DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

DIATOM STRATIGRAPHY OF THE MONTEREY FORMATION AND RELATED ROCKS, SAN JOSE 30' BY 60' QUADRANGLE, CALIFORNIA

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INTRODUCTION

During the middle and late Miocene sediments now assigned to the Monterey Formation in the area of the San Jose 30' X 60' sheet (1:100,000) were deposited on a tectonic high lying mostly south of the Livermore Basin, east of the La Honda Basin, and west of the Great Valley-San Joaquin Basin (Fig. 1). Consequently, diatomaceous and other fine-grained sediments which typify the Monterey Formation elsewhere in central and southern California are rare in the area of the San Jose 30' X 60" sheet.

Middle and upper Miocene strata in the Livermore Basin and in the foothills east of San Jose commonly are represented by clastic rocks, and Bramlette (1946) followed Lawson (1914) in using the term "Monterey Group" in these areas to refer to fine-grained rocks lithologically similar to the Monterey Formation which are separated by thicker units of sandstone. In the Livermore Basin, strata assigned to the Monterey Group consist of the following units of Lawson (1914): the Sobrante Sandstone, Claremont Shale, Oursan Sandstone, Tice Shale, Hambre Sandstone, Rodeo Shale, and Briones Sandstone. Hall (1958) argues that none of these units should be considered as belonging to the Monterey Formation or Monterey Group, because the Monterey Formation cannot be traced laterally from its type area near Monterey into the eastern San Francisco Bay region, and that each of the units is a distinct, mappable unit. The general tendency in the literature, however, has been to consider at least the Sobrante Sandstone, the Claremont Shale, the Oursan Sandstone, the Tice Shale, the Hambre Sandstone, and the Rodeo Shale as part of the Monterey group (Bramlette, 1946; Weaver, 1949).

In northern Contra Costa County Weaver (1949) measured the following average thicknesses for the units of the Monterey Group: the Sobrante Sandstone, 520 feet (158 m); the Claremont Shale, 800 feet (244 m), the Oursan Sandstone, 600 feet (183 m); the Tice Shale, 460 feet (140 m); the Hambre Sandstone, 1200 feet (366 m); the Rodeo Shale, 670 feet (204 m); and the Briones Sandstone, 2500 feet (762 m). Kleinpell (1938) suggested the following provincial ages for units of the Monterey Group east of San Francisco Bay based on his study of benthic foraminifers and on published molluscan studies: the Sobrante Sandstone, Relizian; the Claremont Shale, latest Relizian to early Luisian; the Oursan Sandstone, late Luisian; the Tice Shale, early Mohnian; the Hambre Sandstone, middle Mohnian; the Rodeo Shale, middle Mohnian, the Briones Sandstone, late Mohnian, and the San Pablo Formation, Delmontian.

Diatom Biostratigraphy

Within the typical diatomaceous sediments of the Monterey Formation, diatom biostratigraphy provides good correlation to the international geological time scale and has allowed age resolution approaching 300,000 years (Barron, 1981, 1986)(Fig. 2). Benthic foraminiferal biostratigraphy is considerably less precise (Fig. 2) and has proven to be time transgressive in part (Crouch and Bukry, 1979). Numerous sections in the Monterey Formation have been studied for diatom biostratigraphy in central and northern California (Barron, 1986; White, written comm., 1988); however, in northern California north of the city of Monterey the study of diatoms has been limited to coastal sections at Ano Nuevo and Point Reyes (White, written comm., 1988) and to sections in the

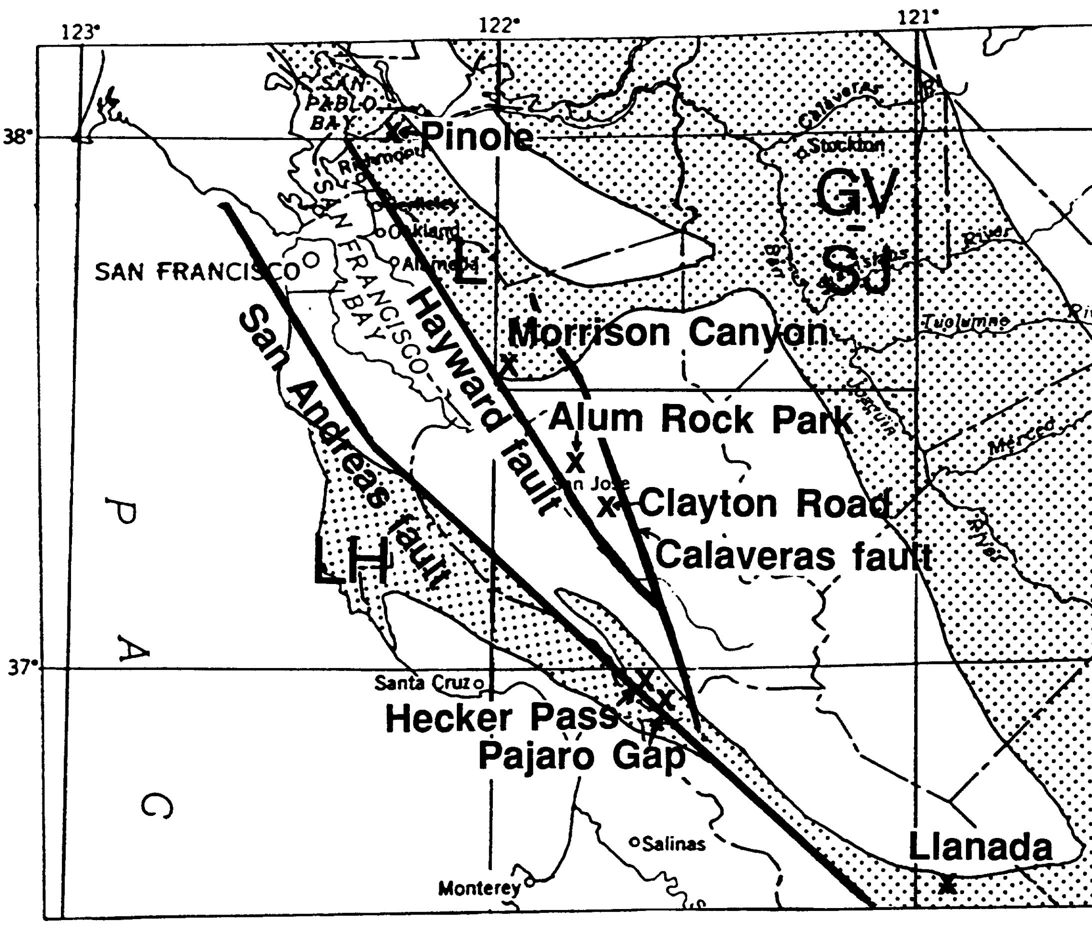

Figure 1. Map of the western part of central California showing the outline of the San Jose 30' X 60' sheet, rectangle between 37°00' and 37°30' N and 121°00' and 122°00' W; localities collected for diatoms, X; La Honda (LH), Livermore (L), and Great Valley-San Joaquin (GV-SJ) Neogene basins after Blake and others (1978), stippled; and the San Andreas, Hayward, and Calaveras faults.

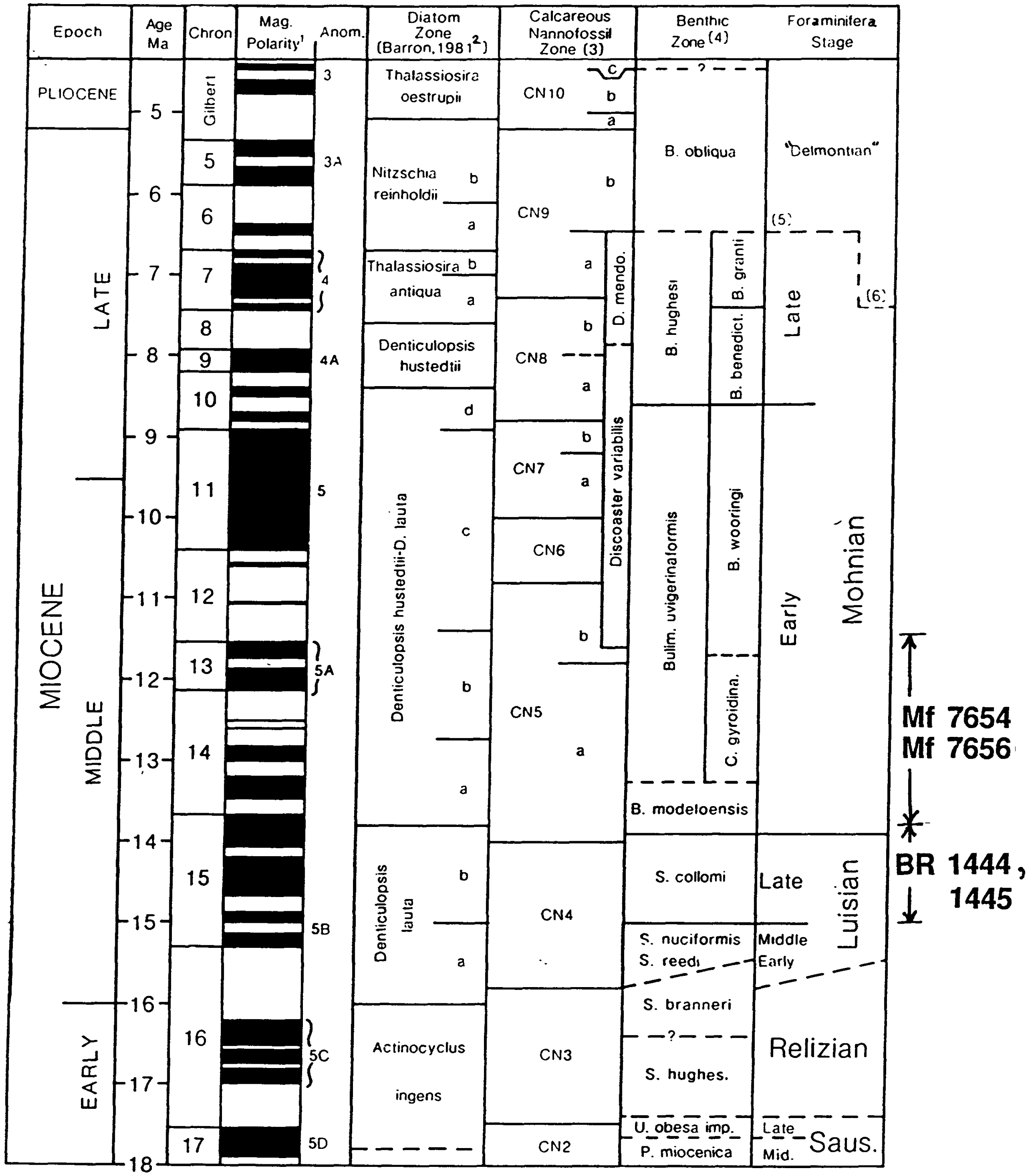

Figure 2. Correlation of samples studied from the San Jose sheet area (Mf 7654 and Mf 7656 from the Llanada area and BR 1444 and BR 1445 from the Pinole area) with the biostratigraphic time scale of Barron (1986) for California between 18 and 4 Ma. 1, Berggren and others, 1985; 2, as modified by Barron and Keller (1983) and Barron and Baldauf (1986); 3, tropical zonation of Bukry (1973a, 1975; with notation after Okada and Bukry, 1980) with the temperate zones of Bukry (1973b) included on the left; 4, Kleinpell (1938) and Warren (1972); 5, Kleinpell (1938); 6, Kleinpell (1980).

Humboldt Basin area south and east of Eureka (Barron, 1986). Sections of the Monterey Formation lying east of the San Andreas fault and north of about 36° N have been virtually untouched for diatom biostratigraphy.

The purpose of this study is to provide a reconnaissance study of the diatom biostratigraphy of the Monterey Formation and Monterey Group in the area of the San Jose Sheet (1:100,000) and adjacent regions.

Acknowledgments

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MATERIALS AND METHODS

Diatoms are expected to occur in the shale units of the Monterey Group, namely the Claremont Shale, the Tice Shale, and the Rodeo Shale. The Rodeo shale, however, does not extend south of Oakland (Hall, 1958). In the southern Santa Clara Valley south of San Jose, siliceous shales mapped as the Monterey Formation by Allen (1946) have not been related to either the Claremont Shale or the Tice Shale, but they should also be appropriate for diatom biostratigraphic study.

Diatom frustules are readily destroyed when burial temperatures exceed 50°C as the opal-A of the diatom frustule is first converted to opal-CT to form the rock porcelanite and eventually to quartz to form chert (Issacs and others, 1983). Consequently, softer rocks that have experienced little diagenesis are preferred for diatom studies.

Reconnaissance collecting of shaley Monterey rocks in the San Jose Sheet area, therefore, must first be aimed at fine-grained diatomaceous rocks that have undergone little diagenesis and which contain opal-A rather than opal-CT. Unfortunately, however, throughout most of the San Jose sheet area, shale intervals within the Monterey have undergone considerable diagenesis and are either porcelaneous or cherty. In such cases, diatom frustules can only be recovered from dolomite concretions or dolomite beds, which have been formed early in the diagenetic history and have protected the diatom frustule from dissolution (Bramlette, 1946).

Utilizing geologic maps published by Allen (1946), Weaver (1949), Crittenden (1951), and Hall (1958), a number of shaley Monterey outcrops were visited from Pinole in the north to the hills south of Gilroy in the south. Samples were collected from the Tice Shale near Pinole, the Claremont Shale in Morrison Canyon east of Fremont, the Claremont Shale in Alum Rock Park east of San Jose, exposures along Clayton Road east of San Jose, and from a siliceous shale mapped as the Monterey Shale by Allen (1946) on Hecker Pass Road (State Highway 152), and in Pajaro Gap (State Highway 29) south of Gilroy (Fig. 1). These collections were supplemented by two samples collected by Robert McLaughlin (USGS, Menlo Park) from tufaceous siltstone in the Llanada area south of Hollister (Fig. 1). These localities form a northwest-southeast-trending transect of the region east of the San Andreas fault between about 38°N and 36 °N. In all localities other that the Pinole and Llanada areas, the predominant lithology encountered was porcelaneous or cherty shale, and collecting was concentrated in dolomite beds.

Processing for diatoms involved treatment in hydrochloric acid and hydrogen peroxide following Barron (1976). At least one strewn slide (30 x 22 mm) was examined in entirety at X500 under the light microscope, and stratigraphically-significant diatoms were recorded.

RESULTS

Pinole Area

Samples were collected from outcrops of the Tice Shale as mapped by Weaver (1949) near locality #9 of Simonsen & Kanaya (1961), the type locality of Denticulopsis lauta (Bailey) Simonsen. This approximates locality #1369 of the California Academy of Sciences (Fig. 3).

BR 1444 (Field No.-Pinole #1). Forty meters up the side street leeding to the church, west of San Pablo Avenue. See locality data for BR 1445 below.

Diatoms observed:

Actinocyclus ingens Rattray
A. ingens var. nodus Baldauf
Actinoptychus splendens (Shadbolt) Ralfs in Pritchard
Azpeitia sp. cf. A. salisburyana (Lohman) Sims
Coscinodiscus radiatus Ehrenberg
Denticulopsis hyalina (Schrader) Simonsen -few
D. lauta (Bailey) Simonsen -few
Paralia sulcata (Ehrenberg) Cleve
Stephanopyxis sp.
Synedra jouseana Sheshukova-Poretzkaya
Thalassionema nitzschioides Cleve & Grunow -few
Thalassiosira praeyabei (Schrader) Akiba & Yanagisawa

Age: early middle Miocene. Subzone b of the Denticulopsis lauta Zone. Equivalent to the late Luisian benthic foraminiferal stage.

BR 1445 (Field No.-Pinole #2). Sample taken from south end of road cut on San Pablo Avenue, stratigraphically about 20 feet below BR 1444; 1500 ft. north, 2.06 mi. west, of southeast corner of Mare Island 7.5' quadrangle. Approximately 38°0'20"N, 122°18'W.

Diatoms observed:

Actinocyclus ingens Rattray
A. ingens var. nodus Baldauf
A. octonarius Ehrenberg
Actinoptychus splendens (Shadbolt) Ralfs in Pritchard
A. senarius (Ehrenberg) Ehrenberg
Azpeitia sp. cf. A. salisburyana (Lohman) Sims
Coscinodiscus oculus-iridis Ehrenberg
Denticulopsis hyalina (Schrader) Simonsen -very rare
D. lauta (Bailey) Simonsen -few
Stephanopyxis sp.

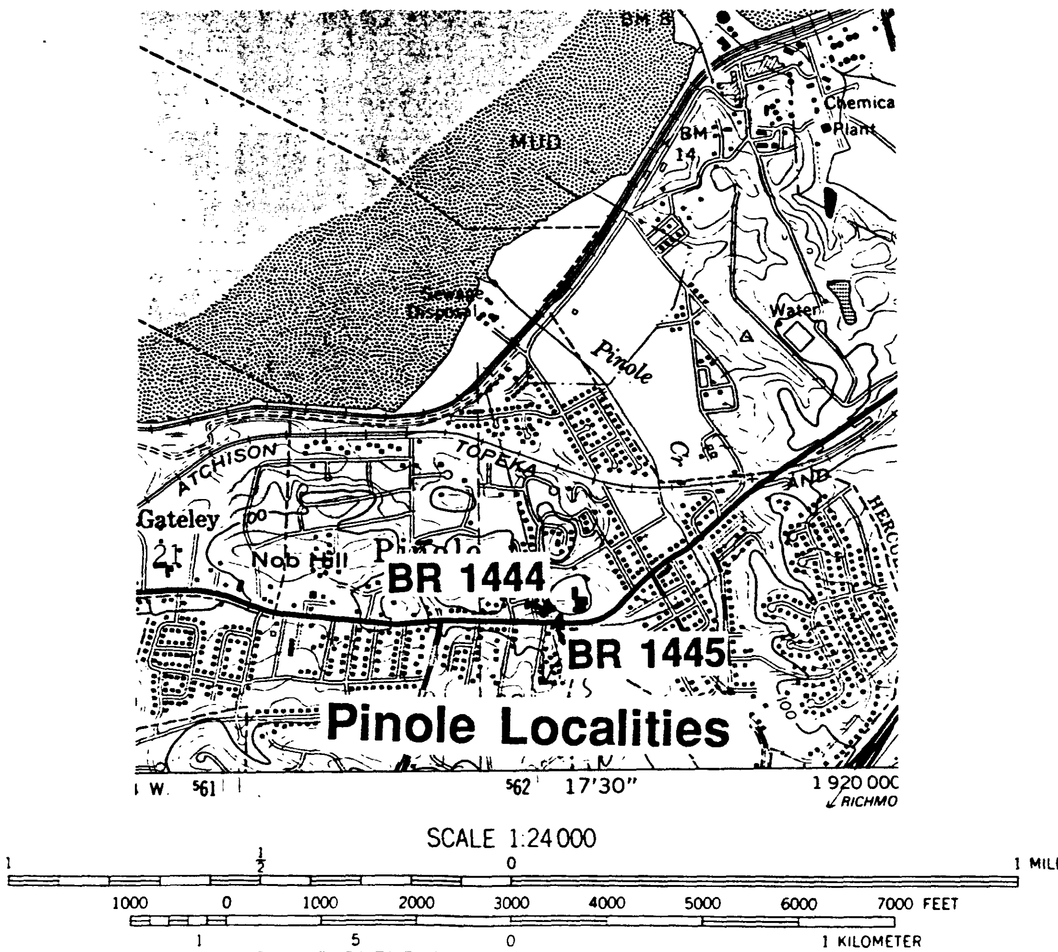

Figure 3. Location of samples BR 1444 and BR 1445 from the Tice Shale near Pinole, California. Mare Island 7.5' quadrangle. Refer to Weaver (1949) for geology.

Synedra jouseana Sheshukova-Poretzkaya-few
Thalassionema nitzschioides Grunow -few
Thalassiosira praeyabei (Schrader) Akiba & Yanagisawa
Thalassiosithrix longissima Cleve & Grunow

Age: early middle Miocene. Subzone b of the Denticulopsis lauta Zone. Equivalent to the late Luisian benthic foraminiferal stage.

Comments: Kleinpell (1938) and Weaver (1949) considered the Tice shale in the Pinole area to belong to the early Mohnian benthic foraminiferal stage. Diatom correlation of outsrops of the Tice Shale south of Pinole (Fig. 3), however, suggests equivalence with the late Luisian benthic foraminiferal stage (Fig. 2).

Morrison Canyon (Fremont Area)

Five samples were collected from the Claremont Shale in roadcuts on the north side of Morrison Canyon Road (Fig. 4). All samples are in the Niles 7.5' quadrangle, section 13, T.4 S., R.1 W. 37°34'N, 121°57'W.

MC-1 -Stratigraphically, the lowest sample collected. The remaining samples were collected in a sequence extending upsection. A dolomite bed 2520 feet north, 2070 feet east of the southwest corner section 13.
-Barren of diatoms.

MC-2 -A dolomite nodule, 2430 feet north, 1800 feet east of the southwest corner of section 13.
-Barren of diatoms.

MC-3 -A dolomite bed, 2360 feet north, 1620 feet east of the southwest corner of section 13.
-Barren of diatoms.

MC-4. -A dolomite bed, 2360 feet north, 1550 feet east of the southwest corner of section 13.
-Contains poorly preserved, non age-diagnostic diatoms:
Actinoptychus senarius Ehrenberg
Coscinodiscus sp.
Stephanopyxis spp.
Comments: These diatoms indicate deposition in a nearshore environment, possibly on the shelf.

MC-5 -A dolomite bed, 2280 feet north, 1450 feet east of the southwest corner of section 13.
-Barren of diatoms.

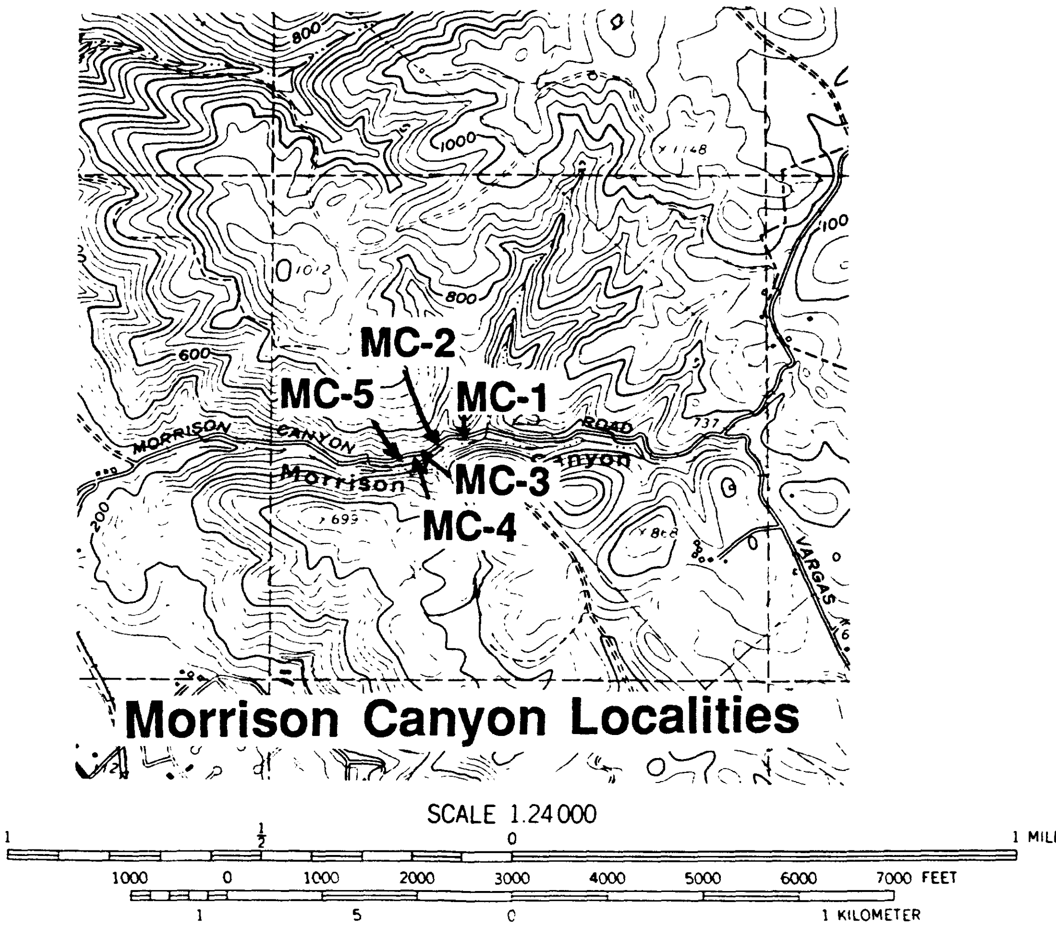

Figure 4. Location of samples MC-1 through MC-5 from the Claremont Shale in Morrison Canyon east of Fremont, California. Niles 7.5' quadrangle. Refer to Hall (1958) for geology.

Alum Rock Park (East of San Jose)

Locality -Calaveras Reservoir 7.5' quadrangle.
Samples were taken from outcrops in the main stream bed in Alum Rock Park within a black, banded chert sequence (Fig. 5). The unit is mapped as the middle member of the Monterey Shale by Crittenden (1948) and is most likely correlative with the Claremont Shale. 37°23'40"N, 121°48'W.

BR 1477 -A dolomite bed, west of stream bed above two spring baths. 2120 feet east of R.1E./R.2E. boundary, 1.66 mile north of south edge of quadrangle. The stratigraphically highest sample taken in Alum Rock Park.
-Barren of diatoms.

BR 1478 -A dolomite bed in the stream bed. 2050 feet east of R.1E./R.2E. boundary, 1.61 mile north of south edge of the quadrangle.

-Barren of diatoms.

BR 1479 -A dolomite bed in the stream bed. 2000 feet east of R.1E./R.2E. boundary, 1.56 mile north of south edge of the quadrangle. The stratigraphically lowest sample taken in Alum Rock Park.

-Barren of diatoms.

Clayton Road (East of San Jose)

Locality - Outcrops in road cuts along the west side of Clayton Road, east of San Jose (Fig. 6) were sampled. They are mapped as the middle member of the Monterey Shale by Crittenden (1948) and are most likely correlative with the Claremont Shale.

BR 1475 - A dolomite bed 2640 feet S of north edge of T.7S., 1.6 mi west of east edge of San Jose East 7.5' quadrangle. 37°21'20"N, 121°47'W

-Barren of diatoms.

BR 1476 -A dolomite bed stratigraphically below BR 1475. 2850 feet south of north edge of T.7S., 1.66 mile west of east edge of San Jose East 7.5' quadrangle. 37°21'20"N, 121°47'W

-Barren of diatoms.

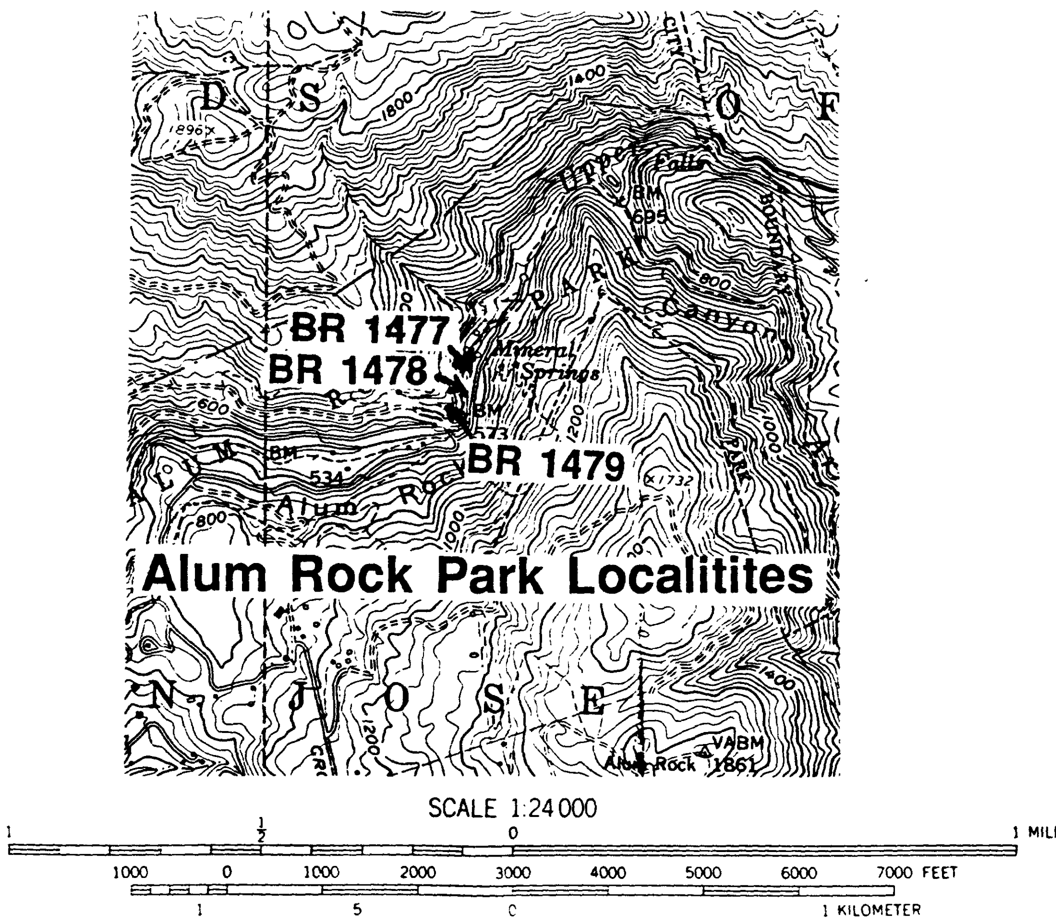

Figure 5. Location of samples BR 1477 through BR 1479 from the middle member of the Monterey Formation in Alum Rock Park east of San Jose. Calaveras Reservoir 7.5' quadrangle. Refer to Crittenden (1948) for geology.

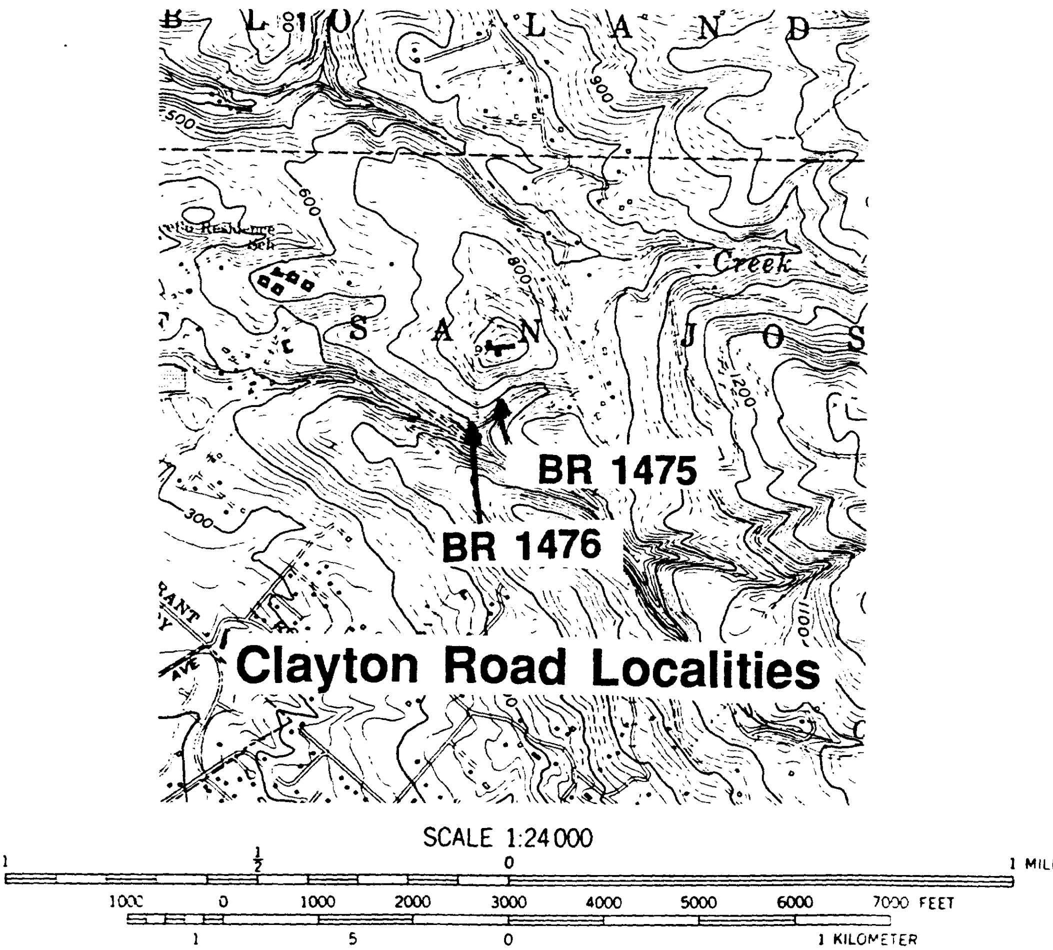

Figure 6. Location of samples BR 1475 and BR 1475 from the middle member of the Monterey Formation along Clayton Road east of San Jose. San Jose East 7.5' quadrangle. Refer to Crittenden (1948) for geology.

Hecker Pass (South of Gilroy)

Field No. HP-1 (4/17/89) -A dolomite bed on the north side of Hiway 152 in road cut, north of Watsonville on the Hecker Pass Road (Fig. 7). 400 feet south of the intersection with Gaffey Road. Monterey Shale (unit Tmd) of Allen (1946). Watsonville East 7.5' quadrangle. 36°58'20"N, 121°43'W.

-Barren of diatoms.

Field No. HP-2 (4/17/89) -Dolomite bed on east side of Highway 152 in road cut, north of Watsonville on the Hecker Pass Road (Fig. 7). 1500 feet south of the summit of the pass. Monterey Shale (unit Tmd) of Allen (1946). Watsonville East 7.5' quadrangle. 36°59'20"N, 121°43'W

-Barren of diatoms.

Pajaro Gap (South of Gilroy)

Field No. PG-1 (4/17/89) -Porcelaneous shale on north side of road cut on Highway 29 at Pajaro Gap (Fig. 8). 2.4 mile north, 1300 feet east of the southwest corner of the Chittenden 7.5' quadrangle. At the eastern edge of the road cut, approximately 20 feet west of a road intersection. Monterey shale (unit Tmd) of Allen (1946). 36°54'30"N, 121°37'20"W.

-Barren of diatoms.

Field No. PG-2 (4/17/89) -Porcelaneous shale on north side of road cut on Highway 29 at Pajaro Gap (Fig. 8). 2.6 mile north, 230 feet west, of the southeast corner of the Watsonville East 7.5' quadrangle. Monterey Shale (unit Tmd) of Allen (1946). 36°54'30"N, 121°37'40"W.

-Barren of diatoms

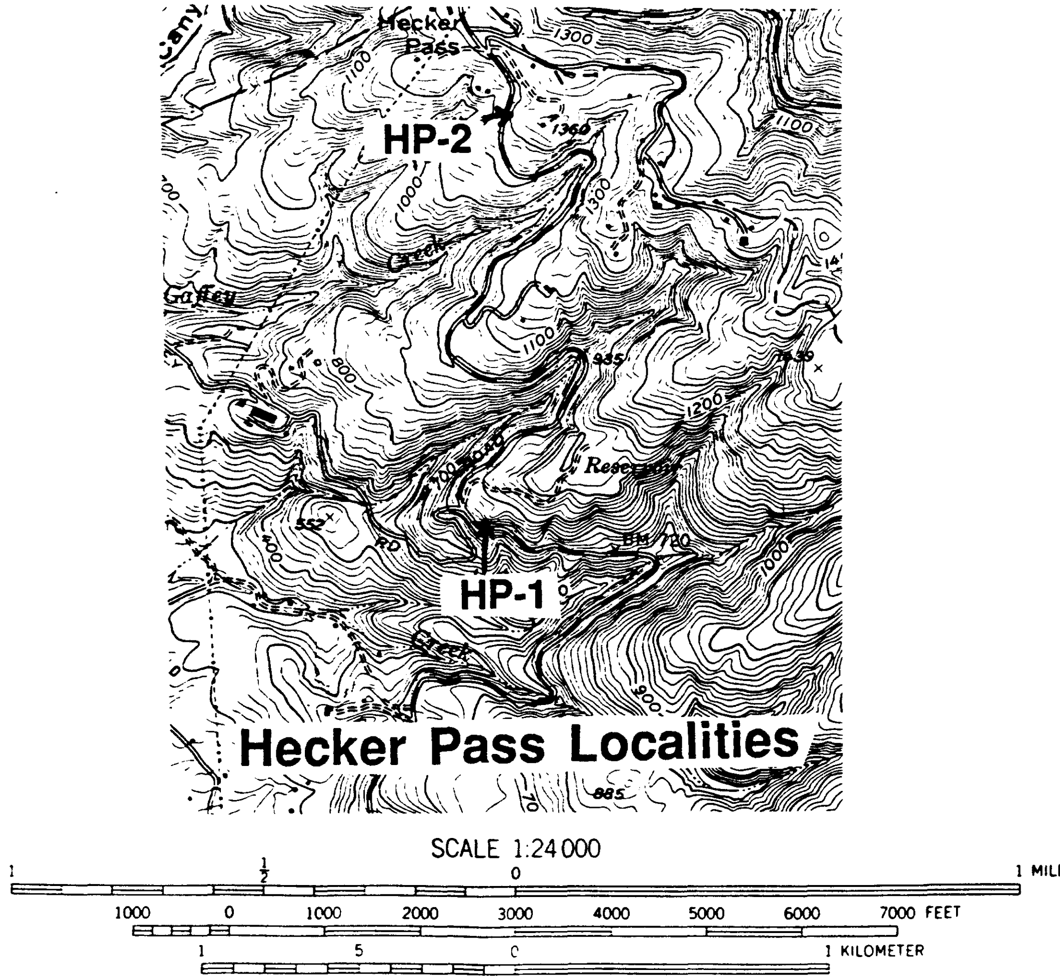

Figure 7. Location of samples HP-1 and HP-2 from the Monterey Shale along Hecker pass Road (California Highway 152) south of Gilroy, California. Watsonville East 7.5' quadrangle. Refer to Allen (1946) for geology.

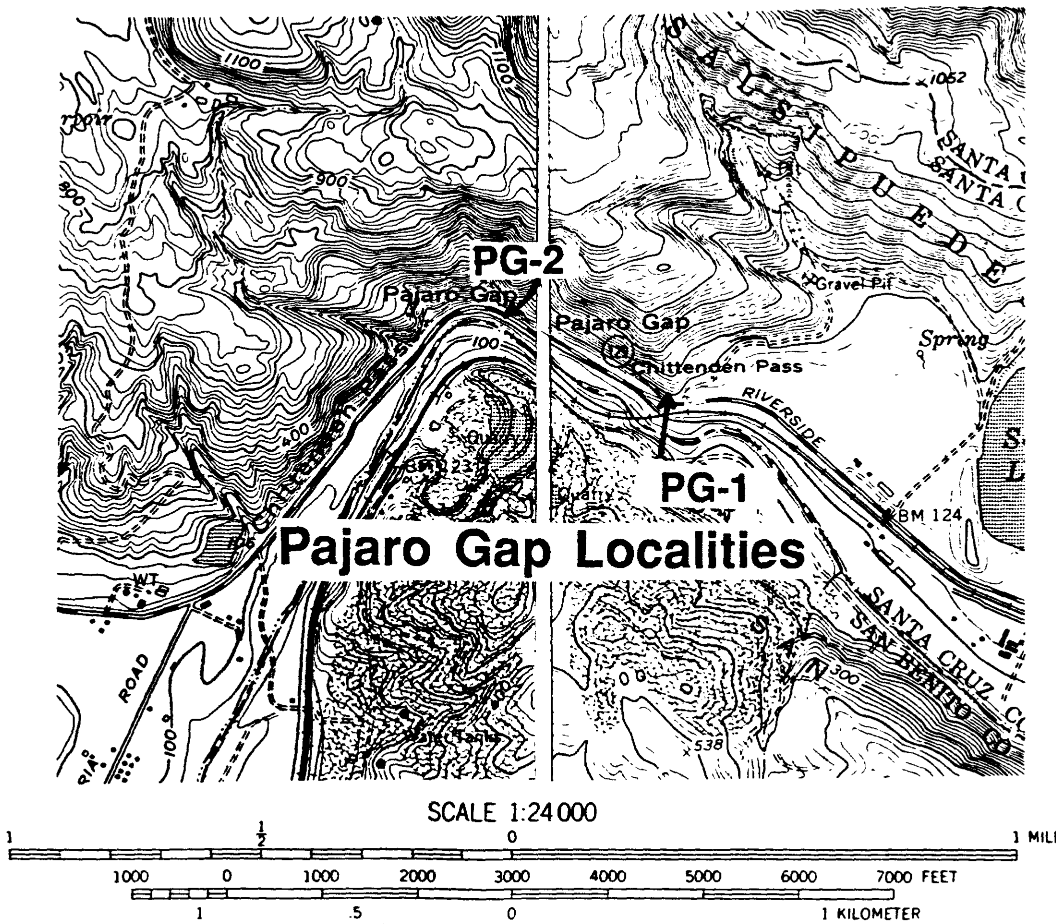

Figure 8. Location of samples PG-1 and PG-2 from the Monterey Shale in road cuts at Pajaro Gap along California Highway 29 south of Gilroy, California. Watsonville East 7.5' quadrangle on the left, Chittenden 7.5' quadrangle on the right. Refer to Allen (1946) for geology.

Llanada Area

Mf 7654 (Field No. 88 SGV-25A). Tufaceous siltstone above basalt flow in NE 1/4 of NW 1/4, section 29, T.15S., R10E., Llanada 7.5' quadrangle, San Benito County, California (Fig. 9). Lat. 36°36.0'N, Long. 120 °54.3'W. Collected by Robert McLaughlin, 1988.

Diatoms observed include :

Coscinodiscus marginatus Ehrenberg
Coscinodiscus fragments
Paralia sulcata Grunow
Rhaphoneis sp. cf. R. gemmifera Ehrenberg
Stephanopyxis sp.
Thalassionema nitzschioides Grunow

Age: most likely the same as Mf 7656 (see below).

Mf 7656 (Field No. 88 SGPV-24B). Diatomaceous volcanic ash underlying Mf. 7654 (88 SGV-25A) and stratigraphically below another basalt flow. Near the base of the southwest 1/4 of the southeast 1/4, section 20, T.15S., R.10E., Llanada 7.5' quadrangle, San Benito County, California (Fig. 9). Lat. 36°36.0'N, Long. 120°54.3'W. Collected by Robert McLaughlin, 1988.

Diatoms observed include:

Actinocyclus cubitus Hanna & Grant
A. octonarius Ehrenberg
A. ingens Rattray
Actinoptychus splendens (Shadbolt) Ralfs
A. senarius (Ehrenberg) Ehrenberg
Aulacodiscus concentricus (Mann) Boyer
Chaetoceros spores
Cocconeis sp.
Coscinodiscus sp. cf. C. rothii (Ehrenberg) Grunow
C. marginatus Ehrenberg
C. curvatulus Grunow
C. sp. cf. C. confusus Rattray
Cosmiodiscus elegans Greville
Endictya oceanica Ehrenberg
Eupodiscus californicus Grunow
Hyalodiscus scoticus (Kützing) Grunow
Navicula optima Hanna
Paralia sulcata Grunow
Rhaphoneis sp. cf. R. gemmifera Ehrenberg
R. amphiceros Ehrenberg sensu Andrews (1976)
Stephanopyxis turris (Greville & Arnott) Ralfs
S. lineata (Ehrenberg) Forti
S. spinossima Grunow
S. grunowii Grove & Sturt
Synedra jouseana Sheshukova-Poretzkaya -(thin, fine form)
Thalassionema nitzschioides Grunow

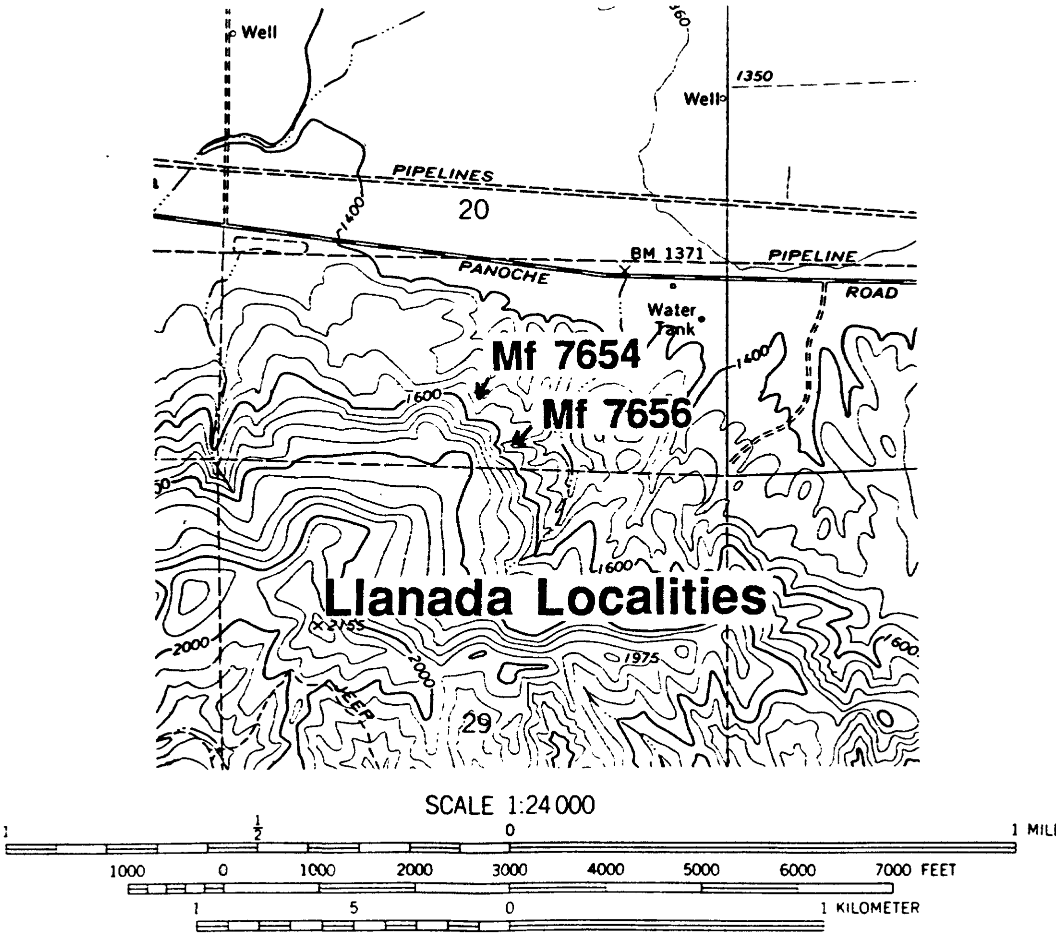

Figure 9. Location of samples Mf7654 and Mf7656 from tufaceous diatomaceous rocks underlying the Quien Sabe Volcanics of Taliaferro (1948) in the Llanada 7.5' quadrangle, south of Hollister, California. Geology is in preparation by Robert McLaughlin, USGS, Menlo Park.

Nonmarine diatoms:
Aulacosira granulata (Ehrenberg) Simonsen
Mesodictyon sp.

Age: late middle Miocene. Appears similar to East Coast Diatom Zone 6 of Andrews (1988)(ca. 13.8 to 12.8 Ma) but it could be younger, because younger uppermost middle Miocene diatomaceous rocks are poorly represented on the east coast. Comparison with Barron (1976) and unpublished notes of diatom ranges at Newport Beach in southern California suggests a correlation with either Subzone a or Subzone b of the Denticulopsis hustedtii - D. lauta Zone in the North Pacific or 13.8 to 11.4 Ma (Fig. 2).

Paleoecology: The dominance of neritic and benthic taxa and the scarcity of open ocean planktonic forms suggests deposition on the shelf with some obstruction to open and free communication to the North Pacific.

SUMMARY REMARKS

Based on this reconnaissance study, diatom biostratigraphy appears to have limited use in dating Monterey Group rocks in the San Jose (1:100,000) sheet area. Fine-grained facies of Monterey age rocks (middle and late Miocene) are restricted in the region, as it is centered on a Miocene tectonic high lying between Neogene basins. Where present, fine-grained rocks assigned to the Monterey are typically porcelaneous or cherty implying that diagenesis has destroyed the diatom frustules in these once diatomaceous rocks. Although dolomite beds and concretions in porcelaneous and cherty Monterey rocks have yielded datable diatom assemblages elsewhere in California (mostly coastal sections), all dolomites collected during this study from the San Jose sheet area were either barren of diatoms or contained only poorly preserved, non-age-diagnostic forms.

Only softer lithologies from the Tice Shale near Pinole and from tufaceous diatomaceous rocks in the Llanada area south of Hollister yielded good diatom assemblages. These rocks are assigned respectively to Subzone b of the Denticulopsis lauta Zone and to undifferentiated Subzones a and b of the Denticulopsis hustedtii - D. lauta Zone (both middle Miocene)(Fig. 2).

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