DIATOMS FROM THE MODELO FORMATION

(UPPER MIOCENE)

NEAR GIRARD, LOS ANGELES COUNTY, CALIFORNIA

Thesis by

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INTRODUCTION

The abundance of organic shales in the Upper Miocene strata of Southern California and the uncertainty which often has attended the determination of their age, has made a study of the diatoms which they contain desirable. These Upper Miocene shales have been variously mapped as belonging wholly or in part to the Pico, Fernando, Puente, Monterey, and Modelo formations, and it was with the hope of aiding in the clarification of this complex that the present investigation was undertaken. The Upper Miocene is well exposed in many places in Southern California, but seldom are the relations to the underlying formations so well shown as along the North flank of the Santa Monica Mountains in the vicinity of Girard, near the western border of Los Angeles County. Due to numerous road cuts, both for real estate subdivision and for highway purposes, excellent exposures are obtainable across the entire Upper Miocene.

The general locality is indicated on Plate I, which shows Los Angeles County, California, as well as portions of adjacent counties. Plate II, a portion of the Reseda, Calif., and Dry Canyon, Calif., Quadrangles of the United States Geological Survey, shows in more detail the section investigated, as well as the location of the fossil collections.

Plate I

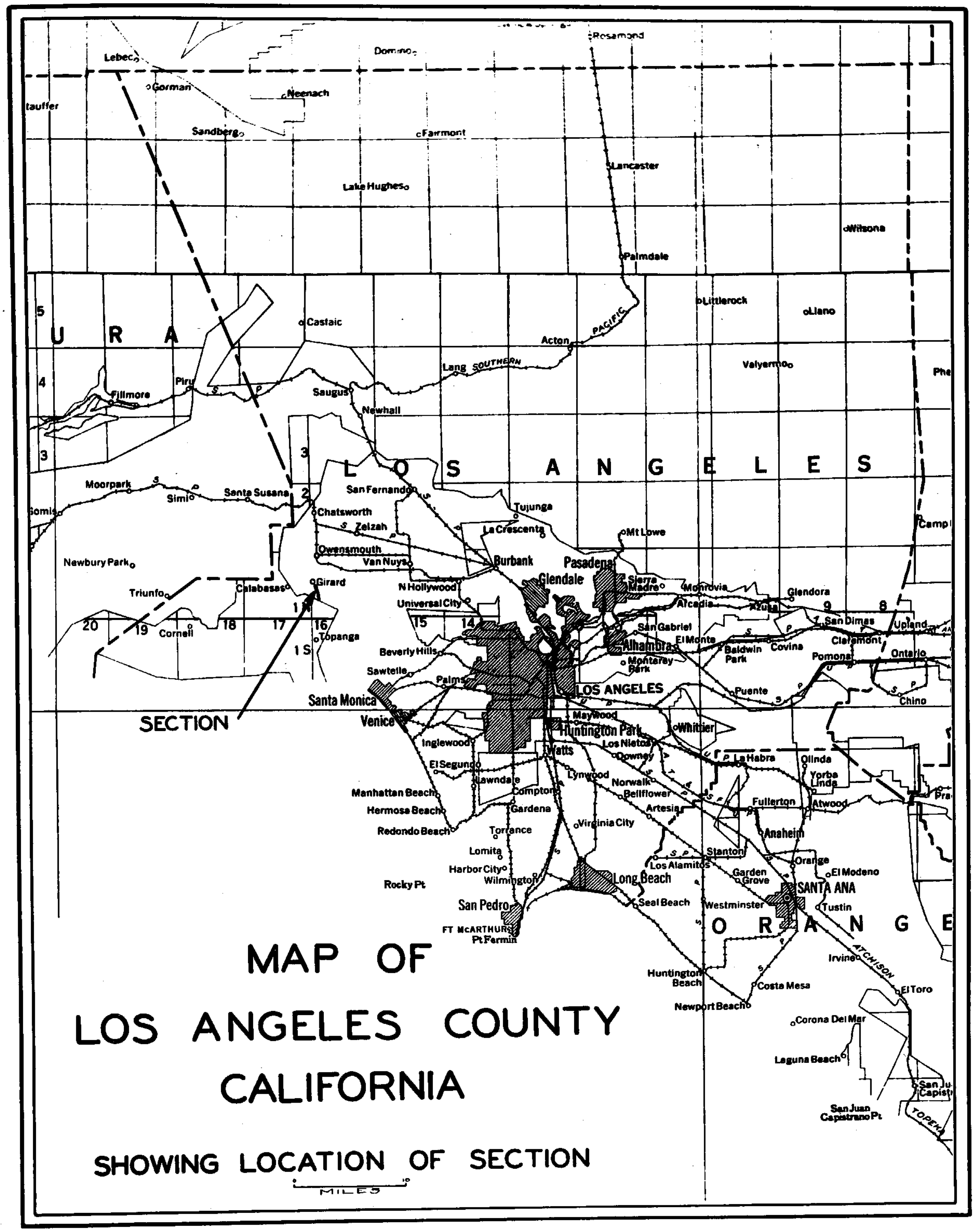
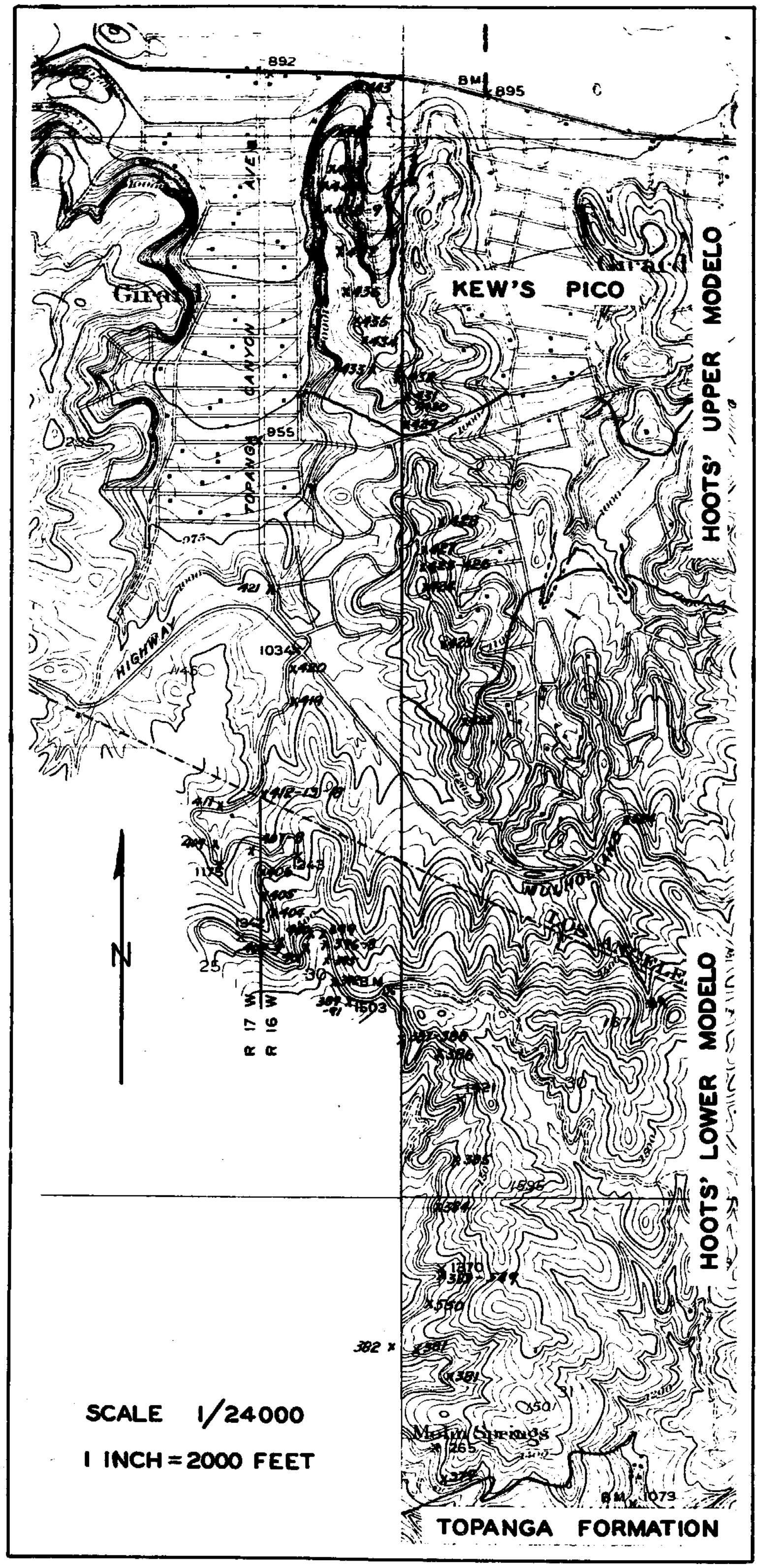

MAP OF
LOS ANGELES COUNTY
CALIFORNIA
SHOWING LOCATION OF SECTION
MILES
SECTION
L O S A N G E L E S
O R A N G E
Lebec
Gorman
Neenach
Sandberg
Fairmont
Rosamond
Lake Hughes
Lancaster
Palmdale
Wilsona
Littlerock
Llano
Castaic
Acton
Valyermo
Lang
SOUTHERN
PACIFIC
Saugus
Newhall
Fillmore
Piru
Moorpark
Simi
Santa Susana
San Fernando
Chatsworth
Zelzah
Tujunga
La Crescenta
Mt Lowe
Owensmouth
Van Nuys
Burbank
Pasadena
Glendale
Newbury Park
Triunfo
Calabasas
Girard
N Hollywood
Universal City
Sierra Madre
Monrovia
Arcadia
Azusa
Glendora
Cornell
Topanga
Beverly Hills
Sawtelle
Palms
San Gabriel
Alhambra
El Monte
Monterey Park
Baldwin Park
Covina
San Dimas
Claremont
Pomona
Upland
Ontario
Chino
Santa Monica
Venice
LOS ANGELES
Puente
Maywood
Huntington Park
Whittier
Inglewood
El Segundo
Watts
Los Nietos
Downey
La Habra
Olinda
Yorba Linda
Manhattan Beach
Hermosa Beach
Redondo Beach
Lawndale
Compton
Gardena
Lynwood
Norwalk
Bellflower
Artesia
Fullerton
Atwood
Torrance
Virginia City
Anaheim
Lomita
Harbor City
Wilmington
Rocky Pt
San Pedro
FT McARTHUR
Pt Fermin
Long Beach
Los Alamitos
Stanton
Garden Grove
Orange
El Modeno
SANTA ANA
Tustin
Seal Beach
Westminster
Irvine
ATCHISON
El Toro
Huntington Beach
Costa Mesa
Newport Beach
Corona Del Mar
Laguna Beach
San Juan Capistrano Pt
TOPEKA

Plate II



PORTION OF DRY CANYON AND RESEDA QUADRANGLES SHOWING LOCATION OF SAMPLES

ACKNOWLEDGEMENTS

The writer is under obligations to Dr. H. W. Hoots, of the Union Oil Company of California, for the original suite of samples with which the work was begun; to Dr. W. P. Woodring, of the California Institute of Technology, for planning and guiding the investigation and for his inspiring example of the true scientific method; to Dr. G. Dallas Hanna, of the California Academy of Sciences, for aid in identifying several of the species; to Mr. W. D. Rankin, of the Continental Oil Company and Mr. D. D. Hughes of the Texas Company, for aid in the determination of the age of the strata under consideration; and to Miss M. Kathryn McGee for material aid in typing, bibliographic work and reading of the manuscript.

PREVIOUS WORK

The Modelo formation was first named by G. H. Eldridge[1] in 1907, after Modelo Canyon, Ventura County, California, where the formation is well exposed. W.S.W. Kew[2] redefined the Modelo formation in 1924, at which time he first mapped the region under discussion, placing the upper 500 feet of the beds exposed in the region of Girard (com-

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1 Eldridge, G. H., The Santa Clara Oil District, Southern California, U.S.G.S. Bulletin 309, pp. 17-21, 1907.

2 Kew, W.S.W., Geology and Oil Resources of a part of Los Angeles and Ventura Counties, California. U.S.G.S. Bulletin 753, pp. 64, 76. 1924.

posed of diatomaceous shales) in the Pico formation (Lower Pliocene).

In 1928-29, H. W. Hoots[3] remapped this region on a larger scale and divided the Modelo formation into a lower and an upper member, the latter including the beds which Kew had mapped as belonging to the Pico formation. This relation is shown in the Columnar section, Plate III, and is the usage followed in the present report.

W.D. Rankin[4] made a detailed study of the foraminifera from the same section considered in the present report in 1930. His results will be considered in detail later.

D. D. Hughes[5] made a detailed study of the foraminifera from the Modelo formation at the type locality in 1929.

A detailed study of the geologic age of the Modelo formation was made in 1929 by F. S. Hudson and F. K. Craig[6], who propose to restrict the term "Modelo formation" to in-

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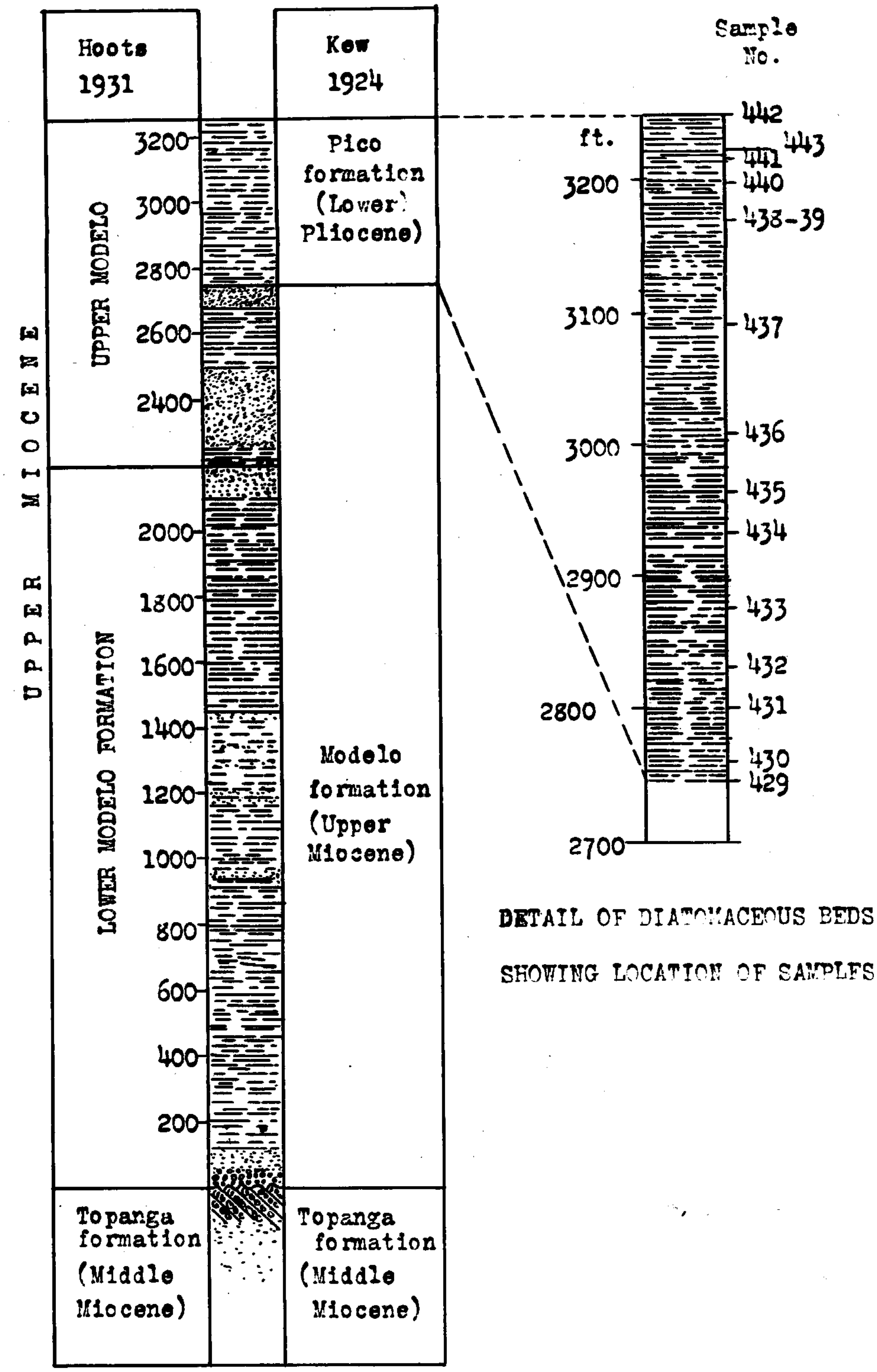
[3] Hoots, H. W., Geology of a part of the Santa Monica Mountains, U.S.G.S. Prof. Paper ______ 1931.

[4] Rankin, W.D., Foraminiferal Study of the Modelo formation exposed along the Topanga Canyon Road, Los Angeles County, California. Ms read before the Jan. 2, 1930 meeting of the Pacific Coast Section of the Society of Economic Paleontologists and Mineralogists at Los Angeles, Calif.

[5] Hughes, D. D., Foraminifera from the Modelo of Modelo Canyon, Ventura County, Calif. MS read before the Pacific Coast Section of the Society of Economic Paleontologists and Mineralogists at Los Angeles, Calif., Dec. 5, 1929.

[6] Hudson, F.S. and E.K. Craig, Geologic Age of the Modelo Formation, California. Bull. A.A.P.G. Vol. 13, pp. 509-518, 1929.

PLATE III



COLUMNAR SECTION OF THE MODELO FORMATION

AS EXPOSED NEAR GIRARD, CALIF.

clude only the upper sandstone and part of the upper shale.

METHOD OF INVESTIGATION

Due to the fact that the Modelo formation here forms the south limb of a large syncline extending under the San Fernando Valley to the North, the structure is quite simple, permitting accurate stratigraphic measurements. A series of road cuts going directly across the strike of the beds has exposed the whole section, so that collections and measurements may be made continuously.

A suite of 63 samples, covering the entire section consisting of 3250 feet from the unconformity at the base of the Modelo formation to the valley alluvium, was collected under the direction of Dr. Hoots in December, 1927. It was this suite which Mr. Rankin used in his study of the foraminifera mentioned above. A duplicate set was given to the writer and each sample was carefully cleaned and examined for the presence of diatoms. All of the samples represented in the lower 2750 feet of the section proved barren of diatoms, while a good flora of some 60 species was obtained from the upper 500 feet.

Following this preliminary study, a careful sampling of the whole section was undertaken by the writer with the hope of finding some beds containing diatoms lower in the section. Many beds lower in the section which at first appeared to be diatomaceous, proved upon subsequent examination under the microscope, to consist of volcanic ash.

The lower part of the section was measured by means of a plane table traverse (scale, 500' = 1"), while the upper part was measured by means of a steel tape and Brunton Compass. Due to the simplicity of the structure and the excellence of the exposures it is believed that the results are quite accurate.

All of the samples collected were carefully cleaned and strewn slides made from the diatom concentrates obtained. Special care was taken to prevent contamination from one sample to the next, a very important consideration when working with such small fossils as diatoms. In addition to the strewn slides, group slides were made, in which individual diatoms were mounted by means of a mechanical finger.

From an examination of these slides, a list of species of diatoms occurring in each sample was made, the results of which are shown in Plate IV, where they are listed in the order of their first occurrence going up in the section.

GEOLOGY

As previously stated, the Modelo formation here forms the south limb of a syncline, dipping 6° - 27° North, with an average strike of N. 65° E. and overlies the Topanga formation (Middle Miocene) with marked unconformity. The contact is well shown near Mohn Springs Cafe, on the new Topanga Canyon Road, along which the whole lower part of the section is quite well exposed. The unconformable nature of the contact is shown in Fig. 1, which was taken about 200 feet east of Mohn Springs Cafe. Both the base of the Modelo and the top of the Topanga are conglomerates of quite similar composition and texture. The basal conglomerate (see Figure 2) extends for 10 feet above the contact, when it is rather suddenly replaced by 12 feet of buff sandstone interbedded with sandy shale (Figure 3). The next 1400 feet consists of sandy and silty shales interbedded with thin sandstone beds (Figure 4) up to 5 inches in thickness, with occasional beds of hard buff sandstone up to 2 feet in thickness. Muddy shales (see Figure 5) containing abundant foraminifera occupy the next 600 feet of the section, the upper 200 feet of which is intercalated with thin beds of volcanic ash. (Figure 6). This part of the section grades rather gradually from quite muddy shale to fairly sandy shale. The next 75 feet consists of hard, cherty shale (Figure 7) which is in turn overlain by 110 feet of massive, coarse, buff to white sandstone (Figure 8). The upper 25 feet of this sandstone contains numerous large concretions varying from 6 inches to 2 feet in diameter (Figure 9), while the extreme top is marked by a bright yellow laminated sandstone bed two feet thick. This bed was mapped by Dr. Hoots[7] as the contact between the upper and lower members of the Modelo formation, and occurs 2204 feet above the unconformity.

The base of the upper member consists of a dark buff

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7 Op. cit.

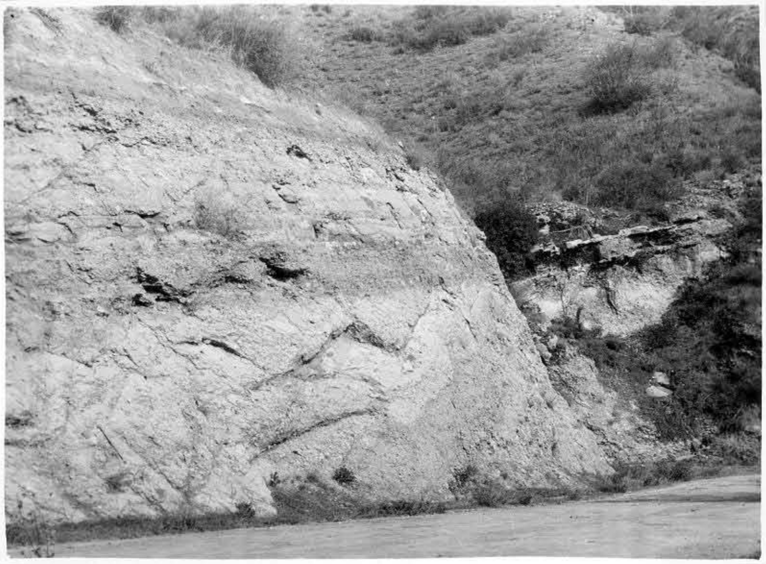

Figure 1.

Unconformity between the Modelo (Upper Miocene) and Topanga (Middle Miocene) formations. Both the basal Modelo and the Upper Topanga are massive conglomerates.

Figure 2.

Basal conglomerate of the Modelo formation.

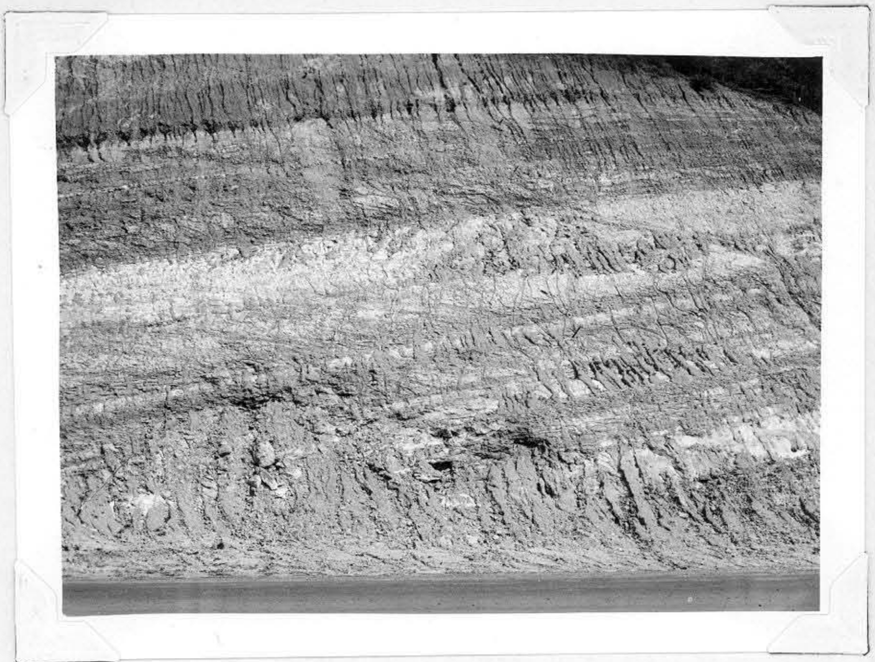

Figure 3

Alternating sandstone and sandy shwle immediately overlying the basal conglomerate

Figure 4

Laminated sandstones and shales 1400 feet above the base.

Figure 5

Muddy shales at Summit of Topanga Canyon Road. 1600 feet above the base.

Figure 6

Fine sandy shales interbedded with volcanic ash, with occasional hard limy beds up to 1 foot thick. 2000 feet above the base.

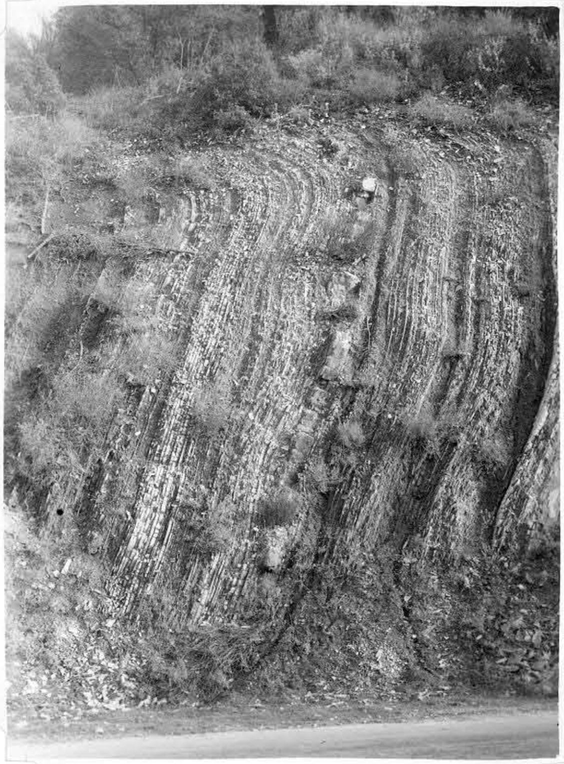

Figure 7

Hard, cherty shales underlying the massive sandstone near the top of the Lower Modelo. 2050 feet above the base.

Figure 8

Massive sandstone near the top of the lower Modelo formation. 2100 feet above the base.

clayey shale 50 feet thick which grades rapidly into a massive sandstone bed 250 feet thick quite similar to that occurring at the top of the lower member. This is again overlain by 200 feet of buff shale, in part clayey to punky and in part quite hard and cherty, with occasional thin beds of hard concretionary sandstone up to 8 inches in thickness. The last massive sandstone bed (Figure 10) going up in the section has a probable thickness of 50-60 feet. The bottom of this bed is not well exposed, but the maximum thickness is well within the above limits, grading laterally to a thickness of 20-30 feet. In places this sandstone contains irregular masses of shale fragments and mud balls, as shown in Figure 11.

The remaining 500 feet of the section as exposed in the vicinity of Girard consists of diatomaceous shale, increasing in diatom content (both as to number of species and number of individuals) towards the top. (See Figures 12 and 13). Dr. Kew[8] originally mapped these diatomaceous shales as a part of the Pico formation (Lower Pliocene), placing the contact between the Pico and Modelo formations at the top of the massive sandstone just described. This series of diatomaceous beds will be discussed in more detail under "Discussion of Results."

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[8] Op. cit.

Figure 9

Large concretion from concretionary sandstone overlying that shown in Fig. 8.

Figure 10

Massive sandstone near the base of Kew's Pico formation. 2700 feet above the base.

Figure 11

Eastward extension of same sandstone shown in Figure 10, here containing shale fragments and mud balls.

Figure 12

Finely laminated diatomaceous shale near the top of the section. The dark irregular band is a sandstone dike of considerable extent. 3220 feet above the base.

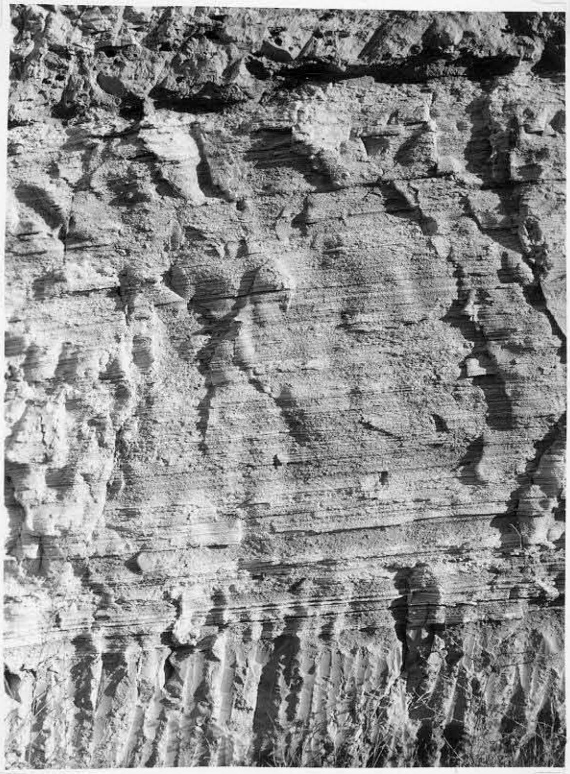

Figure 13

Closer view of a portion of Fig. 12, showing the nature of the bedding.

EVIDENCE OF AGE

Dr. Kew's original assignment of the diatomaceous beds here exposed to the Pico formation (Lower Pliocene) was made on the basis of lithology, without reference to the diatoms and foraminifera which they contain.

Mr. W. D. Rankin[9], who has studied the foraminifera from this section, reports as follows:

> "The relative age of these strata will be considered separately for the lower and upper members.
>
> "1. The lower member contains a molluscan-fauna at the base of the formation that Dr. Woodring has reported upon as being equivalent to or slightly older than the Briones fauna of the Mt. Diablo region. The foraminiferal fauna of this group of strata is not present in the Modelo Canyon Section presented by Mr. D. D. Hughes. This fauna includes Bolivina beyrichi Reuss var. alata (Seguenza), Buliminella californica Cushman, Buliminella sp., Bolivina hughesi Cushman, Bolivina affinis d'Orbigny, and Eponides aff. broeckiana (Karror). This assemblage was also found in samples collected from the Upper Puente Shale of English in La Habra Canyon, Puente Hills. The Miocene strata at Malaga Cove, presented by Hutcheson and Kuffel September 6, 1928, can also be correlated with this fauna.
>
> "2. The upper member contains a foraminiferal fauna consisting of such species as Bolivina seminuda Cushman, Bolivina sinuata Galloway and Wissler, Bolivina aff. spissa Cushman, Bolivina sp. A., Buliminella sp. A, Cassidulina delicata Cushman, Pulvinulinella bradyana Cushman, and Pulvinulina pacifica Cushman var. This fauna may be correlated with the Upper Modelo Shale as exposed in Modelo Canyon."

Mr. D. D. Hughes, who has made a detailed study[10] of the foraminifera of the Modelo formation at the type locality (Modelo Canyon, Ventura County, California) has come to the following conclusions regarding the age of the Upper Modelo Shale:

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[9] Op cit.

[10] Op. cit.

"The upper shale member has afforded a fairly abundant foraminiferal fauna represented by sixty-six species and varieties. This fauna seems to be the same as that contained in the strata directly underlying the so-called 'Lower Pliocene' of the Los Angeles Basin. The upper shale fauna seems also to bear an affinity to the fauna of the uppermost foraminiferal Miocene strata developed in the coastal region of Santa Barbara County.. . . . This upper Miocene assemblage is younger than the uppermost foraminiferal fauna of the 'Monterey' exposed on the east side of the Salinas Valley."

Evidence of age of the strata deduced from the diatoms will be considered below.

DISCUSSION OF RESULTS

Altho a careful search was made, no diatoms were found in the lower 2750 feet of the Modelo formation, so that the following discussion is confined to the upper 500 feet of the section as exposed near Girard, Calif.

The following list of species of diatoms was found in the upper 500 feet of strata exposed:

Actinoptychus undulatus Ehrenberg
    marmoreus Brun
    simbirskianus Schmidt (?)
    stella Schmidt var. thumii Schmidt
Arachnoidiscus ornatus Ehrenberg
Campyloneis grevillei (Wm. Smith) Grunow
Chaetoceros incurvum Bailey
Cocconeis baldjikiana Grunow
    distans (Gregory) Grunow
Coscinodiscus argus Ehrenbert
    asteromphalus Ehrenberg
    curvatulus var. latius-striata Schmidt
    decrescens Grunow
    denarius Schmidt
    elegans Greville
    excentricus Ehrenberg
    lineatus Ehrenberg
    marginatus Ehrenberg
    oculus-iridis Ehrenberg
    radiatus Ehrenberg
    subtilis Ehrenberg

Coscinodiscus woodwardii Eulenstein
Cyclotella antiqua Smith (?)
Denticula lauta Bailey
Dicladia capreolus Ehrenberg
Diplôneis densistriata (Schmidt)
pelagi (Schmidt) Boyer
smithii (Brebisson) Cleve
suborbicularis (Gregory) Fricke
Dosettia caballeroi Azpeitia
Endictya robusta (Greville)
Fragilaria arctica Grunow
Grammatophora angulosa Ehrenberg
merletta Hanna & Grant
Hemidiscus simplissimus Hanna & Grant
Hercotheca mammilaris Ehrenberg
Liradiscus ovalis Greville
Melosira clavigera Grunow
exspectata Schmidt
sol (Ehrenberg) Kützing
sulcata (Ehrenberg) Kützing
Muelleriella limbata (Ehrenberg) Van Heurck
Navicula lyra Ehrenberg
Omphalotheca californica Hanna
Opephora schwartzii Ehrenberg
Periptera tetracladia Ehrenberg
Rhaphoneis archeri O'Meara
Stephanogonia actinoptychus Ehrenberg
Stephanopyxis appendiculata Ehrenberg
turris (Gregory) Ralfs.
Stictodiscus californicus Greville
Syndendrium diadema Ehrenberg
Synedra affinis Kützing
Synedra (?) cf. fimbriata Castracane
Thalassionema nitzschiodes Grunow
Triceratium sp.
Xanthiopyxis cingulata Ehrenberg
oblonga Ehrenberg
umbonatus Greville.

In addition to those in the above list, some 15 additional species were found which have not yet been identified, due to lack of literature. It is quite possible that nearly all of these unidentified forms may represent new species, but in view of the lamentable synonomy which already exists in diatom literature it has been thought best not to name any new species until more literature has been consulted.

By referring to Plate IV it will be seen that there is a gradual increase in the number of species going up in the section. The number of species per sample varies all the way from one in sample No. 429 to fifty in sample No. 441.

While large numbers of cosmopolitan species are present in nearly every sample, a number of species are present which appear to have had a much more restricted vertical range and which are useful as indicators for definite zones. The following species are found in the Upper Modelo formation and apparently nowhere else in this region. They do not occur in the Temblor formation (Middle Miocene) nor in the Pliocene diatomites of California.

Melosira clavigera Grunow
Actinoptychus marmoreus Brun
Hemidiscus simplissimus Hanna & Grant
Muelleriella limbata (Ehrenberg) Van Heurck
Synedra (?) cf. fimbriata Castracane
Denticula lauta Bailey
Grammatophora merletta Hanna & Grant.

This list will ultimately be considerably augmented by the addition of the unidentified species mentioned on the preceding page. These species are also found at the top of the Miocene section exposed at Timms Point, San Pedro, California, in the Upper Modelo exposed along the north flank of the San Pedro Hills, in the Upper Modelo exposed on the west bank of the Newport Lagoon, Newport, California, and in the Upper Puente Shale in the

Plate IV

DIATOMS FROM THE MODELO FORMATION NEAR GIRARD, CALIFORNIA.

STRAT. INTERVAL ABOVE BASE	2745	2782	2800	2830	2876	2933	2964	3019	3090	3170	3170	3199	3215	3226	3247
SAMPLE NO.	429	430	431	432	433	434	435	436	437	438	439	440	441	443	442
Melosira exspectata Schmidt	R	R	R	R									R		
Coscinodiscus argus Ehrenberg		R													
Coscinodiscus elegans Greville		R								R	R		R	F	
Coscinodiscus oculus-iridis Ehrenberg		F											F		
Denticula lauta Bailey		R						R				R	F	R	R
Endictya robusta (Greville)		F	F	F	C	C	C	C	F			F	F	F	
Stephanopyxis appendiculata Ehrenberg		F													
Stephanopyxis turris (Gregory) Ralfs		F													
Stictodiscus californicus Greville		R											R		
Arachnoidiscus ornatus Ehrenberg			R										R	R	
Coscinodiscus excentricus Ehrenberg			F										F	F	
Coscinodiscus marginatus Ehrenberg			F			R					F		F	R	
Grammatophora marletta Hanna & Grant			R					R					R		
Liradiscus ovalis Greville			C		F					R	R	R	C	F	
Melosira sol (Ehrenberg) Kuetzing			R		R						R				
Melosira sulcata (Ehrenberg) Kuetzing			R								F		R	R	R
Omphalotheca californica Hanna			R								F		F		
Synedra affinis Kuetzing			F												
Xanthiopyxis oblonga Ehrenberg			C												
Hemidiscus simplissimus Hanna & Grant					R								F	R	R
Diploneis smithii (Brebisson) Cleve						R					R		F	R	
Cocconeis baldjikiana Grunow						F				R	R		R		
Thalassionema nitzschioides Grunow						R	R	F			A		A	F	
Xanthiopyxis cingulata Ehrenberg									R				C	F	
Coscinodiscus asteromphalus Ehrenberg									R	R		R	F	F	
Diploneis densistriata (Schmidt)										R			R	R	
Coscinodiscus denarius Schmidt											F		F		F
Cyclotella antiqua Wm. Smith (?)											R		R		
Diploneis suborbicularis (Gregory) Fricke											R		R		
Actinoptychus marmoreus Brun													F		
Actinoptychus simbirskianus Schmidt (?)													F		
Actinoptychus stella var. thumii Schmidt													F	F	
Actinoptychus undulatus Ehrenberg													C	F	F
Campyloneis grevillei (Wm. Smith) Grunow													F		
Chaetoceros incurvum Bailey													R		
Cladogramma californicum Ehrenberg													F	R	
Coscinodiscus curvatulus var. latius-striata Schmidt													F		
Coscinodiscus decrescens Grunow													F		
Coscinodiscus lineatus Ehrenberg													R		
Coscinodiscus radiatus Ehrenberg													F	F	
Coscinodiscus subtilis Ehrenberg													R		
Coscinodiscus woodwardii Eulenstein													F		
Dicladia capreolus Ehrenberg													F		
Diploneis pelagi (Schmidt) Boyer													F		
Dosettia caballeroi Azpeitia													F	R	R
Fragilaria arctica Grunow													F		
Grammatophora angulosa Ehrenberg													R		
Hercotheca mammilaris Ehrenberg													R		
Melosira clavigera Grunow													F	R	
Muelleriella limbata (Ehrenberg) Van Heurck													F		
Navicula lyra Ehrenberg													F	R	
Opephora schwartzii Ehrenberg													R		
Periptera tetracladia Ehrenberg													F		
Stephanogonia actinoptychus Ehrenberg													F		
Syndenirium diadema Ehrenberg													C		
Synedra (?) cf. fimbriata Castracane													C	F	
Tricoratium sp.													F		
Xanthiopyxis umbonatus Greville													F		
Rhaphoneis archeri O'Meara														R	
Cocconeis distans (Gregory) Grunow															R

SYMBOLS R = RARE F = FREQUENT C = COMMON A = ABUNDANT

Puente Hills, California.

In addition to these actual marker species, certain asssemblages of more cosmopolitan and even living forms are quire characteristic of the Upper Miocene strata of Southern California. The following species are included in this category:

Cladogramma californicum Grunow
Coscinodiscus asteromphalus Ehrenberg
Coscinodiscus elegans Greville
Dicladia capreolus Ehrenberg
Diploneis densistriata (Schmidt)
Diploneis pelagi (Schmidt) Boyer
Hercotheca mammilaris Ehrenberg
Liradiscus ovalis Greville
Opephora schwartzii Ehrenberg
Stictodiscus californicus Greville
Xanthiopyxis oblonga Ehrenberg
Xanthiopyxis umbonatus Greville
Dosettia caballeroi Azpeitia

Several definite zones in the Upper Modelo formation are of particular interest as they appear to be continuous over a considerable area and are usually dominated by some one species. One of these zones has Denticula lauta Bailey as the dominant species and can be picked up in the San Pedro Hills, the Puente Hills, and the Santa Monica Mountains. Another zone in the Santa Monica Mountains, exposed one and one-half miles east of the section under consideration, is dominated by Coscinodiscus asteromphalus Ehrenberg, a large and beautifully ornate diatom.

The extent, both areally and vertically in the geologic column, of these zones has not yet been worked out, but remains as an interesting extension of the present investigation. The Denticula lauta zone, mentioned above is apparently a very definite one extending over large areas, and has been observed in many oil well cores as well as in surface outcrops.

The fact that the beds in which these diatoms were found have been determined to be of Upper Miocene age on the basis of their foraminiferal content, and the further fact that practically the same assemblage of diatoms is found in other beds previously determined as Upper Miocene, fixes their age fairly definitely. This is corroborated by the fact that the so-called "Marker species" of the Upper Miocene are found neither in the underlying Middle Miocene beds nor in the overlying Lower Pliocene. Thus this section has been set up as a sort of secondary working standard for the Upper Miocene and by extending the same type of work to cover other sections and comparing them with this original section, a basis for correlating the Upper Miocene diatomacedus shales may be reached.

A great many such sections have been carefully measured and collections at known stratigraphic intervals are being studied with this end in view.

SYSTEMATIC PALEONTOLOGY

In the following discussion, the classification of Schuett[11] is adopted. It is the simplest and most widely used classification of the diatoms which has been devised to date and, being based on the structure and markings of the frustule itself, is particularly adaptable to fossil forms.

For the sake of compactness the bibliographic references have been abbreviated, full titles of the works quoted being given in the bibliography at the end of this paper.

C R Y P T O G A M I A

T H A L L O P H Y T A

Class ALGAE

Order DIATOMACEAE

Family CENTRICAE

Subfamily DISCOIDEAE

Tribe COSCINODISCEAE

Subtribe MELOSIRINAE

Genus MELOSIRA Agardh

Melosira clavigera Grunow — Plate V, fig. 1

Melosira clavigera Grunow, Sch. Atl., Pl. 175, fig. 21-24, (1892). Van Heurck, Synopsis, pl. 91, fig. 1,2. (1881). Gaylord & Hanna, Bull. A.A.P.G., Vol. 9, pl. 5, fig. 3, (1925). Laporte & Lefebure, I, pl. 4, fig. 29, (1929).

Although this form has been reported from rocks as

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11 Schuett, F., in Pflanzenfamilien by A. Engler & K. Prantl, Theil I, Abteilung 16, Leipzig, 1896.

old as possible Eocene in other parts of the world, it apparently is confined to the Upper Miocene in this region. It is fairly frequent in the uppermost part of the Upper Modelo near Girard, California.

This is a very fragile form, seldom found whole. The specimen figured unfortunately had the center broken during mounting. Diameter of valve, 0.068 mm.

Melosira exspectata Schmidt

Melosira exspectata Schmidt, Sch. Atl., pl. 177, fig. 54-58, (1892).

This diatom occurred the lowest down of any in the section, represented by a sufficiently complete valve to make identification certain.

Melosira sol (Ehrenberg) Kützing

Melosira sol (Ehr.) Kz., Prit. Inf. 4th ed. p. 819, (1861). Van Heurck, Synopsis, pl. 91, fig. 7-9, (1881). Sch. Atl., pl. 179, fig. 21, (1892). Wolle, Diat. N.A., pl. 58, fig. 1-2. (1894). Castracane, Rep. Chall. Vol. 2, pl. 10, fig. 3; pl. 17, fig. 3; pl. 21, fig. 7, p. 93, (1886). Boyer, N.A. Diat., p. 28 (1927). Mann, Diat. Alb. Voy., p. 239, (1907).
Gallionella sol Ehrenberg. Ehr. Mik., pl. 35A, group XXII, fig. 12, (1854).

This large and beautiful diatom was represented by fragments only. Ranges from Upper Miocene to recent.

Melosira sulcata (Ehrenberg) Kützing

Melosira sulcata (Ehr.) Kz. Kz. Bac., p. 58, pl. 2, fig. 7, (1844). Prit. Inf. 4th ed., p. 819, pl. 9, fig. 131; pl. 11, fig. 26, (1861). Sch. Atl., pl. 177, fig. 23-39, (1892).

This is one of the long-lived forms mentioned, having been found in the lowermost Miocene[12] as well as in the Pacific Ocean[13] living at the present time. It is fairly well distributed in the Girard section, altho never abundant.

Genus STEPHANOPYXIS Ehrenberg

Stephanopyxis appendicula Ehrenberg

Stephanopyxis appendicula Ehrenberg. Ehr. Mik., pl. 18, fig. 4, (1854). Sch. Atl., pl. 130, fig. 18, 19, 21, 23, 24. (1888). Wolle, Diat. N.A., pl. 62, fig. 12-15. (1894). Mann, Diat. Alb. Voy., p. 244, (1907).

When sufficient work is done on this group, it is quite possible that many species will be included with this form as mere varieties.

Stephanopyxis turris (Gregory) Ralfs.

Stephanopyxis turris (Greg.) Ralfs. Prit. Inf. pl. 5, fig. 74, p. 826, (1861). Sch. Atl., pl. 130, fig. 42-43. (1888).

This variable and cosmopolitan form may well be included under the preceding species, as Mann[14] has done. It is retained here only provisionally until its true status is determined. Frequent in sample No. 430 of the Girard section and, strangely enough, not found higher.

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[12] Hanna, G.D., The Lowest Known Tertiary Diatoms in California. Journ. Paleont., Vol. 1, p. 115, (1927).

[13] Mann, A.A., Diat. Albatross Voyages, p. 239, (1907)

[14] Ibid, p. 244.

Genus CYCLOTELLA Kützing

Cyclotella antiqua Wm Smith.

Cyclotella antiqua Wm Smith., Brit. Diat., I, pl. 5, fig. 49, (1856). Van Heurck, Synopsis, pl. 92, fig. 1, (1881).

Although always found living in fresh water, this diatom occurs in two different samples from the Girard section. Its apparently anomolous presence here may be due to its having been carried by some river emptying into the Modelo Sea.

Subtribe PYXILLINAE

Genus STEPHANOGONIA Ehrenberg

Stephanogonia actinoptychus Ehrenberg   Plate V, fig. 2

Stephanogonia actinoptychus Ehr. Van Heurck, Treatise, p. 437, fig. 163, (1896). Wolle, Diat. N.A., pl. 67, fig. 6. (1894).

This minute, though distinctive, diatom is apparently confined to the Middle and Upper Miocene, and constitutes a fairly good marker for the upper half of the Miocene.

Genus DICLADIA Ehrenberg

Dicladia capreolus Ehrenberg

Dicladia capreolus Ehrenberg. Ehr. Mik., pl. 35A, group 18, fig. 5; pl. 18, fig. 101, 102. (1854). Wolle, Diat. N.A., pl. 64, fig. 5-7, (1894).

Boyer[15] considers this to be a spore of Chaetoceros mitra (Bailey) Cleve. Although Dicladia capreolus has been observed in many collections of Modelo shale, and often quite

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15 Boyer, C.S., Synopsis of North American Diatomaceae., Proc. Acad. Nat. Sci. Phila. Vol. LXXVIII, p. 110, (1926)

common, Chaetoceros mitra has never been observed in the same sample. The only Chaetoceros which is at all common in the Modelo formation is Chaetoceros incurvum Bailey, which is uniformly smaller than the Dicladia of which it is supposed to be the parent. In one locality on the north flank of the San Pedro Hills, Los Angeles County, California, the Upper Modelo formation contains countless numbers of Dicladia capreolus, and considerable search has failed to find one valve of Chaetoceros mitra , or anything approaching it. Certainly a few of the parent valves would have survived and be preserved in the fossil record.

From the point of view of the micropaleontologist, Dicladia capreolus is a good fossil and deserves separate rank as it is never found associated with its allegedly parent form.

Genus XANTHIOPYXIS Ehrenberg

Xanthiopyxis cingulata Ehrenberg

Xanthiopyxis cingulata Ehr. Ehr. Mik., pl. 35, group 17, fig. 18, (1854).

This minute form is very common in Sample No. 441 of the Girard Section. Its range has not been determined with certainty, but it is apparently confined to the Middle and Upper Miocene, and possibly only to the Upper Miocene.

Xanthiopyxis oblonga Ehrenberg

Xanthiopyxis oblonga Ehr. Ehr. Mik., pl. 33, group 17, fig. 17, (1854).

Both this and the preceding form were first described from the Miocene of Rappahannock, Virginia, and have been consistently found in the Upper Miocene shales of California and Lower California.

Xanthiopyxis umbonatus Greville

Xanthiopyxis umbonatus Greville., Trans. Mic. Soc. Lond., 1866, p. 2, pl. 1, fig. 5. Wolle, Diat. N.A., pl. 74, fig. 16, (1894).

Genus OMPHALOTHECA Ehrenberg

Omphalotheca californica Hanna

Omphalotheca californica Hanna, Journ. Paleont. Vol. 1, p. 117, pl. 20, fig. 6,7. (1927).

This form very closely resembles Dosettia caballeroi Azpeitia in many details, the essential difference being that Omphalotheca californica is always circular in valve view, whereas Dosettia caballeroi is oval. The marginal spines on the latter are usually longer and much more robust. It is frequent in the upper part of the Girard section, altho originally described from the Lower Miocene, so that its range includes at least all of the Miocene.

Genus MUELLERIELLA Van Heurck

Muelleriella limbata (Ehrenberg) Van Heurck   Plate V, fig. 3.

Muelleriella limbata (Ehr.) V.H. Van Heurck, Treatise, p. 435, fig. 160, (1896).
Stephanopyxis? limbata Ehr. Mik., pl. 18, fig. 7, (1854).

This interesting diatom is found frequently in the upper part of the Girard section. Altho frequent, it is very rarely found whole, the one figured being the only complete form ever found by the writer.

Ehrenberg (see above reference) questioned including this form with Stephanopyxis, finally calling it a Pyxidicula, where it remained until Van Heurck set up the present genus in 1896. Taylor[16] in 1929 tentatively considered it allied to Dóssetia for no good reason, as they have little in common. It is an excellent marker for the Upper Miocene in California, although originally described from Richmond, Virginia, (Calvert formation?).

Length of figured specimen, 0.094 mm.

Subtribe COSCINODISCINAE

Genus ENDICTYA Ehrenberg

Endictya robusta (Greville)

Endictya robustus (Greville), Hanna & Grant, Proc. Calif. Acad. Sci. 4th Ser. Vol. 15, (1926) pl. 16, fig. 2,3, p. 144.
Coscinodiscus robustus Greville, Trans. Micr. Soc. Lond. n.s. Vol. 14, (1866), p. 3, pl. 1, fig. 8. Sch. Atl., pl. 62, fig. 16, 17. (1877). Mann, Diat. Alb. Voy., pl. 48, fig. 4, p. 258, (1907). Mann, Phil. Diat., pp. 67, 68. (1925).

Ehrenberg proposed the genus Endictya in 1845, without defining it with sufficient accuracy to stabalize it. The result has been that considerable confusion has arisán, some accepting, some refusing to accept it as a valid genus. Mann (see last reference above) has so well crystallized the

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16 Taylor, F.B., Notes on Diatoms, Cambridge, Eng., 1929, p. 206.

whole situation that his remarks are worth repeating:

> "It is advisable that the genus _Endictya_ shall not be combined with _Coscinodiscus_, as is done by Rattray (Rev. Cosc. p. 450), an arrangement accepted by me in my Diatoms of the Albatross Voyages. It should be retained to accomodate such forms as have valves sharply bent downward at the rim to form vertical sides or flanges at right angles to the surface of the circular portion. This is the position taken by Van Heurck and others. It is, however, further to be said that those forms which Castracane includes in his new genus _Ethmodiscus_ should perhaps also be considered to be _Endictyae_, their structure differing from such species as _E. oceanica_ mainly in the fineness of their markings and the general delicacy of their entire frustules. This would leave for the genus _Coscinodiscus_ that large class of diatoms the valves of which, whether flat, concave, or convex, terminate at the rim, where they join the girdle and are not bent vertically down to form deep sides or flanges ornamented with markings continuous with those of the rest of the valve. In fact _Endictya_ is more closely related to _Stephanopyxis_, or even to that subdivision of _Melosira_ called _Orthosira_ than to _Coscinodiscus_."

This sturdy diatom is particularly common in the lower part of the Girard section (Samples 430-436), where it is easily the dominant form, becoming less important in the upper part of the section.

Genus COSCINODISCUS Ehrenberg

Coscinodiscus argus Ehrenberg

Coscinodiscus argus Ehr. Mik., pl. 21, fig. 2, (1854). Sch. Atl., pl. 113, fig. 7, (1886). Rattray, Rev. Cosc. p. 527, (1889). Boyer, Phil. Diat., pl. 3, fig. 7, p. 23, (1916).

This form is rare in the Girard section, and confined to the lower part. It is apparently confined to the Miocene, although including both Middle and Upper. Some of the localities from which it has been reported may be as old as Eocene, but exact data is not available. It has not been reported living.

Coscinodiscus asteromphalus Ehrenberg

Coscinodiscus asteromphalus Ehr. Mik., pl. 18, fig. 45; pl. 33, group 15, fig. 7. Sch. Atl., pl. 63, fig. 5, 12. (1878). Rattray, Rev. Cosc., p. 549, (1889). Boyer, Phil. Diat., pl. 2, fig. 16; pl. 40, fig. 12, p. 23,(1916). Wolle, Diat. N.A., pl. 87, fig. 4, (1894).

Although not occurring in any amount above frequent in the Girard Section, Coscinodiscus asteromphalus forms the dominant diatom in a bed outcropping about one and one-half miles east of the Girard section. Here it occurs in such abundance that all other forms are rare. This bed has only a limited areal extent (as far as is known at present), and hence may represent a localized epidemic, such as have been observed at Copalis Beach, Washington[17].

Coscinodiscus curvatulus Grunow var. latius-striata Schmidt

Plate V, fig. 4, 5.

Coscinodiscus curvatulus var. latius-striata Schmidt, Sch. Atl., pl. 57, fig. 30, 34. (1878). Rattray, Rev. Cosc., p. 487, (1889).

Schmidt gives two figures, one from Monterey, and one from Santa Monica. The Girard forms agree quite perfectly, both with Schmidt's figures and with Rattray's description. Frequent in the upper part of the Girard section.

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17 Becking, L.B., C.F. Tolman, and H.C. McMillan, John Field, and Tadaichi Hashimoto, Preliminary Statement regarding the diatom "Epidemics" at Copalis Beach, Washington. Economic Geology, Vol. 22, pp. 356-368, (1927).

<u>Coscinodiscus decrescens Grunow</u> Plate V, fig. 6

Coscinodiscus decrescens Grunow, Sch. Atl., pl. 61, fig. 7-9. (1886). Rattray, Rev. Cosc., p. 525, (1889).

This very minute diatom is frequent in the upper part of the Girard section. Diameter of figured specimen, 0.019 mm., smaller than Rattray's minimum value.

<u>Coscinodiscus denarius Schmidt</u>

Coscinodiscus denarius Schmidt., Sch. Alt., pl. 57, fig. 19-21, (1886). Rattray, Rev. Cosc., p. 504, (1889). Boyer, Phil. Diat., p. 22, pl. 2, fig. 13, (1916).

Frequent in the upper part of the Girard section.

<u>Coscinodiscus elegans Greville</u> Plate VI, fig. 1

Coscinodiscus elegans Greville, Trans. Micr. Sco. Lond. n.s. Vol. 14, p. 3, pl. 1, fig. 6, (1866). Sch. Atl., pl. 57, fig. 7, (1886); pl. 163, fig. 10, (1891). Wolle, Diat. N.A., pl. 94, fig. 1, (1894). Mann, Diat. Alb. Voy., p. 251, (1907).

While this diatom is still living in the North Pacific Ocean (see last reference above), it does not occur in the rocks older than Middle Miocene in California. There are several zones of fairly large areal extent near the top of the Upper Miocene in Southern California, where this form is quite prevalent and in places dominates the entire flora. Diameter of figured specimen, 0.034 mm.

<u>Coscinodiscus excentricus Ehrenberg</u> Plate VI, fig. 2

Coscinodiscus excentricus Ehr. EHr. Mik., pl. 18, fig. 32; pl. 21, fig. 6, (1854). Sch. Atl., pl. 58, fig. 46-49, (1886). Van Heurck, Treatise, p. 531, pl. 23 fig. 666, (1896). Rattray, Rev. Cosc., p. 461, (1889). Mann, Diat. Alb. Voy., p. 251, (1907).

This cosmopolitan diatom is frequent in both the top and bottom of the Girard section, but avsent in the central portion. While it apparently started in the Lower Miocene, this form did not reach its maximum development until Pliocene time, when it was one of the dominating species of diatoms.

Diameter of figured specimen, 0.035 mm.

Coscinodiscus lineatus Ehrenberg Plate VI, fig. 3

Coscinodiscus lineatus Ehr., Ehr. Mik., pl. 18, fig. 33; pl. 22, fig. 6 a-b, (1854). Sch. Atl., pl. 59, fig. 26-32, (1886). Rattray, Rev. Cosc., p. 472, (1889). Mann, Diat. Alb. Voy., p. 253, (1907).

This widely distributed form is only found rarely in the upper part of the Girard section. The specimen figured is the only perfect one found, even fragments being rare. Like the preceding species, this diatom becomes much more abundant in the Pliocene shales, where it often dominates the flora.

Diameter of figured specimen,

Coscinodiscus marginatus Ehrenberg

Coscinodiscus marginatus Ehr., Ehr. Mik., pl. 18, fig. 44; pl. 33, group XII, fig. 13; pl. 35B, group XXII, fig. 8, (1854). Sch. Atl., pl. 62, fig. 1-5, 9, 11, 12. (1878). Rattray, Rev. Cosc., p. 509, (1889). Mann, Diat. Alb. Voy., p. 253, pl. 49, fig. 2, (1907). Mann, Phil. Diat., p. 67, (1925).

For a good discussion of this difficult species, see Mann, Diatoms of the Albatross Voyages, p. 253-4, who has attempted to limit this species to those forms having broad, massive borders, certainly the best disposition under the circumstances.

Fairly well distributed thruout the section.

<u>Coscinodiscus oculus-iridis Ehrenberg</u>

Coscinodiscus oculus-iridis Ehr., Ehr. Mik., pl. 18, fig. 42; pl. 19, fig. 2, (1854). Sch. Atl., pl. 60, fig. 7; pl. 63, fig. 4,6-9, (1877); pl. 113, fig. 1, 3-5, 20, (1888). Rattray, Rev. Cosc., p. 559, (1889). Hanna, Journ. Paleont., Vol. 1 p. 112, pl. 18, fig. 1, (1927). Mann, Diat. Alb. Voy,, p. 256, (1907).

I agree with Mann (last reference above) that Rattray's lumping of this form with <u>C. omphalanthus Grun</u>., <u>C. asteromphalus Ehr</u>., and <u>Céstodiscus radiatus Ehr.</u> is most unfortunate and wholly unwarranted.

Occurs only in the top and bottom of the section.

<u>Coscinodiscus radiatus Ehrenberg</u>

Coscinodiscus radiatus Ehr., Ehr. Mik., pl. 39, group III, fig. 17; pl. 35A, group XVII, fig. 6. (1854). Sch. Atl., pl. 60, fig. 9; pl. 62, fig. 18. (1886). Mann, Diat. Alb. Voy., p. 257, (1907). Van Heurck, Treatise, p. 530, pl. 23, fig. 663, (1896).

Frequent in the upper part of the section.

<u>Coscinodiscus subtilis Ehrenberg</u>

Coscinodiscus subtilis Ehr., Ehr. Mik., pl. 18, fig. 35a-b, (1854). Sch. Atl., pl. 57, fig. 11-16, 28, 29; pl. 58, fig. 37, (1886). Van Heurck, Treatise, p. 532, pl. 34, fig. 901, (1896).

This delicate form is only rarely found in the upper part of the Girard section and not at all in the lower part.

Coscinodiscus woodwardii Eulenstein

Coscinodiscus woodwardii Eul., Sch. Atl., pl. 60, fig. 8; pl. 61, fig. 2,3; pl. 65, fig. 2, (1886). Rattray, Rev. Cosc., p. 571, (1889). Wolle, Diat. N.A., pl. 90, fig. 4, (1894).

Frequent in the top of the Girard section.

Genus LIRADISCUS Greville

Liradiscus ovalis Greville

Liradiscus ovalis Grev., Grev. Trans. Micr. Soc. Lond., Vol. 13, p. 5, pl. 1, fig. 15, 16, (1865). Van Heurck, Treatise, p. 511, fig. 260. Hanna, Journ. Paleont. Vol. 1, p. 114, pl. 19, fig. 4,5,6, (1927). Hanna, Cret. Diat., p. 23, pl. 3, fig. 5, (1927).

This curious little diatom has had a long history, starting at least as early as Cretaceous time, and extending up through the Upper Miocene andpossibly into the Pliocene. While it is in no sense a marker, there are certain concentrations of this form at various places in the geological column, so that it may be of value for local zoning.

Tribe ACTINODISCEAE

Subtribe STICTODISCINAE

Genus ARACHNOIDISCUS Ehrenberg

Arachnoidiscus ornatus Ehrenberg Plate VI, fig. 4

Arachnoidiscus ornatus Ehr., Sch. Atl., pl. 73, fig. 4-6, 10, (1887). Prit. Inf., pl. 15, fig. 18-21, (1861). Boyer, Syn. N.A. Diat., p. 69, (1926).

This large and ornate diatom rarely occurs in the Girard section, the specimen figured being the only perfect one found. Diameter of figured specimen, 0.280 mm.

Genus STICTODISCUS Greville

<u>Stictodiscus californicus Greville</u> Plate VI, fig. 5.

Stictodiscus californicus Grev., Sch. Atl., pl. 74, fig. 4, (1887). Grev., Trans. Micr. Soc. Lond., n.s. Vol. 9, p. 79, pl. 10, fig. 1, (1861). Hanna & Grant, Proc. Calif. Acad. Sci., 4th Ser. Vol. XV, p. 167, pl. 20, fig. 12, (1926).

In spite of the fact that it has been reported living in various localities, this strikingly beautiful diatom is a fairly good marker for the Upper Miocene strata of California. It is not found in the Temblor formation (Middle Miocene) nor in the overlying Lower Pliocene.

Diameter of figured specimen, 0.160 mm.

Genus CLADOGRAMMA Ehrenberg

<u>Cladogramma californicum Ehrenberg</u>

Cladogramma californicum Ehr., Ehr. Mik., pl. 33, group 13, fig. 1** (1854). Mic. Dict., p. 171, pl. 42, fig. 14, (1875).
Cladogramma cebuense Grunow, Van Heurck, Treatise, p. 502, fig. 246, (1896).

This minute though distinctive form is frequent in the upper part of the section.

Subtribe ACTINOPTYCHINAE

Genus ACTINOPTYCHUS Ehrenberg

<u>Actinoptychus marmoreus Brun.</u> Plate VI, fig. 6.

Actinoptychus marmoreus Brun. Sch. Atl., pl. 154, fig. 7, (1890).

This is the first occurrence of this diatom in

North America, the type having come from the island of Jedo, Japan, where it occurs in rocks of Upper Miocene age.

Unfortunately two of the sectors of the specimen figured have air bubbles trapped in them, giving a grotesque appearance. Diameter of figured specimen, 0.048 mm.

Actinoptychus simbirskianus Schmidt ? Plate VII, fig. 1.

Actinoptychus simbirskianus Schmidt, Sch. Atl., pl. 29, fig. 11.

Considerable search has failed to reveal a form more like Schmidt's species than the one in question. In my form, one set of sectors have fine puncta arranged accurately in quincunx, whereas the alternate sectors have the puncta (somewhat larger than the others) in no definite arrangement. The processes are in the marginal center of the quincunx sectors. These quincunx sectors have also a faint areolation underlying the puncta, whereas the sectors with the scattered puncta have a perfectly hyaline background.

It is frequent in the upper part of the Girard section. Diameter of figured specimen, 0.077 mm.

Actinoptychus stella Schmidt var. thumii Schmidt.

Plate VII, fig. 2

Actinoptychus stella var. thumii Sch., Sch. Atl., pl. 90, fig. 3-5, (1886). Laporte & Lefebure, II, pl. 22, fig. 150, (1930).

Forms having both 6 and 8 sectors were found, again indicating the inconstancy of this character and its utter uselessness in differentiation of species.

Diameter of figured specimen, 0.050 mm.

Actinoptychus undulatus (Bailey) Ralfs.

Actinoptychus undulatus (Bail) Ralfs., Prit. Inf., p. 839, pl. 5, fig. 88, (1861). Sch. Atl. pl. 1, fig. 1-6, (1874). Van Heurck, Treatise, p. 496, pl. 22, fig. 648, (1896).

This quite variable form is fairly abundant, especially near the top of the Girard section. The present form has coarse areolae, quite similar to A. senarius Ehrenberg, which Mann doubtfully includes under A. undulatus. Ralfs also recognized that these two forms were probably the same species.

Sub-family BIDDULPHIOIDEAE

Tribe CHAETOCEREAE

Genus CHAETOCEROS Ehrenberg

Chaetoceros incurvum Bailey

Chaetoceros incurvum Bailey, Bail. Smith. Contr. Vol. 7, pl. 3, fig. 31, 32, (1853). Wolle, Diat. N.A., pl. 65, fig. 9, 10, (1894). Boyer, Syn. N.A. Diat., p. 111, (1926).

This diatom is rare in the upper part of the Girard section and totally lacking in the lower part. Common in the Upper Modelo formation exposed along the north flank of the San Pedro Hills, Los Angeles County, Calif.

Genus HERCOTHECA Ehrenberg

Hercotheca mammilaris Ehrenberg

Hercotheca mammilaris Ehr., Ehr. Mik., pl. 33, group 18, fig. 7, (1854). Van Heurck, Treatise, p. 427, fig. 147, (1896). Wolle, Diat. N.A., pl. 64, fig. 22, (1894).

It is possible that this will prove to be nothing but a spore-case of some Chaetoceros, but its value as a fossil is definite, so it is here admitted to generic rank.

Genus SYNDENDRIUM Ehrenberg

Syndendrium diadema Ehrenberg

Syndendrium diadema Ehr., Ehr. Mik., pl. 35A, group 18, fig. 13, (1854). Van Heurck, Treatise, p. 427, fig. 146, (1896). Wolle, Diat. N.A., pl. 63, fig. 11-13, 38, (1894).

Common in the upper part of the Girard section. Cleve, Castracane, Mann, and others, consider this to be a spore case of Chaetoceros, but its abundance in strata devoid of a parent Chaetoceros makes this assignment doubtful. Cleve, Castracane, and Mann, came their conclusions while working on living, or at least recent, material, where both forms could be observed. Apparently the Chaetoceros to which this Syndendrium belonged was poorly silicified, as it is never present in fossil collections.

Genus PERIPTERA Ehrenberg

Periptera tetracladia Ehrenberg

Periptera tetracladia Ehr., Ehr. Mik., pl. 33, group 18, fig. 9, (1854). Prit. Inf., p. 865, pl. 6, fig. 30, (1861). Mic. Dict. p. 587, pl. 18, fig. 66, (1883).

The same remarks apply here as in the case of the preceding species.

Tribe BIDDULPHIEAE

Genus TRICERATIUM Ehrenberg

Triceratium sp. Plate VII, fig. 3.

Although it was originally intended not to include any of the unidentified species into the discussion at this time, the present case was deemed to be an exception.

This form is totally unlike anything in Schmidt't Atlas, where a great many species of Triceratium are figured. The parallel rows of beads near the apices as well as the scattering of the beads towards the center are constant characters found in a large number of individuals. The valve is quite flat and without processes. This would put the form in Cleve's Trigonium, where it might properly belong. While the genus Triceratium is at present in a rather chaotic shape, in spite of several revisions and divisions, yet in view of the effect on the literature of changing from genus to genus without complete revision, it has been thought best to tentatively assign this form to Triceratium. Length of one side of figured specimen, 0.048 mm.

Tribe EUODIEAE

Genus HEMIDISCUS Wällich

Hemidiscus simplissimus Hanna & Grant Plate VII, fig. 4,5.

Hemidiscus simplissimus Hanna & Grant, Proc. Calif. Acad. Sci., 4th Ser. Vol. XV, p. 147, pl. 16, fig. 13, (1926).

The Girard form may possibly be a variety of the above, as the original authors specified that the border was everywhere convex. The Girard diatom has the two straight edges leaving the angle, although it is in all other respects identical with the type. It is a most important marker for the Upper Miocene, being found only in the upper part of the Upper Modelo, and never (at least to date) in the overlying Lower Pliocene. strata.

Lenggh of figured specimens, Fig. 4, 0.053 mm, Fig. 5, 0.069 mm.

Family PENNATAE

Subfamily BACILLOIDEAE

Tribe FRAGILARIEAE

Subtribe FRAGILARINAE

Genus FRAGILARIA Lyngbye

Fragilaria arctica Grunow

Fragilaria arctica Grunow, Boyer, Phil. Diat., pl. 10, fig. 22, 23, (1916). Boyer, Syn. N.A. Diat., p. 185, (1926).

Frequent in the upper part of the Girard section.

Genus RHAPHONEIS Ehrenberg

Rhaphoneis archeri O'Meara

Rhaphoneis archeri O'Meara, Mic. Journ., 1867, p. 247, pl. 7, fig. 12. Wolle, Diat. N.A., pl. 63, fig. 8, (1894). De Toni, Syl. Alg., p. 702, (1891).

Very rare, only represented by two specimens from samples taken near the top of the Girard section.

Genus OPEPHORA Petit

Opephora schwartzii Ehrenberg

Opephora schwartzii Ehr., Van Heurck, Treatise, p. 333, fig. 90, (1896).

Two undoubted valves of this diatom were found in the upper part of the Girard section.

Genus SYNEDRA Ehrenberg

Synedra affinis Kützing

Synedra affinis Kz., Kz. Bac., pl. 15, fig. 6, 11. (1844). Smith, Brit. Diat. I: pl. 12, fig. 97, (1853). Sch. Atl., pl. 304, fig. 6-12, (1914). Van Heurck, Treatise, p. 314, pl. 10, fig. 430, (1896).

Frequent in the lower part of the Girard section.

Synedra (?) cf. fimbriata Castracane   Plate VII, fig. 6.

Synedra fimbriata Castracane, Rep. Chall. Exp. pl. 25, fig. 14, p. 52. (1886).

Castracane's form is fairly close to the present species except for the margin, which in my form is raised to form a sort of keel. Castracane's figure shows no keep, altho the presence of one might be inferred from his discussion, "The surface of the valve is ornamented with continuous transverse striae, which become salient near the margins, and thus form a more prominent outline."

The presence of the keel on both margins of each valve make the assignment to Synedra doubtful, in fact the general structure of the valve makes its assighment to any known genus doubtful.. It may quite possibly be a new genus.

This diatom is a most excellent marker for the Upper Miocene strata of California.

Genus THALASSIONEMA Grunow

Thalassionema nitzschioides Grunow

Thalassionema nitzschioides Grunow, Van Heurck, Treatise, p. 319, fig. 75, (1896): Synopsis, pl. 43, fig. 7-10, (1881).
Synedra nitzschioides Grunow, Van Heurck, Treatise, p. 314, pl. 10, fig. 434.

On page 319 of the Treatise, Van Heurck says under Thalassionema nitzschioides, "In my Atlas, pl. 43, fig. 7-10, Mr. Grunow has proposed to raise Synedra nitzschioides to the rank of a genus. I have preferred to preserve this form (as I have done in the text of the Synopsis) among the Synedra with which I arranged it in the first instance."

On page 314 of the Treatise, Van Heurck, says under Synedra nitzschioides, "This diatom is not a true Synedra. Perhaps a new genus should be created for it."

From the above it would appear that Van Heurck was confused as to just what to do with this form, which, as he says, is not a true Synedra. It has therefore been thought best to follow Grunow, recognizing the form as a separate genus, a course which becomes imperative, when this diatom is critically compared with any known Synedra.

Very abundant in the upper part of the Girard section, where it nearly dominates the flora.

Tribe TABELLARIEAE

Genus GRAMMATOPHORA Ehrenberg

Grammatophora angulosa Ehrenberg

Grammatophora angulosa Ehr., Van Heurck, Treatise, p. 355, pl. 31, fig. 862, (1896). Kütz. Bac., pl. 29, fig. 79* (1844). De Toni, Syl. Alg., p. 757, (1891).

This form occurs only rarely in the upper part of the Girard section.

Grammatophora merletta Hanna & Grant.

Grammatophora merletta Hanna & Grant., Proc. Calif. Acad. Sci., 4th Ser. Vol. XV, pl. 16, fig. 11, 12, 14, p. 146, (1926).

This form occurs fairly well distributed thru the section, but in rare amounts. It is a very good marker for the Upper Miocene strata of California, and is sufficiently distinctive to be easily identified.

Subfamily HETEROIDEAE

Tribe ACHNANTHEAE

Subtribe COCCONEIDINAE

Genus CAMPYLONEIS Grunow

Campyloneis grevillei (Wm. Smith) Grunow

Campyloneis grevillei (Wm. Smith) Grunow, Novara-Exp. Bot., 1:10, (1868). Van Heurck, Treatise, p. 285, fig. 64, pl. 8, fig. 344, (1896).
Cocconeis grevillei Wm. Smith, Syn. Brit. Diat., I, pl. 3, fig. 35. Van Heurck, Synopsis, pl. 28, fig. 10- 12*.

Occurs frequently in the upper part of the section.

Genus COCCONEIS Ehrenberg

Cocconeis baldjikiana Grunow

Cocconeis baldjikiana Grunow, Sch. Atl., pl. 190, fig. 7-10 (1894), Mann, Diat. Alb. Voy., p. 328, (1907).

Boyer (Syn. N.A. Diat. p. 252) makes this a variety of Cocconeis scutellum Ehrenberg. I have preferred to recognize it as a separate species on account of the much greater spacing of the markings, agreeing with Mann and Schmidt.

Fairly well distributed in the upper two-thirds of the Girard section.

Cocconeis distans Gregory

Cocconeis distans Gregory, Sch. Atl., pl. 193, fig. 29-37, 40, (1894). Mann, Diat. Alb. Voy., p. 330, (1907).

Boyer (Syn. N.A. Diat. p. 246) also lumps this form under C. scutellum, which is also objectionable. C. scutellum has become a huge complex of unlike forms thru functioning as a sort of dumping ground for odd species of Cocconeis.

It occurs rarely at the extreme top of the section.

Subfamily NAVICULOIDEAE

Tribe NAVICULEAE

Subtribe NAVICULINAE

Genus NAVICULA Bory

Navicula lyra Ehrenberg

Navicula lyra Ehr., Sch. Atl., pl. 2, fig. 4,5,8,9,16,18. (1878). Cleve, Nav. Diat., Vol. II, p. 63, (1895). Van Heurck, Treatise, p. 203, pl. 4, fig. 161, (1896). Van Heurck, Synopsis, pl. 10, fig. 1-2, p. 93, (1881).

This beautiful diatom is frequent in the upper part of the Girard section.

Although this species is usually somewhat variable, the forms found in the Upper Modelo are fairly constant and near the type.

Genus DIPLONEIS Ehrenberg

This genus, originally set up by Ehrenberg and subsequently re-established and re-defined by Cleve in his Synopsis of the Naviculoid Diatoms, has many points in favor of its retention. By separating it from that large and unwieldy genus, Navicula, much good is accomplished for both. The whole appearance and structure of Diploneis is so different from Navicula that their union defies the whole concept of a genus. The massive horns in Diploneis, the two distinct sets of beading, the arrangement of ribs and beading are totally unlike anything found in the true Navicula. It has been argued that they cannot be separated because they grade into one another and that there are some species which might as well be one genus as another. If the concept of grading is pushed far enough, the whole idea of a genus is lost, as it is only logical to suppose that all diatoms are related else they would not all be diatoms. Certainly Diploneis shows a greater difference from the typical Navicula than does Cymbella, and yet it is universally agreed that Cymbella is a separate genus. It is therefore urged that Cleve's re-definition of Diploneis be adopted as a step toward reducing the really huge genus Navicula.

Diploneis densistriata (Schmidt) Boyer.

Diploneis densistriata (Sch.) Boyer, N.A. Diat., p. 349, (1927). Sch. Atl. pl. 70, fig. 54, (1887).
Navicula densistriata Schmidt, Hanna & Grant, Proc. Calif. Acad. Sci. 4th Ser. Vol. XV, p. 150, pl. 17, fig. 8-10 (1896)

Diploneis pelagi (Schmidt) Boyer

Diploneis pelagi (Schmidt) Boyer, Syn. N.A. Diat. p. 357, (1927).
Navicula pelagi Schmidt, Sch. Atl., pl. 7, fig. 25,26, (1875). Hanna & Grant, Proc. Calif. Acad. Sci. 4th Ser. Vol. XV, p. 154, pl. 18, fig. 9, (1926).

Hanna's figure shows distinctly double beading between the costae in the outer portion, whereas Schmidt's original figure shows only single beading. Hanna's figure more nearly resembles Diploneis smithii (Breb.) Cleve.

Diploneis smithii (Brebisson) Cleve.

Diploneis smithii (Breb.) Cleve., Nav. Diat. Pt. 1, p. 96, (1894). Boyer, Syn. N.A. Diat., p. 354, (1927).
Navicula smithii Breb. Sch. Atl., pl. 7, fig. 14-22, (1885), Van Heurck, Treatise, p. 197, pl. 4, fig. 151, (1896). Mann, Diat. Alb. Voy., p. 354, (1907).

This cosmopolitan diatom deserves little mention except to again voice the insistence that it be called a Diploneis instead of a Navicula.

Diploneis suborbicularis (Gregory) Cleve.

Diploneis suborbicularis (Greg.) Cleve., Nav. Diat., I, p. 81, (1894). Boyer, Syn. N.A. Diat., p. 347, (1927).
Navicula suborbicularis (Greg.) Donkin, Brit. Diat., p. 9, pl. 1, fig. 9, (1870). Sch. Atl., pl. 8, fig. 2,3,5. (1875).

This species occurs only near the top of the Girard section and then only rarely.

Subfamily NITZSCHIOIDEAE

Tribe NITZSCHIEAE

Genus DENTICULA Kützing.

Denticula lauta Bailey

Denticula lauta Bailey, Wolle, Diat. N.A., pl. 46, fig. 10; pl. 68, fig. 16, 17, (1894). Van Heurck, Synopsis, pl. 49, fig. 1, 2.

This curious and striking little diatom occurs fairly well distributed thru the Girard section. It is quite abundant to dominating in some horizons in the Upper Modelo in other localities in Southern California, where it forms definite zones of at least local stratigraphic value.

In addition to those listed above, a number of species have been found in the Girard section which are thought to be new. There are several papers which are not at present available to the writer which should be consulted before making a final determination of these supposedly new species. It is hoped that these will be available in the near future, at which time a supplement will be issued covering the remaining species collected.

PLATE V

Fig. 1 Melosira clavigera Grunow x 660 p. 25

Fig. 2 Stephanogonia actinoptychus Ehrenberg x 1400, p. 28

Fig. 3 Muelleriella limbata (Ehr.) Van Heurck x 530, p. 30

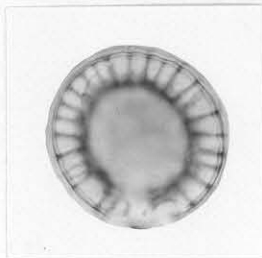
Fig. 4 Coscinodiscus curvatulus var. latius-striata Schmidt
x 1100, p. 33.

Fig. 5 Coscinodiscus curvatulus var. latius-striata Schmidt
x 1260 p. 33

Fig. 6 Coscinodiscus decrescens Grunow x 1450 p. 34

PLATE V

2.



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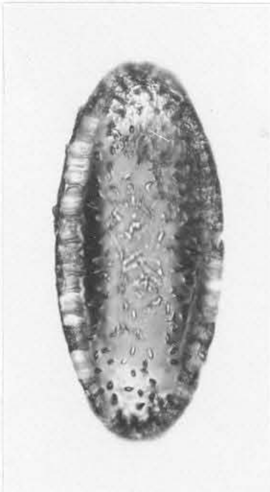

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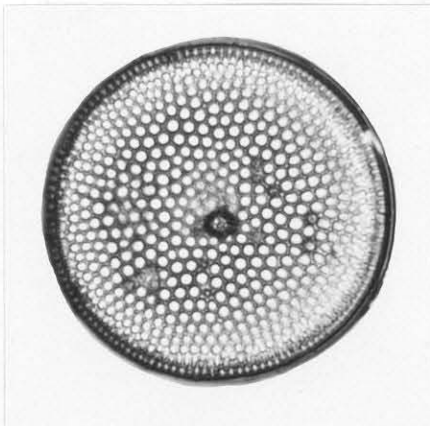

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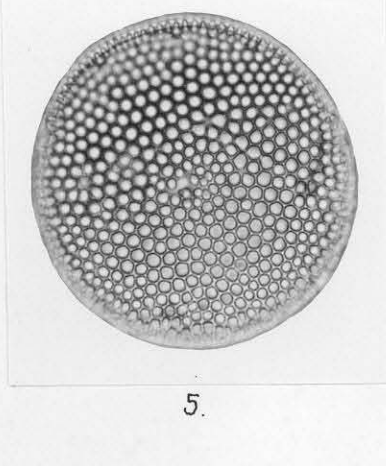

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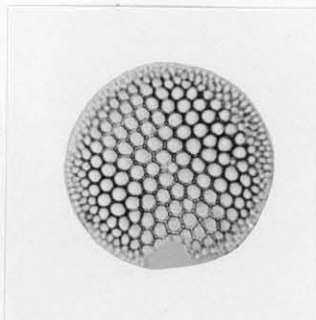

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PLATE VI

Fig. 1. Coscinodiscus elegans Greville x 1000 p. 34

Fig. 2. Coscinodiscus excentricus Ehrenberg x 1150 p. 34

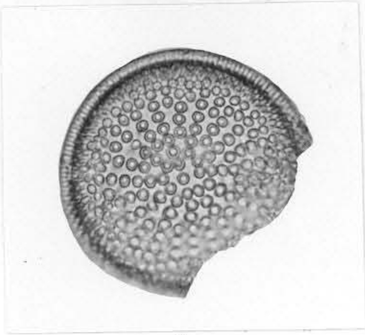
Fig. 3. Coscinodiscus lineatus Fhrenberg. x 780, p. 35.

Fig. 4. Arachnoidiscus ornatus Ehrenberg x 200, p. 37

Fig. 5. Stictodiscus californicus Greville. x 400, p. 38

Fig. 6. Actinoptychus marmoreus Brun. p. 38, x 1060.

PLATE VI



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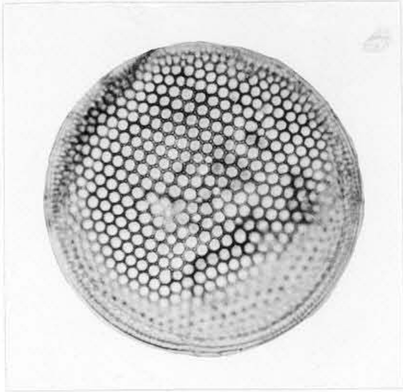

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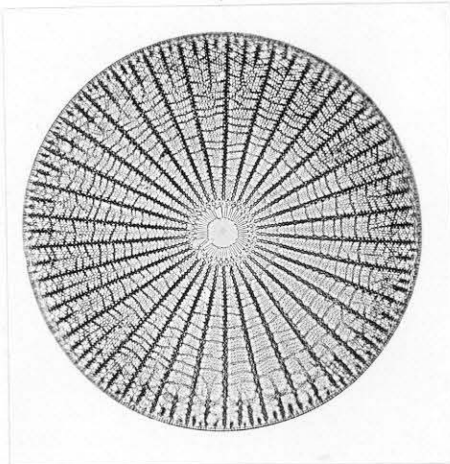

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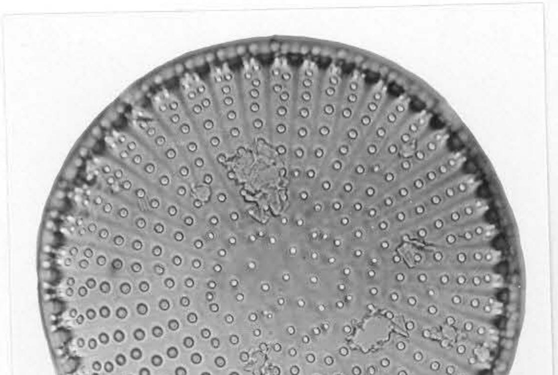

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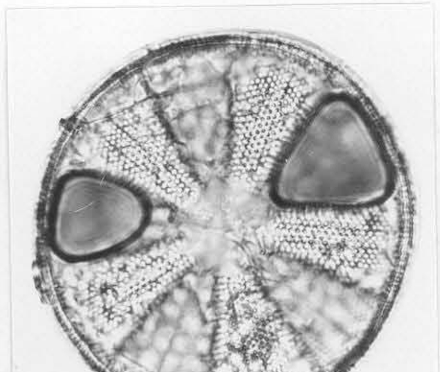

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PLATE VII

Fig. 1. Actinoptychus simbirskianus Schmidt ? x 590, p. 39

Fig. 2. Actinoptychus stella var. thumii Schmidt x 1000, p. 39

Fig. 3. Triceratium sp. x1000, p. 42.

Fig. 4. Hemidiscus simplissimus H. & G. x 1000, p. 42

Fig. 5. Hemidiscus simplissimus H. & G. x 1000, p. 42.

Fig. 6. Synedra (?) cf. fimbriata Castracane x 770, p. 44

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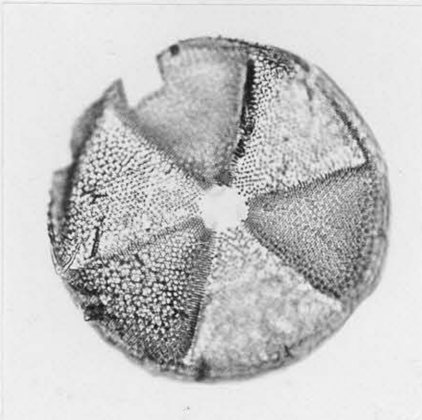

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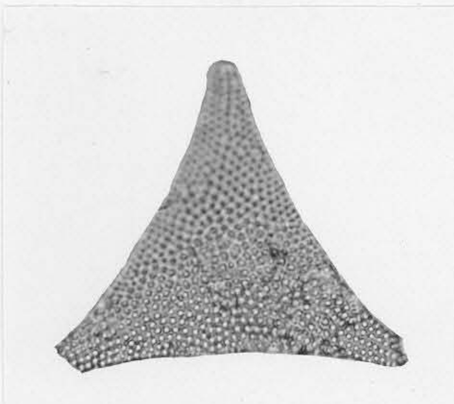

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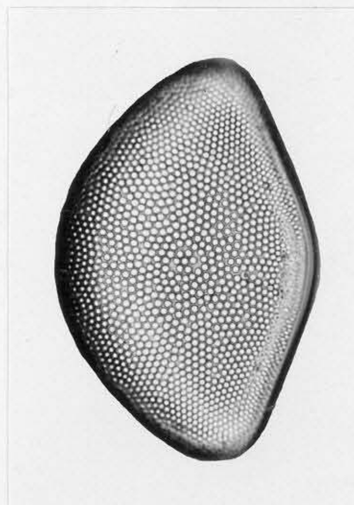

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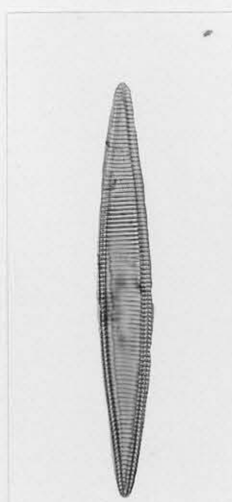

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INDEX TO SPECIES

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