39.65 | *G. sacculifer* | 300–355 | −0.90 | 1.44 |
| A 89/315 | 39.70 | *G. sacculifer* | 300–355 | −1.00 | 1.42 |
| A 89/316 | 39.75 | *G. sacculifer* | 300–355 | −0.78 | 1.40 |
| A 89/317 | 39.80 | *G. sacculifer* | 300–355 | −0.78 | 1.42 |
| A 89/318 | 39.85 | *G. sacculifer* | 300–355 | −0.63 | 1.48 |
| A 89/319 | 39.90 | *G. sacculifer* | 300–355 | −0.79 | 1.43 |
| A 89/320 | 39.95 | *G. sacculifer* | 300–355 | −0.71 | 1.31 |
| A 89/330 | 40.00 | *G. sacculifer* | 300–355 | −0.68 | 1.24 |
| A 89/331 | 40.05 | *G. sacculifer* | 300–355 | −0.70 | 1.31 |
| A 89/333 | 40.10 | *G. sacculifer* | 300–355 | −0.73 | 1.35 |
| A 89/334 | 40.15 | *G. sacculifer* | 300–355 | −0.74 | 1.40 |
| A 89/335 | 40.20 | *G. sacculifer* | 300–355 | −0.82 | 1.05 |
| A 89/336 | 40.25 | *G. sacculifer* | 300–355 | −0.59 | 1.22 |
| A 89/602 | 40.30 | *G. sacculifer* | 300–355 | −0.88 | 1.21 |
| A 89/338 | 40.35 | *G. sacculifer* | 300–355 | −0.83 | 1.29 |
| A 89/339 | 40.40 | *G. sacculifer* | 300–355 | −0.81 | 1.12 |
| A 89/603 | 40.45 | *G. sacculifer* | 300–355 | −1.11 | 1.20 |
| A 89/341 | 40.50 | *G. sacculifer* | 300–355 | −0.79 | 1.39 |
| A 89/342 | 40.55 | *G. sacculifer* | 300–355 | −0.92 | 1.10 |
| A 89/343 | 40.60 | *G. sacculifer* | 300–355 | −0.96 | 1.29 |
| A 89/344 | 40.65 | *G. sacculifer* | 300–355 | −1.09 | 1.35 |
| A 89/345 | 40.75 | *G. sacculifer* | 300–355 | −0.85 | 1.37 |
| A 89/346 | 40.80 | *G. sacculifer* | 300–355 | −1.05 | 1.56 |
| A 89/347 | 40.85 | *G. sacculifer* | 300–355 | −0.68 | 1.18 |
| A 89/348 | 40.90 | *G. sacculifer* | 300–355 | −0.99 | 1.43 |
| A 89/349 | 40.95 | *G. sacculifer* | 300–355 | −1.09 | 1.36 |
| A 89/350 | 41.00 | *G. sacculifer* | 300–355 | −1.09 | 1.32 |
| A 89/351 | 41.05 | *G. sacculifer* | 300–355 | −1.02 | 1.11 |
| A 89/352 | 41.10 | *G. sacculifer* | 300–355 | −0.87 | 1.25 |
| A 89/353 | 41.15 | *G. sacculifer* | 300–355 | −0.83 | 1.22 |
| A 89/354 | 41.20 | *G. sacculifer* | 300–355 | −0.84 | 1.19 |
| A 89/355 | 41.25 | *G. sacculifer* | 300–355 | −1.31 | 1.26 |
| A 89/356 | 41.30 | *G. sacculifer* | 300–355 | −1.21 | 1.23 |
| A 89/357 | 41.35 | *G. sacculifer* | 300–355 | −1.02 | 1.16 |
| A 89/358 | 41.40 | *G. sacculifer* | 300–355 | −0.91 | 1.37 |
| A 89/359 | 41.45 | *G. sacculifer* | 300–355 | −0.90 | 1.44 |
| A 89/360 | 41.50 | *G. sacculifer* | 300–355 | −0.66 | 1.35 |
| A 89/361 | 41.55 | *G. sacculifer* | 300–355 | −0.84 | 1.52 |
| A 89/362 | 41.60 | *G. sacculifer* | 300–355 | −0.83 | 1.34 |
| A 89/363 | 41.65 | *G. sacculifer* | 300–355 | −0.68 | 1.36 |
| A 89/364 | 41.70 | *G. sacculifer* | 300–355 | −0.89 | 1.42 |
| A 89/365 | 41.75 | *G. sacculifer* | 300–355 | −0.98 | 1.27 |
| A 89/366 | 41.80 | *G. sacculifer* | 300–355 | −0.89 | 1.24 |
| A 89/367 | 41.85 | *G. sacculifer* | 300–355 | −0.78 | 1.19 |
| A 89/368 | 41.90 | *G. sacculifer* | 300–355 | −0.90 | 1.19 |
| A 89/369 | 41.95 | *G. sacculifer* | 300–355 | −0.64 | 1.36 |
| A 89/370 | 42.00 | *G. sacculifer* | 300–355 | −0.83 | 1.34 |
| A 89/371 | 42.05 | *G. sacculifer* | 300–355 | −1.07 | 1.17 |
| A 89/372 | 42.10 | *G. sacculifer* | 300–355 | −1.36 | 1.45 |
| A 89/373 | 42.15 | *G. sacculifer* | 300–355 | −1.14 | 1.09 |
| A 89/374 | 42.25 | *G. sacculifer* | 300–355 | −0.65 | 1.25 |
| A 89/375 | 42.30 | *G. sacculifer* | 300–355 | −0.70 | 1.27 |
| A 89/376 | 42.35 | *G. sacculifer* | 300–355 | −0.68 | 1.06 |
| A 89/377 | 42.40 | *G. sacculifer* | 300–355 | −0.75 | 1.05 |
| A 89/378 | 42.45 | *G. sacculifer* | 300–355 | −0.84 | 1.23 |
| A 89/379 | 42.50 | *G. sacculifer* | 300–355 | −0.91 | 1.26 |
| A 89/380 | 42.55 | *G. sacculifer* | 300–355 | −0.64 | 1.52 |
| A 89/381 | 42.60 | *G. sacculifer* | 300–355 | −1.00 | 1.33 |
| A 89/382 | 42.65 | *G. sacculifer* | 300–355 | −0.87 | 1.35 |
| A 89/383 | 42.70 | *G. sacculifer* | 300–355 | −0.81 | 1.52 |
| A 89/384 | 42.75 | *G. sacculifer* | 300–355 | −0.79 | 1.44 |
| A 89/385 | 42.80 | *G. sacculifer* | 300–355 | −0.50 | 1.25 |
| A 89/386 | 42.85 | *G. sacculifer* | 300–355 | −0.39 | 1.39 |
| A 89/387 | 42.90 | *G. sacculifer* | 300–355 | −0.70 | 1.77 |
| A 89/388 | 42.95 | *G. sacculifer* | 300–355 | −0.50 | 1.53 |
| A 89/389 | 43.00 | *G. sacculifer* | 300–355 | −0.53 | 1.51 |
| A 89/390 | 43.05 | *G. sacculifer* | 300–355 | −0.39 | 1.48 |
| A 89/391 | 43.10 | *G. sacculifer* | 300–355 | −0.73 | 1.63 |
| A 89/392 | 43.15 | *G. sacculifer* | 300–355 | −0.67 | 1.49 |
| A 89/393 | 43.20 | *G. sacculifer* | 300–355 | −0.61 | 1.48 |
| A 89/394 | 43.25 | *G. sacculifer* | 300–355 | −0.93 | 1.47 |
| A 89/395 | 43.30 | *G. sacculifer* | 300–355 | −0.54 | 1.42 |
| A 89/604 | 43.35 | *G. sacculifer* | 300–355 | −0.68 | 1.62 |
| A 89/397 | 43.40 | *G. sacculifer* | 300–355 | −0.58 | 1.57 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| A 89/398 | 43.45 | *G. sacculifer* | 300–355 | −0.49 | 1.46 |
| A 89/399 | 43.50 | *G. sacculifer* | 300–355 | −0.53 | 1.39 |
| A 89/400 | 43.55 | *G. sacculifer* | 300–355 | −0.80 | 1.49 |
| A 89/401 | 43.60 | *G. sacculifer* | 300–355 | −0.60 | 1.45 |
| A 89/402 | 43.65 | *G. sacculifer* | 300–355 | −0.57 | 1.44 |
| A 89/403 | 43.75 | *G. sacculifer* | 300–355 | −1.02 | 1.56 |
| A 89/404 | 43.80 | *G. sacculifer* | 300–355 | −0.86 | 1.44 |
| A 89/405 | 43.85 | *G. sacculifer* | 300–355 | −0.76 | 1.54 |
| A 89/406 | 43.90 | *G. sacculifer* | 300–355 | −0.81 | 1.52 |
| A 89/407 | 43.95 | *G. sacculifer* | 300–355 | −0.43 | 1.31 |
| A 89/408 | 44.00 | *G. sacculifer* | 300–355 | −0.56 | 1.38 |
| A 89/409 | 44.05 | *G. sacculifer* | 300–355 | −0.97 | 1.52 |
| A 89/410 | 44.10 | *G. sacculifer* | 300–355 | −0.67 | 1.56 |
| A 89/411 | 44.15 | *G. sacculifer* | 300–355 | −0.77 | 1.56 |
| A 89/412 | 44.20 | *G. sacculifer* | 300–355 | −0.64 | 1.53 |
| A 89/413 | 44.35 | *G. sacculifer* | 300–355 | −0.73 | 1.57 |
| A 89/414 | 44.40 | *G. sacculifer* | 300–355 | −0.75 | 1.59 |
| A 89/415 | 44.45 | *G. sacculifer* | 300–355 | −0.91 | 1.73 |
| A 89/416 | 44.50 | *G. sacculifer* | 300–355 | −0.55 | 1.55 |
| A 89/417 | 44.55 | *G. sacculifer* | 300–355 | −0.83 | 1.47 |
| A 89/418 | 44.60 | *G. sacculifer* | 300–355 | −1.20 | 1.56 |
| A 89/419 | 44.65 | *G. sacculifer* | 300–355 | −1.16 | 1.34 |
| A 89/420 | 44.70 | *G. sacculifer* | 300–355 | −1.16 | 1.50 |
| A 89/421 | 44.75 | *G. sacculifer* | 300–355 | −1.01 | 1.46 |
| A 89/422 | 44.80 | *G. sacculifer* | 300–355 | −0.95 | 1.50 |
| A 89/423 | 44.85 | *G. sacculifer* | 300–355 | −0.98 | 1.65 |
| A 89/424 | 44.90 | *G. sacculifer* | 300–355 | −0.60 | 1.51 |
| A 89/425 | 44.95 | *G. sacculifer* | 300–355 | −0.74 | 1.22 |
| A 89/426 | 45.05 | *G. sacculifer* | 300–355 | −0.75 | 1.47 |
| A 89/427 | 45.10 | *G. sacculifer* | 300–355 | −0.90 | 1.47 |
| A 89/428 | 45.15 | *G. sacculifer* | 300–355 | −0.81 | 1.39 |
| A 89/429 | 45.20 | *G. sacculifer* | 300–355 | −0.89 | 1.42 |
| A 89/430 | 45.25 | *G. sacculifer* | 300–355 | −0.97 | 1.39 |
| A 89/431 | 45.30 | *G. sacculifer* | 300–355 | −0.89 | 1.32 |
| A 89/432 | 45.35 | *G. sacculifer* | 300–355 | −1.05 | 1.29 |
| A 89/433 | 45.40 | *G. sacculifer* | 300–355 | −0.77 | 1.28 |
| A 89/434 | 45.45 | *G. sacculifer* | 300–355 | −0.94 | 1.43 |
| A 89/435 | 45.50 | *G. sacculifer* | 300–355 | −0.50 | 1.39 |
| A 89/436 | 45.55 | *G. sacculifer* | 300–355 | −0.61 | 1.26 |
| A 89/437 | 45.60 | *G. sacculifer* | 300–355 | −0.87 | 1.50 |
| A 89/438 | 45.65 | *G. sacculifer* | 300–355 | −0.93 | 1.64 |
| A 89/439 | 45.70 | *G. sacculifer* | 300–355 | −0.70 | 1.63 |
| A 89/440 | 45.75 | *G. sacculifer* | 300–355 | −0.73 | 1.61 |
| A 89/441 | 45.85 | *G. sacculifer* | 300–355 | −0.52 | 1.55 |
| A 89/442 | 45.95 | *G. sacculifer* | 300–355 | −0.83 | 1.25 |
| A 89/443 | 46.00 | *G. sacculifer* | 300–355 | −0.79 | 1.45 |
| A 89/444 | 46.05 | *G. sacculifer* | 300–355 | −0.98 | 1.43 |
| A 89/445 | 46.10 | *G. sacculifer* | 300–355 | −0.92 | 1.34 |
| A 89/446 | 46.15 | *G. sacculifer* | 300–355 | −0.37 | 1.45 |
| A 89/447 | 46.20 | *G. sacculifer* | 300–355 | −0.23 | 1.46 |
| A 89/448 | 46.25 | *G. sacculifer* | 300–355 | −0.53 | 1.63 |
| A 89/449 | 46.30 | *G. sacculifer* | 300–355 | −0.71 | 1.35 |
| A 89/450 | 46.35 | *G. sacculifer* | 300–355 | −0.92 | 1.49 |
| A 89/451 | 46.40 | *G. sacculifer* | 300–355 | −1.08 | 1.52 |
| A 89/452 | 46.45 | *G. sacculifer* | 300–355 | −1.06 | 1.40 |
| A 89/453 | 46.50 | *G. sacculifer* | 300–355 | −0.93 | 1.37 |
| A 89/454 | 46.55 | *G. sacculifer* | 300–355 | −0.84 | 1.32 |
| A 89/455 | 46.60 | *G. sacculifer* | 300–355 | −0.72 | 1.38 |
| A 89/605 | 46.65 | *G. sacculifer* | 300–355 | −0.95 | 1.77 |
| A 89/457 | 46.70 | *G. sacculifer* | 300–355 | −0.79 | 1.56 |
| A 89/458 | 46.75 | *G. sacculifer* | 300–355 | −0.86 | 1.53 |
| A 89/459 | 46.80 | *G. sacculifer* | 300–355 | −0.77 | 1.39 |
| A 89/460 | 46.85 | *G. sacculifer* | 300–355 | −0.92 | 1.39 |
| A 89/461 | 46.90 | *G. sacculifer* | 300–355 | −0.64 | 1.30 |
| A 89/462 | 46.95 | *G. sacculifer* | 300–355 | −0.56 | 1.48 |
| A 89/463 | 47.00 | *G. sacculifer* | 300–355 | −0.54 | 1.67 |
| A 89/464 | 47.05 | *G. sacculifer* | 300–355 | −0.89 | 1.61 |
| A 89/465 | 47.10 | *G. sacculifer* | 300–355 | −0.75 | 1.61 |
| A 89/466 | 47.15 | *G. sacculifer* | 300–355 | −1.17 | 1.56 |
| A 89/467 | 47.20 | *G. sacculifer* | 300–355 | −1.02 | 1.40 |
| A 89/468 | 47.25 | *G. sacculifer* | 300–355 | −0.92 | 1.67 |
| A 89/606 | 47.34 | *G. sacculifer* | 300–355 | −0.61 | 1.47 |
| A 89/607 | 47.44 | *G. sacculifer* | 300–355 | −0.49 | 1.45 |
| A 89/608 | 47.56 | *G. sacculifer* | 300–355 | −0.72 | 1.45 |
| A 89/609 | 47.64 | *G. sacculifer* | 300–355 | −0.80 | 1.79 |
| A 89/610 | 47.75 | *G. sacculifer* | 300–355 | −0.72 | 1.72 |
| A 89/621 | 47.84 | *G. sacculifer* | 300–355 | −0.99 | 1.62 |

**Table 1 (continued).**

| Laboratory reference number | Depth (mbsf) | Species | Size fraction (μm) | $\delta^{18}O$ | $\delta^{13}C$ |
|---|---|---|---|---|---|
| A 89/622 | 47.97 | *G. sacculifer* | 300–355 | −1.01 | 1.72 |
| A 89/623 | 48.07 | *G. sacculifer* | 300–355 | −0.90 | 1.39 |
| A 89/624 | 48.14 | *G. sacculifer* | 300–355 | −0.58 | 1.54 |
| A 89/625 | 48.26 | *G. sacculifer* | 300–355 | −0.50 | 1.57 |
| A 89/626 | 48.34 | *G. sacculifer* | 300–355 | −0.63 | 1.58 |
| A 89/627 | 48.44 | *G. sacculifer* | 300–355 | −0.62 | 1.85 |
| A 89/628 | 48.56 | *G. sacculifer* | 300–355 | −0.88 | 1.63 |
| A 89/629 | 48.64 | *G. sacculifer* | 300–355 | −0.56 | 1.78 |
| A 89/630 | 48.74 | *G. sacculifer* | 300–355 | −0.49 | 1.65 |
| A 89/631 | 48.84 | *G. sacculifer* | 300–355 | −0.44 | 1.65 |
| A 89/632 | 48.94 | *G. sacculifer* | 300–355 | −0.45 | 1.60 |
| A 89/633 | 49.06 | *G. sacculifer* | 300–355 | −0.73 | 1.63 |
| A 89/634 | 49.14 | *G. sacculifer* | 300–355 | −0.69 | 1.54 |
| A 89/677 | 49.19 | *G. sacculifer* | 300–355 | −0.32 | 0.65 |
| A 89/635 | 49.24 | *G. sacculifer* | 300–355 | −0.50 | 1.33 |
| A 89/636 | 49.34 | *G. sacculifer* | 300–355 | −0.92 | 1.59 |
| A 89/646 | 49.45 | *G. sacculifer* | 300–355 | −0.64 | 1.40 |
| A 89/637 | 49.57 | *G. sacculifer* | 300–355 | −0.46 | 1.43 |
| A 89/638 | 49.64 | *G. sacculifer* | 300–355 | −0.56 | 1.30 |
| A 89/639 | 49.76 | *G. sacculifer* | 300–355 | −0.68 | 1.30 |
| A 89/640 | 49.84 | *G. sacculifer* | 300–355 | −0.54 | 1.44 |
| A 89/641 | 49.94 | *G. sacculifer* | 300–355 | −0.76 | 1.45 |
| A 89/642 | 50.06 | *G. sacculifer* | 300–355 | −0.86 | 1.50 |
| A 89/643 | 50.14 | *G. sacculifer* | 300–355 | −0.56 | 1.61 |
| A 89/647 | 50.24 | *G. sacculifer* | 300–355 | −0.56 | 1.14 |
| A 89/648 | 50.34 | *G. sacculifer* | 300–355 | −0.53 | 1.29 |
| A 89/649 | 50.44 | *G. sacculifer* | 300–355 | −0.47 | 1.28 |
| A 89/671 | 50.56 | *G. sacculifer* | 300–355 | −1.11 | 1.57 |
| A 89/672 | 50.64 | *G. sacculifer* | 300–355 | −1.01 | 1.67 |
| A 89/674 | 50.84 | *G. sacculifer* | 300–355 | −0.69 | 1.29 |
| A 89/675 | 50.94 | *G. sacculifer* | 300–355 | −0.69 | 1.19 |
| A 89/676 | 51.06 | *G. sacculifer* | 300–355 | −0.52 | 1.15 |
| A 89/679 | 51.14 | *G. sacculifer* | 300–355 | −0.41 | 1.72 |
| A 89/680 | 51.24 | *G. sacculifer* | 300–355 | −0.10 | 1.31 |
| A 89/681 | 51.34 | *G. sacculifer* | 300–355 | −0.90 | 1.36 |
| A 89/683 | 51.56 | *G. sacculifer* | 300–355 | −0.88 | 1.36 |
| A 89/684 | 51.64 | *G. sacculifer* | 300–355 | −0.58 | 1.45 |
| A 89/644 | 51.71 | *G. sacculifer* | 300–355 | −0.62 | 1.47 |
| A 89/685 | 51.71 | *G. sacculifer* | 300–355 | −0.65 | 1.24 |
| A 89/686 | 51.84 | *G. sacculifer* | 300–355 | −0.95 | 1.38 |
| A 89/687 | 51.94 | *G. sacculifer* | 300–355 | −0.91 | 1.39 |
| A 89/688 | 52.06 | *G. sacculifer* | 300–355 | −0.79 | 1.57 |
| A 89/645 | 52.14 | *G. sacculifer* | 300–355 | −0.75 | 1.67 |
| A 89/650 | 52.24 | *G. sacculifer* | 300–355 | −0.78 | 1.46 |
| A 89/690 | 52.24 | *G. sacculifer* | 300–355 | −0.83 | 1.40 |
| A 89/881 | 52.34 | *G. sacculifer* | 300–355 | −1.01 | 1.23 |
| A 89/882 | 52.47 | *G. sacculifer* | 300–355 | −1.15 | 1.17 |
| A 89/883 | 52.57 | *G. sacculifer* | 300–355 | −0.55 | 1.17 |
| A 89/884 | 52.64 | *G. sacculifer* | 300–355 | −0.40 | 1.14 |
| A 89/885 | 52.75 | *G. sacculifer* | 300–355 | −0.69 | 1.04 |
| A 89/886 | 52.84 | *G. sacculifer* | 300–355 | −0.97 | 1.19 |
| A 89/887 | 52.94 | *G. sacculifer* | 300–355 | −0.87 | 1.31 |
| A 89/888 | 53.06 | *G. sacculifer* | 300–355 | −0.56 | 1.63 |
| A 89/889 | 53.14 | *G. sacculifer* | 300–355 | −0.46 | 1.69 |
| A 89/890 | 53.24 | *G. sacculifer* | 300–355 | −0.96 | 1.39 |
| A 89/892 | 53.44 | *G. sacculifer* | 300–355 | −0.86 | 1.22 |
| A 89/893 | 53.56 | *G. sacculifer* | 300–355 | −0.40 | 1.09 |
| A 89/894 | 53.64 | *G. sacculifer* | 300–355 | −0.40 | 1.13 |
| A 89/895 | 53.74 | *G. sacculifer* | 300–355 | −0.55 | 1.21 |
| A 89/896 | 53.84 | *G. sacculifer* | 300–355 | −0.93 | 1.28 |
| A 89/897 | 53.94 | *G. sacculifer* | 300–355 | −1.02 | 1.49 |
| A 89/898 | 53.96 | *G. sacculifer* | 300–355 | −0.83 | 1.63 |

Notes: Asterisks denote unreliable measurements. Where insufficient specimens in the 300–355 μm size range were available, larger and/or smaller specimens were selected.

picted. Superimposed on this is a significant low-frequency swell with a distinct temperature maximum (or ice-volume minimum) at around 3.25 Ma and generally lower temperatures (or higher ice volumes) before and after that. This temperature maximum is visible in the single-species data in Figures 1 and 2, and thus is not an artifact of the adjustment used to present the data for *G. ruber* and *G. sacculifer* on a single figure. Superimposed on this

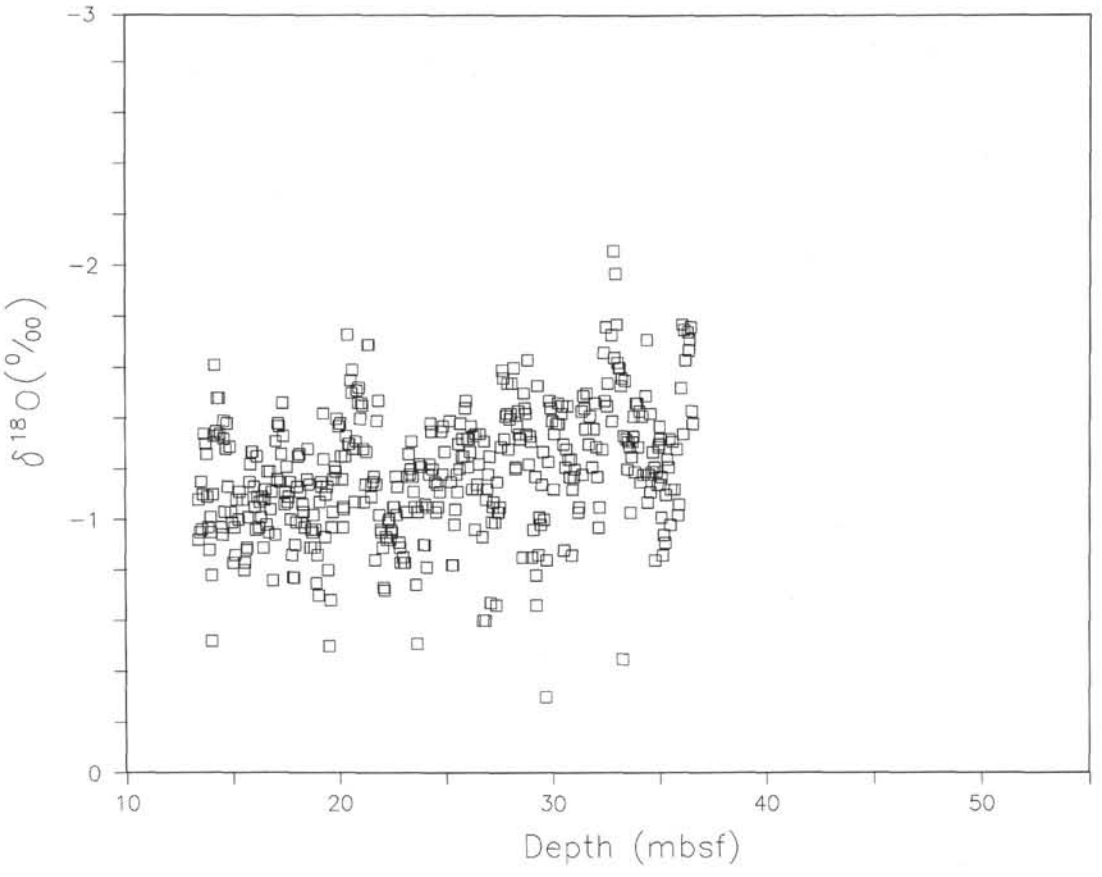


Figure 1. Oxygen isotope analyses of *Globigerinoides ruber* in Hole 709C.

low-frequency trend are lesser peaks that appear to be around 400 ka apart. Again, we stress that the true climatic significance of these trends must take account of benthic records with comparable stratigraphic resolution.

Time-series analyses were performed with the object of establishing whether or not orbital variations are clearly impressed on this Pliocene record. A simplified age model was used to avoid poorly constrained changes in the accumulation rate, and only that part of the record older than 2.1 Ma was analyzed in view of the very low accumulation rate above that point. To detect the 41-ka tilt cycle, we used a fairly wide band width (80 lags for an interpolation interval of 4 ka [giving 625 data points]). This analysis is illustrated in Figure 5 and clearly reveals a significant concentration of power at a period of about 40 ka. As would be expected with a crude time scale, the spectral peak is split if a higher resolution is selected. In principle, a more refined time scale could be constructed using the hypothesis that this variance does in fact arise as a result of forcing by the regular tilt cycle, the strategy adopted by Pisias and Moore (1981). In practice, it will probably prove more reliable first to correlate the record of Hole 709C with the astronomically calibrated record of DSDP Hole 607 (Ruddiman et al., 1986; Raymo et al., 1989) in view of the fact that the signal appears so much clearer in the benthic isotope record of that site than in the record for Hole 709C presented here. However, before this can be done, it will be necessary to document the continuity of the Hole 709C record.

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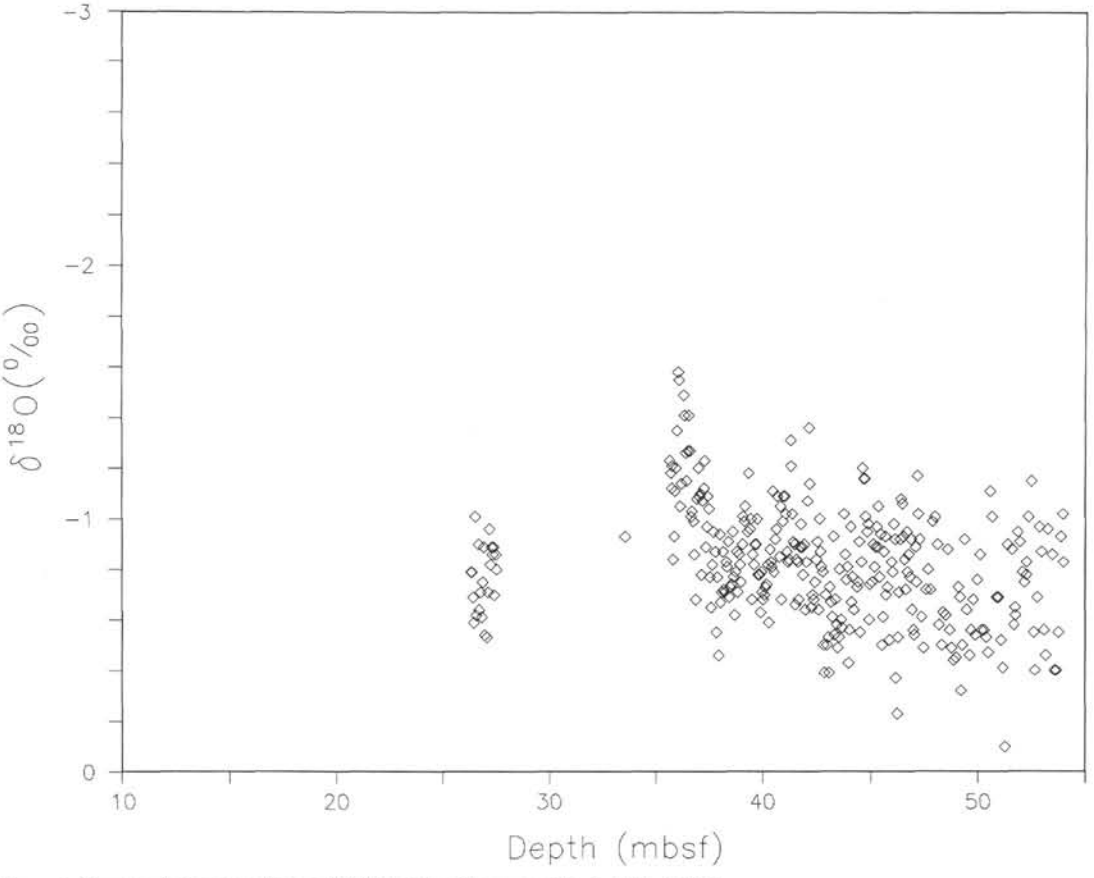


Figure 2. Oxygen isotope analyses of *Globigerinoides sacculifer* in Hole 709C.

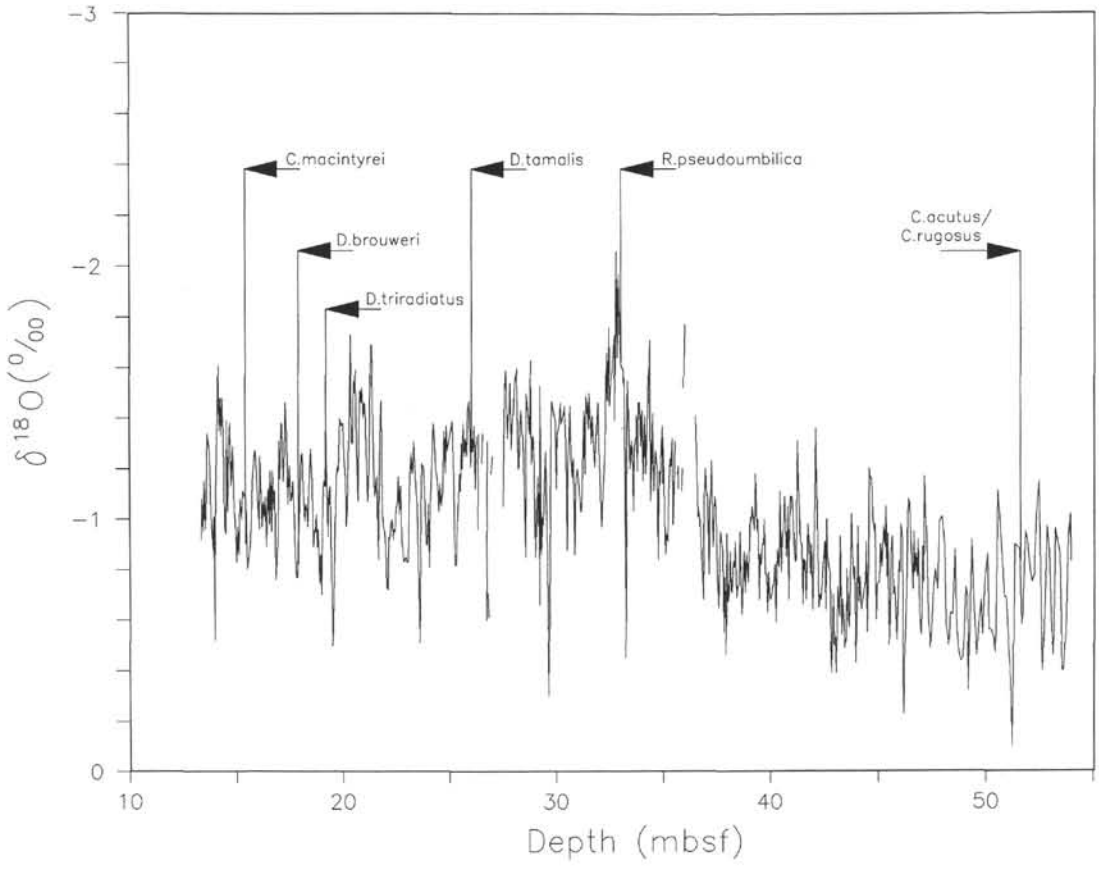


Figure 3. Oxygen isotope analyses of *Globigerinoides ruber* (adjusted by +0.25‰) and *G. sacculifer* in Hole 709C, plotted on a depth scale. Arrows indicate the position of the LAD of *Cyclococcolithina macintyrei* (1.45 Ma); the LAD of *Discoaster brouweri* (1.89 Ma); the base of the *D. triradiatus* acme (2.1 Ma); the LAD of *Discoaster tamalis*; the LAD of *Reticulofenestra pseudoumbilica* (3.55 Ma); and the *Ceratolithus acutus/C. rugosus* transition (4.6 Ma).

**Table 2. Age control points shown on Figure 3 and used to construct Figure 4.**

| Datum | Depth (mbsf) | Age adopted[a] |
|---|---|---|
| *C. macintyrei* LAD | [b]15.45 | 1.45 |
| *D. brouweri* LAD | [b]17.90 | 1.89 |
| *D. trirdiatus* acme FAD | [b]19.25 | 2.1 |
| *D. tamalis* LAD | [b]26.0 | 2.65 |
| *R. pseudoumbilica* LAD | [b]33.00 | 3.55 |
| [c]*C. acutus/C.rugosus* transition | [d]53.15 | [c]4.6 |
| *C. acutus* FAD | [d]58.15 | 4.85 |

Note: LAD = last appearance datum and FAD = first appearance datum.
[a] Backman and Shackleton (1983).
[b] Chepstow-Lusty, pers. comm., 1989.
[c] Not used in generating time series for spectral analysis.
[d] Rio, this volume.

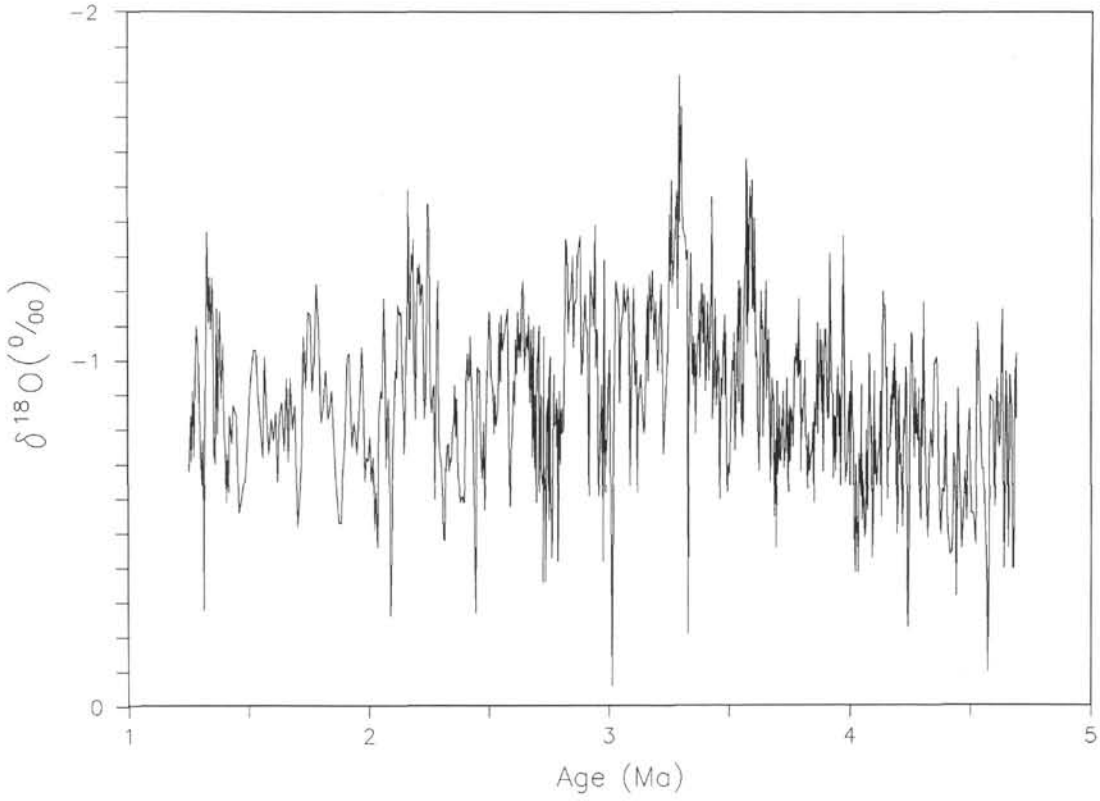


Figure 4. Oxygen isotope analyses of *G. sacculifer* and *G. ruber* (+0.25‰) on an age scale obtained by interpolating between the points in Table 2.

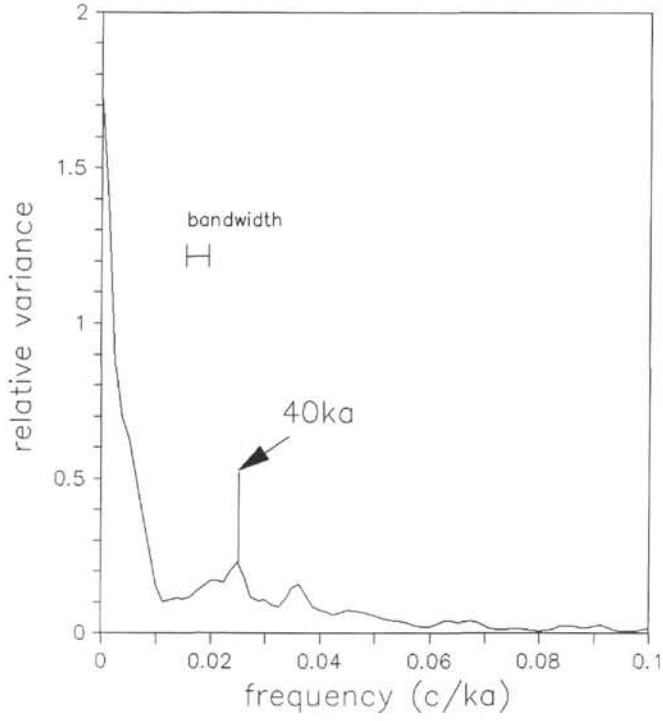


Figure 5. Low-resolution spectral analysis of the combined $\delta^{18}O$ records in Figure 4 (below 2.1 Ma) after offsetting the *G. ruber* values by 0.25‰. The concentration of variance at a period of about 40 ka is indicated.