UNITED STATES DEPARTMENT OF THE INTERIOR

PLIOCENE DIATOMS

FROM THE

KETTLEMAN HILLS, CALIFORNIA

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KETTLEMAN HILLS, CALIFORNIA

BY

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PLIOCENE DIATOMS FROM THE KETTLEMAN HILLS, CALIFORNIA

By K. E. Lohman

ABSTRACT

The Kettleman Hills form a range of foothills about 30 miles long and 4 to 5 miles wide on the western edge of San Joaquin Valley, Calif., about 75 miles northwest of Bakersfield. Two marine Pliocene formations, the Etchegoin and the San Joaquin, and one brackish- and fresh-water Pliocene and Pleistocene (?) formation, the Tulare, crop out in the hills. A total of 232 species and varieties of diatoms were obtained from the three formations, all from beds assigned to the Pliocene. These are listed according to their distribution and abundance. Characteristic groups from each formation are illustrated, and their stratigraphic and ecologic significance is discussed. Five new species are described and figured.

INTRODUCTION

The Kettleman Hills form a low-lying range of foothills of the Coast Range about 30 miles long and 4 to 5 miles wide, on the western edge of San Joaquin Valley, Calif., about 75 miles northwest of Bakersfield. The line dividing Kings County on the southeast from Fresno County on the northwest passes through the northwest end of the hills. They are divided into three structural and topographic units—the North, Middle, and South Domes.

W. P. Woodring and Ralph Stewart, of the United States Geological Survey, while engaged in mapping the Kettleman Hills, collected samples from beds that gave promise of containing diatoms and submitted them to me for study. I have visited most of the localities and collected two of the samples studied for this report. Acknowledgment is due to Mr. Woodring for many valuable suggestions and much information concerning the geology and stratigraphy of the Kettleman Hills.

A total of 232 species and varieties of diatoms, including 5 new species, were found in 12 samples representing the three formations exposed in the hills. Most of the diatoms are represented in living floras, but some are extinct forms and appear to have had short ranges in geologic time. Three formations—the Etchegoin, San Joaquin, and Tulare (named in ascending order)—crop out in the Kettleman Hills, and diatoms were collected from all three formations. The Etchegoin and San Joaquin and the lower part of the Tulare (the part from which diatoms were collected) are assigned to the Pliocene, and the upper part of the Tulare is doubtfully assigned to the Pleistocene.

A complete check list of the diatoms found in the Kettleman Hills as a result of the present study is given in the accompanying table, together with their relative abundance indicated by the following symbols: R, rare; F, few; C, common; A, abundant. These symbols have no exact numerical significance but are fairly comparable, as all the samples received approximately the same degree of condensation in their preparation and mounting. It is believed that this gives a much better picture of the flora as a whole and of the relative value of the various species for purposes of ecology or correlation than is obtained by merely listing the species as present. This is particularly true when an attempt is made to obtain some idea of the ecologic conditions which the various floras represent.

The diatoms indicate a change from marine deposition in the older beds to brackish-water and fresh-water deposition in the younger beds. Certain beds were found to contain diagnostic species which were not found in any of the other beds studied. These are discussed under the different stratigraphic units.

The geology of the Kettleman Hills is discussed in a report now in preparation by W. P. Woodring, Ralph Stewart, and R. W. Richards. The present paper, therefore, contains only general statements regarding the stratigraphy.

Pliocene diatoms from Kettleman Hills, Calif.

	Tulare formation				San Joaquin formation					Etchegoin formation		
					Tuffaceous sandstone			*Neverita* zone		Upper part	Lower part	
	1061	839	838	1053	1054	1056	1057	1052	1051	1058	1117	1060
Melosira sulcata (Ehrenberg) Kützing (pl. 22, fig. 15)				F	F	C	C	C	F	R	F	
recedens Schmidt (pl. 22, figs. 13, 14)						A	C	F	R			
sol (Ehrenberg) Kützing				R	R	F				R		
polaris Grunow									R			
cf. *M. clavigera* Grunow									R			
undulata (Ehrenberg) Kützing var. *normanii* Arnott				R								
solida Eulenstein			F		R					R		
solida var. *haitiensis* Grunow												R
solida var. *multiformis* Frenguelli										R		
distans Kützing var. *lirata* (Ehrenberg) Bethge			F									
granulata (Ehrenberg) Ralfs (pl. 23, fig. 8)	F		C	A			R			R		R
granulata var. *curvata* Grunow (pl. 23, fig. 7)	R		F									R
granulata var. *australiensis* Grunow			R									
granulata var. *muzzanensis* (Meister) Bethge				F								
cf. *M. islandica* Müller								R	R			
italica (Ehrenberg) Kützing								R				
ambigua (Grunow) Müller (pl. 23, fig. 9)			C			R						
crenulata Kützing var. *semilaevis* Grunow			F	F								
Podosira hormoides (Montagne) Kützing var. *adriatica* Grunow						R						
stelliger (Bailey) Mann				R								
febigeri Grunow							F					
Hyalodiscus schmidtii Frenguelli (pl. 23, fig. 5)				A								
Stephanopyxis turris (Greville and Arnott) Ralfs					F				R	R		R
turris var. *cylindrus* Grunow	R						F	R				
corona (Ehrenberg) Grunow (pl. 22, fig. 2)					C			F	F			
bruni Schmidt var.										R		
Endictya oceanica Ehrenberg							F					
robusta (Greville) Hanna and Grant (pl. 20, fig. 4)						R?				F		
Thalassiosira decipiens (Grunow) Joergensen				F	C				F			
Cyclotella meneghiniana Kützing			F	C								
striata (Kützing) Grunow						R			R			
compta (Ehrenberg) Kützing var. *pliocaenica* Krasske				R								
iris Brun and Héribaud			F									
pygmaea Pantocsek			R									
Stephanodiscus dubius (Fricke) Hustedt (pl. 20, fig. 10)			F							F		
astraea (Ehrenberg) Grunow			F					F	R			
carconensis Grunow (pl. 23, fig. 2)			C									
carconensis var. *pusilla* Grunow	F		C									
Coscinodiscus excentricus Ehrenberg (pl. 20, fig. 5; pl. 21, fig. 5)				R	F		F	C	C	A	F	F
anguste-lineatus Schmidt					F							
lineatus Ehrenberg					F	F	R		F	F		
stellaris Roper					R			F	R			
subtilis Ehrenberg (pl. 21, fig. 6)					F	F	F	F	F	F		F
kützingii Schmidt			R				R	F				
cirrus Lohman, n. sp. (pl. 21, fig. 4)						F		C	C			
spinuligerus Rattray									F			
bisculptus Rattray										R		
vetustissimus Pantocsek (pl. 20, fig. 7)										F		
curvatulus Grunow								R				
inclusus Rattray (pl. 20, fig. 3)										R		
denarius Schmidt							F	R				
rothii (Ehrenberg) Grunow var. *normani* (Gregory) Van Heurck									R			
obscurus Schmidt (pl. 21, fig. 1)					F		F	F	C			
radiatus Ehrenberg					F	F	F	F	F		F	
gigas Ehrenberg							F	C				
boliviensis Grunow												F
cf. *C. janischii* Schmidt								R				
biangulatus Schmidt									F			
asteromphalus Ehrenberg (pl. 21, fig. 3)					R	F	F	C	C			C
asteromphalus var. *omphalantha* (Ehrenberg) Grunow (pl. 20, fig. 2)								C		F		C
oculus-iridis Ehrenberg					F	C	F	F				F
pacificus Grunow					R							
kurzii Grunow (pl. 20, fig. 1; pl. 21, fig. 2)					C	F	F	F	F	C		F
cf. *C. elegans* Greville					R							
cf. *C. cribrosus* Truan and Witt												F
Actinoptychus splendens (Shadbolt) Ralfs var.												R
undulatus Ehrenberg (pl. 20, fig. 8; pl. 22, fig. 3)				R	C	C	C	A	C	A		C
cf. *A. areolatus* Ehrenberg						F						
sp.									R			
Arachnoidiscus cf. *A. ehrenbergii* Bailey							R					
Asteromphalus brookei Bailey					R							

Pliocene diatoms from Kettleman Hills, Calif.—Continued

	Tulare formation				San Joaquin formation					Etchegoin formation		
					Tuffaceous sandstone			*Neverita* zone		Upper part	Lower part	
	1061	839	838	1053	1054	1056	1057	1052	1051	1058	1117	1060
Aulacodiscus cf. *A. argus* (Ehrenberg) Schmidt								R				
brownei Norman									R			
Auliscus caelatus Bailey					R							
Actinocyclus ehrenbergii Ralfs (pl. 22, fig. 1)					F	C	A	F	C			C
ehrenbergii var. *ralfsii* (W. Smith) Hustedt					F							
ehrenbergii var. *crassa* (W. Smith) Hustedt									F			
ehrenbergii var. *tenella* (Brébisson) Hustedt					F	C		F				F
subtilis (Gregory) Ralfs					F			C				
Liradiscus oblongus Grunow					R							F
Rhizosolenia sp							R	R	F			
Bacteriastrum hyalinum Lauder					F							
Chaetoceros incurvum Bailey									R			R
Periptera tetracladia Ehrenberg (Spores of *Chaetoceros?*)								F		F		R
Syndendrium diadema Ehrenberg (Spores of *Chaetoceros?*)								R		F		F
Dicladia capreolus Ehrenberg (Spores of *Chaetoceros?*)										F		F
Omphalotheca sp (Spores of *Chaetoceros?*)					C	R	F			R		C
Hercotheca cf. *H. mammillaris* Ehrenberg (Spores of *Chaetoceros?*)										F		
Goniothecium rogersii Ehrenberg					R							
Dossettia sp										F		
Stephanogonia sp					F							
Xanthiopyxis oblonga Ehrenberg					F							
cingulata Ehrenberg					R							R
ovalis Lohman, n. sp. (pl. 20, fig. 6; pl. 22, fig. 12)				R	C	R		F	F			A
Lithodesmium cf. *L. cornigerum* Brun												R
sp										R		
Triceratium uncinatum Schmidt				F								
Biddulphia cf. *B. pulchella* Gray				R								
cf. *B. granulata* Roper							R					
aurita (Lyngbye) Brebisson and Godey								F	F			
roperiana Greville					R		R			R		
peruviana Grunow						R	R					
cf. *B. reticulata* Roper						R						
Terpsinoe americana (Bailey) Ralfs				F		R						
Hemidiscus ovalis Lohman, n. sp. (pl. 22, fig. 9)						F	C	F				
Tetracyclus lacustris Ralfs			F	R						R		
japonicus (Petit) Hustedt			R									
Grammatophora cf. *G. maxima* Grunow				F								
Meridion circulare Agardh			R									
Opephora schwartzii (Grunow) Petit					F							
Fragilaria construens (Ehrenberg) Grunow			R									
construens var. *subsalina* Hustedt			R									
construens var. *venter* (Ehrenberg) Grunow			R									
harrissonii W. Smith var. *dubia* Grunow			R									
harrissonii W. Smith				R								
Synedra ulna (Nitzsch) Ehrenberg				R								
ulna var. *amphirhynchus* (Ehrenberg) Grunow			R									
Thalassionema nitzschioides Grunow						R	F	F	F	F		R
Rhaphoneis amphiceros Ehrenberg					F					R		
affinis Grunow					F							
cf. *R. morsiana* Grunow					F							
angularis Lohman, n. sp. (pl. 22, figs. 6, 7, 8)					F			F	F	F		
fatula Lohman, n. sp. (pl. 22, fig. 5)						C	C					
Grunoviella gemmata (Grunow) Van Heurck					R							
Eunotia robusta Ralfs var. *tetraodon* (Ehrenberg) Ralfs (pl. 23, fig. 6)			F									
praerupta Ehrenberg			F	R								
tenella (Grunow) Hustedt			F									
pectinalis (Kützing) Rabenhorst			R		R							
pectinalis var. *minor* (Kützing) Grunow			R									
pectinalis var. *undulata* (Ralfs) Rabenhorst			R									
pectinalis var. *ventralis* (Ehrenberg) Hustedt				R		R						
lunaris (Ehrenberg) Grunow			R									
cf. *E. gracilis* (Ehrenberg) Rabenhorst				R								
formica Ehrenberg			R									
cf. *E. didyma* Grunow var. *curta* Hustedt			R									
trigibba Hustedt			F									
serpentina Ehrenberg			F									
Cocconeis placentula Ehrenberg			F	F								
placentula var. *lineata* (Ehrenberg) Cleve			R	R								
scutellum Ehrenberg					R							
scutellum var. *baldjikiana* Grunow						R	R			F		
scutellum var. *minutissima* Grunow	F											
sp. undet		C										
Rhoicosphenia curvata (Kützing) Grunow			F									

Pliocene diatoms from Kettleman Hills, Calif.—Continued

	Tulare formation				San Joaquin formation					Etchegoin formation		
					Tuffaceous sandstone			*Neverita* zone		Upper part	Lower part	
	1061	839	838	1053	1054	1056	1057	1052	1051	1058	1117	1060
Mastogloia elliptica Agardh	F											
Gyrosigma attenuatum (Kützing) Rabenhorst			F									
kützingii (Grunow) Cleve			R									
Pleurosigma cf. *P. affine* Grunow							F		F			R
strigosum W. Smith								F				
Caloneis cf. *C. formosa* (Gregory) Cleve					R							
formosa var. *rostrata* Frenguelli			R									
silicula (Ehrenberg) Cleve var. *kjellmaniana* (Grunow) Cleve			R									
trinodis (Lewis) Meister			R									
Diploneis elliptica (Kützing) Cleve			F						R	R		
advena (Schmidt) Cleve	R											
smithii (Brebisson) Cleve (pl. 23, fig. 10)			F	A	F							
Stauroneis phoenicenteron Ehrenberg				R								
cf. *S. anceps* Ehrenberg var. *gracilis* Ehrenberg				R								
parvula Grunow			R									
Navicula cf. *N. cuspidata* Kützing			F			R						
cuspidata var. *heribaudi* M. Peragallo				R								
pupula Kützing var. *capitata* Hustedt			R									
pupula var. *rostrata* Hustedt				R								
radiosa Kützing			F	R								
radiosa var. *tenella* Brebisson			F									
pennata Schmidt (pl. 22, fig. 16)					F	F	F	R	F			
pennata var. *kinkeri* Pantocsek	R						R					
peregrina (Ehrenberg) Kützing var			F									
gastrum Ehrenberg			F									
exigua (Gregory) O. Müller			R									
cf. *N. subtilissima* Cleve			R									
tuscula Ehrenberg			R									
amphibola Cleve			R									
marina Ralfs (pl. 23, fig. 13)				C						F		
lyra Ehrenberg					R							
hennedyi W. Smith										R		
clavata Gregory var. *elliptica* Schmidt (pl. 20, fig. 9)										R		
Pinnularia cf. *P. subcapitata* Gregory										R		
borealis Ehrenberg			R							R		
major (Kützing) Cleve			F	R								
cf. *P. major* var. *subacuta* (Ehrenberg) Cleve	R											
dactylus Ehrenberg			F									
cf. *P. viridis* (Nitzsch) Ehrenberg				R								
nobilis Ehrenberg					R							
fasciata (Lagerstedt) Hustedt			R									
hemiptera Kützing			R									
Amphora ovalis Kützing	R											
ovalis var. *libyca* (Ehrenberg) Cleve			F									
affinis Kützing				F								
Cymbella cuspidata Kützing	R											
prostrata (Berkeley) Cleve (pl. 23, fig. 15)			R									
ventricosa Kützing	R	C		F								
cymbiformis (Kützing) Brebisson			R									
parva (W. Smith) Van Heurck		C	R									
cistula (Hemprich) Kirchner			R	R								
lanceolata (Ehrenberg) Kirchner				R						R		
mexicana (Ehrenberg) Cleve (pl. 23, fig. 14)			F	F						R		
Gomphonema acuminatum Ehrenberg var. *turris* Ehrenberg			R									
augur Ehrenberg var. *gauteri* Van Heurck			R									
intricatum Kützing			R									
constrictum Ehrenberg			F									
scapha M. Schmidt			R									
Gomphoneis mamilla (Ehrenberg) Cleve			F			R						
herculeana (Ehrenberg) Cleve			R	R								
cf. *G. herculeana* var. *robusta* Grunow			R									
elegans (Grunow) Cleve			R	R								
Epithemia argus (Ehrenberg) Kützing			F									
zebra (Ehrenberg) Kützing	F											
zebra var. *saxonica* (Kützing) Grunow (pl. 23, fig. 3)	A		R	F								
zebra var. *porcellus* (Kützing) Grunow			F	R								
turgida (Ehrenberg) Kützing (pl. 22, fig. 4)		C	F	F					F			R
turgida var. *granulata* (Ehrenberg) Grunow		F										
turgida var. *westermanni* (Ehrenberg) Grunow			F	F								
sorex Kützing			R									
Rhopalodia gibba (Ehrenberg) Müller (pl. 23, fig. 4)	C		F									
gibba var. *ventricosa* (Ehrenberg) Müller	C	F	F									
gibberula (Ehrenberg) Müller			F									

Pliocene diatoms from Kettleman Hills, Calif.—Continued

	Tulare formation				San Joaquin formation					Etchegoin formation		
					Tuffaceous sandstone			*Neverita* zone		Upper part	Lower part	
	1061	839	838	1053	1054	1056	1057	1052	1051	1058	1117	1060
Hantzschia amphioxys (Ehrenberg) Grunow			F	F					F			
Nitzschia tryblionella Hantzsch var. *maxima* Grunow				F								
tryblionella var. *victoriae* Grunow			R									
etchegoinia Hanna and Grant (pl. 23, fig. 12)				C						R		
navicularis Grunow (pl. 22, fig. 11)					R	F			R	R		
punctata (W. Smith) Grunow (pl. 23, fig. 11)			F									
granulata Grunow (pl. 22, fig. 10)	F		R	C	F	F	F	R	R	F		R
cf. *N. denticula* Grunow			R									
scalaris (Ehrenberg) W. Smith				R								
Cymatopleura sp			R									
Surirella striatula Turpin				F								
utahensis Grunow (pl. 23, fig. 1)				F								
Campylodiscus echeneis Ehrenberg				F								
clypeus Ehrenberg				R								

STRATIGRAPHY AND DIATOM FLORAS

ETCHEGOIN FORMATION

The name "Etchegoin beds" was first used by F. M. Anderson [1] for 2,500 to 4,000 feet of sand, gravel, and clay exposed near the Etchegoin ranch, about 20 miles northeast of Coalinga, in the NW¼ sec. 1, T. 19 S., R. 15 E., Mount Diablo base and meridian, Fresno County. He divided his Etchegoin beds into a lower part, called the "Etchegoin sands", consisting of 1,200 to 2,500 feet of unconsolidated sand and gravel, and an upper part, called the "San Joaquin clays", consisting of 1,500 feet of sandstone and shale.

Arnold and Anderson [2] used the name "Etchegoin formation" to include both the Etchegoin sands and the San Joaquin clay of F. M. Anderson and applied the name to the beds in the Kettleman Hills under discussion in the present paper.

Woodring and Stewart [3] have used the name "Etchegoin formation" for the lower part of the Etchegoin of Arnold and Anderson in Bulletin 398, and that is the usage followed here.

The Etchegoin is dominantly sandstone, with some shale in the upper part, and contains the oldest rocks exposed in the Kettleman Hills. A marine diatom flora of 57 species and varieties was obtained from this formation, the most characteristic and abundant of which are shown in plate 20.

LOWER PART OF ETCHEGOIN FORMATION

U. S. G. S. diatom locality 1060. East flank of South Dome, Kettleman Hills, Kings County, Calif. 1,700 feet north of southeast corner sec. 34, T. 24 S., R. 19 E., Mount Diablo base and meridian. Estimated to be 1,500 feet stratigraphically below the top of the Etchegoin formation. Pliocene. Collected by W. P. Woodring, December 17, 1931.

A marine diatom flora of 29 species and varieties was obtained from this locality. (See table.) The fresh-water species—such as *Melosira solida* var. *haitiensis*, *M. granulata*, *M. granulata* var. *curvata*, *Epithemia turgida*, and *Nitzschia granulata*—occur only rarely and, furthermore, are species which, while preferring fresh water, also inhabit brackish water. It is quite probable that these fresh-water forms were carried into the basin of deposition by streams. The occurrence of large numbers of distinctly pelagic marine genera, such as *Stephanopyxis*, *Coscinodiscus*, *Chaetoceros*, *Periptera*, *Syndendrium*, *Dicladia*, *Omphalotheca*, *Xanthiopyxis* and *Thalassionema*, suggests deposition from fairly open water.

Several fragments of a *Lithodesmium* in this sample are referred to *L. cornigerum* Brun,[4] a common extinct species in the Pliocene diatomite in the Casmalia Hills and Solomon Hills [5] bordering the Santa Maria Valley, Santa Barbara County, Calif. Other species common to the two localities are *Coscinodiscus oculus-iridis*, *C. subtilis*, and *Actinoptychus undulatus*. These, however, are species that range from Miocene to Recent and hence are not so significant.

Lithodesmium cornigerum has been found so far only in Pliocene rocks in California. Hanna [6] has found the species in a core sample taken from a depth of 800–1,000 feet in the H. B. Porter well no. 1, sec. 2?, T. 28 S., R. 21 E. Mount Diablo meridian, Kern County, Calif., and says: "This material came from a stratum of diatomite which had well-preserved and definitely

[1] Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 3d ser., vol. 2, pp. 178–192, 1905.

[2] Arnold, Ralph, and Anderson, Robert, Preliminary report on the Coalinga oil district: U. S. Geol. Survey Bull. 357, pp. 46–55, 1908; Geology and oil resources of the Coalinga district, Calif.: U. S. Geol. Survey Bull. 398, pp. 113–140, 1910.

[3] Woodring, W. P., Stewart, Ralph, and Richards, R. W., Geologic map of the Kettleman Hills, California (advance ed.), U. S. Geol. Survey, 1934.

[4] Brun, J., Le diatomiste, vol. 2, p. 239, pl. 24, figs. 15, 16, 17, 1896.

[5] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Calif.: U. S. Geol. Survey Bull. 322, p. 41, pl. 10, fig. 16, 1907.

[6] Hanna, G. D., Observations on *Lithodesmium cornigerum* Brun: Jour. Paleontology, vol. 4, pp. 189–191, pl. 14, figs. 9, 10, 1930.

identified Etchegoin Pliocene molluscan fossils, both above and below."

The most abundant species found in the lower part of the Etchegoin formation are *Coscinodiscus excentricus* (pl. 20, fig. 5), *C. asteromphalus*, *C. asteromphalus* var. *omphalantha* (pl. 20, fig. 2), *C. kurzii* (pl. 20, fig. 1), *Actinoptychus undulatus* (pl. 20, fig. 8), *Actinocyclus ehrenbergii* (pl. 22, fig. 1), and *Xanthiopyxis ovalis* (pl. 20, fig. 6). Although the last-named species is abundant in the lower part of the Etchegoin formation, occurs frequently to commonly in the San Joaquin formation, and rarely even in the lower part of the Tulare formation, it was not found in the upper part of the Etchegoin formation (locality 1058). Its great abundance in the lower part and complete absence in the upper part makes it appear to be a characteristic species for the lower Etchegoin formation, at least so far as was indicated by the collections studied for this report.

U. S. G. S. diatom locality 1117. North Dome, Kettleman Hills, Fresno County, Calif., 3,100 feet east and 3,280 feet north from southwest corner of sec. 12, T. 22 S., R. 17 E., Mount Diablo base and meridian, 60 feet stratigraphically below the base of the *Macoma* zone, upper part of the Etchegoin formation. Pliocene. Collected by Ralph Stewart, 1931.

All the diatoms present in this sample (see table) were badly corroded, suggesting leaching by alkaline solutions. The three species found are among the diatoms having relatively thick tests, and it is safe to assume that a large number of species were present before the leaching took place, and that the more delicate forms have been removed altogether. The three species range from Miocene to Recent and indicate little else than marine deposition.

UPPER PART OF ETCHEGOIN FORMATION

U. S. G. S. diatom locality 1058. West flank of South Dome, Kettleman Hills, Kings County, Calif., 1,620 feet north and 330 feet east from southeast corner of sec. 11, T. 25 S., R. 19 E., Mount Diablo base and meridian. About 125 feet stratigraphically below base of San Joaquin formation. Etchegoin formation, Pliocene. Collected by W. P. Woodring, October 10, 1931.

This sample yielded 42 species and varieties of diatoms (see table), some of the more abundant and characteristic of which are illustrated in plate 20. This diatom assemblage strongly indicates deposition under marine conditions. Thirteen fresh-water and brackish-water species at first sight suggest brackish water, but only two, *Stephanodiscus dubius* and *Nitzschia granulata*, occur in amounts greater than rare. It appears reasonable, therefore, to explain their presence on the probability of their introduction into the basin of deposition by streams. *Stephanodiscus dubius* (pl. 20, fig. 10) is now living in lakes and slowly moving rivers, and its presence here in fair amounts suggests a river emptying into the basin somewhere nearby. It is also present in the Tulare formation (locality 838) in about the same relative abundance. A very interesting diatom present in rare amounts is *Melosira solida* var. *multiformis*, originally described from Miocene nonmarine beds in Patagonia by Frenguelli,[7] who figured forms that are circular, oval, and roundly quadrangular in valve view. Only the oval form was found in the Kettleman Hills. I have also found it occurring abundantly in a fresh-water diatomite of supposed Miocene age near Drewsey, Harney County, Oreg. *Nitzschia etchegoinia* (pl. 23, fig. 12), originally described by Hanna and Grant [8] from brackish-water beds on the north end of North Dome, Kettleman Hills, occurs here only rarely and represents the earliest known occurrence of this diatom. The species was originally described from beds now considered to belong to the Tulare formation.

This assemblage is characterized by an abundance of *Coscinodiscus excentricus* (pl. 20, fig. 5), *C. asteromphalus* var. *omphalantha* (pl. 20, fig. 2), *C. kurzii* (pl. 20, fig. 1), and *Actinoptychus undulatus* (pl. 20, fig. 8), all of which range from Miocene to Recent. The following species were found to be limited to the upper part of the Etchegoin formation in the Kettleman Hills, although many of them have longer ranges elsewhere. *Endictya robusta* (pl. 20, fig. 4), a common species in the upper Miocene in California, occurs frequently. Its known range is Miocene to Recent. *Coscinodiscus vetustissimus* (pl. 20, fig. 7) is a very distinctive species characteristic of the upper part of the Etchegoin formation. It was originally described by Pantocsek [9] from marine Tertiary beds in Hungary. The only species found in the Kettleman Hills with which it may be confused is *Coscinodiscus cirrus* (pl. 21, fig. 4), and the differences between the two are discussed under the original description of that species on page 91 of this report. Its known range is from Oligocene (?) to Recent. The occurrence of *Coscinodiscus inclusus* (pl. 20, fig. 3) in the upper part of the Etchegoin formation is particularly interesting, as it marks the upper limit for the known range of this diatom. It was originally described by Rattray [10] from an unnamed figure in Schmidt's Atlas.[11] The original material came from "Richmond, Virginia," presumably from the diatomite in the Calvert formation, of middle Miocene age, which crops out in that city. No other occurrence of this species is known. The short form only of *Rhaphoneis angularis* (pl. 22, fig. 8; see original description, pp. 92–93 of this report) was found frequently in the upper part of the Etchegoin formation. In the collections studied for this report this species was found only in the San Joa-

[7] Frenguelli, Gioacchino, Tecamebiani e diatomee nel Miocene del Neuquén (Patagonia settentrionale): Soc. geol. italiana Boll., vol. 52, pp. 40–42, pl. 5, figs. 8–16, text fig. on p. 41, 1933.

[8] Hanna, G. D., and Grant, W. M., Brackish-water Pliocene diatoms from the Etchegoin formation of central California: Jour. Paleontology, vol. 3, p. 99, pl. 14, fig. 3, 1929.

[9] Pantocsek, Josef, Beiträge zur Kenntniss der fossilen Bacillarien Ungarns, I, p. 71, pl. 20, fig. 186, 1886.

[10] Rattray, John, A revision of the genus *Coscinodiscus* and some allied genera: Royal Soc. Edinburgh Proc., vol. 16, p. 482, 1889.

[11] Schmidt, Adolf, Atlas der Diatomaceenkunde, pl. 57, fig. 47, 1878.

quin formation and the upper part of the Etchegoin formation. The elongate forms (pl. 22, figs. 6 and 7) were found only in the San Joaquin formation. *Navicula clavata* var. *elliptica* (pl. 20, fig. 9)[12] is a tropical form first reported from Samoa and differs from *N. clavata* Gregory only in not having rostrate apices. It is reported as rare in the accompanying table, although several fragments which probably belong to this variety were found. The only *Lithodesmium* found was a very small undetermined species not at all to be confused with *L. cornigerum*.

SAN JOAQUIN FORMATION

The name "San Joaquin clay" was first used by F. M. Anderson [13] for the upper part of the Etchegoin formation. Arnold and Robert Anderson included the beds now called the San Joaquin formation in the Etchegoin in Bulletin 398, without special designation.

Barbat and Galloway [14] described the beds, raised the San Joaquin clay to formation rank and named the North Dome of Kettleman Hills as the type locality. They assigned over three-quarters of the formation to the Pleistocene and the remainder to the Pliocene.

Woodring and Stewart [15] have used the term "San Joaquin formation" to include the upper part of the Etchegoin of Arnold and Anderson and have assigned it all to the Pliocene. They have divided the formation into several faunal zones, a detailed description of which is given in their report now in preparation. Diatoms were obtained from two localities in the *Neverita* zone and from three localities in an overlying tuffaceous sandstone.

NEVERITA ZONE

U. S. G. S. diatom locality 1051. East side of Middle Dome, Kettleman Hills, Kings County, Calif., 1,650 feet south and 2,100 feet west from northeast corner of sec. 33, T. 23 S., R. 19 E., Mount Diablo base and meridian. Rodent debris at locality corresponding to a stratigraphic position about 25 feet above base of *Neverita* zone, San Joaquin formation, Pliocene. Collected by W. P. Woodring, May 30, 1932.

U. S. G. S. diatom locality 1052. West side of Middle Dome, Kettleman Hills, Kings County, Calif., 570 feet south and 1,850 feet west from northeast corner of sec. 8, T. 24 S., R. 19 E., Mount Diablo base and meridian. Rodent debris at locality corresponding essentially to same horizon as locality 1051. *Neverita* zone, San Joaquin formation, Pliocene. Collected by W. P. Woodring, May 31, 1932.

Material from these two localities yielded, as might be expected, very similar diatom assemblages, but with several noteworthy differences. Out of a total of 56 species and varieties from the two localities, 21, or 37 percent, were common to both. If the species reported as rare are eliminated, 66 percent are common to the two localities. The diatom floras from the *Neverita* zone are dominantly marine and are characterized by *Melosira sulcata* (pl. 22, fig. 15), *Stephanopyxis corona* (pl. 22, fig. 2), *Coscinodiscus excentricus* (pl. 21, fig. 5), *C. subtilis* (pl. 21, fig. 6), *C. cirrus*, n. sp. (p. 90, pl. 21, fig. 4), *C. obscurus* (pl. 21, fig. 1), *C. asteromphalus* (pl. 21, fig. 3), *C. asteromphalus* var. *omphalantha* (pl. 20, fig. 2), *C. kurzii* (pl. 21, fig. 2), *Actinoptychus undulatus* (pl. 22, fig. 3), *Actinocyclus ehrenbergii* (pl. 22, fig. 1), *A. subtilis*, and *Xanthiopyxis ovalis*, n. sp. (p. 91, pl. 22, fig. 12). Most of the forms are pelagic, suggesting fairly open water at the time of deposition.

Several species inhabiting only fresh and brackish waters are present, usually in rare amounts, but it seems reasonable to assume that they were introduced by streams, as the assemblage is overwhelmingly marine in character.

Melosira recedens (pl. 22, figs. 13, 14) was found only in the San Joaquin formation in the Kettleman Hills. It was found more abundantly in the overlying tuffaceous sandstone than in the *Neverita* zone. This species was first described [16] from the Eocene "Cementstein" on the island of Mors, Jutland. Heretofore it has been recorded only from the type locality, and this Pliocene occurrence in the Kettleman Hills marks the upper limit of its known geologic range. *Coscinodiscus cirrus*, n. sp. (pl. 21, fig. 4; see original description on p. 90 of this report) is one of the most distinctive species found in the collections studied. It occurs commonly in both collections from the *Neverita* zone and frequently in one collection (locality 1056) from the overlying tuffaceous sandstone, but at no other locality. It appears to be one of the most characteristic diatoms in the *Neverita* zone and can usually be found in a strewn slide of diatoms from the localities mentioned. It can be distinguished immediately by the small excentric circlet of enlarged areolae. The genus *Aulacodiscus* was found only in this zone, represented by many fragments assigned to *A.* cf. *A. argus* and one good valve of *A. brownei*. *Biddulphia aurita*, which ranges from Miocene to Recent, was found frequently in both collections from this zone but at no other locality in the Kettleman Hills. *Hemidiscus ovalis*, n. sp. (pl. 22, fig. 9; see original description, p. 91) was found only at locality 1052 in this zone and at two localities (1056 and 1057) in the overlying sandstone. In the collections studied, this species is limited to the San Joaquin formation. A closely related species, *H. margaritaceus*,[17] was described from rocks of supposed Pliocene age in Japan. Both the long and short forms of *Rhaphoneis angularis*, n. sp. (pl. 22, figs. 6, 7, and 8; see original description, p. 92) were found frequently in both collections from this zone and in one collection (locality 1054) from the overlying tuffaceous sandstone. The long forms (pl. 22,

[12] Schmidt, Adolf, op. cit., pl. 3, fig. 13.

[13] Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 3d ser., vol. 2, pp. 178–192, 1905.

[14] Barbat, W. F., and Galloway, John, San Joaquin clay, California: Am. Assoc. Petroleum Geologists Bull., vol. 18, no. 4, pp. 476–499, 1934.

[15] Woodring, W. P., Stewart, Ralph, and Richards, R. W., Geologic map of the Kettleman Hills, California (advance ed.), U. S. Geol. Survey, 1934.

[16] Schmidt, Adolf, Atlas der Diatomaceenkunde, pl. 176, fig. 54; pl. 177, figs. 62–64, 1892.

[17] Brun, J., and Tempère, J., Diatomées fossiles du Japon: Soc. phys. et hist. nat. Genève Mém., tome 30, no. 9, p. 37, pl. 4, fig. 6a, 1889.

figs. 6 and 7) were found only in the San Joaquin formation. *Navicula pennata* (pl. 22, fig. 16) was fairly uniformly distributed through all five of the collections from the San Joaquin formation and in no others. Its known range is "Tertiary" [18] to Recent.[19]

TUFFACEOUS SANDSTONE OVERLYING NEVERITA ZONE

U. S. G. S. diatom locality 1054. West side of North Dome, Kettleman Hills, Fresno County, Calif., 1,500 feet north and 1,230 feet east from southwest corner of sec. 3, T. 22 S., R. 17 E., Mount Diablo base and meridian. Tuffaceous sandstone about 125 feet stratigraphically above base of *Neverita* zone, San Joaquin formation, Pliocene. Collected by W. P. Woodring, June 22, 1932.

U. S. G. S. diatom locality 1056. East flank of North Dome, Kettleman Hills, Kings County, Calif., cut on south side of Cottonwood Pass road, 1,430 feet south and 80 feet east from northwest corner of sec. 6, T. 23 S., R. 19 E., Mount Diablo base and meridian. Tuffaceous sandstone about 125 feet stratigraphically above base of *Neverita* zone, San Joaquin formation, Pliocene. Collected by W. P. Woodring, September 30, 1931.

U. S. G. S. diatom locality 1057. East flank of North Dome, Kettleman Hills, Kings County, Calif. Same locality as 1056. Silty clay about 20 feet lower stratigraphically. Tuffaceous sandstone and clay overlying *Neverita* zone, San Joaquin formation, Pliocene. Collected by W. P. Woodring, September 30, 1931.

A marine diatom assemblage of 78 species and varieties was obtained from the three localities in the tuffaceous sandstone and associated clay. This assemblage indicates deposition under marine conditions and is characterized by *Melosira sulcata* (pl. 22, fig. 15), *M. recedens* (pl. 22, figs. 13, 14), *Stephanopyxis corona* (pl. 22, fig. 2), *Coscinodiscus subtilis* (pl. 21, fig. 6), *C. cirrus* (pl. 21, fig. 4), *C. obscurus* (pl. 21, fig. 1), *C. radiatus*, *C. kurzii* (pl. 21, fig. 2), *Actinoptychus undulatus* (pl. 20, fig. 8; pl. 22, fig. 3), *Actinocyclus ehrenbergii* (pl. 22, fig. 1), *Omphalotheca* sp., *Xanthiopyxis ovalis* (pl. 20, fig. 6; pl. 22, fig. 12), *Hemidiscus ovalis* (pl. 22, fig. 9), *Rhaphoneis angularis* (pl. 22, figs. 6–8), *R. fatula* (pl. 22, fig. 5), *Navicula pennata* (pl. 22, fig. 16), and *Nitzschia granulata* (pl. 22, fig. 10).

Many pelagic genera are present in this assemblage, such as *Stephanopyxis*, *Thalassiosira*, *Coscinodiscus*, *Rhizosolenia*, *Bacteriastrum*, *Omphalotheca*, *Stephanogonia*, *Xanthiopyxis*, and *Thalassionema*.

Melosira recedens (pl. 22, figs. 13, 14) was found in the samples from the tuffaceous sandstone much more abundantly than in the underlying *Neverita* zone. It was not found in the sample from locality 1054. The known geologic range of this species is Eocene to Pliocene. *Coscinodiscus cirrus* (pl. 21, fig. 4) was found in only one sample (locality 1056) in the tuffaceous sandstone, although it is one of the most characteristic and abundant forms found in the *Neverita* zone. It is known only from the San Joaquin formation. *Coscinodiscus oculus-iridis*, which has a known range from Eocene to Recent, occurs more abundantly in the tuffaceous sandstone than in other parts of the section in the Kettleman Hills. *Coscinodiscus asteromphalus* (pl. 21, fig. 3) was found in much fewer numbers than in the *Neverita* zone, although the variety *omphalantha* is common in the tuffaceous sandstone but absent in both samples from the *Neverita* zone. *Hemidiscus ovalis* occurs much more abundantly in the tuffaceous sand than in the *Neverita* zone. It is known only from the San Joaquin formation. *Rhaphoneis fatula* (pl. 22, fig. 5) appears to be one of the most distinctive species in the tuffaceous sandstone, where it was found commonly in two collections (localities 1056 and 1057) out of the three studied. It occurred in no other collection from the Kettleman Hills. This species bears a superficial resemblance to *R. parilis* Hanna,[20] originally described from the Temblor formation near Sharktooth Hill, Kern County, Calif. The differences between the two are discussed in the original description of *R. fatula* on pages 93–94 of this report. *Navicula pennata* (pl. 22, fig. 16) is another distinctive species found in all collections from the San Joaquin and in no other sample from the Kettleman Hills.

TULARE FORMATION

The Tulare formation was originally proposed by F. M. Anderson [21] for the beds overlying his San Joaquin clay in the Kettleman Hills along the western border of the former Tulare Lake. He assigned it doubtfully to the Pliocene. Arnold and Anderson [22] gave a discussion of its occurrence, lithology, and characteristic fossils and assigned it to upper Pliocene and lower Pleistocene. They gave a maximum thickness of 3,100 feet in what is now called the Middle Dome, consisting of gravel, gypsiferous sand, and clay. At the present time the Tulare formation is assigned to the Pliocene and Pleistocene (?).

On the basis of the collections studied for this report, the Tulare formation exceeds all others in the Kettleman Hills in the diversity of its diatom floras. Four collections from the Tulare formation yielded a total of 136 species and varieties of diatoms, of which only 26, or 19 percent, occur in the Etchegoin and San Joaquin formations. This abrupt change is due to the fact that the diatom floras in the two older formations were marine, whereas those in the Tulare formation were deposited in brackish and fresh water. The most characteristic and abundant Tulare diatoms are shown in plate 23.

The four collections fall into two groups—(1) 838, 839, and 1053, from three different geographic localities in the North Dome, in a bed of white clay that occurs at the base of the Tulare formation and (2) 1061, in the

[18] Pantocsek, Joseph, Beiträge zur Kenntniss der fossilen Bacillarien Ungarns, I, p. 28, 1886.

[19] Schmidt, Adolf, Atlas der Diatomaceenkunde, pl. 48, figs. 41–43, 1876.

[20] Hanna, G. D., The diatoms of Sharktooth Hill, Kern County, Calif.: California Acad. Sci. Proc., 4th ser., vol. 20, no. 6, p. 214, pl. 16, figs. 2, 3, 4. 1932.

[21] Anderson, F. M., A stratigraphic study in the Mount Diablo Range, Calif.: California Acad. Sci. Proc., 3d ser., vol. 2, p. 181, 1905.

[22] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga district, Calif.: U. S. Geol. Survey Bull. 398, pp. 140–154, 1910.

Middle Dome from the lower *Amnicola* zone, about 180 feet above the base of the Tulare formation.

U. S. G. S. diatom locality 838. North end of North Dome, Kettleman Hills, Fresno County, Calif., 2,340 feet east of northwest corner of sec. 35, T. 21 S., R. 17 E., Mount Diablo base and meridian. White clay at base of Tulare formation, Pliocene. Collected by W. P. Woodring and K. E. Lohman, December 2, 1930.

This collection yielded a diatom flora of 91 species and varieties representing deposition in fresh or slightly brackish water. The most abundant and characteristic diatoms are *Melosira granulata* (pl. 23, fig. 8), *M. ambigua* (pl. 23, fig. 9), *Stephanodiscus carconensis* (pl. 23, fig. 2), and *S. carconensis* var. *pusilla*. Other species, less abundant but characteristic of the flora, are *Eunotia robusta* var. *tetraodon* (pl. 23, fig. 6), *E. serpentina*, *Cymbella prostrata* (pl. 23, fig. 15), *Navicula peregrina*, and *Nitzschia punctata* (pl. 23, fig. 11). This locality yielded the most diverse diatom flora found in the Kettleman Hills, including a large number of species that occurred in none of the other collections.

Stephanodiscus carconensis (pl. 23, fig. 2) has been found in fresh-water lake beds of supposed Pliocene age in Oregon and has not been reported living. *Cyclotella iris* is an extinct species, first described [23] from upper Pliocene fresh-water lake beds in Auxillac, Cantal, France, and has not been found before in North America. *Cyclotella pygmaea*, another extinct species, was first described [24] from an andesitic tuff deposited in a fresh-water lake bed of Sarmatian age in Szliacs, Hungary. Pantocsek's original figure, cited above, is very poor. He subsequently published two better figures,[25] which should be used for comparison with the Kettleman Hills form. *Diploneis smithii* (pl. 23, fig. 10) occurred frequently at locality 838 but was much more abundant at locality 1053. At present this species usually lives in a brackish- to salt-water environment, although it has been found in a few fresh-water lakes in Germany. *Nitzschia punctata* (pl. 23, fig. 11) is another brackish-water species found frequently at locality 838 but in no other sample from the Kettleman Hills. Although many species inhabiting both fresh and brackish waters are present, and a much smaller number that are usually found only in brackish waters, only one typically marine species, *Coscinodiscus kützingii*, was found, and that only rarely. The diatom flora as a whole is dominantly of fresh-water habitat, with a brackish-water influence present, such as might be found in a nearly land-locked basin slightly above tide level.

U. S. G. S. diatom locality 839. East side of North Dome, Kettleman Hills, Fresno County, Calif., 980 feet north and 730 feet west from southeast corner of sec. 20, T. 21 S., R. 17 E., Mount Diablo base and meridian. White clay at base of Tulare formation, Pliocene. Collected by W. P. Woodring and K. E. Lohman, December 2, 1930.

This collection yielded a large number of diatoms which were so badly corroded that only 6 species could be identified. The corrosion suggests leaching by alkaline solutions. The few species identified indicate ecologic conditions similar to those at locality 838.

U. S. G. S. diatom locality 1053. East side of North Dome, Kettleman Hills, Kings County, Calif., 1,040 feet south and 2,760 feet east from northwest corner of sec. 25, T. 22 S., R. 18 E., Mount Diablo base and meridian. White clay at base of Tulare formation, Pliocene. Collected by W. P. Woodring, June 18, 1932.

This collection yielded a diatom flora of 56 species and varieties, which include 13 out of the 16 species recorded by Hanna and Grant [26] from what is probably the same bed. The most characteristic species are *Melosira granulata* (pl. 23, fig. 8), *Hyalodiscus schmidtii* (pl. 23, fig. 5), *Cyclotella meneghiniana*, *Diploneis smithii* (pl. 23, fig. 10), *Navicula marina* (pl. 23, fig. 13), *Cymbella mexicana* (pl. 23, fig. 14), *Nitzschia etchegoinia* (pl. 23, fig. 12), *N. granulata* (pl. 22, fig. 10), *Surirella striatula*, and *S. utahensis* (pl. 23, fig. 1).

The occurrence of large numbers of such marine species as *Melosira sulcata*, *M. sol*, *Podosira stelliger*, *Thalassiosira decipiens*, *Coscinodiscus excentricus*, *Actinoptychus undulatus*, *Xanthiopyxis ovalis*, and *Triceratium uncinatum*, together with such brackish-water and marine species as *Hyalodiscus schmidtii*, *Terpsinoe americana*, *Diploneis smithii*, *Navicula marina*, *Campylodiscus echeneis*, and *C. clypeus* strongly indicates brackish-water conditions during deposition.

The large number of fresh-water and fresh- and brackish-water species suggests that truly marine conditions did not prevail, but rather that deposition took place at or near tide level, where a mixing of fresh-water, brackish-water, and marine forms would occur.

An extinct variety found rarely in this collection, *Cyclotella compta* var. *pliocaenica*, was originally described [27] from an upper Pliocene clay near Willerhausen, South Hanover, Germany, in which bones of *Mastodon arvernense* were also found. *Xanthiopyxis ovalis* (pl. 22, fig. 12) was found in the Tulare formation in this collection only, although it occurs much more commonly in both the San Joaquin and Etchegoin formations. *Nitzschia etchegoinia* (pl. 23, fig. 12), which was originally described [28] from what is probably the same bed as that represented at locality 1053, is a very distinctive and common species in this locality. It was found, and then rarely, in only one other sample (from locality 1058, in the Etchegoin formation) among the collections studied from the Kettleman Hills.

[23] Héribaud, Joseph, Les diatomées d'Auvergne, p. 224, pl. 6, figs. 1–4, 1893.

[24] Pantocsek, Josef, Beschreibung und Abbildung der fossilen Bacillarien des Andesittuffes von Szliacs in Ungarn, p. 17, pl. 2, fig. 67, 1903.

[25] Pantocsek, Josef, Beiträge zur Kenntniss der fossilen Bacillarien Ungarns, III, p. 37, pl. 2, fig. 22; pl. 4, fig. 59, 1905.

[26] Hanna, G. D., and Grant, W. M., Brackish-water diatoms from the Etchegoin formation of central California: Jour. Paleontology, vol. 3, no. 1, pp. 87–100, pl. 11–14, 1929.

[27] Krasske, Georg, Diatomeen aus dem Oberpliocän von Willerhausen: Archiv für Hydrobiologie, Band 24, Heft 3, p. 435, pl. 16, figs. 1–6, Berlin, 1932.

[28] Hanna, G. D., and Grant, W. M., op. cit., p. 99, pl. 14, fig. 3.

Although the collections from the three localities (838, 839, and 1053) described above were obtained from the same 12-foot bed of white clay at the base of the Tulare formation at different points along the strike, the diatom flora obtained at locality 1053 is quite different from those obtained at localities 838 and 839. The diatoms from locality 839 were so badly leached that the flora is very incomplete and hence is left out of the present discussion. The diatom floras from the other two localities show a definite change from fresh-water conditions at locality 838 to brackish-water conditions at locality 1053. The exact position in the 12-foot bed of these two collections is not known, so it is not possible to state whether the change in the floras represents an increase or decrease in salinity for the time represented by the deposition of this bed. As the collections were made at points some distance apart, it is possible that different ecologic conditions were present in different parts of the basin at the same time or at slightly different times. During the summer of 1934 I collected a suite of 26 samples at 6-inch intervals from bottom to top of this bed at locality 838. A study of this material may provide an answer to the question of the changing ecologic conditions during this part of early Tulare time at this locality. I have had no opportunity as yet to make this study but hope to do so in the near future.

U. S. G. S. diatom locality 1061. East flank of Middle Dome, Kettleman Hills, Kings County, Calif., arroyo along old Dudley-Lemoore road, 1,690 feet south and 1,870 feet east from northwest corner of sec. 17, T. 23 S., R. 19 E., Mount Diablo base and meridian. Lower *Amnicola* zone, about 180 feet stratigraphically above the base of the Tulare formation, Pliocene. Collected by W. P. Woodring, December 17, 1931.

This collection yielded a diatom flora of 16 species and varieties, of which three—*Stephanopyxis turris* var. *cylindrus*, *Cocconeis scutellum* var. *minutissima*, and *Diploneis advena*—are marine, and the rest now live in fresh or brackish waters. The most characteristic forms are *Epithemia zebra*, particularly the variety *saxonica* (pl. 23, fig. 3), *Rhopalodia gibba* (pl. 23, fig. 4) and the variety *ventricosa*, *Melosira granulata* (pl. 23, fig. 8), and *Mastogloia elliptica*. These forms suggest deposition in fresh to brackish water of lower salinity than that indicated by the diatom flora from locality 1053.

One extinct variety, *Navicula pennata* var. *kinkeri*, first described by Pantocsek [29] from "Tertiary" marl in Szákal, Hungary, and also known from the Calvert formation (middle Miocene) exposed near Petersburg, Va., was found rarely in this collection. Whether this variety was living in Tulare time or was redeposited from Miocene diatom-bearing rocks then being eroded cannot be determined. Arnold and Anderson [30] recorded the occurrence in the lower part of the Tulare formation of angular fragments of hard white siliceous shale, derived presumably from their Tejon or Santa Margarita (?) formations. (The upper part of the Tejon formation of Arnold and Anderson is now assigned to the Kreyenhagen shale; their Santa Margarita(?) formation is designated the McLure shale.) Reef Ridge, southwest of Kettleman Hills, is the most probable source of the angular fragments of siliceous shale from the Kreyenhagen and the McLure shales recorded by Arnold and Anderson. I have obtained well-preserved diatoms from hard calcareous concretions in the McLure shale on Reef Ridge, but preserved diatoms have not been obtained from either the McLure or the Kreyenhagen shale in this region. Good impressions of diatoms have been seen in both, but the shales are so highly silicified that none of the original material of the diatoms is present, and their positive determination is impossible. Arnold and Anderson [31] also reported the occurrence of porcelain shale in the Etchegoin formation in the Kettleman Hills, which indicates that the silicification of the shales mentioned above took place before Tulare time. It thus appears extremely unlikely that the diatom mentioned above could have been derived from either the Kreyenhagen or the McLure shale.

[29] Pantocsek, Josef, Beiträge zur Kenntnis der fossilen Bacillarien Ungarns, II, p. 49, pl. 9, fig. 169, 1889.

[30] Arnold, Ralph, and Anderson, Robert, U. S. Geol. Survey Bull. 398, p. 145, 1910.

DESCRIPTIONS OF NEW SPECIES

ALGAE

Class DIATOMACEAE
Order CENTRALES
Suborder DISCINEAE
Family COSCINODISCACEAE
Subfamily COSCINODISCOIDEAE
Genus COSCINODISCUS Ehrenberg

Coscinodiscus cirrus Lohman, n. sp.

Plate 21, figure 4

Valve circular, slightly convex, especially near the margin. Areolae hexagonal, arranged in curved rows, subfasciculate, 5 to 6 in 0.01 mm at half the radius, 6 to 7 in 0.01 mm near the center and 11 to 12 in 0.01 mm very near the margin. Central papillae large but very faint and clearly visible only when mounted in medium of high refractive index. No central space or rosette. A ring of areolae slightly larger than those adjacent form a circle 0.010 to 0.013 mm in diameter and about one-seventh of the radius from the center of the valve; markings converge to its center. Secondary curved oblique decussating rows evident, especially in the central portion. Margin narrow, bearing short radial striae, 12 to 13 in 0.01 mm. Larger areolae occur just within the margin and 0.006 to 0.007 mm apart. Diameter of valve 0.10 to 0.13 mm.

Diameter of figured specimen 0.121 mm.

Holotype: No. 1630–1, U. S. G. S. diatom collection. Collected by W. P. Woodring May 31, 1932, from rodent debris at locality corresponding to stratigraphic position about 25 feet above base of *Neverita* zone, 570 feet south and 1,850 feet west from northeast corner of sec. 8, T. 24 S., R. 19 E., Mount Diablo base and

[31] Idem, p. 123.

meridian, west side of Middle Dome, Kettleman Hills, Kings County, Calif., U. S. G. S. diatom locality 1052. *Neverita* zone, San Joaquin formation, Pliocene.

This species bears a superficial resemblance to *Coscinodiscus subtilis* Ehrenberg as figured in Schmidt's Atlas, plate 57, figures 13 and 14. The following consistent differences serve to distinguish the two:

C. subtilis	*C. cirrus*
Areolae always in straight rows.	Areolae always in curved rows.
Areolae forming definite fasciculi with rows parallel to central radial row in each fasciculus.	Areolae forming indefinite fasciculi with rows concentric to one marginal row in each fasciculus.
Ring (when present) concentric.	Ring always present and always excentric.

C. vetustissimus (pl. 20, fig. 7), a frequent species in the Etchegoin formation, bears a superficial resemblance to *C. cirrus*, especially under very low magnifications. The former species has an irregular hyaline ring at or near the center of the valve. In *C. cirrus* the ring is much more excentric and composed of large areolae with no hyaline space.

This species is one of the most distinctive found in the Kettleman Hills. It occurred commonly in both samples (1051 and 1052) from the *Neverita* zone of the San Joaquin formation and frequently in one sample (1056) from the overlying tuffaceous sandstone. Its known geologic range is confined to the Pliocene.

Genus XANTHIOPYXIS Ehrenberg

Xanthiopyxis ovalis Lohman, n. sp.

Plate 20, figure 6; plate 22, figure 12

Valve oval in valve view and convex in zone view, the center 0.003 to 0.004 mm higher than the margin. Surface of valve irregularly covered with short heavy spines 0.0015 to 0.003 mm apart. Short striae, averaging 0.001 mm long and spaced 11 in 0.01 mm, project inward from the margin, giving a crenulate appearance. No spines project outward beyond the margin. Length 0.020 to 0.030 mm, width 0.014 to 0.019 mm, length-width ratio 1.4 to 1.6.

Measurements of figured specimens: Holotype, no. 1517–1, length 0.021 mm, width 0.015 mm; paratype, no. 1515–2, length 0.027 mm, width 0.018 mm.

Holotype: No. 1517–1, U. S. G. S. diatom collection. Collected by W. P. Woodring, May 30, 1932, from rodent debris at locality corresponding to a stratigraphic position about 25 feet above the base of the *Neverita* zone, San Joaquin formation, 1,650 feet south and 2,100 feet west from northeast corner of sec. 33, T. 23 S., R. 19 E., Mount Diablo base and meridian. East side of Middle Dome, Kettleman Hills, Kings County, Calif., U. S. G. S. diatom locality 1051, *Neverita* zone, San Joaquin formation, Pliocene.

Paratype: No. 1515–2, U. S. G. S. diatom collection, collected by W. P. Woodring, December 17, 1931, from locality estimated to be 1,500 feet stratigraphically below the top of the Etchegoin formation, 1,700 feet north of southeast corner of sec. 34, T. 24 S., R. 19 E., Mount Diablo base and meridian. East flank of South Dome, Kettleman Hills, Kings County, Calif., U. S. G. S. diatom locality no. 1060, Etchegoin formation, Pliocene.

This species is always distinctly oval in outline, and the spines never project beyond the margin in the plane of the valve. *Xanthiopyxis oblonga* Ehrenberg[32] is much more elongated, with approximately parallel sides and spines projecting beyond the margin. *Xanthiopyxis hirsuta* Hanna and Grant[33] has nearly the same shape but much more numerous and much finer spines, many of which extend beyond the margin. This diatom should receive a new name, as the name *hirsuta* was used by Ehrenberg[34] for a *Pyxidicula* which Ralfs[35] later changed to *Xanthiopyxis hirsuta*, a form quite distinct from Hanna's species.

It is possible that the genus *Xanthiopyxis* may represent resting spores of *Chaetoceros*, but it would be difficult, if not impossible, to assign the different species of *Xanthiopyxis* to any particular species of *Chaetoceros* until much more is known of both groups. Various species of *Xanthiopyxis* are frequently found in beds that never yield even fragments of *Chaetoceros*, and while this lack might be explained on the ground that species of *Chaetoceros* are less completely silicified and hence less likely to be preserved, the fact remains that many beds which yield *Chaetoceros* in fairly large numbers contain few if any *Xanthiopyxis*. Certain species of *Xanthiopyxis*, furthermore, have been found to have short geologic ranges and hence are particularly promising for stratigraphic correlation. It seems best, therefore, to retain the genus *Xanthiopyxis*.

This species occurs abundantly in the lower part of the Etchegoin formation (locality 1060), is distributed fairly well through the San Joaquin formation (localities 1051, 1052, 1054, 1056), and occurs rarely in one sample (locality 1053) from the Tulare formation. Its known geologic range is confined to the Pliocene.

Family EUODIACEAE

Genus HEMIDISCUS Wallich

Hemidiscus ovalis Lohman, n. sp.

Plate 22, figure 9

Valve oval, nearly symmetrical, with the length about 1⅓ times the width. Cuneate in zone view. Markings round, 11 to 12 in 0.01 mm, arranged in radial rows with secondary curved oblique decussating rows evident. Central space large, containing an irregular ring of larger, conical granules with one, still larger, near the center. Margin narrow, bearing short radial striae, 17 to 18 in 0.01 mm. Marginal apiculi absent,

[32] Ehrenberg, C. G., Mikrogeologie, pl. 33, group 17, fig. 17, 1854.
[33] Hanna, G. D., and Grant, W. M., Miocene marine diatoms from Maria Madre Island, Mexico: California Acad. Sci. Proc., 4th ser., vol. 15, p. 170, pl. 21, fig. 10, 1926.
[34] Ehrenberg, C. G., K. preuss. Akad. Wiss. Berlin Ber. Verh., p. 86, 1840.
[35] Ralfs, John, in Pritchard, Andrew, A history of Infusoria, 4th ed., p. 827, 1861.

but spaces suggesting apiculi occur near the margin at intervals of 0.002 to 0.004 mm. A narrow, irregular hyaline space occurs along the margin of least curvature, causing a break in the otherwise fairly regular markings. Length 0.020 to 0.030 mm, width 0.016 to 0.023 mm.

Dimensions of figured specimen, length 0.028 mm, width 0.022 mm.

Holotype: No. 1508–1, U. S. G. S. diatom collection. Collected by W. P. Woodring, September 30, 1931, from tuffaceous sandstone about 105 feet stratigraphically above the base of the *Neverita* zone, San Joaquin formation, 1,430 feet south and 80 feet east from the northwest corner of sec. 6, T. 23 S., R. 19 E., Mount Diablo base and meridian, cut on south side of Cottonwood Pass road, east flank of North Dome, Kettleman Hills, Kings County, Calif., U. S. G. S. diatom locality 1057. San Joaquin formation, Pliocene.

This species somewhat resembles *Hemidiscus margaritaceus* (Brun),[36] from the Pliocene of Yedo, Japan, but is much smaller, has fewer granules in the central space, and is more symmetrical. Brun's species has a pseudonodule near the ventral margin. Many species of *Hemidiscus* have a pseudonodule on one valve only, and it is entirely possible that the mate to the specimen figured may have one. As a large number of individuals were examined, and all of them lacked a pseudonodule, however, it appears probable that it is normally absent on this species. The irregular though definite loop formed by the large granules with the single larger granule near the center of the central area is a consistent feature and clearly distinguishes *H. ovalis* from *H. margaritaceus*. In the latter species the granules are much more numerous and arranged without order. The nearly perfect symmetry of *H. ovalis* is another consistent feature which distinguishes it. That the two species are closely related seems certain, and it is significant that both were found in Pliocene rocks, although the vague stratigraphic data given by Brun make the assignment of his material to the Pliocene uncertain.

This species was found at localities 1056 and 1057 in the North Dome and at locality 1052 in the Middle Dome. Locality 1052 is in the *Neverita* zone, and the other two are in the tuffaceous sandstone overlying the *Neverita* zone. The range of the species is apparently restricted to the San Joaquin formation in the Kettleman Hills.

Order **PENNALES**
Suborder **ARAPHIDINEAE**
Family **FRAGILARIACEAE**
Subfamily **FRAGILARIOIDEAE**
Genus **RHAPHONEIS** Ehrenberg

Rhaphoneis angularis Lohman, n. sp.

Plate 22, figures 6, 7, 8

Valve broadly lanceolate, with tapering, produced apices, 0.003 to 0.004 mm wide, near the ends. Central portion inflated, with margins forming a distinct angle of 135° to 160°. Puncta large, round, arranged in parallel to slightly curved, radiating transverse rows, 5 to 6 in 0.01 mm, and in nearly parallel to slightly curved longitudinal rows, 7 to 8 in 0.01 mm. Transverse rows distinctly radiating in some forms and perpendicular to longitudinal axis in others. Pseudoraphe narrow but very distinct, 0.0011 to 0.0013 mm wide. Small semicircular areas at apices frequently contain 2 to 8 very small granules arranged in radial rows or without regular arrangement. Length variable, from 0.050 to 0.150 mm, owing almost entirely to variation in the length of the apices. Width much more nearly constant, 0.017 to 0.021 mm.

Measurements of figured specimens

U. S. G. S. diatom collection	Length (mm)	Width (mm)	Angle	Transverse rows in 0.01 mm	Longitudinal rows in 0.01 mm
Holotype no. 1524–1	0. 142	0. 0195	158°	5. 4	7. 1
Paratype no. 1524–2	0. 119	0. 020	142°	5. 9	7. 1
Paratype no. 1524–3	0. 066	0. 020	137°	5. 9	7. 9

All from U. S. G. S. diatom locality 1051. Collected by W. P. Woodring, May 30, 1932, from rodent debris at locality corresponding to a stratigraphic position about 25 feet above the base of the *Neverita* zone, San Joaquin formation, 1,650 feet south and 2,100 feet west from northeast corner of sec. 33, T. 23 S., R. 19 E., Mount Diablo base and meridian, east side of Middle Dome, Kettleman Hills, Kings County, Calif. *Neverita* zone, San Joaquin formation, Pliocene.

This species is rather variable in length but remarkably uniform in width, measurements on many individuals deviating not more than 10 percent from the mean and only rarely more than 5 percent. The principal distinguishing feature is the definite angle made by the margins opposite the center of the valve. The most variable feature is the length of the apices. If only a form with short apices and one with long apices were encountered, they might be considered to be separate species. In the large number of individuals available from the Kettleman Hills material, however, all gradations between the shortest and longest forms were found associated in the same sample, and no doubt is felt in assigning them all to the same species. In some forms the transverse rows of puncta are practically straight and parallel to the minor axis, as in plate 22, figure 6. Others have somewhat curved, radial transverse rows of puncta, as in plate 22, figures 7 and 8. With the exception of these two variable features—length of apices and direction of transverse rows—the different individuals in a large group are remarkably uniform, and the measurements given for the figured specimens are typical.

Some of the shorter forms with only slightly rostrate apices approach *R. rhombus* Ehrenberg,[37] to which *R.*

[36] Brun, J., and Tempère, J., Diatomées fossiles du Japon: Soc. phys. et hist. nat. Genève Mém., tome 30, no. 9, p. 37, pl. 4, fig. 6a, 1889.

[37] Ehrenberg, C. G., Mikrogeologie, pl. 33, group 13, fig. 19, 1854.

angularis is probably related. It differs from Ehrenberg's species, however, in its distinctly produced rostrate apices, larger and more widely spaced puncta, and greater length. According to Ehrenberg's original conception of *R. rhombus*, it varied from a short rhomboid form [38] to a rounded form with stubby rostrate apices.[39] These two forms are probably different species, and Hanna [40] has recently selected the first figure cited above as the type figure of *R. rhombus*. This appears to be the wisest choice, as it fits the name better than the rounded form. Although the shortest forms of *R. angularis* approach *R. rhombus* and are probably related to it, the longer forms with greatly produced apices are increasingly different. It seems best, therefore, in view of the confusion which already exists in the case of *R rhombus*, to consider the Kettleman Hills form a separate species with the relationship indicated.

As only the short form (pl. 22, fig. 8) was found in the upper part of the Etchegoin formation, the lowest stratigraphic horizon known for the species, it is possible that the short form is the parent form of this variable species. The long forms differ from the short ones only in the greatly produced apices, and it is possible that the long forms found in the San Joaquin formation are aberrant developments of the earlier symmetrical form with short apices. This idea is strengthened somewhat by the fact that in the long forms the two apices are usually of different lengths. The fact that the short form is apparently more closely related to *R. rhombus*, first found in Miocene rocks, than the longer forms is further evidence along the same line. When these forms were first studied, it was decided to make the short form the type of the species and the long forms varieties, but as all variations between the long and short forms exist, it was impossible to draw a sharp boundary between species and variety, and it seemed more satisfactory to consider them all as belonging to one species with the variations indicated. The possibility that the long forms should be considered varieties of the short form still exists, however, and can be settled only by the examination of additional material from the Etchegoin sandstone. In making this decision material from the same horizon at widely separated geographic localities will be necessary.

This species was found in the Kettleman Hills at U. S. G. S. diatom localities 1051, 1052, 1054, and 1058. The elongated forms were found only in the San Joaquin formation at localities 1051, 1052, and 1054. Only the short form was found in the upper part of the Etchegoin formation, at locality 1058. All these localities are in rocks of Pliocene age.

Rhaphoneis fatula Lohman, n. sp.

Plate 22, figure 5

Valve flat, lanceolate, with gently tapering, produced, and slightly expanded apices. Puncta large, round, arranged in nearly parallel longitudinal rows, 8 to 10 in 0.01 mm in central part and 11 to 12 in 0.01 mm near apices; and in parallel to slightly radiate transverse rows 6 to 7 in 0.01 mm. Pseudoraphe evident but not pronounced; average distance between longitudinal rows of puncta in central part of valve 0.0012 mm, width of pseudoraphe in central portion 0.0017 mm. Length 0.033 to 0.046 mm, width 0.007 to 0.009 mm.

Measurements of figured specimen, length 0.046 mm, width 0.009 mm, longitudinal rows of puncta, center, 8 in 0.01 mm, apices, 11 in 0.01 mm; transverse rows (average) 6 in 0.01 mm.

Holotype: No. 1508-3, U. S. G. S. diatom collection. Collected by W. P. Woodring from tuffaceous sandstone in cut on south side of Cottonwood Pass road, 1,430 feet south and 80 feet east from northwest corner of sec. 6, T. 23 S., R. 19 E., Mount Diablo base and meridian, about 125 feet stratigraphically above the base of the *Neverita* zone, San Joaquin formation. East flank of North Dome, Kettleman Hills, Kings County, Calif., U. S. G. S. diatom locality 1056. Pliocene.

This species is somewhat similar to *R. parilis* Hanna [41] and to *R. lancettula* Grunow.[42] The differences are best shown in the following table:

Comparison of species of Rhaphoneis

	R. fatula	*R. parilis*	*R. lancettula*
Length ... millimeters	0. 033 to 0. 046	0. 034 to 0. 060	0. 053 to 0. 083.
Width ... millimeters	0. 007 to 0. 009	0. 010	0. 007 to 0. 010.
Length-width ratio	4. 7 to 5. 1	3. 4 to 6. 0	7. 6 to 8. 3.
Pseudoraphe	Present	Absent	Faint.
Transverse rows of puncta	6–7 in 0. 01 mm	7 in 0.01 mm	5–5½ in 0. 01 mm.
Longitudinal rows of puncta	8–12 in 0. 01 mm	7 in 0. 01 mm	No data.
Apices	Expanded	Not expanded	Not expanded.
Puncta	Round	Round	Quadrilateral.

[38] Ehrenberg, C. G., op. cit., pl. 33, group 13, fig. 10.

[39] Idem, pl. 18, figs. 84 85.

[40] Hanna, G. D., The diatoms of Sharktooth Hill, Kern County, Calif.: California Acad. Sci. Proc., 4th ser., vol. 20, no. 6, p. 212, 1932.

[41] Hanna, G. D., The diatoms of Sharktooth Hill, Kern County, Calif.: California Acad. Sci. Proc., 4th ser., vol. 20, no. 6, p. 214, pl. 16, figs. 2, 3, 4, 1932.

[42] Grunow, Albert, in Pantocsek, Josef, Beiträge zur Kenntniss der fossilen Bacillarien Ungarns, I, p. 35, pl. 27, fig. 271, 1886.

In *R. parilis* the puncta are "separated uniformly from each other",[43] from which it may be assumed that the spacing of the longitudinal rows of puncta is 7 in 0.01 mm, the same as is given for the transverse rows. The figures do not bear out this statement except for the two rows of puncta on each side of the longitudinal axis. In general external shape *R. fatula* is broader than *R. lancettula* and narrower than *R. parilis*. Although the spacing of the transverse rows of puncta is the same as in *R. belgica* Grunow,[44] the Kettleman Hills species is only about half as long, the pseudoraphe is less evident, and the apices are much narrower, with enlarged ends.

This species was found in the Kettleman Hills only at U. S. G. S. diatom localities 1056 and 1057, where it occurred commonly. Both localities are in the tuffaceous sandstone overlying the *Neverita* zone of the San Joaquin formation.

[43] Hanna, G. D., op. cit., p. 214.

[44] Grunow, Albert, in Van Heurck, H., Synopsis des diatomées de Belgique, pl. 36, figs. 25, 29, 1881.

PLATES 20–23

PLATE 20

DIATOMS FROM THE ETCHEGOIN FORMATION

FIGURE 1. *Coscinodicus kurzii* Grunow. U. S. G. S. diatom catalog no. 1515–1, locality 1060. Diameter 0.135 mm.

2. *Coscinodiscus asteromphalus* Ehrenberg var. *omphalantha* (Ehrenberg) Grunow. U. S. G. S. diatom catalog no. 1523–4, locality 1058. Diameter 0.266 mm.

3. *Coscinodiscus inclusus* Rattray. U. S. G. S. diatom catalog no. 1523–B, locality 1058. Diameter 0.040 mm.

4. *Endictya robusta* (Greville) Hanna and Grant. U. S. G. S. diatom catalog no. 1523–5, locality 1058. Diameter 0.057 mm.

5. *Coscinodiscus excentricus* Ehrenberg. U. S. G. S. diatom catalog no. 1523–7, locality 1058. Diameter 0.066 mm.

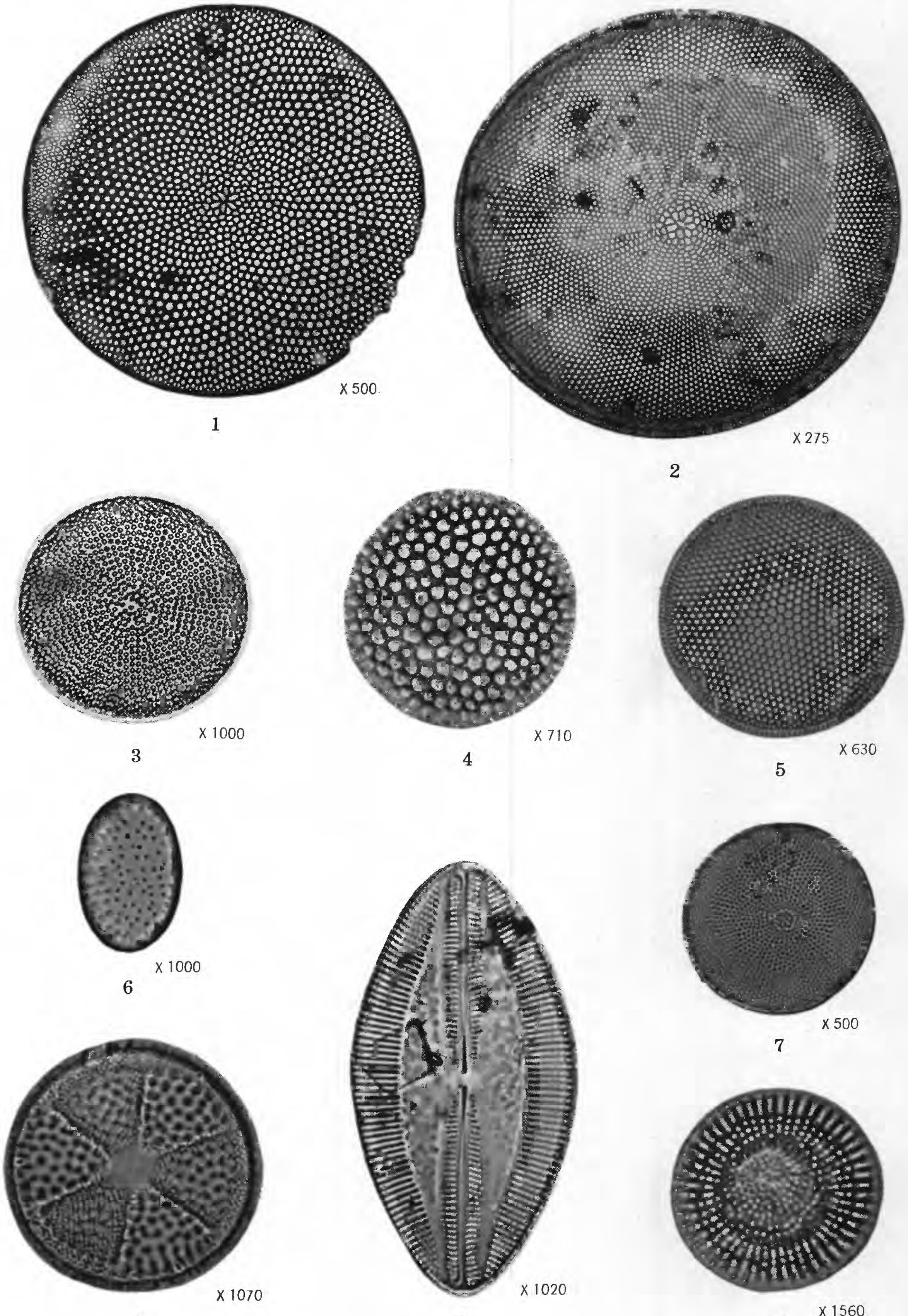
6. *Xanthiopyxis ovalis* Lohman, n. sp. Paratype: U. S. G. S. diatom catalog no. 1515–2, locality 1060. Length 0.027 mm, width 0.018 mm.

7. *Coscinodiscus vetustissimus* Pantocsek. U. S. G. S. diatom catalog no. 1523–6, locality 1058. Diameter 0.066 mm.

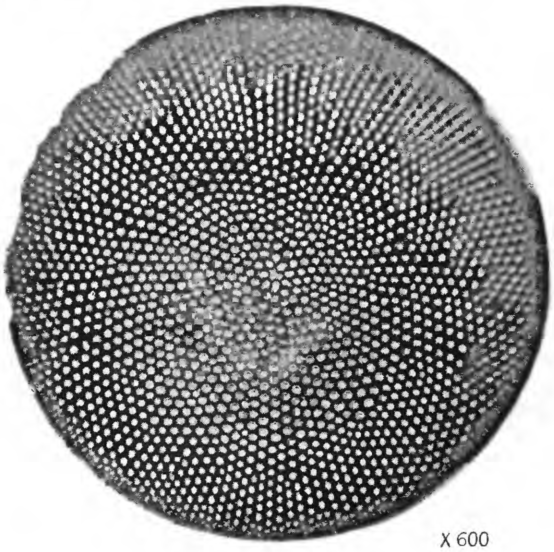
8. *Actinoptychus undulatus* Ehrenberg. U. S. G. S. diatom catalog no. 1523–5, locality 1058. Diameter 0.041 mm.

9. *Navicula clavata* Gregory var. *elliptica* Schmidt. U. S. G. S. diatom catalog no. 1523–9, locality 1058. Length 0.072 mm, width 0.038 mm.

10. *Stephanodiscus dubius* (Fricke) Hustedt. U. S. G. S. diatom catalog no. 1523–3, locality 1058. Diameter 0.023 mm.



DIATOMS FROM THE ETCHEGOIN FORMATION OF SOUTH DOME, KETTLEMAN HILLS.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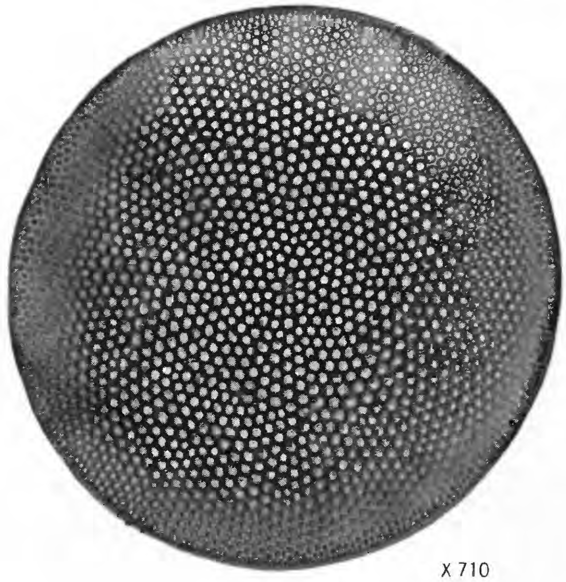
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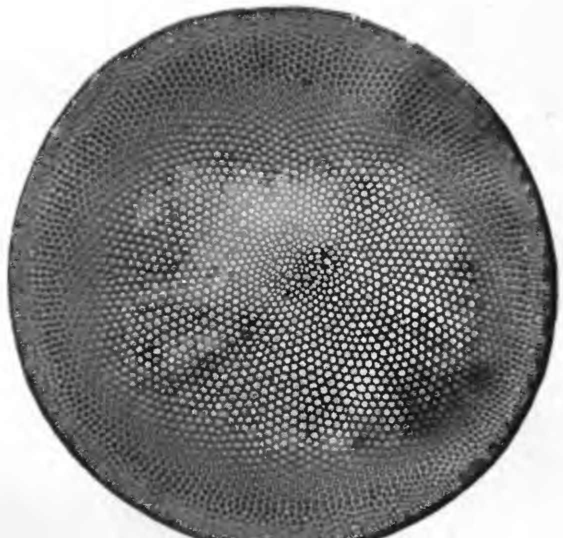
X 505

3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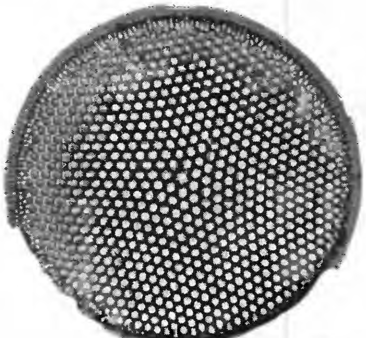
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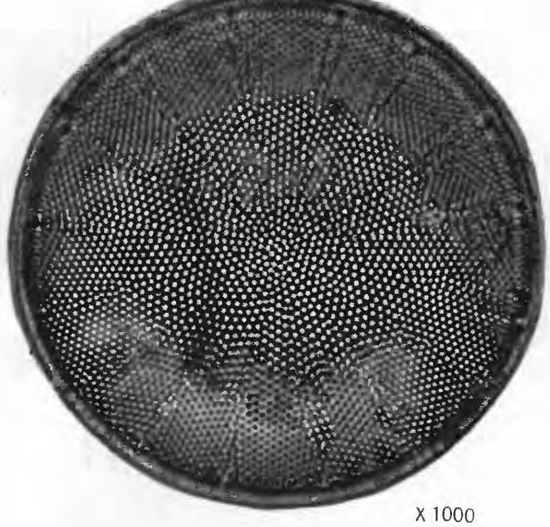
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DIATOMS FROM THE NEVERITA ZONE AND OVERLYING TUFFACEOUS SANDSTONE AND CLAY OF THE SAN JOAQUIN FORMATION, KETTLEMAN HILLS.

PLATE 21

DIATOMS FROM THE SAN JOAQUIN FORMATION

FIGURE 1. *Coscinodiscus obscurus* Schmidt. U. S. G. S. diatom catalog no. 1524–7, locality 1051. Diameter 0.118 mm.
2. *Coscinodiscus kurzii* Grunow. U. S. G. S. diatom catalog no. 1630–3, locality 1052. Diameter 0.105 mm.
3. *Coscinodiscus asteromphalus* Ehrenberg. U. S. G. S. diatom catalog no. 1508–4, locality 1057. Diameter 0.170 mm.
4. *Coscinodiscus cirrus* Lohman, n. sp. Holotype: U. S. G. S. diatom catalog no. 1630–1, locality 1052. Diameter 0.121 mm.
5. *Coscinodiscus excentricus* Ehrenberg. U. S. G. S. diatom catalog no. 1630–2, locality 1052. Diameter 0.066 mm.
6. *Coscinodiscus subtilis* Ehrenberg. U. S. G. S. diatom catalog no. 1507–1, locality 1054. Diameter 0.071 mm.

PLATE 22

DIATOMS FROM THE SAN JOAQUIN FORMATION

FIGURE 1. *Actinocyclus ehrenbergii* Ralfs. U. S. G. S. diatom catalog no. 1630–4, locality 1052. Diameter 0.063 mm.

2. *Stephanopyxis corona* (Ehrenberg) Grunow. U. S. G. S. diatom catalog no. 1524–6, locality 1051. Diameter 0.037 mm.

3. *Actinoptychus undulatus* Ehrenberg. U. S. G. S. diatom catalog no. 1524–4, locality 1051. Diameter 0.065 mm.

4. *Epithemia turgida* (Ehrenberg) Kützing. U. S. G. S. diatom catalog no. 1524–8, locality 1051. Length, 0.091 mm, width 0.019 mm.

5. *Rhaphoneis fatula* Lohman, n. sp. Holotype: U. S. G. S. diatom catalog no. 1508–3, locality 1057. Length 0.046 mm, width 0.008 mm.

6. *Rhaphoneis angularis* Lohman, n. sp. Holotype: U. S. G. S. diatom catalog no. 1524–1, locality 1051. Length 0.142 mm, width 0.020 mm.

7. *Rhaphoneis angularis* Lohman, n. sp. Paratype: U. S. G. S. diatom catalog no. 1524–2, locality 1051. Length 0.119 mm, width 0.020 mm.

8. *Rhaphoneis angularis* Lohman, n. sp. Paratype: U. S. G. S. diatom catalog no. 1524–3, locality 1051. Length 0.066 mm, width 0.020 mm.

9. *Hemidiscus ovalis* Lohman, n. sp. Holotype: U. S. G. S. diatom catalog no. 1508–1, locality 1057. Length 0.028 mm, width 0.021 mm.

10. *Nitzschia granulata* Grunow. U. S. G. S. diatom catalog no. 1522–1, locality 1056. Length 0.038 mm, width 0.016 mm.

11. *Nitzschia navicularis* Grunow. U. S. G. S. diatom catalog no. 1524–9, locality 1051. Length 0.033 mm, width 0.012 mm.

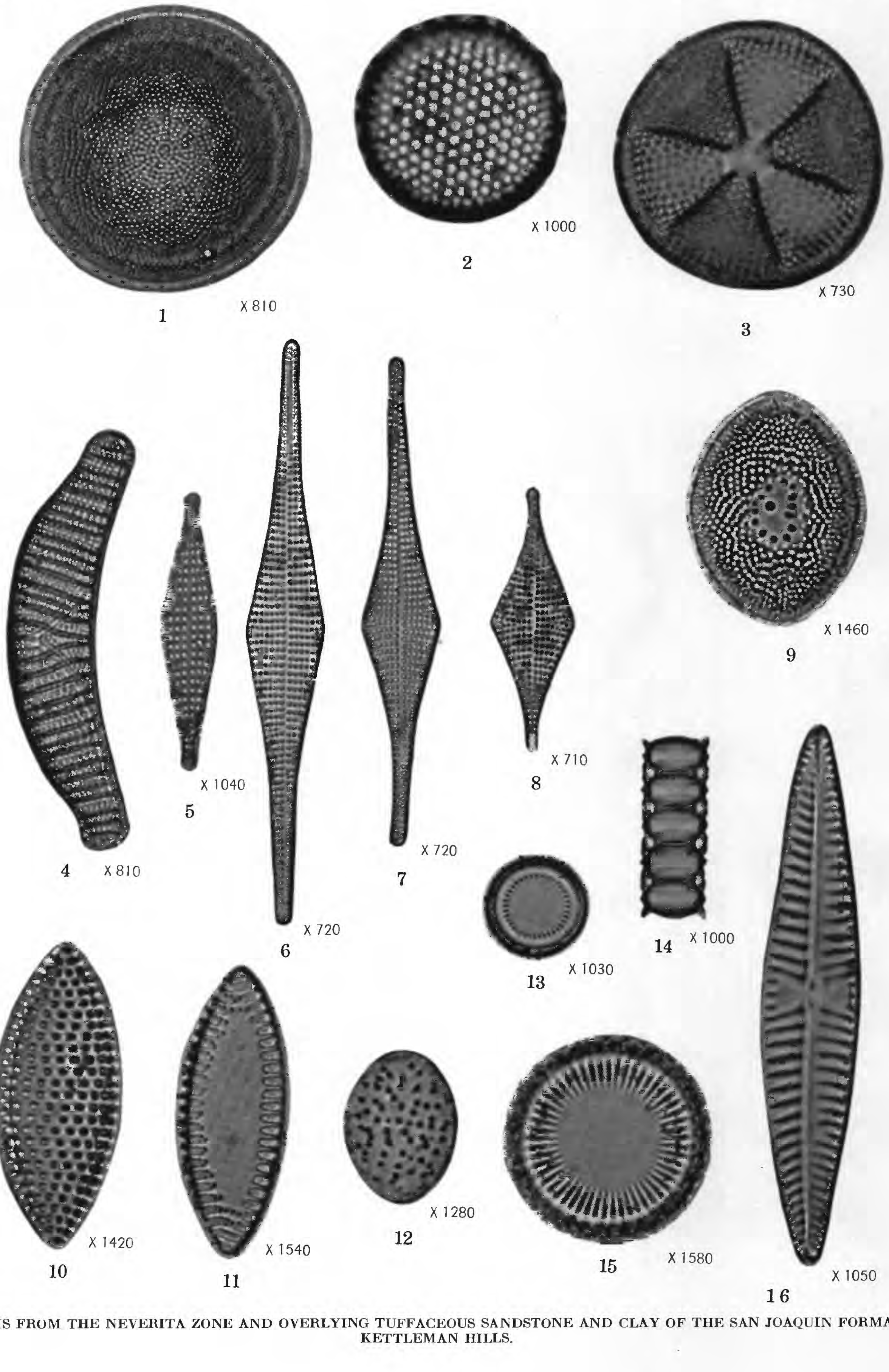
12. *Xanthiopyxis ovalis* Lohman, n. sp. Holotype: U. S. G. S. diatom catalog no. 1517–1, locality 1051. Length 0.021 mm, width 0.015 mm.

13. *Melosira recedens* Schmidt. Valve view. U. S. G. S. diatom catalog no. 1522–3, locality 1056. Diameter 0.017 mm.

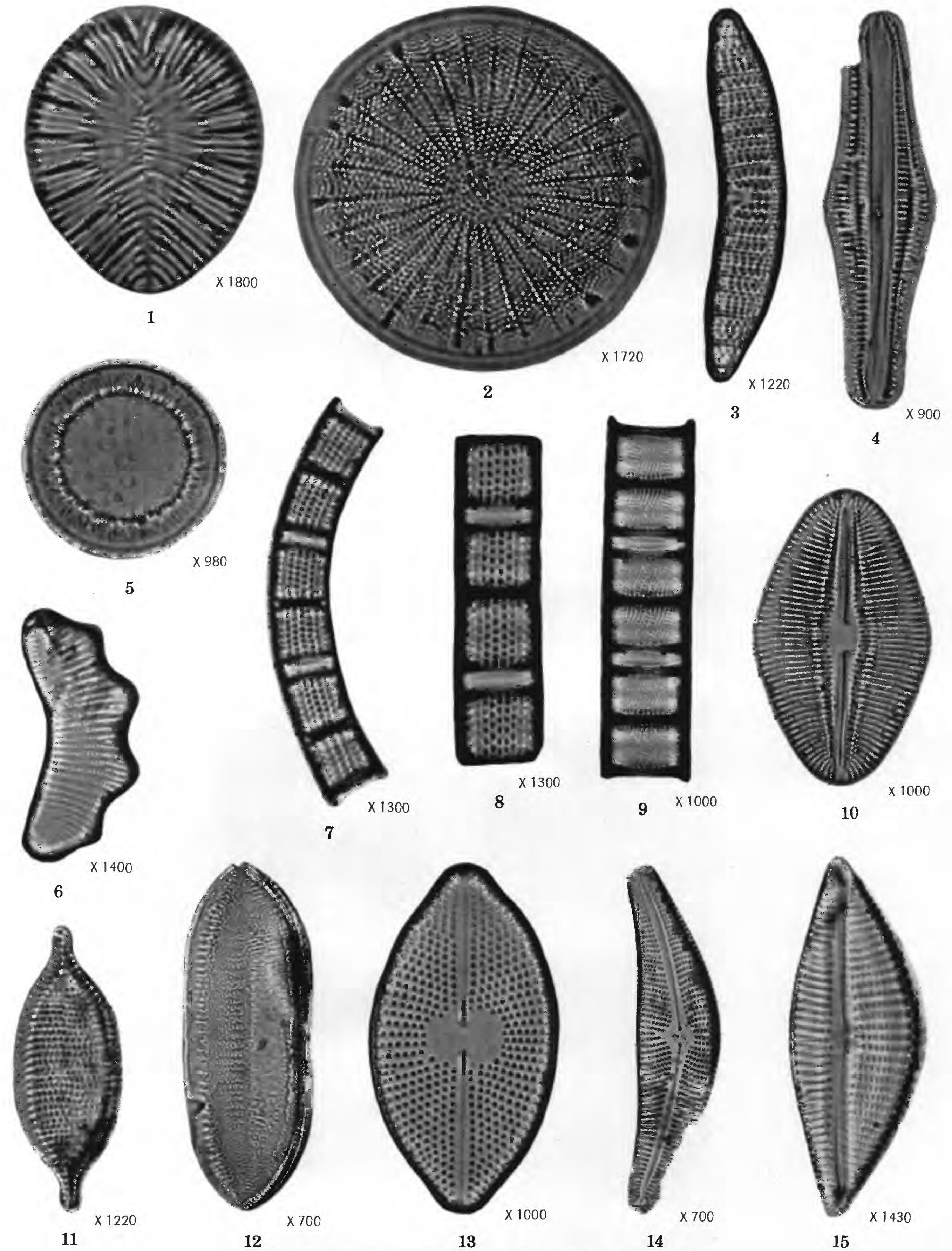
14. *Melosira recedens* Schmidt. Zone view, five frustules. U. S. G. S. diatom catalog no. 1522–2, locality 1056. Diameter 0.011 mm, length, over all, 0.032 mm.

15. *Melosira sulcata* (Ehrenberg) Kützing. U. S. G. S. diatom catalog no. 1524–5, locality 1051. Diameter 0.023 mm.

16. *Navicula pennata* Schmidt. U. S. G. S. diatom catalog no. 1507–2, locality 1054. Length 0.090 mm, width 0.017 mm.



DIATOMS FROM THE NEVERITA ZONE AND OVERLYING TUFFACEOUS SANDSTONE AND CLAY OF THE SAN JOAQUIN FORMATION, KETTLEMAN HILLS.



DIATOMS FROM THE TULARE FORMATION, KETTLEMAN HILLS.

PLATE 23

DIATOMS FROM THE TULARE FORMATION

FIGURE 1. *Surirella utahensis* Grunow. U. S. G. S. diatom catalog no. 1520–4, locality 1053. Length 0.030 mm, width 0.024 mm.

2. *Stephanodiscus carconensis* Grunow. U. S. G. S. diatom catalog no. 1602–5, locality 838. Diameter 0.040 mm.
3. *Epithemia zebra* (Ehrenberg) Kützing var. *saxonica* (Kützing) Grunow. U. S. G. S. diatom catalog no. 1520–3, locality 1053. Length 0.058 mm, width 0.010 mm.
4. *Rhopalodia gibba* (Ehrenberg) Müller. U. S. G. S. diatom catalog no. 1512–1, locality 1061. Length 0.083 mm, width 0.022 mm.
5. *Hyalodiscus schmidtii* Frenguelli. U. S. G. S. diatom catalog no. 1518–1, locality 1053. Diameter 0.039 mm.
6. *Eunotia robusta* Ralfs var. *tetraodon* (Ehrenberg) Ralfs. U. S. G. S. diatom catalog no. 1602–7, locality 838. Length 0.034 mm, width 0.011 mm.
7. *Melosira granulata* var. *curvata* Grunow. U. S. G. S. diatom catalog no. 1602–3, locality 838. Diameter 0.009 mm.
8. *Melosira granulata* (Ehrenberg) Ralfs. U. S. G. S. diatom catalog no. 1602–2, locality 838. Length (two frustules) 0.047 mm, diameter 0.013 mm.
9. *Melosira ambigua* (Grunow) Muller. U. S. G. S. diatom catalog no. 1602–4, locality 838. Length (two frustules and two valves) 0.069 mm; diameter 0.016 mm.
10. *Diploneis smithii* (Brebisson) Cleve. U. S. G. S. diatom catalog no. 1518–2, locality 1053. Length 0.060 mm, width 0.033 mm.
11. *Nitzschia punctata* (W. Smith) Grunow. U. S. G. S. diatom catalog no. 1602–11, locality 838. Length 0.045 mm, width 0.017 mm.
12. *Nitzschia etchegoinia* Hanna and Grant. U. S. G. S. diatom catalog no. 1520–5, locality 1053. Length 0.096 mm, width 0.034 mm.
13. *Navicula marina* Ralfs. U. S. G. S. diatom catalog no. 1519–1, locality 1053. Length 0.066 mm, width 0.035 mm.
14. *Cymbella mexicana* (Ehrenberg) Cleve. U. S. G. S. diatom catalog no. 1520–2, locality 1053. Length 0.095 mm, width 0.023 mm.
15. *Cymbella prostrata* (Berkeley) Cleve. U. S. G. S. diatom catalog no. 1602–9, locality 838. Length 0.048 mm, width 0.017 mm.

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