U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PRELIMINARY CORRELATION AND AGE OF ROCK SAMPLES (KG-1 TO KG-24) IN THE COOPERATIVE MONTEREY ORGANIC GEOCHEMISTRY STUDY, SANTA MARIA AND SANTA BARBARA-VENTURA BASINS, CALIFORNIA

by

Caroline M. Isaacs[1]
Janice H. Tomson[1]
Michael D. Lewan[2]
Robert G. Arends[3]
Mary Lou Cotton[3]
Mark V. Filewicz[3]

Open-File Report 92-539-D

[1]U.S. Geological Survey
345 Middlefield Road, MS 999
Menlo Park, California 94025

[2]U.S. Geological Survey
Federal Center, Box 25046
Denver, Colorado 80225

[3]Unocal Corporation
2323 Knoll Drive
Ventura, California 93006

1992

CONTENTS

INTRODUCTION

This chapter describes the preliminary stratigraphic position and preliminary age of rock samples being analyzed in the Cooperative Monterey Organic Geochemistry Study (CMOGS). CMOGS, its purposes and participants, are more generally described in the *Preface* (Chapter A, this report). The samples reported here are all from (1) the Naples Beach section near Goleta, California, in the Santa Barbara-Ventura basin, or (2) the Lions Head section near Lompoc, California, in the Santa Maria basin. Geologic data on the rock samples is listed in *Preliminary Rock Sample Data* (Chapter C, this report).

The correlation of CMOGS samples to published measurements is preliminary and represents only part of a larger project in progress to make precise physical correlations among various measurements of Naples Beach and Lions Head. The primary purpose of the chapter is to provide relative positions and document evidence about the age of CMOGS samples. A secondary purpose is to provide correlation to the DePaolo and Finger (1991) section so that samples identified by those measurements can be stratigraphically integrated with CMOGS samples.

The collection of samples, and photographing and recording of sample positions, was done by C. M. Isaacs and J. H. Tomson. Stratigraphic positions were mainly determined by correlation to existing measured sections by C. M. Isaacs and J. H. Tomson with the invaluable help of M. D. Lewan. Paleontologic analyses were made by M. L. Cotton (Chapter C, this report), M. G. Filewicz (Chapter C, this report), and R. G. Arends (Chapter C, this report). C. M. Isaacs is solely responsible for physical correlation to published sections and tentative age assignments.

NAPLES BEACH SECTION

Explanation of Headings

Preliminary stratigraphic position: Positions are given in feet above the top of the bentonite at the base of the Monterey Formation, based on unpublished measurements by H. D. Gower (1965) and by M. D. Lewan and others. The boundary between the Monterey Formation and the Sisquoc Formation is placed at 1212 feet.

Microfossil zonation: Figure 1 summarizes the biostratigraphic framework (from Barron, 1986) used.

Foraminifera: Age determinations were made by M. L. Cotton (Chapter C, this report) based on the zonation of Kleinpell (1938, 1980).

Calcareous nannofossils: Age determinations were made by M. V. Filewicz (Chapter C, this report) based on the zonation of Okada and Bukry (1980).

Siliceous microfossils: Age determinations were made by R. G. Arends (Chapter C, this report) based on the zonation of Barron (1981, 1986).

Preliminary correlation to Arends-Blake zonation of Naples: Preliminary determinations are based on physical correlation of our sample localities to samples

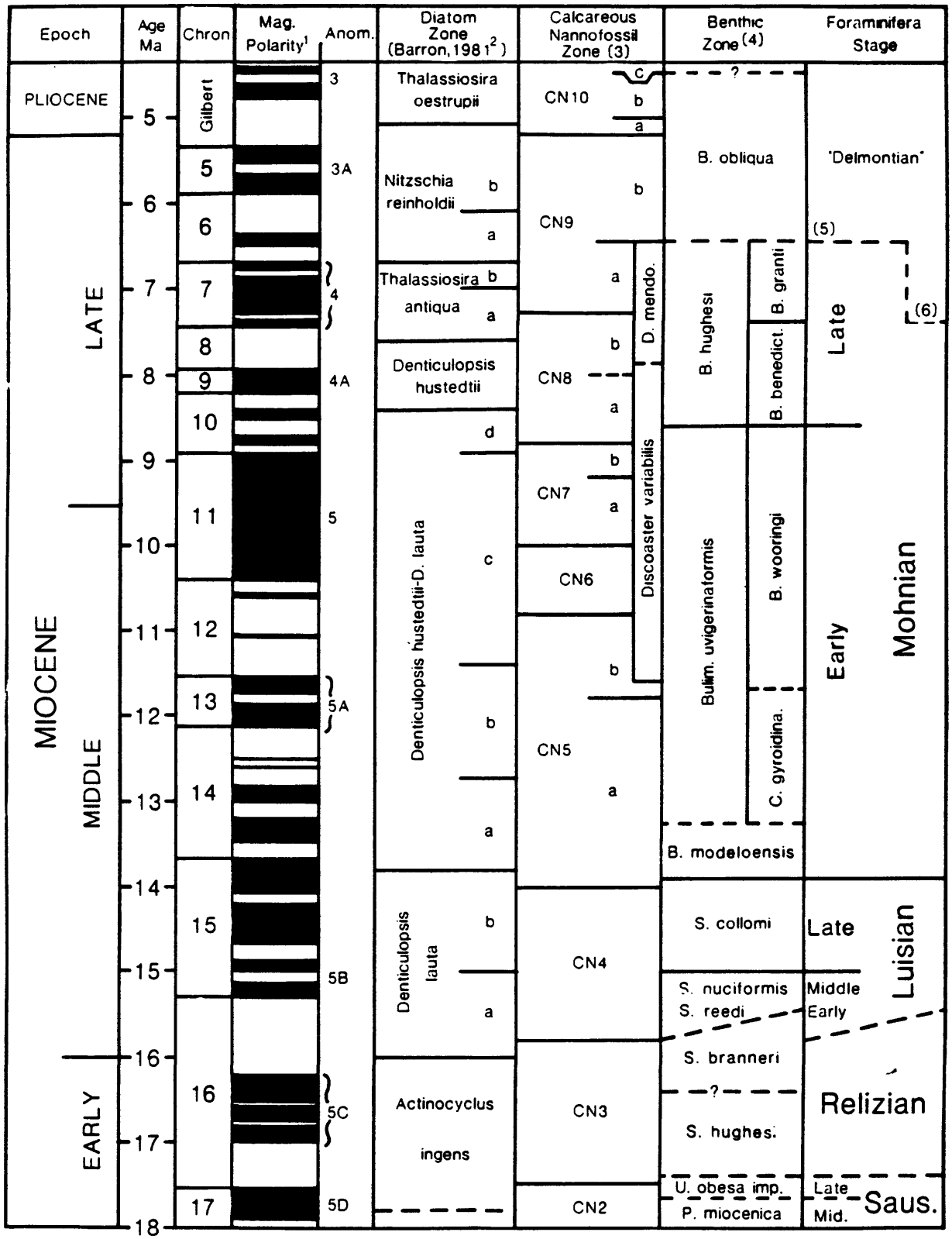

Figure 1. Biostratigraphic framework for diatom, calcareous nannofossil, and benthic foraminiferal zones, subzones, and stages in California (from Barron, 1986). Footnotes: (1) Berggren and others (1985); (2) Barron (1981) as modified by Barron and Keller (1983) and Barron and Baldauf (1986); (3) tropical zonation of Okada and Bukry (1980) with temperate zones of Bukry (1973) included on the left; (4) Kleinpell (1938) and Warren (1972); (5) Kleinpell (1938); (6) Kleinpell (1980).

from the Naples Beach section that are discussed in Arends and Blake (1986). The Arends-Blake zonation is based on about 210 samples all analyzed for benthic foraminifera, calcareous microfossils, and siliceous microfossils. Only generalized correlation to their diatom zones is given here.

Preliminary correlation to DePaolo-Finger section of Naples: Preliminary determinations are based on physical correlation of our sample localities to samples from the Naples Beach section that are discussed in DePaolo and Finger (1991). Most samples in the DePaolo-Finger section are composite samples representing five or more stratigraphic feet collected in 1963 and 1964 by J. H. Lipps, with some additional samples collected in 1989 (K. L. Finger, personal communication, 1992). The DePaolo-Finger section is based on about 110 samples analyzed for foraminifera including about 30 samples examined for siliceous microfossils, and about 20 samples analyzed by strontium isotope dating techniques.

Tentative absolute age: preliminary estimate based on data presented and comments.

Sample Positions and Ages

KG-12
Preliminary stratigraphic position: 1335 ft
Microfossil zonation:
Foraminifera: barren.
Calcareous nannofossils: barren.
Siliceous microfossils: *Nitzschia reinholdii* zone, subzone b (5.1-6.1 Ma, see Figure 1).
Preliminary correlation to Arends-Blake zonation of Naples: This sample lies in strata assigned to the *Nitzschia reinholdii* zone, subzone b (5.1-6.1 Ma, see Figure 1).
Preliminary correlation to DePaolo-Finger section of Naples: This sample overlies by several hundred feet the highest sample in the DePaolo and Finger (1991) section; the highest sample (NB-73) has a final assigned age of 7.4-7.5 Ma, and KG-12 is younger.
Tentative absolute age: within the range 5.1-6.1 Ma.

KG-13:
Preliminary stratigraphic position: 1315 ft
Microfossil zonation:
Foraminifera: barren.
Calcareous nannofossils: barren.
Siliceous microfossils: *Nitzschia reinholdii* zone, subzone b (5.1-6.1 Ma, see Figure 1).
Preliminary correlation to Arends-Blake zonation of Naples: This sample lies in strata assigned to the *Nitzschia reinholdii* zone, subzone b (5.1-6.1 Ma, see Figure 1).

Preliminary correlation to DePaolo-Finger section of Naples: This sample overlies by several hundred feet the highest sample in the DePaolo and Finger (1991) section; the highest sample (NB-73) has a final assigned age of 7.4-7.5 Ma, and KG-13 is younger.
Tentative absolute age: within the range 5.1-6.1 Ma.

KG-7:
Preliminary stratigraphic position: 1125 ft
Microfossil zonation:
Foraminifera: indeterminate.
Calcareous nannofossils: barren.
Siliceous microfossils: barren.
Preliminary correlation to Arends-Blake zonation of Naples: This sample lies in strata assigned to the *Nitzschia reinholdii* zone, subzone a (6.0-6.7 Ma, see Figure 1) or the *Thalassiosira antiqua* zone, subzone b (6.7-7.0 Ma, see Figure 1).
Preliminary correlation to DePaolo-Finger section of Naples: This sample overlies by at least one hundred feet the highest sample in the DePaolo and Finger (1991) section; the highest sample (NB-73) has a final assigned age of 7.4-7.5 Ma, and KG-7 is younger.
Tentative absolute age: within the range 6.1-7.0 Ma.

KG-8:
Preliminary stratigraphic position: 1125 ft
Microfossil zonation:
Foraminifera: indeterminate.
Calcareous nannofossils: barren.
Siliceous microfossils: indeterminate.
Preliminary correlation to Arends-Blake zonation of Naples: This sample lies in strata assigned to the *Nitzschia reinholdii* zone, subzone a (6.0-6.7 Ma, see Figure 1) or the *Thalassiosira antiqua* zone, subzone b (6.7-7.0 Ma, see Figure 1).
Preliminary correlation to DePaolo-Finger section of Naples: This sample overlies by at least one hundred feet the highest sample in the DePaolo and Finger (1991) section; this highest sample (NB-73) has a final assigned age of 7.4-7.5 Ma, and KG-8 is younger.
Tentative absolute age: within the range 6.1-7.0 Ma.

KG-5:
Preliminary stratigraphic position: 1000 ft
Microfossil zonation:
Foraminifera: Delmontian to late Mohnian.
Calcareous nannofossils: Miocene to early Pliocene undifferentiated.

Siliceous microfossils: *Denticulopsis hustedtii* zone (7.6-8.4 Ma, see Figure 1). Note that this assignment is inconsistent with the age of underlying strata and with correlation to the Arends-Blake zonation.

Preliminary correlation to Arends-Blake zonation of Naples: This sample lies in strata assigned to the *Thalassiosira antiqua* zone (6.7-7.6 Ma, see Figure 1), probably subzone a (7.0-7.6 Ma, see Figure 1).

Preliminary correlation to DePaolo-Finger section of Naples: This sample probably overlies the highest sample (NB-73) in the DePaolo and Finger (1991) section, which has a final assigned age of 7.4-7.5 Ma.

Comments: the age assignment of KG-5 by siliceous microfossils (above) is disregarded in view of its inconsistency with other evidence, including correlation to the more complete section of Naples in Arends and Blake (1986).

Tentative absolute age: within the range 6.7-7.6 Ma, probably 7.0-7.6 Ma.

KG-6:

Preliminary stratigraphic position: 970 ft

Microfossil zonation:

Foraminifera: Late Mohnian (6.4-8.6 Ma, see Figure 1).

Calcareous nannofossils: barren.

Siliceous microfossils: *Thalassiosira antiqua* zone, subzone a (7.0-7.6 Ma, see Figure 1).

Preliminary correlation to Arends-Blake zonation of Naples: This sample lies in strata assigned to the *Thalassiosira antiqua* zone (6.7-7.6 Ma, see Figure 1), probably subzone a (7.0-7.6 Ma, see Figure 1).

Preliminary correlation to DePaolo-Finger section of Naples: Sample positions in this part of the DePaolo and Finger (1991) section are not precisely reproducible, but sample KG-6 overlies their sample NB-64 by at least 95 stratigraphic feet and thus probably slightly overlies their sample NB-73 (which is the highest sample in their section). Sample NB-73 is assigned an age within the range 7.4-13.8 Ma on the basis of Mohnian benthic foraminifera, 7.4-10.0 on the basis of calcareous nannofossils, 6.7-7.6 Ma on the basis of siliceous microfossils, and 7.2-7.5 Ma on the basis of strontium-isotope dating. Their final assigned age for NB-73 is 7.4-7.5 Ma, and KG-6 is about the same age or slightly younger.

Tentative absolute age: within the range 7.0-7.6 Ma, probably about 7.4-7.5 Ma.

KG-1

Preliminary stratigraphic position: 690 ft

Microfossil zonation:

Foraminifera: Mohnian or older, undifferentiated.

Calcareous nannofossils: definitely middle Miocene, probably CN5 zone.

Siliceous microfossils: barren.

Preliminary correlation to Arends-Blake zonation of Naples: This sample lies in strata which are barren of diatoms in a 20-foot-thick hiatus or condensed zone encompassing the upper portion (including the top) of *Denticulopsis lauta* subzone b, the entire *Denticulopsis hustedtii-Denticulopsis lauta* subzones a and b, and the lower portion (including the base) of *Denticulopsis hustedtii-Denticulopsis lauta* subzone c. Time represented by the hiatus (or condensed zone of strata) includes at the least the interval in the range 11.2-13.7 Ma, and possibly much of the time intervals 8.9-11.2 Ma and 13.7-15.0 Ma, with the best estimate 9.3-14.8 Ma (Arends and Blake, 1986).

Preliminary correlation to DePaolo-Finger section of Naples: This sample probably lies near the boundary between the lower 8-foot composite Lipps sample NB-37 (JHL-41) and the upper 10-foot composite Lipps sample NB-38 (JHL-42) and is probably encompassed by the 10-foot composite Finger sample NB-89-8. For all three samples, DePaolo and Finger (1991) show the final age as 13.7-14.8 Ma (corrected to 13.7-15.0 Ma) based on the same zonation assignment for siliceous microfossils in the uppermost sample (NB-38) and in an underlying sample (NB-36).

However, (1) the physical correlation of sample KG-1 to the DePaolo-Finger section is only preliminary and not definite, (2) the details of the diatom assemblages (especially for NB-38) have not been published and are thus difficult to assess, and (3) strontium-isotope dating above (in the range 7.5-11.2 Ma) and below (11.2-15.7 Ma) this interval yields very imprecise ages. Thus assignment of sample KG-1 to the time interval 13.7-15.0 Ma is far from certain.

Tentative absolute age: probably within the range 13.7-15.0 Ma, but possibly as young as 8.9 Ma.

KG-4:

Preliminary stratigraphic position: 665 ft

Microfossil zonation:

Foraminifera: Mohnian or older, undifferentiated.

Calcareous nannofossils: barren.

Siliceous microfossils: *Denticulopsis lauta* zone (13.7-16.0 Ma, Figure 1).

Preliminary correlation to Arends-Blake zonation of Naples: This sample lies in strata assigned to the *Denticulopsis lauta* zone, subzone b (13.7-15.0 Ma, Figure 1).

Preliminary correlation to DePaolo-Finger section of Naples: This sample is located within or just overlying (by no more than 8 feet) the 6-foot composite Lipps sample NB-36 (JHL-38), and about 3 feet below the 5-foot composite Finger sample NB-89-5. The age of both samples are constrained by siliceous microfossils within the range 13.7-15.0 Ma.

Tentative absolute age: within the range 13.7-15.0 Ma.

KG-2:

Preliminary stratigraphic position: 605 ft

Microfossil zonation:

Foraminifera: Luisian.

Calcareous nannofossils: probable middle Miocene, probable CN4 (possible CN3) zone.

Siliceous microfossils: *Denticulopsis lauta* zone, subzone a (15.0-16.0 Ma, see Figure 1).

Preliminary correlation to Arends-Blake zonation of Naples: This sample lies near the boundary of strata assigned to diatom zone *Denticulopsis lauta* subzone a (15.0-16.0 Ma) and strata assigned to *Denticulopsis lauta* subzone b (13.7-15.0 Ma).

Preliminary correlation to DePaolo-Finger section of Naples: This sample is probably located within the 10-foot composite Lipps sample NB-30 (JHL-32). Based on correlation to calcareous nannofossil zone CN4 (14.0-15.7 Ma) and North Pacific diatom zone *Denticulopsis lauta* subzone b (13.7-15.0 Ma), DePaolo and Finger (1991) show an age of 14.0-15.0 Ma.

Comments: The siliceous microfossil zone assignment of sample KG-2 (above) is inconsistent with the age assignment in DePaolo and Finger (1991). Physical correlation of samples examined from the Naples section by Barron (1986) shows that sample KG-2 is located well within strata that he assigned to *Denticulopsis lauta* subzone b (13.7-15.0 Ma) and well above (>150 ft) strata assigned to *Denticulopsis lauta* subzone a (15.0-16.0 Ma), and physical correlation of samples reported by DePaolo and Finger (1991) show a similar relation. This relation is inconsistent with Arends and Blake's (1986) zonation. However, Arends and Blake's (1986) study involved much denser sampling than either other study, so both age assignments are included in the tentative age range.

Tentative absolute age: within the range 14.0-16.0 Ma.

KG-11:

Preliminary stratigraphic position: 180 ft

Microfossil zonation:

Foraminifera: Middle to early Miocene undifferentiated.

Calcareous nannofossils: indeterminate.

Siliceous microfossils: barren.

Preliminary correlation to Arends-Blake zonation of Naples: This sample underlies the lowest preserved age-diagnostic diatoms in the section.

Preliminary correlation to DePaolo-Finger section of Naples: This sample lies stratigraphically above the composite Lipps sample NB-83 (JHL-90) in the DePaolo and Finger (1991) section, probably near the boundary between NB-88 and the overlying sample NB-89. According to DePaolo and Finger (1991), samples NB-83, NB-88, and NB-93 (the next sample dated above NB-88) are all assigned (a) an age in the range 15.7-18.0 Ma based on calcareous nannofossils; and (b) an age in the range 17.4-18.0 Ma based on identification with the late Saucesian benthic foraminiferal stage and N5-N8 planktic foraminiferal zones. NB-83 yielded a strontium-isotope age of 17.6 Ma, NB-88 of 17.7 Ma, and NB-93 of 17.6-17.7 Ma.

Tentative absolute age: probably within the range 17.6-17.7 Ma.

KG-10:
Preliminary stratigraphic position: 180 ft
Microfossil zonation:
Foraminifera: Saucesian.
Calcareous nannofossils: indeterminate.
Siliceous microfossils: barren.
Preliminary correlation to Arends-Blake zonation of Naples: This sample underlies the lowest preserved age-diagnostic diatoms in the section.
Preliminary correlation to DePaolo-Finger section of Naples: This sample lies stratigraphically above the composite sample NB-83 (JHL-90) in the DePaolo and Finger (1991) section, probably near the boundary between NB-88 and the overlying sample NB-89. According to DePaolo and Finger, samples NB-83, NB-88, and NB-93 (the next sample dated above NB-88) are all assigned (a) an age in the range 15.7-18.0 Ma based on calcareous nannofossils; and (b) an age in the range 17.4-18.0 Ma based on identification with the late Saucesian benthic foraminiferal stage and N5-N8 planktic foraminiferal zones. NB-83 yielded a strontium-isotope age of 17.6 Ma, NB-88 of 17.7 Ma, and NB-93 of 17.6-17.7 Ma.
Tentative absolute age: within the range 17.6-17.7 Ma.

KG-9:
Preliminary stratigraphic position: -155 ft
Microfossil zonation:
Foraminifera: Saucesian (17.4 - ca 24 Ma; see Figure 1 and, for the age range of the Saucesisan stage, see Kleinpell, 1980, Appendix Figure 4).
Calcareous nannofossils: Early to Middle Miocene.
Siliceous microfossils: barren.
Preliminary correlation to Arends-Blake zonation of Naples: This sample underlies by at least 100 feet the section analyzed by Arends and Blake (1986).
Preliminary correlation to DePaolo-Finger section of Naples: This sample underlies by at least 100 feet the lowest sample in the DePaolo and Finger (1991) section. This lowest sample (NB-78, 2-2) has a final assigned age of 17.7-17.9 Ma, and KG-9 is older.
Tentative absolute age: within the range 17.7-24 Ma.

KG-3:
Preliminary stratigraphic position: -230 ft
Microfossil zonation:
Foraminifera: Saucesian (17.4 - ca 24 Ma, Figure 1 and Kleinpell, 1980, Appendix Figure 4).
Calcareous nannofossils: barren.

Siliceous microfossils: barren.
Preliminary correlation to Arends-Blake zonation of Naples: This sample underlies by at least 200 feet the section analyzed by Arends and Blake (1986).
Preliminary correlation to DePaolo-Finger section of Naples: This sample underlies by at least 200 feet the lowest sample in the DePaolo and Finger (1991) section. This lowest sample (NB-78, 2-2) has a final assigned age of 17.7-17.9 Ma, and KG-3 is older.
Tentative absolute age: within the range 17.7-24 Ma.

LIONS HEAD SECTION

Explanation of Headings

Preliminary stratigraphic position: These positions are given in feet above the base of lowermost strata in the Monterey Formation exposed above fault contact with underlying basement rock, based on unpublished measurements by M. D. Lewan and others.
Microfossil zonation: Figure 1 summarizes the biostratigraphic framework (from Barron, 1986) used.
Foraminifera: Age determinations were made by M. L. Cotton (Chapter C, this report) based on the zonation of Kleinpell (1938, 1980).
Calcareous nannofossils: Age determinations were made by M. V. Filewicz (Chapter C, this report) based on the zonation of Okada and Bukry (1980).
Preliminary correlation to White section: This preliminary correlation is based on physical correlation of our sample localities to samples from the middle member of the Monterey Formation at the Lions Head section discussed in White (1989).
Tentative absolute age: preliminary estimate based on data presented and comments.

Sample Positions and Ages

KG-16
Preliminary stratigraphic position: 985 ft
Microfossil zonation:
Foraminifera: barren.
Calcareous nannofossils: barren.
Preliminary correlation to White section: This sample lies in strata assigned to the *Denticulopsis hustedtii-Denticulopsis lauta* zone, subzone c (8.9-11.4 Ma), probably the upper part of the subzone (8.9-10.5 Ma).
Tentative absolute age: within the range 8.9-11.4 Ma, probably 8.9-10.5 Ma.

KG-19
Preliminary stratigraphic position: 795 ft
Microfossil zonation:
Foraminifera: barren.
Calcareous nannofossils: barren.
Preliminary correlation to White section: This sample lies in strata assigned to the *Denticulopsis hustedtii-Denticulopsis lauta* zone, subzone c (8.9-11.4 Ma) near the boundary with underlying strata assigned to subzone b (11.4-12.7 Ma).
Tentative absolute age: about 11.4 Ma or slightly younger.

KG-24
Preliminary stratigraphic position: 780 ft
Microfossil zonation:
Foraminifera: barren.
Calcareous nannofossils: barren.
Preliminary correlation to White section: This sample lies in strata assigned to the *Denticulopsis hustedtii-Denticulopsis lauta* zone, subzone c (8.9-11.4 Ma) near the boundary with underlying strata assigned to subzone b (11.4-12.7 Ma).
Tentative absolute age: about 11.4 Ma or slightly younger.

KG-17
Preliminary stratigraphic position: 595 ft
Microfossil zonation:
Foraminifera: Luisian (13.8-15.7 Ma, see Figure 1).
Calcareous nannofossils: middle Miocene, CN4 zone (14.0-15.7 Ma, see Figure 1).
Tentative absolute age: within the range 14.0-15.7 Ma.

KG-22
Preliminary stratigraphic position: 500 ft
Microfossil zonation:
Foraminifera: Luisian (13.8-15.7 Ma, see Figure 1).
Calcareous nannofossils: early to middle Miocene undifferentiated.
Tentative absolute age: within the range 13.8-15.7 Ma.

KG-18
Preliminary stratigraphic position: 215 ft
Microfossil zonation:
Foraminifera: barren.
Calcareous nannofossils: barren.

Tentative absolute age: based on sample position, within the range 13.8-15.7 Ma.

KG-14
Preliminary stratigraphic position: 205 ft
Microfossil zonation:
Foraminifera: possibly Relizian.
Calcareous nannofossils: CN4 zone (14.0-15.7 Ma).
Tentative absolute age: within the range 14.0-15.7 Ma.

KG-15
Preliminary stratigraphic position: 130 ft
Microfossil zonation:
Foraminifera: Relizian (15.4-17.4 Ma, see Figure 1).
Calcareous nannofossils: CN4 or CN3 (14.0-17.5 Ma, see Figure 1).
Tentative absolute age: within the range 15.4-17.4 Ma.

KG-20
Preliminary stratigraphic position: 95 ft
Microfossil zonation:
Foraminifera: Relizian (15.4-17.4 Ma, see Figure 1).
Calcareous nannofossils: CN4 or CN3 (14.0-17.5 Ma, see Figure 1).
Tentative absolute age: within the range 15.4-17.4 Ma.

ACKNOWLEDGMENTS

We thank Kenneth L. Finger of Chevron Oil Field Research (La Habra, California) for photographs and notes of the positions of samples in the DePaolo and Finger (1991) section of Naples Beach. Robert E. Garrison of the University of California Santa Cruz (Santa Cruz, California) and Kenneth J. Bird of the U.S. Geological Survey (Menlo Park, California) reviewed preliminary versions of the manuscript.

REFERENCES

Arends, R. G., and Blake, G. H., 1986, Biostratigraphy and paleoecology of the Naples Bluff coastal section based on diatoms and benthic foraminifera, *in* Casey, R. E., and Barron, J. A., eds., *Siliceous Microfossil and Microplankton of the Monterey Formation and Modern Analogs*: Pacific Section Society of Economic Paleontologists and Mineralogists Book 45, Los Angeles California, p. 121-135.

Barron, J. A., 1981, Late Cenozoic diatom biostratigraphy and paleoceanography of the middle-latitude eastern North Pacific, Deep Sea Drilling Project Leg 63: *Initial Reports of the Deep Sea Drilling Project*, v. 63, p. 507-538.

Barron, J. A., 1986, Updated diatom biostratigraphy for the Monterey Formation of California, *in* Casey, R. E., and Barron, J. A., eds., *Siliceous Microfossil and Microplankton of the Monterey Formation and Modern Analogs*: Pacific Section Society of Economic Paleontologists and Mineralogists Book 45, Los Angeles California, p. 105-119.

Barron, J. A., and Baldauf, J. G., 1986, Diatom stratigraphy of the lower Pliocene part of the Sisquoc Formation, Harris Grade section, California: Micropaleontology, v. 32, no. 4, p. 357-371.

Barron, J. A., and Keller, G., 1983, Paleotemperature oscillations in the middle and late Miocene of the northeastern Pacific: Micropaleontology, v. 29, no. 2, p. 150-181.

Berggren, W. A., Kent, D. V., Flynn, J. J., and Van Couvering, J. A., 1985, Cenozoic geochronology: Geological Society of America Bulletin, v. 96, p. 1407-1418.

Bukry, D., 1973, Coccolith and silicoflagellate stratigraphy, Deep Sea Drilling Project Leg 18: *Initial Reports of the Deep Sea Drilling Project*, v. 18, p. 817-831.

DePaolo, D. J., and Finger, K. L., 1991, High-resolution strontium-isotope stratigraphy and biostratigraphy of the Miocene Monterey Formation, central California: Geological Society of American Bulleton, v. 103, p. 112-124.

Kleinpell, R. M., 1938, *Miocene Stratigraphy of California*: American Association of Petroleum Geologists, Tulsa, Oklahoma, 450 p.

Kleinpell, R. M., 1980, *The Miocene Stratigraphy of California Revisited*: American Association of Petroleum Geologists, Tulsa, Oklahoma, 349 p.

Okada, H., and Bukry, D., 1980, Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973, 1975): Marine Micropaleontology, v. 5, p. 321-325.

Warren, A. D., 1972, Luisian and Mohnian biostratigraphy of the Monterey Shale at Newport Lagoon, Orange County, California, *in* Stinemeyer, E. H., ed., *The Pacific Coast Miocene Biostratigraphic Symposium*: Society of Economic Paleontologists and Mineralogists Pacific Section Book, p. 27-36.

White, L. D., 1989, Age of the Lions Head section, Santa Maria basin, California, *in* Garrison, R. E., ed., *Japan-US Seminar on Neogene Siliceous Sediments of the Pacific Region Syllabus and Fieldtrip Guidebook*, p. 121-123.