37. ISOTOPIC ANALYSES OF PLANKTONIC FORAMINIFERA FROM THE CENOZOIC OF THE NORTHWEST PACIFIC, LEG 6[1]

Robert G. Douglas and Samuel M. Savin
Department of Geology, Case Western Reserve University, Cleveland, Ohio

INTRODUCTION

Isotopic determinations for oxygen and carbon are reported here for formainifera from forty-two core samples from three sites drilled during Leg 6 (Figure 1). The sites are: Site 44 (Hole 44.0) on the Horizon Ridge, latitude 19° 18.5'N, longitude 169° 00'W; Site 47 (Hole 47.2) on the Shatsky Rise, latitude 32° 26.9'N, longitude 157° 42.7'E; Site 55 (Hole 55.0) on the Caroline Ridge, latitude 19°18.1'N, longitude 142° 32.9'E. Cores from Site 47 contain material from the Pleistocene to Upper Miocene and the Middle Eocene to Upper Maestrichtian; the Oligocene and portions of the adjacent epochs are missing in this hole. At Site 55 a nearly complete Neogene section with the exception of the top of Miocene was recovered. The Lower Oligocene and the Upper Eocene were cored at Site 44. When combined, the three sites offer a nearly complete sequence from the latest Cretaceous through the Tertiary. The basic lithology at the three sites is a calcareous ooze, predominantly a nannofossil-foraminifera chalk ooze.

Sample horizons were selected at levels where, 1) the microfauna was very well preserved, 2) planktonic foraminifera were abundant, and 3) the zonal stratigraphy was well defined. Pertinent sample data are shown in Table 1. The foraminiferal zones given in the table are those used by the shipboard paleontologists and are discussed in the Leg Synthesis. Correlation of the zones and their approximate geochronologic age is based on the work of Berggren (1969).

SAMPLE PREPARATION

Isotopic determinations were made on whole assemblages of planktonic foraminifera. The assemblages were obtained by microsplitting the coarser than 150-micron fractions which had first been ultrasonically cleaned, wet seived to remove the clay and silt size material and dried. Before microsplitting the dried residues, several specimens were broken and the chamber interiors examined to make certain the fossils were free of adhering matrix. The microsplit samples for analysis were carefully examined under the microscope and benthonic foraminifera, debris and other microfossils removed. In addition to the analysis of foraminiferal assemblages, species from five samples were divided into two morphologic groups: globigerine-types and keeled-types; these two types were analyzed separately. The globigerine-types include trochospiral species with rounded chamber margins that resemble the genus *Globigerina* through not necessarily belonging to that taxon. The keel-types include species with acute chamber margins that belong to *Globorotalia, Globotruncana* and *Abathomphalus.* Species with intermediate features, such as orbuline forms, acarinids, etc. and biserial species were excluded. Planktonic foraminifera exhibiting signs of dissolution and species which in any way appeared to be anomalous to the sample (e.g., reworked) were excluded. The microfossils for isotopic analysis were washed in distilled water, reacted with acid, uncrushed, and isotopically analyzed using standard techniques (Epstein *et al.,* 1951). All isotopic results are reported with respect to PDB-I. Precision of the isotopic determinations is generally better than 0.15 per mil. Temperatures are calculated using the equation given by Criag (1965) and assuming that the isotopic composition of the sea water in which the planktonic foraminiferal shells grew was nil relative to Standard Mean Ocean Water (S.M.O.W.).

RESULTS

The isotopic results are listed in Table 1 and paleotemperatures calculated from this data are shown in Figure 2. Although the determinations are from sites separated by over 20° of latitude, the combined values may be used to describe a generalized temperature curve for the Tertiary. This curve is similar in some, but not all respects, to paleotemperature curves derived for Southern Pacific regions by Dorman (1966) and Devereux (1967). Salient results are summarized below.

Temperature Variation With Time

Upper Maestrichtian, Paleocene, and Lower Eocene

Whole assemblage analyses for the Upper Maestrichtian, Paleocene and Lower Eocene of the Shatsky Rise yielded values which clustered about -1.0%, approximately 20°C. These data points represent samples separated in time by one to three million years using Berggren's (1969) correlation, and suggest that a rather uniform marine climate existed in mid-latitudes during the early Tertiary.

[1]Contribution No. 66, Department of Geology, Case Western Reserve University, Cleveland, Ohio.

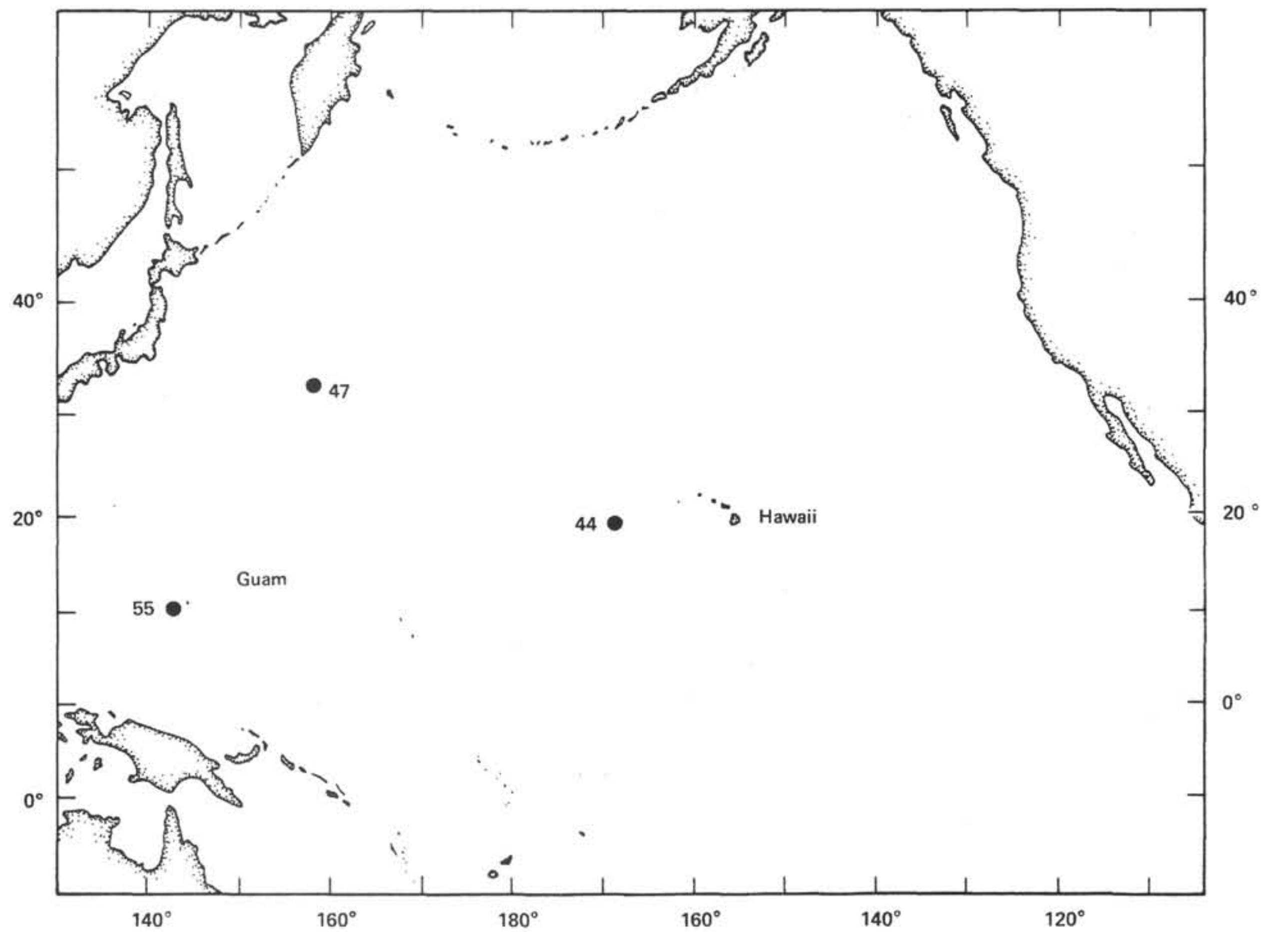

Figure 1. *Location of the drilling sites at which cores were isotopically analyzed.*

Middle and Upper Eocene Oligocene and Lower Miocene

Samples from this portion of the Tertiary gave markedly lower isotopic temperatures than did the earlier samples, and suggest that a temperature minimum occurred some time in this period. Core recovery was sparse in this area and no samples are available for the Upper Oligocene. Our data are not in agreement with those of Devereux (1967) who found a warming rather than a temperature decline in the South Pacific.

Middle and Upper Miocene and Pliocene

Miocene temperatures rise gradually from the arly part of the epoch (*Globigerina dissimilis* Zone) through the Middle Miocene. Samples from the upper Middle Miocene to the Lower Pliocene are absent. Pliocene temperatures are comparable to those of the Middle Miocene. In contrast with the authors' results, Dorman's (1967) results based on Australian molluscs show an abrupt drop in temperature from the Middle Miocene to a temperature plateau in the Upper Miocene and Pliocene. Devereux's (1967) curve is more similar to the authors', but differs in detail. The meaning of these differences is not clear because of the differences in fossils used for analysis, biostratigraphic correlation of the sample horizons, and latitudinal positions. It is interesting to note that the greatest disagreement is in the Miocene, which has been suggested by some (for example, Bandy *et al.*, 1969), as the time of initiation of glaciation in high latitudes.

Geographic Temperature Variation

δO^{18} for the Pliocene and early Pleistocene samples from the Shatsky Rise are 1.75 to 2.0 per mil higher than correlative samples from the Caroline Ridge. This corresponds to a temperature difference of approximately 7°C. The two sites are presently separated by 13° of latitude and have a present day mean ocean temperature difference of about 5°C.

Interspecific Isotope Differences

Present day planktonic foraminifera tend to occupy different depths within the upper few hundred meters of the ocean (Berger, 1969). For example, species of

TABLE 1

Sample Designation	Age	Zone	Whole Sample		Globigerine Type		Keel Type	
			δO^{18} (%)	δC^{13} (%)	δO^{18} (%)	δC^{13} (%)	δO^{18} (%)	δC^{13} (%)
44.0-1-2, 145	Lower Oligocene	*Globigerina ampliapertura*	+0.49	+1.69				
44.0-1-CC	Lower Oligocene	*G. ampliapertura*	+0.50	+1.52				
44.0-2-CC	Upper Eocene	*Globigerina corpulenta*	+0.18	+1.88				
44.0-3-CC	Middle Eocene	*Orbulinoides beckmanni*	-0.26	+1.95				
47.2-1-CC	Middle Pleistocene	*Globorotalia truncatulinoides*	+1.27	+1.25				
47.2-2-CC	Upper Pliocene	*G. tosaensis*	+1.55	+0.84				
47.2-3-CC	Lower Upper Plio.	*G. altispira-S. dehiscens*	+1.03	+0.85				
47.2-5-CC	Upper Miocene	*G. tumida-S. paenedehiscens*	+1.09	+1.09	+0.74	+1.37	+1.16	+1.30
47.2-7-2, 20	Middle Eocene	*Globorotalia bullbrooki*	-1.02	+2.29				
47.2-7-CC	Lower Eocene	*G. aragonensis*	-1.24	+1.83				
47.2-8-2, 104	Lower Eocene	*G. marginadentata*	-1.14	+2.21				
47.2-8-CC	Upper Paleocene	*G. velascoensis*	-1.14	+3.22				
47.2-9-5, 108	Upper Paleocene	*G. pseudomenardii*	-1.10	+3.87	-0.87	+3.35	-1.25	+3.25
47.2-9-CC	Upper Paleocene	*G. pseudomenardii*	-0.97	+3.77	-0.62	+2.88	-1.08	+4.23
47.2-10-2, 6	Danian	*G. angulata*	-1.18	+2.65				
47.2-10-5, 100	Danian	*Acarinina uncinata*	-1.17	+2.64				
47.2-11-1, 145	Lower Danian	*Globorotalia trinidadensis*	-0.94	+1.92				
47.2-11-3, 145	Lower Danian	*Globigerina taurica*	-0.96	+2.02				
47.2-12-CC	Upper Maestrichtian	*Abathomphalus mayaroensis*	-0.63	+2.86				
47.2-14-CC	Middle Maestrichtian	*Globotruncana gansseri*	(-1.01)		-1.03	+3.51	-0.91	+3.18
55.0-1-CC	Lower Pleistocene	*Globorotalia truncatulinoides*	-0.50	+0.97				
55.0-2-CC	Upper Pliocene	*G. tosaensis*	-0.77	+1.50				
55.0-3-CC	Lower Pliocene	*G. altispira-S. dehiscens*	-0.79	+2.03				
55.0-4-CC	Middle Miocene	*Globorotalia menardii*	-0.68	+1.87				
55.0-5-CC	Middle Miocene	*G. menardii*	-0.82	+1.62				
55.0-6-CC	Middle Miocene	*G. fohsi*	-0.28	+2.17				
55.0-7-CC	Middle Miocene		-0.25	+2.44	-0.20	+2.51	-0.30	+1.85
55.0-9-CC	Lower Miocene	*Praeorbulina glomerosa*	-0.02	+2.40				
55.0-11-1, 54	Lower Miocene	*Globoquadrina dehiscens*	+0.17	+2.69				
55.0-11-CC	Lower Miocene	*Globigerina dissimilis*	+0.18	+2.15				
55.0-12-CC		*G. dissimilis*	+0.09	+2.04				
55.0-14-CC	Lower Miocene	*Globigerina kugleri*	+0.01	+2.99				

CC = Core catcher sample

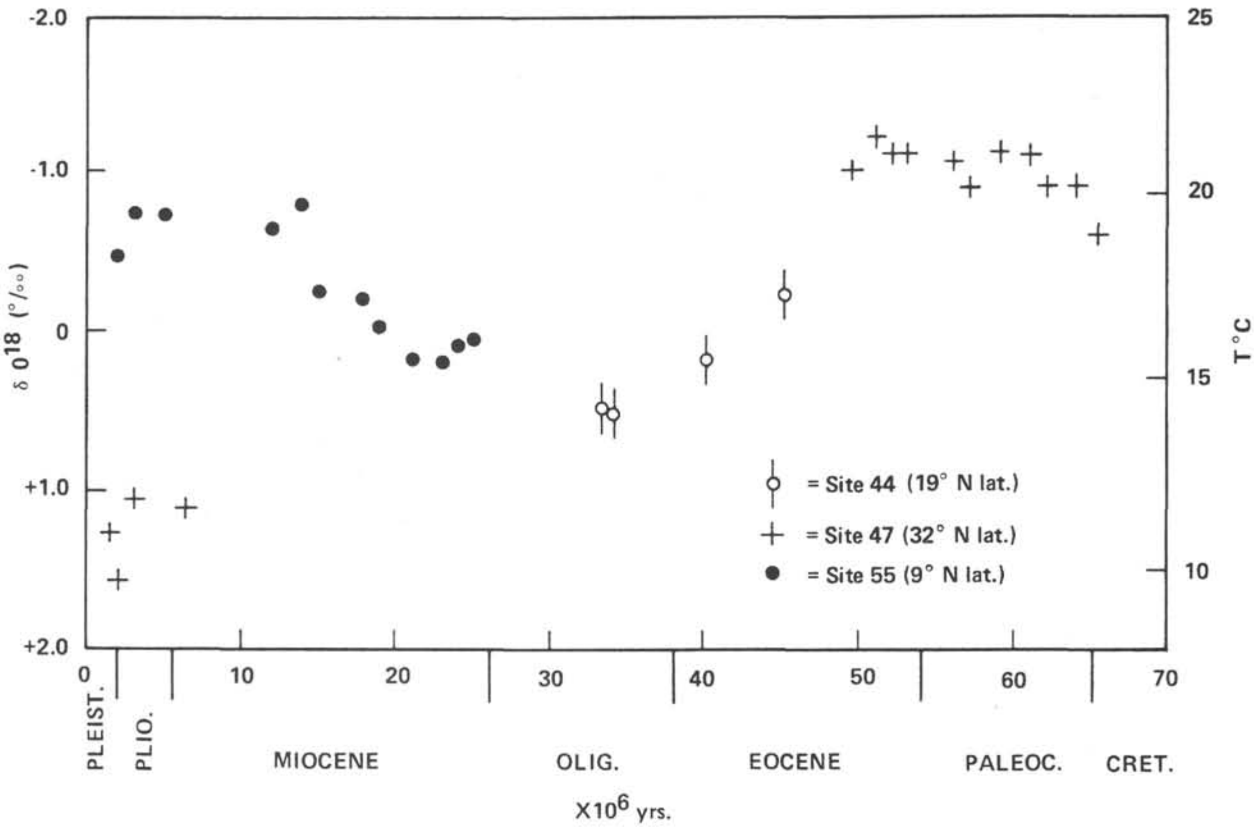

Figure 2. *Oxygen isotope determinations and calculated paleotemperature. Biostratigraphy of the samples is given in Table 1.*

Globorotalia inhabit intermediate and deeper water layers whereas *Globigerinoides* and many species of *Globigerina* are found in the shallow surface layer. Isotopic paleotemperatures for different depth-stratified species from the same sediment surface sample can give results which differ by 10°C (Lidz *et al.*, 1968). Assuming that fossil planktonic foraminifera were depth stratified in a manner similar to modern faunas, it seems likely that 1) different species may yield different isotopic temperatures and, 2) whole assemblage analyses will give temperatures lower than surface temperatures. To test the assumption and to gain an impression of the range of isotopic variation in a single sample, the species in five samples (Table 1) were separated into morphologic types roughly analagous to present-day depth-stratified species and isotopically analyzed. The results are mixed: in one case, the globigerine-types gave warmer isotopic temperatures than the keel-types in two samples, the results were reversed; and, in two cases the temperatures were essentially the same. Since no single species or species-group can be traced from the Paleocene to the Pleistocene, it is important that further study of the variation in isotopic content of the shells of single species be undertaken.

Carbon Isotope Results

The variation of carbon isotope ratios with time is shown in Figure 3. A spread of over 3 per mil is observed, and while variations are large within a single hole, differences between adjacent samples are generally very much smaller than the total range of variation for the hole.

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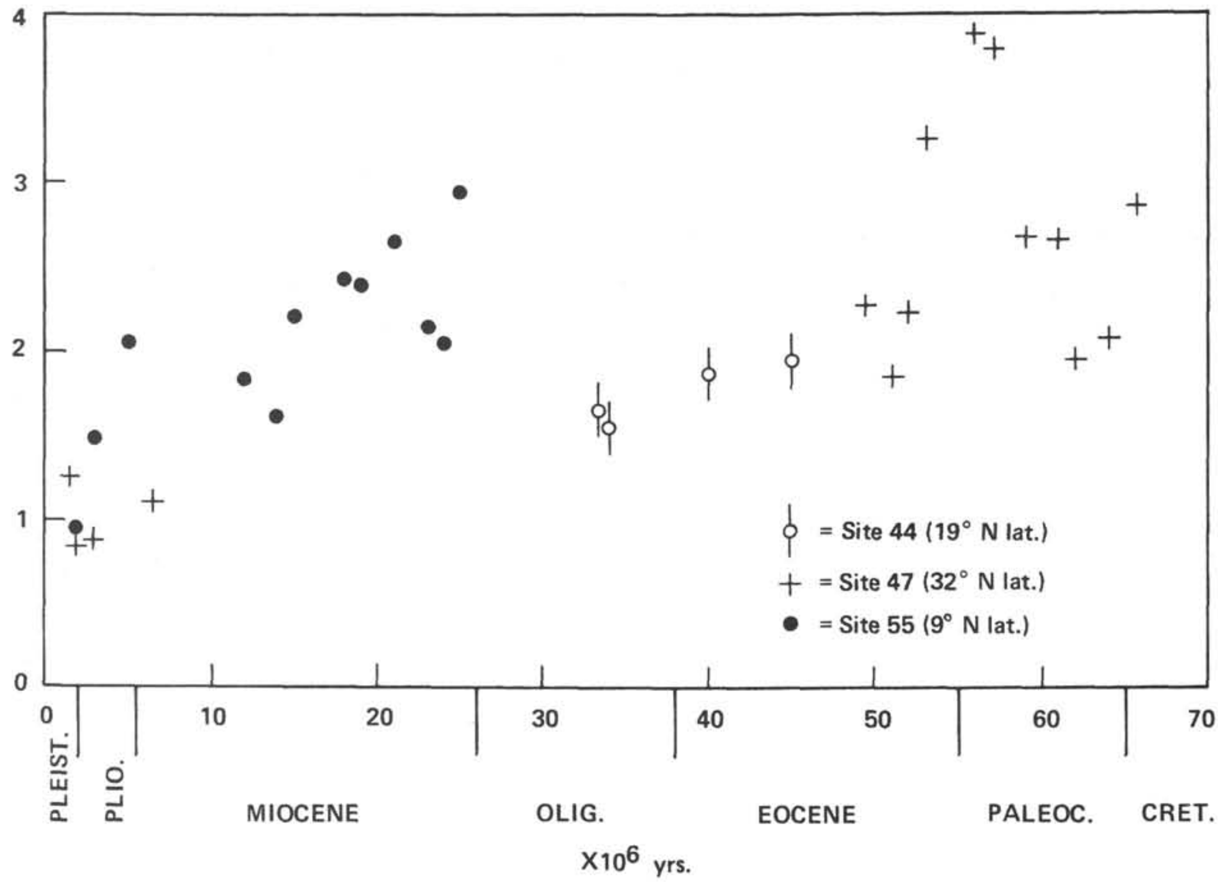

Figure 3. *Carbon iostope determinations. Biostratigraphy of the samples is given in Table 1.*

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