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PRELIMINARY DATA AND AGE-CORRELATION FOR EXTRA ROCK SAMPLES (KG-25 TO KG-47) IN THE COOPERATIVE MONTEREY ORGANIC GEOCHEMISTRY STUDY, SANTA MARIA AND SANTA BARBARA-VENTURA BASINS, CALIFORNIA

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CONTENTS

Figure

INTRODUCTION

This report provides preliminary geologic data and correlation for extra samples being analyzed by selected 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 main samples being analyzed in the study. These earlier reports, hereafter referred to as "CMOGS preliminary geology 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 D; Isaacs, 1992c); and *Preliminary Petroleum Geology Background* (Chapter F; Isaacs, 1992d).

The samples reported here are all from (1) an interval 1565 ft (475 m) thick within the Naples Beach section near Goleta, California, in the Santa Barbara-Ventura basin, or (2) an interval 890 ft (270 m) thick within the Lions Head section 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).

Not all the samples KG-25 to KG-47 are discussed here. Data are presented only on KG-25, KG-26, KG-27, KG-30, KG-31, KG-32, KG-33, KG-34, KG-35, KG-36, KG-38, KG-39, KG-41, KG-42, and KG-47.

SAMPLE SELECTION

The basic set of rock samples collected for CMOGS (KG-1 to KG-24) were selected in order to examine lithologic and sedimentologic features and contrasts characteristic of various parts of the lithologic sequence. By contrast, the supplemental samples were selected principally to fill in sampling gaps in the stratigraphic sequence where preliminary results of porphyrin analysis (P. Sundararaman, personal communication, 1990) showed stratigraphic boundaries of organic facies. The supplemental samples were (for the most part) intentionally selected to be specially rich in calcite and/or clay relative to biogenic and diagenetic silica (and thus for the most part likely to be rich in organic matter); they are not average representatives of the stratigraphic sequence.

EXPLANATION OF HEADINGS FOR SAMPLES

Purpose of sample: the intention in selecting the sample and which other samples were intended to be closely compared in exploring questions about the organic matter. (See also "Purpose of sample set" under Naples and Lions Head in *Preliminary Geologic Background*, Chapter B, CMOGS preliminary geology reports.)

Lithology: rock name commonly used by local geologists (see also discussion of rock classification systems under "Rock" in *Geology Handbook*, Chapter E, CMOGS preliminary geology reports).

ODP-equivalent sediment: the name in the current ODP classification that the rock would have had prior to lithification (Mazzullo and others, 1988) based on inorganic composition only.

Stow-Piper-Dean-equivalent sediment: the name in Dean and others' (1984) classification scheme introduced to handle sediments that are mixtures of detrital mud, biogenic carbonate, and biogenic silica. By analogy with the term "marl" for muddy calcareous sediment, they introduce "sarl" for muddy siliceous sediment, and "smarl" for muddy calcareous siliceous sediment. The sediment name is given according to this scheme as formalized by Stow and Piper (1984).

Lithostratigraphic unit: the formation or member from which the sample was taken (see also discussion under "Formation" and "Member" in *Geology Handbook*, Chapter E, CMOGS preliminary geology reports).

Section position: position of the sample (in feet) within the measured section. For the Naples Beach section, positions are given 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. For the Lions Head section, positions are given 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.

Typicalness: representativeness of the sample in reference to lithologies generally found in the member; see also Figures 11-15 in *Preliminary Geologic Background* (Chapter B, CMOGS preliminary geology reports).

Inorganic composition:

By XRF: values for sedimentary components derived from major oxide analyses by a partitioning scheme developed for the Monterey Formation in the Santa Barbara coastal area (Isaacs, 1980). Values are normalized on an organic-free-basis (and

excluding pyrite) to 100%. Components are calcite, dolomite, apatite, aluminosilicate minerals (including clay minerals), detrital quartz, and biogenic and diagenetic silica.

The XRF (X-ray fluorescence) analyses are quantitative, and reproducibility of duplicate blind splits is <2% of analyzed values of major oxides, except Na_2O, which has an average standard deviation of 3% of analyzed values (0.04 wt% Na_2O). The *reproducibility* of the derived sediment components is excellent, with average standard deviations of 0.5 wt% detrital minerals (aluminosilicate minerals + detrital quartz), 0.4 wt% biogenic silica, 0.1 wt% dolomite, 0.2 wt% calcite, and 0.01 wt% apatite (Isaacs and others, 1989). Regarding accuracy, the partition between dolomite and calcite is not quite accurate due to excess Ca in dolomite, but the sum of dolomite + calcite is quite accurate (Isaacs and others, 1989). Due to variability in the composition of the clay fraction, small calculated amounts of biogenic and diagenetic silica (< 10%) may not actually be present.

Faunal and floral analysis:

Calcareous nannofossils: age determinations are based on the zonation of Okada and Bukry (1980). The significance of placoliths as indicators of upwelling is discussed by Gartner and others (1987) and Gartner (1988).

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).

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

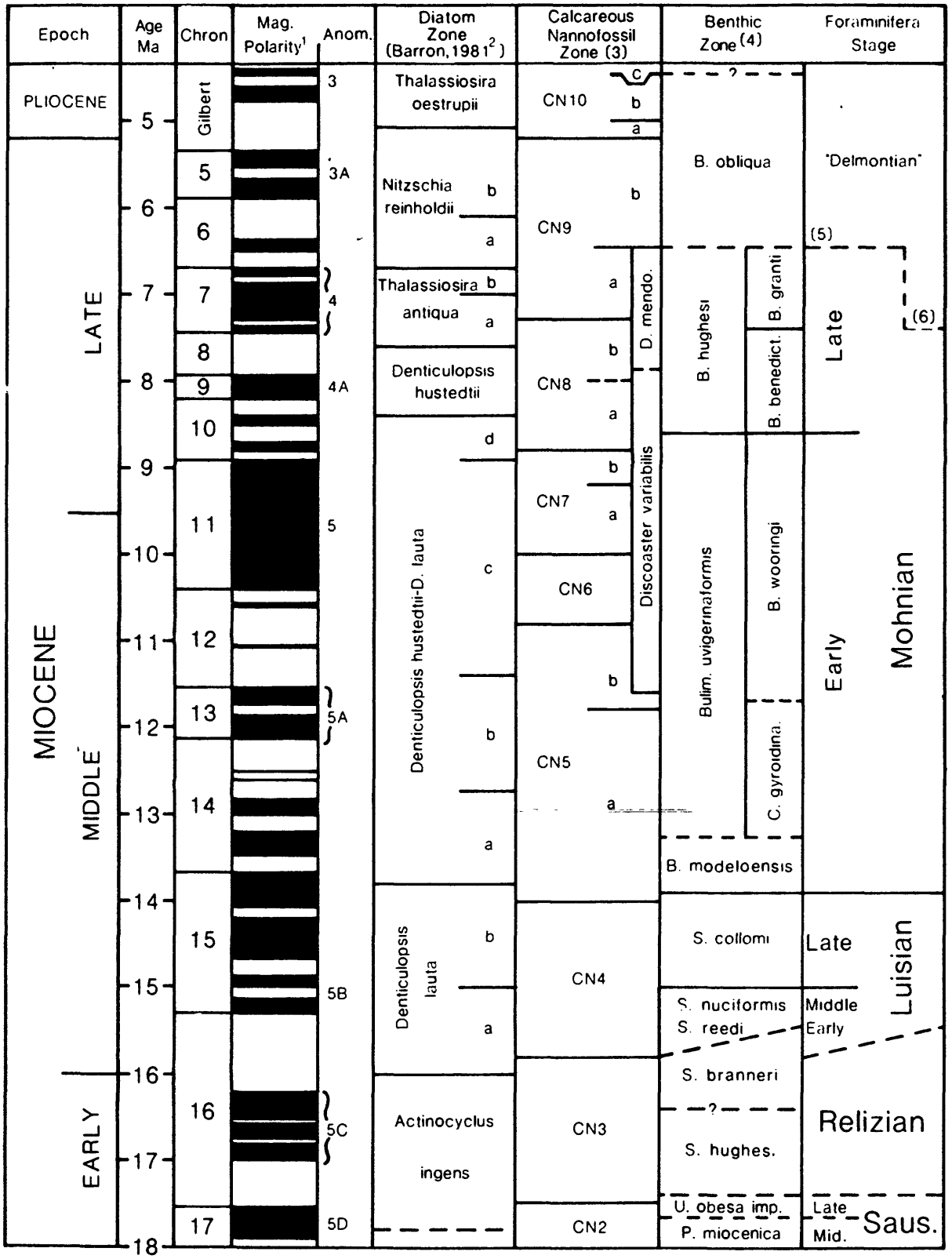

Figure 1. Biostratigraphic framework for diatom, calcareous nannofossil, and benthic foraminiferal zones, subzones, and stages in California (from Barron, 1986). Footnotes: (1) Berggren and others (1985); (2) Barron (1981) as modified by Barron and Keller (1983) and Barron and Baldauf (1986); (3) tropical 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-30

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-6 and KG-1 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: (slightly calcareous) diatomaceous mudstone

ODP-equivalent sediment: mud with diatoms

Stow-Piper-Dean-equivalent sediment: mud

Lithostratigraphic unit: Monterey Formation, upper calcareous-siliceous and transitional marl-siliceous members (of Isaacs, 1984) undifferentiated

Section position: 905 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach but somewhat more clay-rich than samples that are generally present in this part of the sequence in other coastal sections (see Figure 14 *Preliminary Geologic Background*, Chapter B, CMOGS preliminary geology reports).

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 5% calcite, 2% dolomite, 2% apatite, 74% aluminosilicate minerals and detrital quartz, 17% biogenic and diagenetic silica.

Faunal and floral analysis:

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
Chaetoceros spores
Denticulopsis hustedtii
Denticulopsis katayamae
Rouxia californica
Delphineis sachalinensis (common)
**Paralia sulcata* (few)
Rossiella mediopunctata

**Cocconeis* spp.

**Rhaphoneis* spp.

Thalassionema nitzschioides (common; fragmented)

reworked *Denticulopsis praedimorpha*

Silicoflagellate species list:

Distephanus pseudofibula

Sample characteristics: moderate preservation with many fragments, quartz common. The sample appears to be transported downslope based on the presence of benthic and reworked taxa as well as the abundance of quartz grains. In terms of productivity, the sample is ranked as representing moderately high productivity (less productivity than KG-6 and KG-13 but more than KG-34).

Age assignment: *Denticulopsis hustedtii* zone (7.6-8.4 Ma) or subzone d of the *Denticulopsis hustedtii-Denticulopsis lauta* zone (8.4-8.9 Ma), and bearing *Denticulopsis katayamae* (restricted to a range of 7.8-8.7 Ma).

Other correlation data: Preliminary physical correlation to the Gower-Brabb stratigraphic section of Naples Beach shows that sample KG-30 lies very near Barron's (1986) sample P40 which was assigned by Barron (1986) to subzone a of the *Thalassiosira antiqua* zone (7.6-7.0 Ma). The sample is thus within strata assigned to that subzone or in the interval between strata so assigned and strata assigned to the *Denticulopsis hustedtii* zone (7.6-8.4 Ma). Combining this range with the diatom zone assignment (above) places KG-30 in the *Denticulopsis hustedtii* zone, and the age is accordingly restricted tentatively to the range 7.8-8.4 Ma.

Tentative absolute age: within the range 7.8-8.4 Ma.

KG-31

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-6 and KG-1 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: phosphatic calcareous diatomaceous shale

ODP-equivalent sediment: diatomaceous muddy mixed sediment with calcite

Stow-Piper-Dean-equivalent sediment: smarl (or phosphatic sarl)

Lithostratigraphic unit: Monterey Formation, upper calcareous-siliceous and transitional marl-siliceous members (of Isaacs, 1984) undifferentiated

Section position: 865 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 12% calcite, 2% dolomite, 7% apatite, 49% aluminosilicate minerals and detrital quartz, 29% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): cold-water dissolution residue dominated by *Reticulofenestra pseudoumbilica*, *Reticulofenestra sp.*, and *Coccolithus pelagicus*. The assemblage indicates cool-water planktonic conditions and dissolution. Age assignment: Neogene.

Siliceous microfossils (J. A. Barron):

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

Coscinodiscus marginatus (common fragments)
Chaetoceros spores
Delphineis sachalinensis
Denticulopsis hustedtii
Thalassiosira aff. *nativa* (California form)
**Cocconeis* spp. (few)
**Paralia sulcata* (few)
**Grammatophora* spp. (few)
reworked *Crucidenticula nicobarica*

Silicoflagellate species list:

Distephanus pseudofibula

Sample characteristics: the sample consists of fragments of microfossils, generally poorly preserved. The sample appears to be transported based on the presence of benthic and reworked taxa. In terms of preservation, the sample is ranked as representing significant postdepositional transport and dissolution (like KG-32 and KG-42, more dissolved than KG-34, less dissolved than KG-8, KG-33, KG-4, and KG-2). Consequently, no productivity estimate is given.

Age assignment: none.

Other correlation data: Preliminary physical correlation to the Gower-Brabb stratigraphic section of Naples Beach shows that sample KG-31 lies just above Barron's (1986) sample P39 and thus in the interval between strata assigned to the *Denticulopsis hustedtii* zone (7.6-8.4 Ma) and strata assigned to subzone a of the *Thalassiosira antiqua* zone (7.6-7.0 Ma).

Tentative absolute age: within the range 7.0-8.4 Ma.

KG-32

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-6 and KG-1 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: phosphatic calcareous diatomaceous shale

ODP-equivalent sediment: muddy mixed sediment with diatoms, calcite, and apatite

Stow-Piper-Dean-equivalent sediment: smarl

Lithostratigraphic unit: Monterey Formation, carbonaceous marl member (of Isaacs, 1984)

Section position: 815 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 16% calcite, 3% dolomite, 11% apatite, 50% aluminosilicate minerals and detrital quartz, 20% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): Etched flora includes *Catinaster* sp., *Discoaster* sp. cf. *Discoaster bellus*, *Discoaster braarudii*, and *Discoaster variabilis*, with sparse *M. convallis*(?). Age assignment: middle or late Miocene, zones CN7 or CN8.

Siliceous microfossils (J. A. Barron):

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

Actinocyclus ingens
Coscinodiscus marginatus (fragments)
Chaetoceros spores
Delphineis sachalinensis
Denticulopsis cf. *katayamae*
reworked *Denticulopsis hyalina*
reworked *Denticulopsis praedimorpha*
Thalassionema robusta
**Cocconeis* spp. (few)
**Paralia sulcata* (common)
Rhizosolenia miocenica
**Stictodiscus* sp.

Silicoflagellate species list:

Distephanus pseudofibula

Sample characteristics: moderate to poor preservation, the sample appears to have been transported and winnowed. In terms of preservation, the sample is ranked as representing significant postdepositional transport and dissolution (like KG-31 and KG-42, more dissolved than KG-34, less dissolved than KG-8, KG-33, KG-4, and KG-2). Consequently, no productivity estimate is given.

Age assignment: *Denticulopsis hustedtii* zone (7.6-8.4 Ma) or subzone d of the *Denticulopsis hustedtii-Denticulopsis lauta* zone (8.4-8.9 Ma), and bearing *Denticulopsis* cf. *katayamae* (restricted to a range of 7.8-8.7 Ma).

Other correlation data: Preliminary physical correlation to the Gower-Brabb stratigraphic section of Naples Beach shows that sample KG-32 lies between Barron's (1986) samples P37 and P38 and thus within strata assigned to the *Denticulopsis hustedtii* zone (7.6-8.4 Ma). The diatom age assignment (above) is accordingly restricted tentatively to the range 7.8-8.4 Ma.

Tentative absolute age: within the range 7.8-8.4 Ma.

KG-33

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-6 and KG-1 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: phosphatic calcareous diatomaceous shale

ODP-equivalent sediment: muddy mixed sediment with calcite, diatoms, and apatite

Stow-Piper-Dean-equivalent sediment: marl

Lithostratigraphic unit: Monterey Formation, carbonaceous marl member (of Isaacs, 1984)

Section position: 760 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 20% calcite, 3% dolomite, 13% apatite, 48% aluminosilicate minerals and detrital quartz, 16% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): Etched, poorly diagnostic flora of *Coccolithus pelagicus*, *Helicosphaera carteri*, and *Reticulofenestra* sp. (4 and 7 μm). Age assignment: Neogene.

Siliceous microfossils (J. A. Barron):

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

Denticulopsis hustedtii (very rare)
Delphineis sachalinensis
Coscinodiscus marginatus (common)
Actinocyclus ingens
Denticulopsis hyalina (probably reworked)
Coscinodiscus lewisanus (probably reworked)
**Paralia sulcata* (common)

Sample characteristics: poor preservation, dissolved assemblage, the sample was probably transported and winnowed. In terms of preservation, the sample is ranked as representing extreme dissolution (like KG-8, KG-4, and KG-2; more dissolution than KG-31, KG-32, and KG-41). Consequently, no productivity estimate is given.

Age assignment: none.

Other correlation data: Preliminary physical correlation to the Gower-Brabb stratigraphic section of Naples Beach shows that sample KG-33 lies very near Barron's (1986) sample P36 and thus either within strata assigned to subzone d of the *Denticulopsis hustedtii-Denticulopsis lauta* zone (8.4-8.9 Ma) or within the interval between strata so assigned and strata assigned to the *Denticulopsis hustedtii* zone (7.6-8.4 Ma). Based on preliminary physical correlation to the Arends-Blake zonation of Naples (Arends and Blake, 1986), the sample lies in strata assigned to subzone d of the *Denticulopsis hustedtii-Denticulopsis lauta* zone (8.4-8.9 Ma). The age assignment is accordingly restricted tentatively to the range 8.4-8.9 Ma.

Tentative absolute age: within the range 8.4-8.9 Ma.

KG-34

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-2 and KG-11 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: phosphatic calcareous diatomaceous shale

ODP-equivalent sediment: calcareous ooze with mud and apatite

Stow-Piper-Dean-equivalent sediment: marl

Lithostratigraphic unit: Monterey Formation, upper part of the lower calcareous-siliceous member (of Isaacs, 1984)

Section position: 535 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 57% calcite, 5% dolomite, 10% apatite, 20% aluminosilicate minerals and detrital quartz, 8% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): odd upwelling flora predominated by tiny placoliths (2 μm) with common *Coccolithus pelagicus*, common *Helicosphaera carteri*, and very sparse *Cyclicargolithus floridanus*, *Pontosphaera anisotrema* and *Sphenolithus abies*. No *Discoaster* spp. or zonal key species. The tiny-placolith flood is repeated below in sample KG-39. Age assignment: Mid? Miocene.

Siliceous microfossils (J. A. Barron):

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

Coscinodiscus marginatus (few)
Denticulopsis hyalina (few)
Coscinodiscus lewisanus
Actinocyclus ingens (common)
Actinocyclus ingens nodus (few)
**Cocconeis* sp.

Silicoflagellate species list:

Distephanus crux longispinus
Dictyocha spp.

Sample characteristics: moderate preservation. The siliceous microfossils represent mostly a planktonic assemblage and relatively warm conditions. In terms of productivity and preservation, the sample represents moderate productivity with some seafloor dissolution (less productivity and more preservation than KG-30, more productivity and preservation than KG-31, KG-32, KG-41).

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-34 lies between Barron's (1986) samples P16 and P17 and thus within strata assigned to subzone b of the *Denticulopsis lauta* zone. Overlying strata are assigned by DePaolo and Finger (1991) to calcareous nannofossil zone CN4 (14.0-15.7 Ma), constraining the sample to older than 14.0 Ma.

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

KG-41

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-2 and KG-11 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: phosphatic calcareous diatomaceous shale

ODP-equivalent sediment: muddy mixed sediment with calcite and apatite

Stow-Piper-Dean-equivalent sediment: marl

Lithostratigraphic unit: Monterey Formation, upper part of the lower calcareous-siliceous member (of Isaacs, 1984)

Section position: 475 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 20% calcite, 3% dolomite, 19% apatite, 55% aluminosilicate minerals and detrital quartz, 3% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): Meager, etched, poor flora includes *Coccolithus pelagicus*, *Discoaster variabilis*, and *Sphenolithus heteromorphus* which indicate the zonation. Age assignment: middle Miocene, possibly CN4 zone.

Siliceous microfossils (J. A. Barron):

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

Actinocyclus ingens
Denticulopsis lauta
Coscinodiscus marginatus
Synedra jouseana
Chaetoceros spores

Sample characteristics: poor preservation, small fragments common (possibly indicating bioturbation), common sponge spicules. The siliceous microfossils represent mostly a planktonic assemblage (with few shelf-dwelling or benthic forms). In terms of preservation, the sample is ranked as representing significant transport and dissolution (more dissolution and KG-34; less

dissolution than KG-8, KG-33, KG-4, and KG-2). Consequently, no productivity estimate is given.

Age assignment: *Denticulopsis lauta* zone (13.7-15.0 Ma), probably subzone a (15.0-16.0 Ma).

Other correlation data: Preliminary physical correlation to the Gower-Brabb stratigraphic section of Naples Beach shows that sample KG-41 lies between Barron's (1986) samples P13 and P14 and thus within strata assigned to subzone a of the *Denticulopsis lauta* zone (15.0-16.0 Ma). Preliminary physical correlation to the Arends-Blake zonation of Naples (Arends and Blake, 1986) also shows that the sample lies in strata assigned to subzone a of the *Denticulopsis lauta* zone (15.0-16.0 Ma). The diatom age assignment (above) is accordingly restricted tentatively to the range 15.0-16.0 Ma.

Tentative absolute age: within the range 15.0-16.0 Ma.

KG-39

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-2 and KG-11 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports). Although stratigraphically well below KG-2 (and KG-41), however, structural complications make the precise position of the sample relative to KG-11 uncertain.

Lithology: calcareous-siliceous mudstone

ODP-equivalent sediment: muddy calcareous mixed sediment with diatoms

Stow-Piper-Dean-equivalent sediment: marl

Lithostratigraphic unit: Monterey Formation, lower part of the lower calcareous-siliceous member (of Isaacs, 1984)

Section position: about 255 ft, but not precisely determined due to structural complications in sand-covered strata; the sample position is possibly as much as 50 ft higher or lower, but more likely is within 10 ft of 255 ft.

Typicalness: a common lithology in this part of the sequence at Naples Beach

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 43% calcite, 6% dolomite, 0.2% apatite, 41% aluminosilicate minerals and detrital quartz, 10% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): Abundant flora predominated by tiny placoliths (2 μm) with common *Reticulofenestra pseudoumbilica* (10-12 μm, large). Other taxa are sparse to meager, including *Cyclicargolithus floridanus*, but no *Sphenolithus heteromorphus*. Odd upwelling flora. Rhombs (8μm) common. Compare sample KG-34. Age assignment: CN4/5 Mid Miocene.

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

Other correlation data: although its section position is not precisely determinable, KG-39 derives from the lower part of the lower calcareous-siliceous member west of the mouth Dos Pueblos Canyon which Arends and Blake (1986) date as older than 15.4 Ma and DePaolo and Finger (1991) date within the range 17.3-17.9 Ma.

Tentative absolute age: probably within the range 17.3-17.9 Ma.

KG-38

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-2 and KG-11 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: calcareous-siliceous shale

ODP-equivalent sediment: calcareous muddy mixed sediment with diatoms

Stow-Piper-Dean-equivalent sediment: marl

Lithostratigraphic unit: Monterey Formation, lower part of the lower calcareous-siliceous member (of Isaacs, 1984)

Section position: 220 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 33% calcite, 6% dolomite, 0.3% apatite, 50% aluminosilicate minerals and detrital quartz, 10% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): abundant flora with common rhombs (5 μm). Tiny placoliths (2 μm) are common to abundant. Small *Helicosphaera ampliaperta* is sparse. There are no *Sphenolithus heteromorphus*. Age assignment: middle or early Miocene, possibly CN3 zone.

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

Other correlation data: Preliminary physical correlation indicates that KG-38 probably lies within strata in the DePaolo and Finger (1991) section representing the composite

Lipps samples NB-93, and certainly lies between the two composite Lipps samples NB-88 (the closest subjacent sample dated) and NB-97 (the closest superjacent sampled dated). The age of NB-88, NB-93, and NB-93 are all constrained by benthic foraminifera interpreted as late Saucesian within the range 17.4-18.0 Ma, and strontium-isotopes indicate an age within the range 17.5-17.7 Ma.

Tentative absolute age: within the range 17.5-17.7 Ma.

KG-36

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-2 and KG-11 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports). However, more detailed stratigraphic examination showed that due to structural repetition, KG-36 was located underlying KG-11.

Lithology: calcareous-siliceous mudstone

ODP-equivalent sediment: calcareous muddy mixed sediment with diatoms

Stow-Piper-Dean-equivalent sediment: smarl

Lithostratigraphic unit: Monterey Formation, lower part of the lower calcareous-siliceous member (of Isaacs, 1984)

Section position: 175 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 33% calcite, 3% dolomite, 0.3% apatite, 42% aluminosilicate minerals and detrital quartz, 22% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): Poor, low-diversity flora with *Helicosphaera carteri*. Eocene reworking suggested by *Micrantholithus* sp. and several *Nannotetrina quadrata* (CP13). Sparse *Discoaster deflandrei* could be Eocene and/or Miocene.

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

Other correlation data: Preliminary physical correlation indicates that KG-36 lies between the composite Lipps samples NB-83 and NB-88 in the DePaolo and Finger (1991) section. The age of both NB-83 and NB-88 are constrained by (late Saucesian) benthic foraminifera within the range 17.4-18.0 Ma, and strontium-isotopes indicate an age of 17.6 Ma for NB-83, and 17.7 Ma for NB-88.

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

KG-35

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-2 and KG-11 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports). However, more detailed stratigraphic examination showed that due to structural repetition, KG-35 was located underlying KG-11.

Lithology: calcareous shale

ODP-equivalent sediment: muddy calcareous mixed sediment

Stow-Piper-Dean-equivalent sediment: marl

Lithostratigraphic unit: Monterey Formation, lower part of the lower calcareous-siliceous member (of Isaacs, 1984)

Section position: 150 ft

Typicalness: a common lithology in this part of the sequence at Naples Beach but at the lower limit of silica abundance in samples generally present in this part of the sequence in coastal sections (see Figure 11, Isaacs, 1992b; *Preliminary Geologic Background*, Chapter B, CMOGS preliminary geology reports).

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 47% calcite, 4% dolomite, 0.3% apatite, 44% aluminosilicate minerals and detrital quartz, 4% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): Abundant flora with common *Discoaster deflandrei* and *Helicosphaera ampliaperta*, but no sphenoliths, including CN3 basal guide *Sphenolithus heteromorphus*. Age assignment: early Miocene, possibly CN3 zone.

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

Other correlation data: Preliminary physical correlation indicates that KG-36 lies between the composite Lipps samples NB-83 and NB-88 in the DePaolo and Finger (1991) section. The age of both NB-83 and NB-88 are constrained by (late Saucesian) benthic foraminifera within the range 17.4-18.0 Ma, and strontium-isotopes indicate an age of 17.6 Ma for NB-83, and 17.7 Ma for NB-88.

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

LIONS HEAD SECTION

KG-42

Purpose of sample: this sample was intended to represent a sample higher stratigraphically than KG-16 to extend the stratigraphic sequence as high as possible, but was collected on the south part of Lions Head beach on the south part of an anticlinal fold where strata are not well exposed and cannot be exactly correlated to the main measured section.

Lithology: siliceous shale

ODP-equivalent sediment: muddy diatomaceous ooze

Stow-Piper-Dean-equivalent sediment: sarl

Lithostratigraphic unit: Monterey Formation, middle member of Woodring and Bramlette (1950)

Section position: not exactly determinable due to major structural complications

Typicalness: a common lithology in the sequence at Lions Head

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 1% calcite, 0% dolomite, 4% apatite, 38% aluminosilicate minerals and detrital quartz, 57% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): barren.

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

Tentative absolute age: indeterminate.

KG-47

Purpose of sample: this sample was selected to represent a glassy chert to explore the organic matter characteristics of a widespread lithology that is thought to represent the highest productivity and upwelling among various rock types in the Monterey Formation, though typically containing very sparse organic matter.

Lithology: glassy chert

ODP-equivalent sediment: diatom ooze

Stow-Piper-Dean-equivalent sediment: siliceous ooze

Lithostratigraphic unit: Monterey Formation, middle member of Woodring and Bramlette (1950)

Section position: 910 ft

Typicalness: a common lithology in this part of the sequence at Lions Head

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 0% calcite, 0% dolomite, 0.1% apatite, 0.6% aluminosilicate minerals and detrital quartz, 99% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): barren.

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

Other correlation data: Based on preliminary physical correlation to the White section (White, 1989), the sample lies in strata assigned to the *Denticulopsis hustedtii-Denticulopsis lauta* zone subzone c (8.9-11.4 Ma).

Tentative absolute age: within the range 8.9-11.4 Ma.

KG-26

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-22 and KG-18 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: phosphatic calcareous-siliceous shale (more often described as "phosphatic shale")

ODP-equivalent sediment: diatomaceous calcareous ooze with mud

Stow-Piper-Dean-equivalent sediment: smarl

Lithostratigraphic unit: Monterey Formation, lower member of Woodring and Bramlette (1950)

Section position: 415 ft

Typicalness: a common lithology in this part of the sequence at Lions Head

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 41% calcite, 2% dolomite, 6% apatite, 20% aluminosilicate minerals and detrital quartz, 32% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): Meager, etched flora in sediment of mixed size and material (?turbidite). The presence of *Coccolithus pelagicus*, *Discoaster variabilis*, and *Sphenolithus abies*, without *Cyclicargolithus floridanus* suggests CN5 or CN6, but if the one specimen of *Sphenolithus heteromorphus* is in place, then the CN4 is correct. Age assignment: middle Miocene, possibly CN4 zone (14.0-15.7 Ma).

Siliceous microfossils (J. A. Barron): contains only fragments of diatoms.

Tentative absolute age: within the range 13.8-15.7 Ma, based on position between KG-22 and KG-18 (see *Preliminary Correlation and Age*, Isaacs and others, 1992; Chapter D, CMOGS preliminary geology reports).

KG-27

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-22 and KG-18 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: phosphatic calcareous-siliceous shale (more often described as "phosphatic shale")

ODP-equivalent sediment: muddy mixed sediment with diatoms and calcite

Stow-Piper-Dean-equivalent sediment: smarl

Lithostratigraphic unit: Monterey Formation, lower member of Woodring and Bramlette (1950)

Section position: 305 ft

Typicalness: a common lithology in the sequence at Lions Head but distinctive in this part of the sequence for having prominent blebby apatite.

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 15% calcite, 5% dolomite, 6% apatite, 50% aluminosilicate minerals and detrital quartz, 24% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): sparse, poorly preserved flora with abundant calcareous debris and rhombs. The presence of *Cyclicargolithus floridanus*, *Discoaster variabilis*, and *Sphenolithus heteromorphus* (1) indicate the zone. But if *Sphenolithus heteromorphus* is reworked, then CN5a is indicated. Age assignment: middle Miocene, probably CN4 zone (14.0-15.7 Ma), possibly CN5a zone (11.5-14.0 Ma).

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

Tentative absolute age: within the range 13.8-15.7 Ma, based on position between KG-22 and KG-18 (see *Preliminary Correlation and Age*, Isaacs and others, 1992; Chapter D, CMOGS preliminary geology reports).

KG-25

Purpose of sample: this sample was selected as an organic-matter-rich sample to fill in the stratigraphic gap between KG-22 and KG-18 (see *Preliminary Data on Rock Samples*, Chapter C, CMOGS preliminary geology reports).

Lithology: calcareous-siliceous shale (more often described as "calcareous shale")

ODP-equivalent sediment: mud with diatoms and calcite

Stow-Piper-Dean-equivalent sediment: mud

Lithostratigraphic unit: Monterey Formation, lower member of Woodring and Bramlette (1950)

Section position: 250 ft

Typicalness: a common lithology in this part of the sequence at Lions Head

Inorganic composition:

by XRF (C. M. Isaacs; normalized to 100% w/o pyrite): 11% calcite, 0% dolomite, 1% apatite, 67% aluminosilicate minerals and detrital quartz, 21% biogenic and diagenetic silica.

Faunal and floral analysis:

Calcareous nannofossils (D. Bukry): common etched flora includes sparse *Cyclicargolithus floridanus*, *Discoaster variabilis*, and *Sphenolithus abies*, but no *Sphenolithus heteromorphus*. Age assignment: middle Miocene, CN5a zone (11.5-14.0 Ma).

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

Tentative absolute age: within the range 13.8-15.7 Ma, based on position between KG-22 and KG-18 (see *Preliminary Correlation and Age*, Isaacs and others, 1992; Chapter D, CMOGS preliminary geology reports).

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