

U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

SUPPLEMENTARY DATA ON DIATOMS AND CALCAREOUS NANNOFOSSILS
AND PRELIMINARY REVISED AGES
FOR ROCK SAMPLES (KG-1 TO KG-24)
IN THE
COOPERATIVE MONTEREY ORGANIC GEOCHEMISTRY STUDY,
SANTA MARIA AND SANTA BARBARA-VENTURA BASINS, CALIFORNIA

by

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Open-File Report 93-182

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1993

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INTRODUCTION

This report provides supplementary data on diatoms, additional data on calcareous nannofossils, and some revised absolute ages for samples being analyzed by participants in the Cooperative Monterey Organic Geochemistry Study (CMOGS). The report supplements an earlier set of reports outlining CMOGS and providing preliminary geologic background and data on the samples being analyzed in the study. These earlier reports are abbreviated as *Preface* (Chapter A; Isaacs, 1992a); *Preliminary Geologic Background* (Chapter B; Isaacs, 1992b); *Preliminary Data on Rock Samples* (Chapter C; Isaacs, Pollastro, Arends, Barron, Cotton, Filewicz, Flower, and Piper, 1992); *Preliminary Correlation and Age* (Chapter D; Isaacs, Tomson, Lewan, Arends, Cotton, and Filewicz, 1992); *Geology Handbook* (Chapter E; Isaacs, 1992c); and *Preliminary Petroleum Geology Background* (Chapter F; Isaacs, 1992d).

The samples reported here are all from (1) a 1565-ft (475-m) thick interval within the Naples Beach section (latitude 34°26'N, longitude 119°58'W) near Goleta, California, in the Santa Barbara-Ventura basin, or (2) an 890-ft (270-m) thick interval within the Lions Head section (34°52'N, longitude 120°37'W) near Lompoc, California, in the Santa Maria basin. Geologic background on these sections is discussed in *Preliminary Geologic Background* (Chapter B, CMOGS preliminary geology reports). More details on the collection and stratigraphic position of the samples are given in *Preliminary Correlation and Age* (Chapter D, CMOGS preliminary geology reports). Additional samples from the same localities are reported in Isaacs, Tomson, Barron, Bukry, and Lewan (1993).

EXPLANATION OF HEADINGS FOR SAMPLES

Calcareous nannofossils: age determinations are based on the zonation of Okada and Bukry (1980).

Siliceous microfossils: age determinations are based on the zonation of Barron (1981, 1986). Estimates of productivity are based on indicators proposed by Barron and Keller (1983) together with evidence on preservation and downslope transport (as indicated by the abundance of benthic or shelf-dwelling taxa).

Revised absolute age: based on Barron's (1981, 1986) biostratigraphy framework (Figure 1).

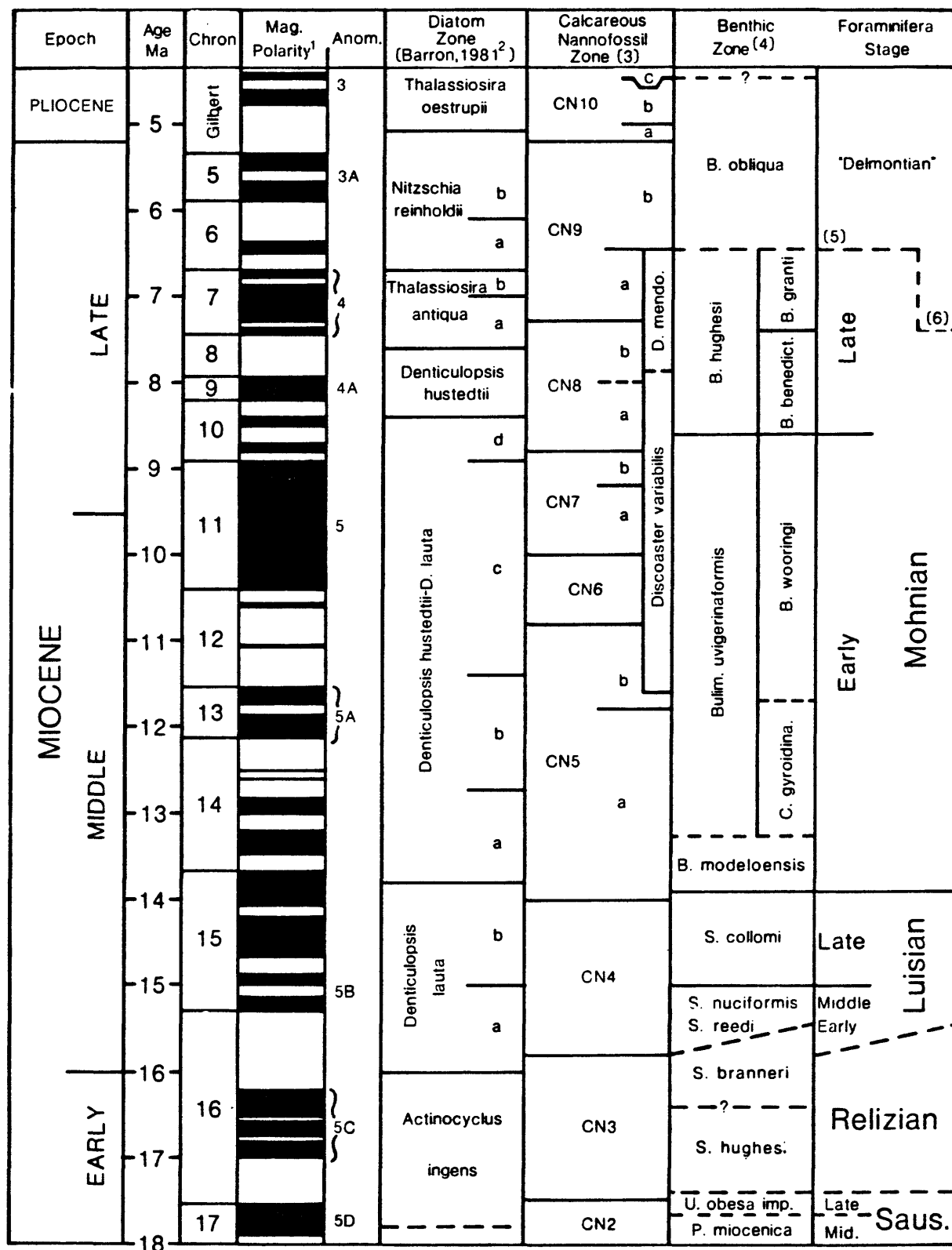


Figure 1. Biostratigraphic framework for diatom, calcareous nannofossil, and benthic foraminiferal zones, subzones, and stages in California (from Barron, 1986). Footnotes: (1) Berggren and others (1985); (2) Barron (1981) as modified by Barron and Keller (1983) and Barron and Baldauf (1986); (3) tropical 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).

PRELIMINARY SAMPLE DATA

Naples Beach Section (in descending stratigraphic order):

KG-12

Calcareous nannofossils (D. Bukry): barren

Siliceous microfossils (J. A. Barron):

Diatom species list (* indicates benthic or shelf-dwelling taxa transported downslope):

Thalassionema nitzschioides (common to abundant)

Nitzschia reinholdii (few; warm element)

Thalassiosira antiqua (few to common)

**Paralia sulcata* (few)

**Rhaphoneis* spp. (few)

**Cocconeis* spp.

**Actinoptychus* spp.

Delphineis sachalinensis

Thalassiosira hyalinopsis

Lithodesmium cf. *cornigerum*

Lithodesmium minusculum

Thalassiosira sp. (small form of Sisquoc Formation)

Coscinodiscus subtilis

Sample characteristics: Good preservation, some fragmentation, no quartz. Very little dissolution, warm oceanic upwelling assemblage with mixed benthic taxa indicating some downslope transport. In terms of productivity, the sample is ranked as representing excellent productivity (among the sample set, highest productivity, similar to KG-5, higher than all other samples with preserved diatoms).

Age assignment: *Thalassiosira hyalinopsis* zone (5.35-5.6 Ma).

Revised absolute age: within the range 5.35-5.6 Ma.

KG-13

Calcareous nannofossils (D. Bukry): barren.

Siliceous microfossils (J. A. Barron):

Diatom species list (* indicates benthic or shelf-dwelling taxa transported downslope):

Thalassionema nitzschioides (common)

Thalassiosira antiqua (few to common)

**Paralia sulcata* (few)

**Rhaphoneis* spp. (few)

**Actinopychus* spp.

Delphineis sachalinensis

Coscinodiscus subtilis

Sample characteristics: Moderate preservation, more quartz than in KG-12; more sea-floor dissolution than in KG-12, and fewer warm-water elements. In terms of productivity, the sample is ranked as representing very good productivity (among the sample set, less than KG-5 and KG-12, similar to KG-6, and greater than other samples with preserved diatoms).

Age assignment: none.

Comments: This sample was tentatively assigned an age of 5.1-6.1 Ma in *Preliminary Age and Correlation* (Isaacs, Tomson, Lewan, Arends, Cotton, and Filewicz, 1992).

Based on subposition to KG-12, the age is greater than 5.35 Ma.

Revised absolute age: within the range 5.35-6.1 Ma.

KG-7

Calcareous nannofossils (D. Bukry): barren.

Siliceous microfossils (J. A. Barron): barren.

KG-8

Calcareous nannofossils (D. Bukry): barren.

Siliceous microfossils (J. A. Barron):

Diatom species list (* indicates benthic or shelf-dwelling taxa transported downslope):

**Paralia sulcata*

Actinocyclus ingens

Sample characteristics: Poor preservation, abundant sponge spicules, common fragments of diatom frustules, common quartz grains. In terms of preservation, the sample is ranked as representing extreme postdepositional transport and dissolution (among the sample set, like KG-2 and KG-4). Consequently, no productivity estimate is given.

Age assignment: none.

KG-5

Calcareous nannofossils (D. Bukry): Cold-water-dissolution residue of *Reticulofenestra pseudoumbilica*. Associated silicoflagellates such as *Distephanus pseudofibula* and *Distephanus speculum minutus* indicate the age. Age assignment: late Miocene.

Siliceous microfossils (J. A. Barron):

Diatom species list (* indicates benthic or shelf-dwelling taxa transported downslope):

Thalassionema nitzschioides (abundant)

Thalassionema schraderi

Thalassiosira antiqua (very rare)

Actinocyclus divisus

Rouxia californica

Synedra jouseana (young form)

Silicoflagellate species list:

Distephanus pseudofibula

Dictyocha spp. (common)

quadrate *Distephanus*

Sample characteristics: Very good preservation, looks like a relatively pure diatomaceous ooze that underwent little or no bioturbation or post-depositional transport. The sample was deposited during a relatively warm period and is dominated by planktonic taxa. In terms of productivity, the sample is ranked as representing excellent productivity (among the sample set, highest productivity, similar to KG-12, and greater than all other samples with preserved diatoms).

Age assignment: subzone a of the *Thalassiosira antiqua* zone (7.6-7.0 Ma).

Other correlation data: Preliminary physical correlation to the Gower-Brabb stratigraphic section of Naples Beach shows that sample KG-5 lies just above Barron's (1986) sample P43 (and thus within strata assigned to subzone b of the *Thalassiosira antiqua* zone, 6.7-7.0) Ma) or between samples P42 and P43 (and thus within strata in the interval between those assigned to subzone a and those assigned to subzone b). However, the presence of the silicoflagellate *Distephanus pseudofibula* restricts the zonation to subzone a (7.0-7.6 Ma).

Revised absolute age: within the range 7.0-7.6 Ma.

KG-6

Calcareous nannofossils (D. Bukry): barren.

Siliceous microfossils (J. A. Barron):

Diatom species list (* indicates benthic or shelf-dwelling taxa transported downslope):

Actinocyclus divisus

Actinocyclus ingens

Coscinodiscus marginatus

Chaetoceros spores (common)

Denticulopsis katayamae

**Paralia sulcata* (rare?)

Thalassionema nitzschioides (common to abundant; fragmented)

Thalassionema schraderi

Silicoflagellate species list:

Distephanus pseudofibula

Dictyocha spp.

Sample characteristics: The sample contains fragments of small diatoms and quartz grains, and looks like a bioturbated version of sample KG-5 or a little more transported. In terms of productivity, the sample is ranked as representing very good productivity (among the sample set, less than KG-5 and KG-12, similar to KG-13, and greater than other samples with preserved diatoms).

Age assignment: 8.7-7.8 Ma.

Comments: The diatom age assignment here is inconsistent with preliminary physical correlation both to the Arends-Blake zonation of Naples (Arends and Blake, 1986) and to the DePaolo-Finger section at Naples (DePaolo and Finger, 1991) as discussed in *Preliminary Correlation and Age* (Isaacs, Tomson, Lewan, Arends, Cotton, and Filewicz, 1992) and is accordingly disregarded. The diatom *Thalassiosira antiqua*, which should be present if this sample belongs to the *Thalassiosira antiqua* zone, was not observed.

Other correlation data: Preliminary physical correlation to the Gower-Brabb stratigraphic section of Naples Beach shows that sample KG-6 lies between Barron's (1986) samples P42 and P43 and thus within strata in the interval between those assigned to subzone a and those assigned to subzone b of the *Thalassiosira antiqua* zone. However, the presence of the silicoflagellate *Distephanus pseudofibula* restricts the sample to subzone a (7.0-7.6 Ma).

KG-1

Calcareous nannofossils (D. Bukry): Low-diversity, slightly etched flora contains common *Coccolithus pelagicus* and *Reticulofenestra pseudumbilica*, but only sparse *Cyclicargolithus floridanus*, *Discoaster* sp. cf. *Discoaster exilis*, *Discoaster* sp. cf. *Discoaster sanmiguelensis*, and *Discoaster variabilis*. Key zonal guide species such as *Sphenolithus heteromorphus* are missing. Age assignment: CN4 (14.0-15.7 Ma) or CN5 (10.4-15.7 Ma).

Siliceous microfossils (J. A. Barron): barren.

KG-4

Calcareous nannofossils (D. Bukry): barren.

Siliceous microfossils (J. A. Barron):

Diatom species list (* indicates benthic or shelf-dwelling taxa transported downslope):

Denticulopsis hyalina (few)

Denticulopsis lauta

Actinocyclus ingens

Actinocyclus ingens nodus

**Paralia clavigera*

Sample characteristics: The sample contains abundant sponge spicules and abundant quartz, the diatom frustules are fragmented, and the assemblage poorly preserved. The abundant sponge spicules and quartz grains indicated a transported and winnowed sediment. In terms of preservation, the sample is ranked as representing extreme postdepositional transport and dissolution (among the sample set, like KG-2 and KG-8). Consequently, no productivity estimate is given.

Age assignment: subzone b of the *Denticulopsis lauta* zone (13.7-15.0 Ma).

KG-2

Calcareous nannofossils (D. Bukry): barren.

Siliceous microfossils (J. A. Barron):

Diatom species list (* indicates benthic or shelf-dwelling taxa transported downslope):

Coscinodiscus marginatus

Denticulopsis lauta

Actinocyclus ingens (common)

Actinocyclus ingens nodus

**Diploneis* sp.

**Stictodiscus* sp.

Synedra jouseana

Sample characteristics: The sample contains abundant sponge spicules and abundant quartz, the diatom frustules are fragmented, and the assemblage is poorly preserved. In terms of preservation, the sample is ranked as representing extreme postdepositional transport and dissolution (among the sample set, like KG-4 and KG-8). Consequently, no productivity estimate is given.

Age assignment: subzone b of the *Denticulopsis lauta* zone (13.7-15.0 Ma).

Other correlation data: Preliminary physical correlation to the Gower-Brabb stratigraphic section of Naples Beach shows that sample KG-2 lies between Barron's (1986) samples P19 and P20 and thus within strata assigned to subzone b of the *Denticulopsis lauta* zone. As noted in *Preliminary Correlation and Age* (Isaacs and others, 1992b), preliminary physical correlation to published zonations of the Naples Beach section show a disagreement between Arends and Blake (1986) and Barron (1986) as to the diatom biostratigraphy in this portion of the Naples Beach section. Barron (1986; also in this report) recognizes rare specimens of *Denticulopsis hyalina* in these strata and assigns them to subzone b of the *Denticulopsis lauta* zone. Arends and Blake (1986) do not recognize *Denticulopsis hyalina*, and assign these strata to subzone a of the *Denticulopsis lauta* zone. However, the absolute age range for the diatom zones is based on paleomagnetostratigraphy at Naples Beach correlated to the assignment by Barron (1986); accordingly, the age range based on diatom zonation is revised to 13.7-15.0 Ma. Preliminary physical correlation of KG-2 to the DePaolo and Finger (1991) section restrict the sample to calcareous nannofossil zone CN4 (14.0-15.7 Ma). The concurrent range of ages based on diatoms and calcareous nannofossils is thus 14.0-15.0 Ma.

Revised absolute age: within the range 14.0-15.0 Ma.

KG-11

Calcareous nannofossils (D. Bukry): Sparse, poor flora with calcareous debris and rhombs diluting the coccoliths. *Helicosphaera carteri* gives the age, otherwise there are only long-ranged placoliths. Age assignment: Neogene.

KG-10

Calcareous nannofossils (D. Bukry): Poor flora dominated by placoliths, including *Cyclicargolithus floridanus* and *Reticulofenestra pseudoumbilica* (12 μm). Very sparse discoasters include only *Discoaster deflandrei* and *Discoaster barbadiensis* (Eocene, reworked). Only one *Sphenolithus heteromorphus* was seen in a 25-minute search. Age assignment: Early or middle Miocene.

KG-9

Calcareous nannofossils (D. Bukry): barren.

Siliceous microfossils (J. A. Barron): not examined.

KG-3

Calcareous nannofossils (D. Bukry): barren.

Siliceous microfossils (J. A. Barron): not examined.

LIONS HEAD SECTION**KG-16**

Calcareous nannofossils (D. Bukry): barren.

KG-19

Calcareous nannofossils (D. Bukry): barren.

KG-24

Calcareous nannofossils (D. Bukry): barren.

KG-17

Calcareous nannofossils (D. Bukry): meager, poor, overgrown flora predominated by ragged placoliths of *Coccolithus pelagicus* and *Cyclicargolithus floridanus*. The only guide species, *Sphenolithus heteromorphus* (2 specimens) indicates the zonal range.

Age assignment: early or middle Miocene, CN3 (14.0-15.7 Ma) or CN4 (14.0-15.7 Ma) zone.

KG-22

Calcareous nannofossils (D. Bukry): Meager etched flora and abundant calcareous debris. The overlap of *Discoaster deflandrei* and *Helicosphaera carteri* shows the stratigraphic range possible. Age assignment: early or middle Miocene, CN1 to CN5a zone.

KG-18

Calcareous nannofossils (D. Bukry): barren.

KG-14

Calcareous nannofossils (D. Bukry): abundant flora with rhombs and debris has *Cyclicargolithus floridanus*, *Discoaster deflandrei*, *Helicosphaera carteri*, and *Sphenolithus heteromorphus*, a typical array for CN3. Age assignment: early or middle Miocene, CN3 zone (15.7-17.5 Ma).

Comments: This zonal assignment is inconsistent with the previous assignment to calcareous nannofossil zone CN4 (14.0-15.7 Ma) in *Preliminary Age and Correlation* (Isaacs, Tomson, Lewan, Arends, Cotton, and Filewicz, 1992); accordingly, the age is revised to include both the CN3 and CN4 zones. By superposition with KG-15 and KG-20, which are assigned to the Relizian benthic foraminiferal stage (15.4-17.4 Ma), KG-14 is inferred to be younger than 17.4 Ma.

Revised absolute age: within the range 14.0-17.4 Ma.

KG-15

Calcareous nannofossils (D. Bukry): sparse, poor flora, mainly *Coccolithus pelagicus* with very sparse *Cyclicargolithus floridanus*, *Discoaster deflandrei*, *Reticulofenestra pseudoumbilica*, and *Sphenolithus heteromorphus* (2 specimens). Age assignment: early or middle Miocene, CN3 or CN4 zones (Ma).

KG-20

Calcareous nannofossils (D. Bukry): sparse etched flora with *Calcidiscus* sp. cf. *Calcidiscus macintyre* (1 specimen), *Cyclicargolithus floridanus*, *Discoaster deflandrei*, and *Sphenolithus heteromorphus*, but no *Helicosphaera ampliaperta*. Age assignment: middle Miocene, probably low in CN4 zone.

ACKNOWLEDGMENTS

We thank James C. Ingle Jr. of Stanford University (Stanford, California) and Arndt Schimmelmann of Scripps Institution of Oceanography (La Jolla, California) for reviewing preliminary versions of this report.

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