

## 4. DATA REPORT: MID-PLIOCENE DIATOM ASSEMBLAGES AT SITES 1016, 1021, AND 1022<sup>1</sup>

John A. Barron<sup>2</sup>

### ABSTRACT

Diatom assemblages from the middle part of the Pliocene (3.2–2.5 Ma) were investigated from Ocean Drilling Program Sites 1016, 1021, and 1022 in an effort to infer paleotemperature fluctuations off California.

Diatoms are very sparse in virtually all of the samples that were examined from Sites 1016 and 1021. This is presumably because these sites were seaward (west) of the coastal zone of diatom productivity during the middle part of the Pliocene.

Diatoms are relatively common in the vast majority of samples that were examined from Hole 1022A. Diatom assemblages are dominated by *Chaetoceros* spores (a coastal upwelling component), the cold-water (subarctic) taxa *Neodenticula kamtschatica* and its descendant *Neodenticula koizumii*, and *Thalassionema nitzschioides*, a temperate taxon that is typically found at the seaward edge of coastal upwelling zones. Paleotemperature interpretations, however, are not possible at this time because of the scarcity of comparative modern core-top data.

### INTRODUCTION

The goal of the Pliocene Research, Interpretation, and Synoptic Mapping (PRISM) project (global reconstruction of the mid-Pliocene) of the U.S. Geological Survey is to reproduce global sea-surface temperatures (SSTs) and other paleoceanographic parameters for the middle part of the Pliocene (herein referred to as mid-Pliocene). Material recovered during Ocean Drilling Program (ODP) Leg 167 presents an excellent opportunity to expand coverage along the California margin in well-dated sediments. Samples were collected from Sites 1016, 1021, and 1022 for diatom and planktonic foraminiferal assemblage studies (Dowsett and Poore, Chap. 5, this volume).

### MATERIALS AND METHODS

Using the shipboard chronologies, time intervals of the mid-Pliocene were chosen from just above the top of the Gauss normal-polarity Chron (2.6 Ma) down through the Mammoth reversed-polarity Subchron (basal age, 3.33 Ma). From Site 1016, samples were collected every 20 cm (roughly every 3 k.y.) from Cores 167-1016B-16H through 17H with additional fill-in samples taken from 167-1016D-16H-3 and 16H-4 (106 total samples taken). At Site 1021, samples were taken every 15 cm (roughly every 4 k.y.) from Cores 167-1021C-10H and 167-1021D-11H (78 samples total). From Site 1022, samples were collected (one per section, or roughly every 20 k.y.) from Cores 167-1022A-1H through 13H (21 samples taken).

Diatom samples (0.5–1.0 cm<sup>3</sup> in size) were processed in hydrogen peroxide and hydrochloric acid. Strawn slides of the residues were initially examined under the light microscope at 500×. Except where preservation was poor, at least 300 diatoms per slide were counted at 1250× from Site 1022 using the techniques of Schrader and Gersonde (1978).

### RESULTS

#### Site 1016

Diatoms are very sparse in the vast majority of the slides that were prepared from Site 1016. Sponge spicules and fragments of reworked Miocene taxa are commonly observed. Where present, the in situ diatom assemblages contain fragments of *Thalassiothrix*, *Thalassionema*, and *Proboscia*; whole valves of resistant genera like *Coscinodiscus* and *Stephanopyxis*; and resting spores of *Chaetoceros*. Because of the poor and sporadic nature of the assemblages, no diatom assemblage counts were completed.

#### Site 1021

Diatoms are very sparse in virtually all of the samples that were prepared for Site 1021. This is presumably because Site 1021 was seaward (west) of the coastal zone of diatom productivity during the mid-Pliocene. Based on modern oceanographic conditions, this may imply that spring SSTs exceeded ~17°C (Dowsett et al., 1996).

#### Site 1022

Diatoms are relatively common in nearly all the samples that were examined, implying that Site 1022 lay within the coastal zone of higher diatom productivity during the mid-Pliocene.

Diatom assemblages are dominated by *Chaetoceros* spores (a coastal upwelling indicator whose numbers may be augmented by lateral advection off the continental shelf), the cold-water (subarctic) taxa *Neodenticula kamtschatica* and its descendant *Neodenticula koizumii*, and *Thalassionema nitzschioides*, a temperate taxon that appears to represent spring-season production within a broader region extending seaward from the coastal zone (Sancetta, 1992). Other significant components include *Coscinodiscus marginatus* (up to 15% of the assemblage) and undifferentiated forms of *Thalassiosira* (e.g., *T. convexa*, *T. eccentrica*, *T. leptopus*, *T. jacksonii*, and *T. pacifica*) (up to 18% of the assemblage; Table 1).

Significant diatom biostratigraphic events include the last common occurrence of *N. kamtschatica* (2.68 Ma) between 82.5 and 81.0 meters below seafloor (mbsf) and the last occurrence of *Nitzschia*

<sup>1</sup>Lyle, M., Koizumi, I., Richter, C., and Moore, T.C., Jr. (Eds.), 2000. *Proc. ODP, Sci. Results*, 167: College Station TX (Ocean Drilling Program).

<sup>2</sup>U.S. Geological Survey, MS910, 345 Middlefield Road, Menlo Park CA 94025, USA. [jbarron@usgs.gov](mailto:jbarron@usgs.gov)

Table 1. Percentage abundance of selected diatom taxa in the mid-Pliocene of Hole 1022A.

Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	<i>Actinopterychus</i> spp.	<i>Aspeitia nodulifera</i>	<i>Delphineis</i> spp.	<i>Chaetoceros</i> spores	<i>Coscinodiscus marginatus</i>	<i>Hemidiscus cuneiformis</i>	<i>Neodenticula kamtschatica</i>	<i>Neodenticula koizumii</i>	<i>Nitzschia reinholdii</i>	<i>Proboscita barboi</i>	<i>Rhizosolenia</i> spp.	<i>Stephanopyxis</i> spp.	<i>Thalassionema nitzeioides</i>	<i>Thalassiosira oestrupii</i>	<i>Thalassiosira</i> spp.	<i>Thalassiothrix longissima</i>	Benthic and freshwater taxa	Reworked taxa	Other planktonic taxa	Total counted
167-1022A-																						
9H-1, 50-52	71.50	2.50	0.0	1.0	3.6	32.3	0.0	0.0	0.0	35.0	0.0	0.0	1.0	4.0	9.9	2.0	9.6	1.0	0.7	0.0	0.0	303
9H-2, 50-52	73.00	2.53	0.0	0.0	4.0	16.8	0.0	0.0	15.0	28.3	0.0	0.0	0.6	0.0	12.1	0.6	18.5	1.7	1.7	0.6	0.0	173
9H-3, 50-52	74.50	2.55	0.0	2.5	1.2	34.6	7.4	0.0	0.0	7.4	0.0	4.9	2.5	12.3	9.9	2.5	12.3	2.5	0.0	0.0	0.0	40
9H-4, 50-52	76.00	2.57	0.0	0.0	1.6	46.4	2.3	0.0	1.8	30.8	0.0	0.0	1.8	0.0	7.4	0.9	6.0	0.5	0.5	0.0	0.0	218
9H-5, 50-52	77.50	2.59	0.3	1.3	0.3	29.4	2.3	1.0	0.7	22.2	0.3	0.3	0.3	2.0	21.2	2.9	12.7	1.3	0.3	0.0	0.7	306
9H-6, 50-52	79.00	2.62	1.7	1.0	0.3	26.0	3.3	0.0	0.3	38.7	0.0	0.7	0.7	0.7	13.3	1.0	10.0	1.7	1.0	0.0	0.7	300
9H-7, 50-52	80.50	2.64	0.3	0.6	1.9	38.2	0.8	0.3	0.8	29.2	0.3	0.3	1.4	1.1	9.2	0.0	11.4	1.1	1.4	0.8	0.6	359
10H-1, 50-52	81.00	2.66	1.0	1.0	2.3	26.2	2.3	1.3	0.7	33.8	0.0	1.7	1.0	1.0	13.9	1.0	8.3	0.7	1.7	0.0	1.7	302
10H-2, 50-52	82.50	2.69	0.0	0.7	3.0	32.0	0.7	0.7	22.8	7.3	0.0	0.3	2.0	3.6	18.2	0.0	6.6	1.0	0.3	0.3	0.3	303
10H-3, 50-52	84.00	2.71	0.0	0.3	2.3	23.0	1.0	0.3	40.8	3.6	0.3	0.3	0.7	0.3	19.4	0.3	5.3	0.3	0.0	0.3	0.7	304
10H-5, 50-52	85.92	2.74	0.7	1.4	2.4	42.0	0.2	0.2	13.2	2.8	0.5	0.2	0.7	3.8	21.2	0.9	6.4	0.9	0.9	0.2	0.9	424
10H-6, 50-52	87.03	2.76	0.0	0.0	1.2	22.7	1.6	0.4	28.5	4.7	0.4	0.4	1.2	0.8	28.1	0.8	5.9	0.4	0.8	0.0	1.2	256
10H-7, 50-52	88.53	2.78	2.0	3.6	0.7	24.4	3.3	1.7	5.6	5.3	0.3	4.0	0.7	4.0	25.7	4.6	8.9	1.3	0.7	0.0	2.6	303
11H-1, 50-52	90.50	2.80	0.4	5.0	2.1	22.1	6.0	1.8	2.1	2.8	0.7	3.9	1.8	2.8	27.0	3.6	15.7	1.8	0.7	0.0	0.0	281
11H-2, 50-52	92.00	2.83	0.3	0.6	2.9	52.4	0.3	1.0	1.9	1.9	0.6	0.6	1.3	2.9	23.3	1.3	4.8	0.6	1.0	0.0	1.3	313
11H-3, 50-52	93.50	2.85	0.4	2.6	1.3	28.8	3.5	1.7	5.2	1.3	1.3	3.1	0.9	3.5	24.5	1.7	10.0	1.7	2.6	0.9	2.6	229
11H-4, 50-52	95.00	2.87	1.9	2.3	2.3	31.5	5.2	1.0	3.2	1.0	0.6	1.9	1.9	2.9	26.6	2.9	11.0	1.3	2.6	0.3	0.6	308
11H-5, 50-52	96.50	2.90	3.0	3.0	2.3	33.2	4.0	0.7	5.0	2.3	0.3	1.3	1.7	2.3	28.2	2.0	8.6	0.3	1.0	1.0	1.3	301
11H-6, 50-52	98.00	2.92	1.6	1.9	1.9	23.7	3.1	0.3	9.3	1.9	0.6	1.9	1.2	3.4	28.7	3.4	11.8	0.9	2.2	0.6	1.6	321
11H-7, 50-52	99.50	2.94	0.7	1.3	0.7	27.6	6.3	0.0	12.0	0.0	0.3	3.0	2.0	0.3	30.2	0.7	9.6	2.7	2.7	0.7	0.0	301
12H-1, 50-52	100.00	2.96	0.7	1.7	0.7	24.9	4.0	0.7	18.6	0.0	0.0	1.7	2.0	2.0	25.6	3.7	11.3	1.0	1.3	0.3	0.3	301
12H-2, 50-52	101.54	2.99	3.1	0.7	0.7	24.2	0.3	0.0	18.0	0.0	0.3	0.3	0.7	1.4	36.7	2.4	7.3	0.7	3.1	0.3	1.4	289
12H-3, 50-52	103.04	3.01	2.1	4.2	2.1	26.6	2.1	0.0	6.3	0.0	0.0	2.1	2.8	3.5	35.0	0.7	6.3	0.7	5.6	2.1	0.0	143
12H-4, 50-52	104.54	3.03	0.7	1.0	1.3	20.5	2.0	0.0	26.1	0.3	0.0	0.3	0.7	0.0	34.7	0.7	5.9	0.7	3.0	0.3	1.3	303
12H-5, 50-52	106.04	3.06	1.6	1.0	1.0	21.0	10.5	0.3	10.8	0.0	0.0	2.9	0.6	3.5	30.6	0.6	8.0	0.6	2.9	0.6	2.5	314
12H-6, 50-52	107.54	3.08	1.9	0.6	0.3	20.2	15.1	0.3	15.7	0.6	0.3	7.1	2.6	3.8	10.9	2.2	11.5	2.9	1.0	0.3	2.2	312
12H-7, 50-52	109.04	3.10	1.3	0.3	1.3	22.4	14.1	0.3	14.1	0.3	1.0	5.6	0.3	6.9	11.5	1.6	14.1	2.6	1.3	0.7	0.7	304
13H-1, 50-52	109.50	3.11	3.0	0.3	1.3	19.6	14.0	0.0	6.3	0.0	0.3	3.0	4.0	3.3	34.6	1.0	5.0	2.0	0.3	1.3	0.7	301
13H-2, 53-55	111.03	3.13	0.3	0.7	0.0	26.9	5.0	0.3	12.6	0.3	0.7	1.0	4.7	3.7	30.6	1.0	5.6	2.7	2.0	0.7	1.3	301
13H-3, 50-52	112.50	3.16	0.8	0.8	0.8	30.5	4.6	0.0	9.2	0.0	0.8	0.8	3.8	6.9	35.1	0.0	2.3	0.0	2.3	1.5	0.0	131
13H-4, 50-52	114.00	3.18	0.3	0.3	0.7	34.7	9.6	0.0	5.9	0.3	0.3	1.3	2.6	7.3	21.5	1.3	7.6	3.3	1.3	0.3	1.3	303
13H-5, 50-52	115.50	3.20	0.7	0.0	1.6	29.2	3.9	0.0	11.5	0.0	0.3	1.6	0.7	4.6	36.1	0.0	6.6	1.3	0.7	0.7	0.7	305
13H-6, 50-52	117.00	3.23	0.0	0.0	1.3	37.5	3.9	0.7	2.0	0.0	0.7	0.7	0.7	3.9	40.8	0.7	3.9	0.7	2.0	0.7	0.0	152
13H-7, 50-52	118.50	3.25	0.6	0.3	0.3	28.2	10.9	0.6	10.9	1.0	2.6	0.6	2.6	4.8	25.3	1.0	5.1	1.9	1.9	0.6	0.6	312

*jouseae* (2.79 Ma) between 90.5 and 88.5 mbsf. These diatom events suggest a sedimentation rate approximating 70 m/m.y.

Color reflectance data for the mid-Pliocene of Hole 1022A displays cycles about every 2.8 m (10 cycles between 117 and 89 mbsf; Shipboard Scientific Party, 1997). If these cycles reflect 41-k.y. obliquity cycles, a sedimentation rate of ~68 m/m.y. results, which is in good agreement with diatom biostratigraphy. A sedimentation rate of 68 m/m.y. and diatom biostratigraphic datum levels indicate that the sequence studied from Hole 1022A ranges in age from ~2.50 (71.5 mbsf) to ~3.22 Ma (118.5 mbsf). Comparison of the last occurrence of the calcareous nannofossil *Reticulofenestra pseudumbilicus* (3.82 Ma; Shipboard Scientific Party, 1997) between 174.80 and 165.20 mbsf in Hole 1022C with the diatom datum levels suggests a slightly higher sedimentation rate of ~78 m/m.y. For the purposes of this report, an age model based on diatom biostratigraphy and a 68-m/m.y. sedimentation rate has been used to assign ages to the samples (Table 1).

## PALEOTEMPERATURE ESTIMATION

Barron (1995) used a diatom paleoclimatic ratio ("Tdf") to estimate mid-Pliocene SSTs at northwest Pacific ODP Sites 881, 883, and 480. This ratio compared relatively small, finely silicified pennate diatoms with different ecological preferences (*Neodenticula* = subarctic; *Thalassionema* = temperate; *Alveus marinus* (and *Nitzschia reinholdii*) = tropical to subtropical). Barron (1995) applied the

Tdf ratio to Constance Sancetta's (pers. comm., 1994) core-top data for the Pacific and found strong linear relationships with February and August SSTs ( $r^2$  values of 0.888 and 0.736, respectively) in the northwest Pacific.

The Tdf ratio was applied to the Hole 1022A diatom counts. The resultant SSTs (Fig. 1) appear to be anomalously cold for February (7°–1°C colder than modern values) and anomalously warm for August (6.0°–1.5°C warmer than modern values) based on PRISM reconstructions for the mid-Pliocene of the North Pacific (Dowsett et al., 1996; J.A. Barron, unpubl. data), which suggests that February and August SSTs were not more than 2°C warmer than modern values during the mid-Pliocene. Presumably, this discrepancy reflects the scarcity of Sancetta core-top data in the offshore California region and the resultant failure of the Tdf ratio to estimate paleotemperatures. In addition, the transitional zone between subarctic and subtropical waters off California is rather broad and oceanographically more complex compared to the more geographically constrained transition across the North Pacific Front in the northwest Pacific. This suggests that estimation of paleotemperatures off California using diatoms would require a detailed core-top data set for the region. Lateral transport of diatoms off the continental shelf is another problem in the offshore northern California region that complicates paleoenvironmental interpretation (Sancetta, 1992). Efforts are under way to compile modern core-top data in the offshore California region that may be more useful for diatom paleoclimatic studies.

The Tdf curves (Fig. 1) suggest that the main cooling event occurred between 2.8 and 2.7 Ma, whereas isotope records demonstrate that major cooling (and/or increased global ice volume) began later, at

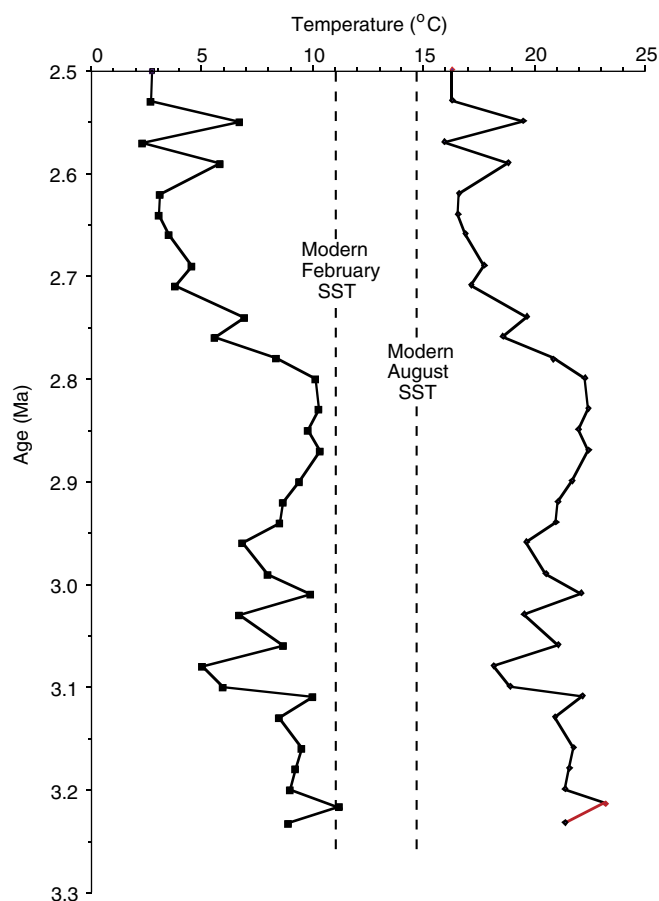


Figure 1. Estimated February and August sea-surface temperatures (SSTs) for the mid-Pliocene at Site 1022 derived from Barron's (1995) Tdf paleoclimate ratio for the North Pacific. Modern SSTs at Site 1022 are indicated by the vertical dashed lines.

~2.7 Ma (Shackleton et al., 1995). The earlier cooling recorded by diatoms reflects the use of the extinct diatom, *Neodenticula kamschatica*, as a cold-water component equivalent in ecological preference to its descendant, *N. koizumii*. An increasing dominance of *N. koizumii* over *N. kamschatica* beginning at ~2.7 Ma is more likely reflective of major cooling of surface waters.

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