Foraminifera of the Monterey Shale and Puente Formation, Santa Ana Mountains and San Juan Capistrano Area, California

GEOLOGICAL SURVEY PROFESSIONAL PAPER 294-M

Smith—FORAMINIFERA OF MONTEREY SHALE AND PUENTE FORMATION, CALIF.—Geological Survey Professional Paper 294–M

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By PATSY BECKSTEAD SMITH

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1960

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price 40 cents (paper cover)

CONTENTS

ILLUSTRATIONS

TABLES

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

FORAMINIFERA OF THE MONTEREY SHALE AND PUENTE FORMATION, SANTA ANA MOUNTAINS AND SAN JUAN CAPISTRANO AREA, CALIFORNIA

By Patsy Beckstead Smith

ABSTRACT

In the Santa Ana Mountains and San Juan Capistrano area, Orange County, Calif., thick sections of Miocene sedimentary rocks are exposed. They are assigned to the Monterey shale of middle and late Miocene age and the Puente formation of late Miocene age. The area described is divided into four geographic units: the northern and central Santa Ana Mountains, the southwestern Santa Ana Mountains, the area east of Oso Creek (east flank of the Capistrano syncline), and the area west of Oso Creek (west flank of the Capistrano syncline). The faunal assemblages of each area are compared with those of the California Miocene stages proposed by Kleinpell (1938).

In the Santa Ana Mountains, the Topanga formation (Relizian(?) stage) and the El Modeno volcanics (Luisian stage) are overlain unconformably by the Puente formation (Mohnian stage).

On the east flank of the Capistrano syncline, south of the El Toro Air Station, the Topanga formation is overlain by the Monterey shale, which ranges in age from late Luisian at the base to Mohnian at the top.

To the west of Oso Creek, the Topanga formation is overlain by the Monterey shale which ranges in age from early Luisian at the base to late Luisian and Mohnian at the top.

Changes in thicknesses of rocks assigned to the Luisian and Mohnian stages are due to unconformities and local depositional variations. No evidence was found to indicate that foraminiferal faunas assigned to the Mohnian stage grade laterally into faunas of the Luisian stage.

INTRODUCTION

The U.S. Geological Survey carried on oil and gas investigations in and near the Santa Ana Mountains, Orange County, Calif. (index map, fig. 155), from 1949 to 1955, and during this time, many hundred foraminiferal samples from this area were collected and examined. This report is a result of a study of Foraminifera of the Monterey shale and Puente formation. The stratigraphic and geographic distribution of the Foraminifera is discussed.

Foraminiferal samples were collected by D. M. Kinney, J. E. Schoellhamer, R. F. Yerkes, J. G. Vedder, and the author, all of the U.S. Geological Survey. The localities sampled are shown on the accompanying maps (figs. 155 and 156) and are described on p. 488–490. The maps also show areas of outcrop of upper middle and upper Miocene rocks and the locations of test wells and core holes that were used in constructing the structure section and that were sampled for Foraminifera. These wells and core holes are listed in table 1.

Table 1.—*Test wells and core holes sampled and measured*

Well No. (on maps)	*Operator and name of well*	*Location*	*Elevation (feet)*	*Total depth (feet)*
1	Shell Oil Co., Moulton contraflush No. 31	West of Aliso Creek, Capistrano area (fig. 156)	330	728
2	Shell Oil Co., Moulton core hole No. 14	Between Aliso and Oso Creeks (figs. 156, 157; table 7).	190	2, 723
3	Shell Oil Co., Moulton contraflush No. 35	Oso Creek, Capistrano area (fig. 156)	311	895
4	Shell Oil Co., Mission contraflush No. 36	Between Oso Creek and Arroyo Trabuco (fig. 156)	446	799
5	Shell Oil Co., Mission contraflush No. 37	Between Oso Creek and Arroyo Trabuco (fig. 156)	684	698
6	Shell Oil Co., Mission contraflush No. 38	Arroyo Trabuco (figs. 156, 157; table 7)	462	766
7	McKee Oil Co., Kokx Community No. 8-1	Southwest of Burruel Ridge (fig. 155)	280	4, 005
8	Rubicon Oil Co., Wilcox No. 1	South of Santa Ana River (figs. 155 and 157)	450	6, 324
9	G. D. Murdoch, Howell No. 1	South of Santa Ana River (fig. 155)	308	4, 370
10	Shell Oil Co., Moulton contraflush No. 32	West of Aliso Creek (fig. 156 and table 9)	165	623

ACKNOWLEDGMENTS

Valuable information provided by G. H. Doane and M. W. Hurley of the Shell Oil Co., M. L. Natland and W. T. Rothwell of the Richfield Oil Corp., and W. H. Holman of the Standard Oil Co. of California is gratefully acknowledged. R. M. Kleinpell of the University of California at Berkeley gave helpful advice and assisted on taxonomic problems. The Jones microsplitter used in preparing samples was borrowed from the California Institute of Technology.

PREVIOUS WORK

Published reports on Foraminifera of Miocene age from this area are very brief and consist chiefly of stratigraphic sections and correlations with more thoroughly studied faunas in other parts of California. Reed and Hollister (1936, p. 114–124) discuss the distribution of Miocene sedimentary rocks in the Los Angeles basin and give columnar stratigraphic sections of the Tertiary rocks of the Santa Ana Mountains and San Joaquin Hills. Kleinpell (1938, p. 124–127) mentions the presence of rocks of middle and upper Miocene age in the Santa Ana Mountains and in the Laguna Beach area.

PREPARATION OF SAMPLES

Samples from 59 localities and three core holes (figs. 155 and 156, and locality list, p. 488–490) were studied. Surface samples were collected, where possible, in stratigraphic sequence. Where systematic sampling was not possible, samples were arranged in stratigraphic sequence on the basis of available geologic information.

No uniform method was used in collecting surface samples, and no consistent attempt was made to sample only a single stratigraphic interval or to take equal amounts of material from each locality. Approximately 150 ml of each sample was washed. Composite samples of 20- to 30-foot intervals were taken in core holes, and 150 ml of material was washed. The material from each sample was washed on 150-mesh screens (0.105 mm openings); the residue was then dried and concentrated by flotation in carbon tetrachloride. Care was taken throughout the operation to avoid contamination. Most samples were not examined before washing and it is possible that some forms such as the upper Mohnian guide, *Cassidulinella renulinaformis* Natland, may have been missed. However, in those samples which were examined unwashed, no forms were noted which were not seen in the washed sample.

The washed and floated samples were then split with a Jones microspliter as described by Otto (1933) until a fraction containing 150 to 200 individuals remained. This commonly required 6 to 10 splits of the original sample. The specimens in the final fraction were then mounted systematically on slides. The remaining portion of the washed sample was examined for species not found in the final split, and specimens of any rare species found were mounted separately.

Tables showing distribution (Nos. 3–9) were prepared from these slides, with samples listed as nearly possible in stratigraphic sequence. The percentage of each species present is represented by a symbol. Total population was calculated on the basis of the number of splits and is given on the table of distribution for each sample.

Some forms were found which, because of poor preservation or a slight difference from the typical form, could not be positively referred to a described species. If these variants appeared to have stratigraphic significance, such as *Nonion* aff. *N. costiferum* (table 3) they were listed separately on the distribution tables. However, if the variant lacked stratigraphic significance, it was included with the typical form, with its aberrant nature indicated by cf. after the abundance symbol. All such variations from typical forms are discussed in the systematic part of this paper.

GENERAL GEOLOGY

STRATIGRAPHY

The marine sedimentary rocks of the northern and central Santa Ana Mountains (fig. 155) range in age from Triassic to Pliocene (Woodford and others, 1955).

Middle and late Miocene time is represented in the Santa Ana Mountains and the San Juan Capistrano area by thick sequences of marine sandstones, siltstones, and shales. The oldest formation discussed in this report is the Topanga formation, which contains typical middle Miocene molluscan faunas. The Topanga formation, consisting almost entirely of sandstone, is present in nearly the entire area.

Locally in the San Juan Capistrano area, the Topanga formation is overlain by remnants of the San Onofre breccia of middle Miocene age. The Topanga formation and the San Onofre breccia are overlain by the Monterey shale. The Monterey, containing rich foraminiferal faunas, is late middle and late Miocene in age, and consists of diatomaceous shales and siltstones.

In the Santa Ana Mountains, the El Modeno volcanics of late middle Miocene age (Yerkes, 1957) locally overlie the Topanga formation. The Puente formation of late Miocene age rests unconformably on the Topanga formation and the El Modeno volcanics. The Puente formation has been divided into four members (Schoellhamer and others, 1954). The lowest member, the La Vida, is predominantly siltstone, and in most places grades upward into the Soquel member, which is largely sandstone. The Soquel member on Burruel Ridge appears to be a large lens which pinches

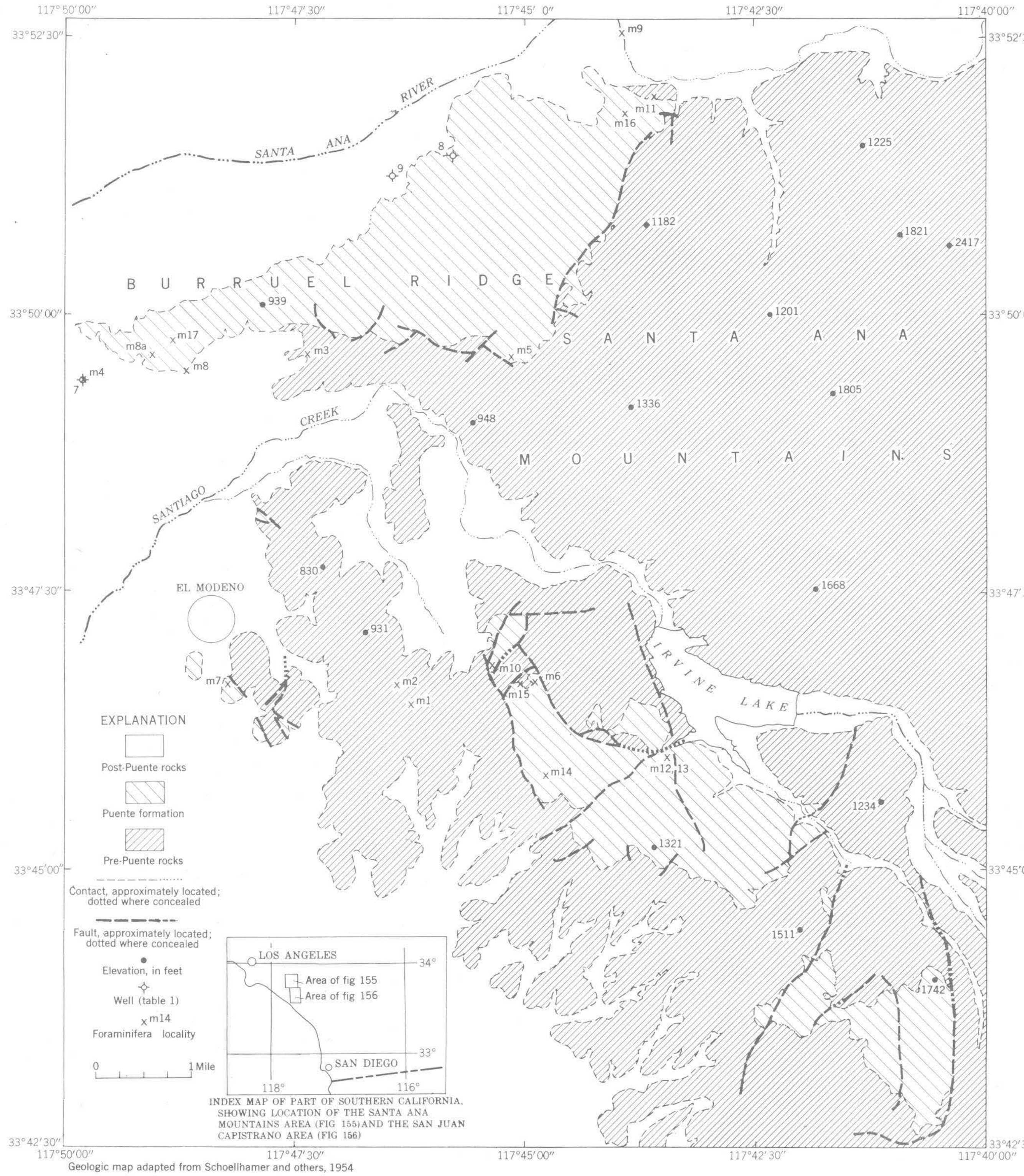


FIGURE 155.—Index map and map showing distribution of the Puente formation in the Santa Ana Mountains.

out to the west and east. Overlying the Soquel member is the Yorba member (siltstone), and locally above this is the Sycamore Canyon member. The La Vida and Soquel members of the Puente formation are present in the syncline south of Irvine Lake.

Along the southwest margin of the Santa Ana Mountains, east of El Toro Air Station, strata assigned to the Puente formation include the La Vida member and the overlying Soquel member. Southeast of the air station the Soquel member is no longer present and the La Vida member becomes indistinguishable from rocks referred to the Monterey shale in this study (fig. 156).

Overlying the older rocks in the Capistrano-El Toro area is the Capistrano formation, of late Miocene to early Pliocene age. On the east limb of the Capistrano syncline, the Capistrano formation is conformable on the Monterey shale, and on the west limb, it is unconformable on the older rocks.

STRUCTURE

The marine sedimentary rocks of the Santa Ana Mountains (fig. 155) range in age from Triassic to Pliocene and are deformed into an intensely faulted westward-plunging anticline. This anticline is bordered on the southwest by a shallow syncline, in which the Puente formation is exposed south of Irvine Lake. Still farther south, southeast of El Toro Air Station, Miocene and Pliocene sedimentary rocks are exposed on the east and west limbs of the southward-plunging Capistrano syncline (fig. 156a). The east limb of this syncline is cut by the northward-trending Cristianitos fault. In general, the rocks to the east of this fault are older than middle Miocene. West of the Capistrano syncline, at the east edge of the San Joaquin Hills, early middle Miocene and older rocks are exposed in the core of a large faulted anticline.

FAUNAS

MIOCENE FORAMINIFERAL STAGES OF KLEINPELL (1938)

Kleinpell (1938) subdivided the Miocene of California into six stages, which from older to younger are: Zemorrian, Saucesian, Relizian, Luisian, Mohnian, and Delmontian (table 2). Each of these stages is "a stratal unit independent of lithologic and faunal facies" (Kleinpell, 1938, p. 90), and thus represents a true "time-stratigraphic unit." Each stage is composed of several faunal zones. Each zone is characterized by an assemblage of Foraminifera of which one abundant and characteristic form is chosen as guide, and for which the zone is named.

In and near the Santa Ana Mountains and San Juan Capistrano area the foraminiferal zones differ somewhat from those defined by Kleinpell. There is enough similarity, however, to permit use of the Kleinpell stage and zone names. Table 2 lists, in accordance with Kleinpell's nomenclature, the stages and zones found to be present in the Santa Ana Mountains and San Juan Capistrano area. Miocene stages represented in the Santa Ana Mountains and San Juan Capistrano area include the Relizian(?), Luisian, and Mohnian.

MIOCENE STAGES OF THE SANTA ANA MOUNTAINS AND SAN JUAN CAPISTRANO AREA

RELIZIAN(?) STAGE

The Topanga formation exposed on the west flank of the Santa Ana Mountains contains a fauna that is probably Relizian. Foraminifera are abundant but belong to only a few species, including *Bolivina advena* var., *Nonion costiferum*, *N.* aff. *N. costiferum*, and *Valvulineria depressa*. This fauna is best represented in the Burruel Ridge area. It is assigned to the Relizian stage because the fauna is not unlike the Relizian faunas described by Kleinpell (1938, p. 121), and because the rocks containing the fauna underlie rocks assigned to the Luisian stage. The Relizian(?) faunas differ greatly from those of all the overlying rocks.

LUISIAN STAGE

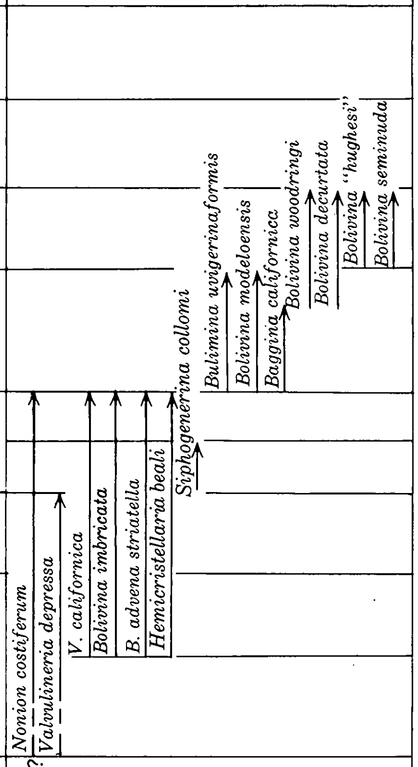
The Luisian stage is characterized by abundant Siphogenerinas (present only locally in this region), *Valvulineria californica* s.s. and varieties, *Nonion costiferum*, and *Bolivina advena* var. *striatella* (Kleinpell, 1938, p. 122–126).

Siphogenerina reedi *zone*.—The lower part of the Luisian stage typically contains *Valvulineria depressa* and *Bulimina pseudotorta*. In the San Juan Capistrano area it is characterized by *V. depressa*. This is the highest occurrence of *V. depressa*. The zone is represented only on the west limb of the Capistrano syncline (table 8).

Siphogenerina collomi *zone*.—Kleinpell divides the upper part of the Luisian stage into the *Siphogenerina nuciformis* zone and the *S. collomi* zone. Type specimens of these two *Siphogenerina* species were examined, and no satisfactory distinction could be made between them (p. 485). None of the other distinctions between these two zones of Kleinpell can be recognized in this area. Therefore, the *Siphogenerina collomi* zone as described in this report includes the interval between the top of the lower Luisian stage and the base of the Mohnian stage. The zone is best represented on the west limb of the Capistrano syncline where rocks of the *Siphogenerina collomi* zone are conformable on beds assigned to the *S. reedi* zone (table 8).

Typically, the upper part of the Luisian stage is characterized by *Siphogenerina collomi*, abundant *Valvulineria californica* s.s. and varieties, the highest occurrence of *Hemicristellaria beali*, *Nonion costiferum*, and *Bolivina imbricata* (Kleinpell, 1938, p. 125, 127). The zone in the Santa Ana Mountains region is characterized by an abundance of *Valvulineria californica* and varieties, "*Uvigerinella*" *californica*, *Bulimina montereyana*, *Bolivina imbricata*, *Nonion costiferum*, and *Hemicristellaria beali.*

TABLE 2.—*Stages and foraminiferal zones of the Miocene of California (after Kleinpell, 1938), correlatives in the Santa Ana Mountains and San Juan Capistrano area, and index Foraminifera*

Series		Stages and zones defined by Kleinpell (1938): Stage		Zone	Zones present in Santa Ana Mountains	Zones present in San Juan Capistrano area	Index Foraminifera in the Santa Ana Mountains San Juan Capistrana area
MIOCENE	UPPER	Delmontian	Upper				
			Lower	*Bolivina obliqua*			
		Mohnian	Upper	*Bolivina hughesi*	*Bolivina hughesi*	(Not known to be present)	
			Lower	*Bulimina uvigerinaformis*	*Bulimina uvigerinaformis*	*Bulimina uvigerinaformis*	
				Bolivina modeloensis			
	MIDDLE	Luisian	Upper	*Siphogenerina collomi*	*Siphogenerina collomi*	*Siphogenerina collomi*	
				Siphogenerina nuciformis			
			Lower	*Siphogenerina reedi*		*Siphogenerina reedi*	
		Relizian	Upper	*Siphogenerina branneri*	Rocks of Relizian age present, zone undetermined.		
			Lower	*Siphogenerina hughesi*			
	LOWER	Saucesian	Upper	*"Uvigerinella" obesa*	Rocks of this age not studied for this report.		
			Lower	*Plectofrondicularia miocenica*			
				Siphogenerina transversa			
		Zemorrian	Upper	*"Uvigerinella" sparsicostata*			
			Lower	*Uvigerina gallowayi*			

MOHNIAN STAGE

The Mohnian stage is characterized by the predominance of the Buliminidae and by lack of the characteristic Luisian Lagenidae and Rotaliidae mentioned above.

Kleinpell divided the Mohnian stage into three zones: two lower, the *Bolivina modeloensis* zone and the *Bulimina uvigerinaformis* zone; and an upper, the *Bolivina hughesi* zone.

Paleontologists working in the Los Angeles basin have replaced Kleinpell's zones with slightly different divisions, called "lower", "middle", and "upper" Mohnian. Lower Mohnian is marked by the occurrence of *Baggina californica*, *Epistominella gyroidinaformis*, *Bolivina modeloensis*, and *Bulimina uvigerinaformis.* The highest occurrence of this assemblage is considered the top of the "lower" Mohnian. "Middle" Mohnian is marked by *Bulimina uvigerinaformis* without the three other forms of the lower. "Upper" Mohnian is marked by *Bolivina "hughesi"* (*B. benedictensis* of Pierce, 1956). In the absence of *Bolivina "hughesi"* (and *Bulimina uvigerinaformis*), *Bolivina woodringi* and *B. decurtata* are considered indicative of "upper" Mohnian, although the ranges of these two forms do extend down into the *Bulimina uvigerinaformis* zones.

This revised zonation is based on the fact that *Bulimina uvigerinaformis* ranges higher than the rest of the forms which characterize the lower Mohnian stage of Kleinpell, and therefore, *B. uvigerinaformis* actually characterizes two Mohnian zones.

In this paper the two lower zones defined by Kleinpell are combined to form the *Bulimina uvigerinaformis* zone.

Bulimina uvigerinaformis *zone.*—Kleinpell (1938, p. 129) divides the lower Mohnian stage into two zones in the type area in the Santa Monica Mountains. In the Santa Ana Mountains, forms which normally characterize the *Bolivina modeloensis* zone (*B. modeloensis*, *Eponides rosaformis*) occur in samples along with *Bulimina uvigerinaformis.* The *B. uvigerinaformis* zone is here considered to include the interval from the top of the Luisian stage to the base of the upper Mohnian stage. Species characteristic of the lower Mohnian stage in this area are *B. uvigerinaformis*, *Eponides rosaformis*, *Baggina californica*, *Valvulineria* cf. *V. grandis*, and the highest occurrence of *Epistominella gyroidinaformis.* The zone containing these species is best developed in the northern Santa Ana Mountains.

Bolivina hughesi *zone.*—The upper Mohnian *Bolivina hughesi* zone (Kleinpell, 1938, p. 130) is typically characterized by the restricted occurrence of *B.* "*hughesi*," *B. bramlettei*, *B. girardensis*, and by the highest occurrence of *B. californica* and *B. decurtata.* This zone is poorly developed in the Santa Ana Mountains. Forms like *Bolivina hootsi* and *B. girardensis*, which normally characterize the zone, have more extended ranges here. *B.* "*hughesi*" is rare. Only on Burruel Ridge can this zone be distinguished (table 3).

GEOGRAPHIC DIVISIONS

Because of rapid lateral facies changes in the Miocene rocks, the region covered by this report is divided into four areas to facilitate discussion of the faunas. These areas are (1) the northern and central Santa Ana Mountains, (2) the southwestern Santa Ana Mountains, (3) the area east of Oso Creek, and (4) the area west of Oso Creek. For each of these areas, the stratigraphic succession and faunal zonation were defined independently; lists of faunal distribution were prepared for each (tables 3–9).

NORTHERN AND CENTRAL SANTA ANA MOUNTAINS

Localities m1 to m4, in the Topanga formation, contain faunas which differ from those found in the overlying units and are in beds containing *Turritella ocoyana* Conrad. They are questionably assigned to the Relizian stage.

Locality m5 is in a claystone bed that rests on the basal member of the El Modeno volcanics. The overlying members of the volcanic sequence that are present farther south have been removed here, and the claystone is immediately overlain by the La Vida member of the Puente formation. At this locality, it is difficult to ascertain whether this claystone is associated with the volcanic rocks or with the Puente formation, but farther south similar claystones are intercalated with the volcanic rocks. Its fauna is certainly very different from any found in the Puente formation. A very similar but better preserved fauna was found east of the mapped area, in rocks questionably assigned to the Topanga formation. The presence of abundant *Nonion costiferum* and *Valvulineria californica* var. *obesa*, and the lack of upper Miocene Bolivinas indicate strongly that the faunas should be referred to the Luisian stage. The presence of abundant *Epistominella gyroidinaformis* and the rare occurrence of *Bulimina* cf. *B uvigerinaformis* place these faunas near the the upper limit of the Luisian stage.

Faunas of probable Luisian age occur at depths of 4,011 to 4,031 feet in the G. D. Murdoch Howell No. 1 (well 9, fig. 155) just south of the Santa Ana River. These faunas appear to be from the top of the Topanga formation.

Samples m6 to m14 are from the La Vida member of the Puente formation. The La Vida belongs entirely to the *Bulimina uvigerinaformis* zone of the Mohnian stage.

Samples m16 and m17 were collected where the Soquel member has pinched out and are probably from the Yorba member of the Puente formation. They are assigned to the *Bolivina hughesi* zone of the Mohnian stage.

No determinable Foraminifera were obtained from the Soquel or the Sycamore Canyon members of the Puente formation, but crushed forms are seen on bedding planes and on weathered surfaces of calcareous concretions.

The localities in the Santa Ana Mountains represented in table 3 are widely dispersed and the relative stratigraphic position of many of them (fig. 155) is uncertain. It is clear that several fairly well defined zones are present, but no thicknesses can be given. Rocks of Relizian (?) age have not yet been thoroughly studied here, and rocks of Luisian age have a small areal extent. The major part of the samples from this area that were examined are from the Puente formation of Mohnian age. Zonation of rocks of Mohnian age, following Kleinpell's usage, is shown in table 3.

TABLE 3.—*Distribution of Foraminifera in rocks of middle and late Miocene age from the northern Santa Ana Mountains*

[Numbers indicate percent of total population of locality: ·, <1; \, 1-3; †, 4-6; ×, 7-10; ○, 11-15; ⊖, 16-20; ⊗, 21-30; ◑, 31-40; ●, 41-60; ⊠, 61-80; ■, 81-100; cf., see p. 464]

Species (arranged in order of lowest occurrence)	Localities (arranged in approximate stratigraphic order)																			
	Middle Miocene					Upper Miocene														
	Topanga formation				El Modeno volcanics	Puente formation														
	Relizian(?) stage				Lower Luisian stage	Lower Mohnian stage												Upper Mohnian stage		
	m1	m2	m3	m4	m5	m6	m7	m8	m8a	m9	m10	m11	m12	m12a	m12b	m12c	m12d	m14	m16	m17
1. *Bolivina advena* var.	⊠	⊠	■																	
2. *Nonion* aff. *N. costiferum*	×	⊗	†	⊖																
3. *Nonion costiferum*	⊖																			
4. *Buliminella curta*	\			×					\	\			\	\		\	\			†
5. *Buliminella subfusiformis*	×		\	⊠	○		○	†	\	⊖			\	\	†	\			·	×
6. *Epistominella?* sp.			\																	
7. *Suggrunda kleinpelli*				\								·				\				
8. *Bolivina tumida*				\	⊖														·	
9. *Bolivina decurtata*				\cf.	⊗	⊖	\			⊗		\		\	\			⊖		⊗
10. *Bolivina* cf. *B. subadvena*				·													\			
11. *Valvulineria depressa*				†																
12. *Bolivina sinuata* var. *alisoensis*					\	×		†				·	\							
13. *Bulimina montereyana*					⊗					⊗cf.										
14. *Valvulineria californica* var. *obesa*					○															
15. *Epistominella gyroidinaformis*					○															
16. *Nonion pizarrensis*					†				\cf.								\cf.			
17. *Epistominella relizensis*					○	†	†	○	×		\	·	⊖	⊖	×	\	×	\	·	\
18. *Bolivina* cf. *B. vaughani*						⊗	○	†	⊠			·	⊖	⊖	◑	◑		†	\	⊗
19. *Bolivina marginata* var. *gracillima*						\	\					·				\	\			
20. *Bolivina* cf. *B. decurtata*						×	\				†	·								⊗
21. *Buliminella ecuadorana*						○														
22. *Valvulineria* cf. *V. grandis*						\		\			\		†	×	\	\	\			
23. *Gyroidina* sp.						\			\		\									
24. *Bolivina* cf. *B. salinasensis*							\													
25. *Bolivina* cf. *B. subhughesi*							○	⊗					⊗	⊗	×	○	●			
26. *Virgulina californiensis*							\								◑	⊖				
27. *Bulimina uvigerinaformis*							×			\		·	\	\	\	\				
28. *Bulimina delreyensis*							×	\			\									
29. *Bulimina* cf. *B. pseudoaffinis*							⊗	×					×	†	†	†	†			
30. *Uvigerina subperegrina*							×cf.					·								\
31. *Globigerina bulloides*							○				⊗	■	†	⊖	\	†	×	●	■	
32. *Eponides rosaformis*							\	†					×	†	\	†	⊖			
33. *Bolivina californica*								⊖				\								
34. *Planulina ornata*								\												
35. *Bolivina obliqua*								\											·	
36. *Bolivina girardensis*								\	\											\
37. *Bolivina modeloensis*								\												
38. *Bolivina pseudospissa*									\cf.	\						\	\			
39. *Uvigerina joaquinensis*									\	◑	●									
40. *Bolivina woodringi*									\		×							×		×cf.
41. *Nonionella miocenica*											\									
42. *Bolivina brevior*													\	\						
43. *Bolivina barbarana*														\						
44. *Cassidulina cushmani*														\						
45. *Baggina californica*															†					
46. *Bolivina interjuncta* var. *bicostata*																\				
47. *Angulogerina* sp.																\				
48. *Hopkinsina magnifica*																		†		
49. *Gyroidina rotundimargo*																				\
Total population (rounded)	130,000	270,000	8,400	550	5,100	32,000	94,000	5,100	29,000	850	7,000	17,000	250,000	280,000	290,000	50,000	290,000	40,000	66,000	6,400

SOUTHWESTERN SANTA ANA MOUNTAINS

The upper Miocene faunas (table 4) of the southwestern Santa Ana Mountains have many anomalous features. Collections m18 and m19 contain forms characteristic of the Luisian stage, but also some forms typical of the Mohnian stage. These two samples were collected from a small outcrop of the Monterey shale isolated by complex faulting from the main part of the formation. The stratigraphic position of these samples is unknown, but faunally they appear to represent the upper part of the Luisian stage.

Samples m20 through m28 were collected on two traverses across the Puente formation (fig. 156). The stratigraphic positions of the samples from one of these traverses is shown in figure 157. Samples m20 to m28 are assigned to the lower Mohnian stage because of the presence of *Valvulineria* cf. *V. grandis*, *Epistominella gyroidinaformis*, and *Baggina californica*. Only one sample (m26) contains *Bulimina uvigerinaformis*.

AREA EAST OF OSO CREEK

Two tables of distribution (tables 5 and 6) were prepared from samples collected in the area east of Oso Creek. Table 5 was prepared from isolated outcrop samples and table 6 from the Shell Oil Co.'s Mission contraflush No. 38 (well 6, fig. 156 and table 1).

Widely dispersed outcrop samples could not be accurately correlated stratigraphically. The base of the Monterey shale in this area is not exposed at the surface, as the lower part of the Monterey is faulted out

TABLE 4.—*Distribution of Foraminifera in the Monterey shale and the Puente formation from the southwestern Santa Ana Mountains*

[Numbers indicate percent of total population of locality: ·, 1; \, 1-3; †, 4-6; ×, 7-10; ○, 11-15; ⊖, 16-20; ⊗, 21-30; ◑, 31-40; ●, 41-50; ⊠, 61-80; ■, 81-100; cf., see p. 464]

Species (arranged in order of lowest occurrence)	Localities (arranged in approximate stratigraphic order)										
	Middle Miocene		Upper Miocene								
	Luisian(?) stage		Lower Mohnian stage								
	m18	m19	m20	m21	m22	m23	m24	m25	m26	m27	m28
1. *Valvulineria williami*	\				\ cf.						
2. *Valvulineria californica* var. *obesa*	\										
3. *Valvulineria* cf. *V. grandis*	\				\	\			○	\	†
4. *Bolivina advena* var. *striatella*	†										
5. *Bolivina marginata* var. *gracillima*	†							\ cf.			
6. *Bolivina decurtata*	○	⊠	\	●	\ cf.	†			\ cf.		†
7. *Bolivina obliqua*	\										
8. *Bolivina tumida*	⊗		⊗		⊠	×		\	\		
9. "*Uvigerinella*" *californica* var	\		●				×				
10. *Nonion costiferum*	†										
11. *Virgulina californiensis*	†										
12. *Buliminella subfusiformis*	⊖	\									
13. *Buliminella curta*	†	†	○			■			†		◑
14. *Epistominella relizensis*	\	×					×	\			×
15. *Planulina ornata*	\	\									
16. *Cassidulina limbata*	\										
17. *Cassidulina* cf. *C. margareta*	\										
18. *Globigerina bulloides*	\	\						†	○	\	◑
19. *Bolivina interjuncta* var. *bicostata*	·								·	● cf.	
20. *Suggrunda kleinpelli*	×	†									⊗
21. *Cibicides* sp	·										
22. *Bolivina* cf. *B. woodringi*	·	\									
23. *Uvigerina subperegrina*	\	\	\					\	\	\ cf.	
24. *Gyroidina rotundimargo*	\										
25. *Bolivina barbarana*		\ cf.			\						
26. *Baggina californica*		\		\							
27. *Bolivina sinuata* var. *alisoensis*			†	†	\	\		\	\		
28. *Epistominella gyroidinaformis*				×							
29. *Epistominella pacifica*			†								
30. *Cibicides illingi*			\						·		
31. *Bolivina rankini*			\								
32. "*Uvigerinella*" *californica*				\							
33. *Buliminella ecuadorana*				⊗	×		⊠	■			
34. *Bolivina* cf. *B. decurtata*					†						
35. *Epistominella subperuviana*					\		\		·		
36. *Uvigerina joaquinensis*						\		\			
37. *Bolivina* cf. *B. vaughani*								\	●	×	
38. *Bulimina uvigerinaformis*									·		
39. *Angulogerina*? sp									\		
40. *Robulus smileyi*									·	◑	
41. *Bolivina pseudospissa*										×	
Total population (rounded)	31,000	51,000	51,000	19,000	130,000	20,000	8,800	2,800	42,000	510	28

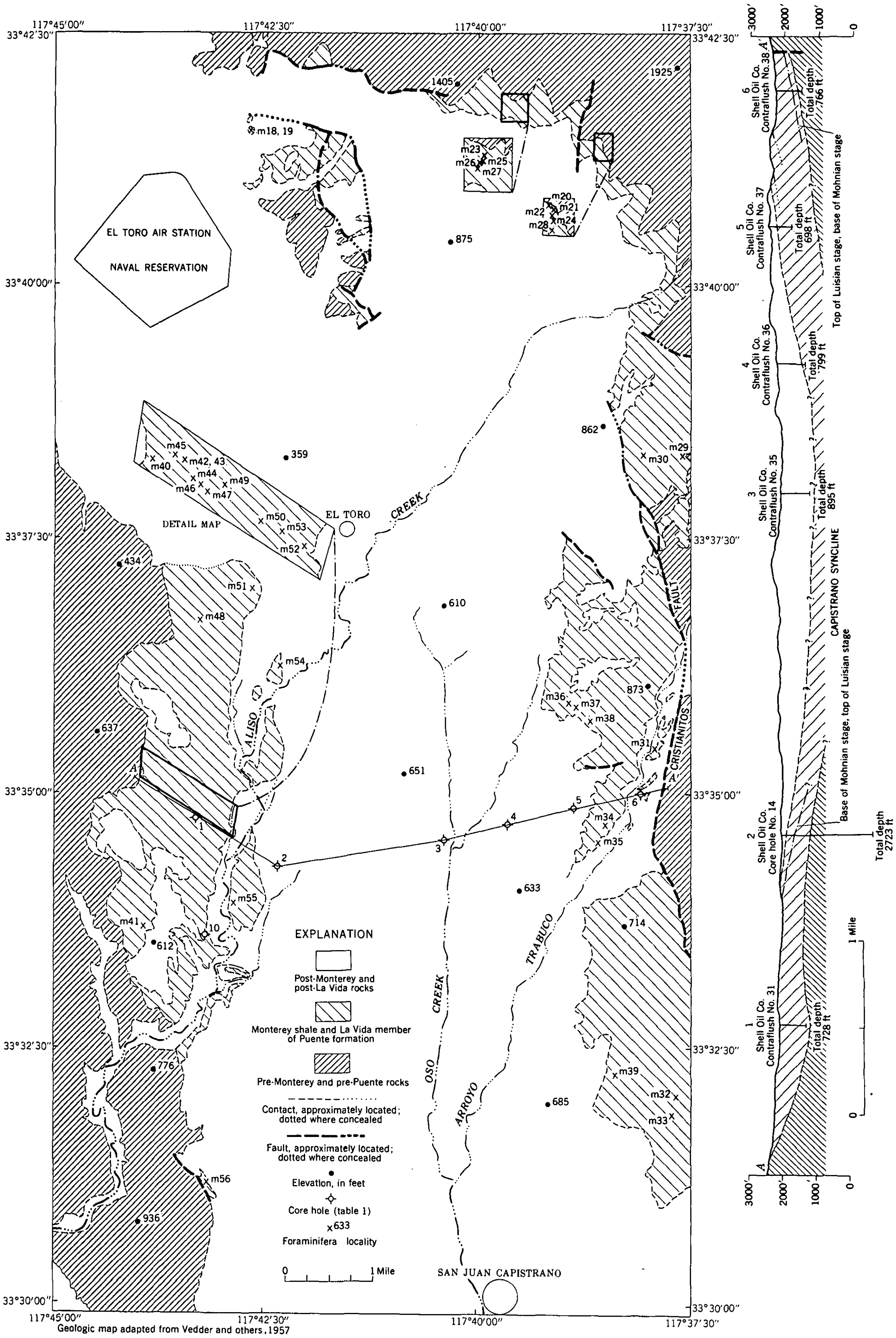


FIGURE 156.—Map of the Monterey shale and Puente formation in the San Juan Capistrano area and structure section across the Capistrano syncline.

by the Cristianitos fault. Two samples (m29 and m30) from the Monterey shale east of the Cristianitos fault contain good Luisian faunas (*Valvulineria californica* and *Nonion costiferum*). All the outcrop samples from west of the fault contain Mohnian faunas, probably lower Mohnian (*Baggina californica*, *Eponides rosaformis*, *Valvulineria* cf. *V. grandis*, and *Epistominella gyroidinaformis*).

The Shell Oil Co.'s Mission contraflush No. 38 (well 6) spudded in siltstone that is stratigraphically near the middle of the Monterey shale and bottomed in sandstone of the Topanga formation at a depth of 766 feet. Samples of Monterey shale from 633 feet to 543 feet contain a good upper Luisian *Siphogenerina collomi* zone fauna, including *S. collomi*, *Valvulineria miocenica*, *V. californica* and *Nonion costiferum.* From 543 feet to 103 feet, where coring began, the faunas are Mohnian in age. The presence of *Epistominella gyroidinaformis* and *Eponides rosaformis* from 543 to 243 feet indicates that this part of the section belongs to the lower Mohnian. Outcrop samples m34 to m38 (table 5) are all higher stratigraphically than the uppermost samples from contraflush No. 38.

Data from contraflush No. 38 indicate a thickness of about 90 feet for rocks of Luisian age, and about 543 feet for rocks of Mohnian age. Data from a structure section from the core hole westward to the contact between the Monterey shale and the Capistrano forma-

TABLE 5.—*Distribution of Foraminifera in Monterey shale from the area east of Oso Creek*

[Numbers indicate percent of total population of locality: ·, <1; \, 1-3; †, 4-6; ×, 7-10; ○, 11-15; ⊖, 16-20; ⊗, 21-30; ◑, 31-40; ●, 41-60; ⊠, 61-80; ■, 80-100; cf., see p. 464.]

Species (arranged in order of lowest occurrence)	Localities (arranged in approximate stratigraphic order)										
	Middle Miocene		Upper Miocene								
	Upper Luisian Stage		Lower Mohnian Stage								
	m29 [1]	m30	m31	m32	m33	m34	m35	m36	m37	m38	m39
1. *Bulimina montereyana*	●										
2. *Nonion costiferum*	◑	·									
3. *Nonionella miocenica*	×										
4. *Buliminella subfusiformis*	†	×	\	⊗	×	†	◑	\		†	
5. *Epistominella gyroidinaformis*	×	●									
6. *Bulimina carnerosensis*		\									
7. *Buliminella curta*		○	○	\	†	×	○	○	†		⊖
8. *Cibicides illingi*		†									
9. *Uvigerina joaquinensis*		×									
10. "*Uvigerinella*" *californica var.*		\									
11. *Valvulineria californica*		†									
12. *Bolivina sinuata* var. *alisoensis*		\	\								
13. *Bolivina tumida*		\									
14. *Bolivina marginata* var. *gracillima*		\									
15. *Virgulina californiensis*		·	†								◑
16. *Epistominella subperuviana*		\							\		
17. *Bolivina californica*		·									
18. *Bolivina rankini*			●	●	⊗	†	○		\	†	⊗
19. *Suggrunda kleinpelli*			×	×		\	\	\	·	†cf.	
20. *Bolivina* cf. *B. decurtata*			\								
21. *Epistominella relizensis*			†	\		×	†	⊗	⊖	†	
22. *Buliminella elegantissima*			\								
23. *Bolivina interjuncta* var. *bicostata*			\								
24. *Globigerina bulloides*			\	\	○		†				
25. *Cassidulina cushmani*			\								
26. *Bulimina* (*Desinobulimina*) sp			\								
27. *Bulimina* cf. *B. pseudoaffinis*			\								
28. *Bulimina uvigerinaformis*			\								
29. *Eponides rosaformis*			\								
30. *Bulimina ovula*			\								
31. *Bolivina decurtata*			\	\	\	●	\	●	◑	●	×
32. *Bolivina pseudospissa*			\	\		\	\				×
33. *Bolivina* cf. *B. vaughani*				⊖	●	×	×	†	◑	⊗	
34. *Uvigerina subperegrina*				\				\	·		
35. *Baggina californica*				†				\	·		
36. *Valvulineria* cf. *V. grandis*						†				\	
37. *Gyroidina rotundimargo*						†			\	\	
38. *Uvigerina hootsi*						\		\			
39. *Bolivina woodringi*							⊖	†cf.	†cf.		
40. *Planulina ornata*							·				
41. *Bolivina* cf. *B. seminuda*									·		
42. *Bolivina brevior*									\		
Total population (rounded)		540,000	200,000	260,000	48,000	31,000	240,000	160,000	23,000	22,000	13

[1] Limy sample, not washed, abundances estimated.

tion show an additional thickness of approximately 600 feet, giving a total thickness of about 1,200 feet of Monterey shale assigned to the lower Mohnian stage.

In this area, the overlying Capistrano formation contains Mohnian Foraminifera in its basal part, and Pliocene Foraminifera in its upper part.

AREA WEST OF OSO CREEK

The Monterey shale exposed west of Oso Creek consists of diatomaceous shale and siltstone, locally sharply folded, and containing abundant Foraminifera.

The check list (table 7) lists samples from Shell Oil Co.'s Moulton core hole No. 14 (well 2, table 1), which was spudded in the Capistrano formation. The samples are composite samples of 20-foot intervals.

The interval from 750 to 730 feet is probably assignable to the *Siphogenerina reedi* zone, as it contains *Valvulineria depressa*. From 730 to about 410 feet are faunas of the *Siphogenerina collomi* zone. The upper limit of this zone is poorly defined. The highest occurrence of *S. collomi*, *Hemicristellaria beali* and other Luisian forms is at 550 feet. However, *Valvulineria californica* var. *obesa* and *V. miocenica* are present up to 410 feet. From 410 to 210 feet (the topmost core sample) *Epistominella gyroidinaformis* and abundant *Eponides rosaformis* indicate the *Bulimina uvigerinaformis* zone.

This core hole is the only one in the area which penetrated a complete section of the Monterey shale. The lower Luisian is about 20 feet thick, the upper Luisian is about 320 feet thick, and the lower Mohnian is about 200 feet thick.

Table 8 is based on samples taken along a traverse across the Monterey shale, plus a few isolated samples (fig. 156). Locality m56 is in an isolated outcrop of the Monterey shale; its stratigraphic position is unknown. The Monterey shale exposed here is strongly folded, and samples were arranged as nearly as pos-

TABLE 6.—*Distribution of Foraminifera in Monterey shale from Shell Oil Co.'s Mission contraflush No. 38*

[Numbers indicate percent of total population of sample: ·, <1; \, 1–3; †, 4–6; ×, 7–10; ○, 11–15; ⊖, 16–20; ⊗, 21–30; ◑, 31–40; ●, 41–60; ⊠, 61–80; ■, 81–100, cf., see p. 464]

Species (arranged in order of lowest occurrence)	Core samples (depth interval in feet)											
	Middle Miocene			Upper Miocene								
	Upper(?) Luisian stage			Lower(?) Mohnian stage								
	603–633	573–603	543–573	13–543	483–513	453–483	333–363	303–333	243–273	193–233	163–193	103–113
1. *Siphogenerina collomi*	×											
2. *Bolvina advena* var. *striatella*	⊖	⊗	○									
3. *Valvulineria miocenica*	×	◑	○									
4. *Valvulineria californica*	⊗											
5. *Valvulineria californica* var. *obesa*	○	\	⊗									
6. *Buliminella curta*	×	⊖		×				×	⊗	\	†	⊗
7. *Uvigerina subperegrina*	×	\										
8. *Nonion costiferum*	×	\	×									
9. *Hemicristellaria beali*	\	\	\									
10. "*Uvigerinella*" *californica*		○	⊖									
11. *Baggina californica*		\	\									
12. *Cassidulina* cf. *C. panzana*		\							×	·	×	⊗
13. *Bolivina sinuala* var. *alisoensis*			\	\	†	×	◑	⊗		\		
14. *Robulus miocenicus*			\									
15. *Robulus smileyi*			\									
16. *Dentalina obliqua*			\									
17. *Buliminella equadorana*			×				○					
18. *Epistominella subperuviana*			\									
19. *Nonion* cf. *N. costiferum*				⊠	◑							
20. *Epistominella gyroidinaformis*				\	●	×	\					
21. *Uvigerina hootsi*				×	†	×	⊗	●	⊗	⊗ cf.	†	
22. *Bolivina pseudospissa*					†		\	\	⊗	◑	●	
23. *Valvulineria araucana*					×	⊠	×			\		
24. *Valvulineria* cf. *V. miocenica*						×	\					
25. *Epistominella pacifica*							⊖					
26. *Bolivina rankini*								\				
27. *Epistominella relizensis*								†	○		\	
28. *Bolivina* cf. *B. vaughani*									\	×	○	●
29. *Eponides rosaformis*									\			
30. *Globigerina bulloides*									○	·	×	
31. *Gyroidina rotundimargo*										†	\	
32. *Bolivina interjuncta* var. *bicostata*										\		
33. *Cibicides illingi*										†	\	
34. *Planulina ornata*										\	\	
35. *Suggrunda kleinpelli*										\		
Total population (rounded)	420	9,300	2,800	14	21	29	480	250	73	71	13	4

Table 7.—*Distribution of Foraminifera in Monterey shale from Shell Oil Co.'s Moulton core hole No. 14*

[Numbers indicate percent of total population of sample: ·, <1; \, 1-3; †, 4-6; ×, 7-10; ○, 11-15; ⊖, 16-20; ⊕, 21-30; ◑, 31-40; ●, 41-60; ⊠, 61-80; ■, 81-100, cf., see p. 464]

Species (arranged in order of lowest occurrence)	Core samples (intervals in feet)																	
	Middle Miocene											Upper Miocene						
	Lower(?) Luisian stage	Upper Luisian stage										Lower(?) Mohnian stage						
	730–750	710–730	630–650	570–590	550–570	510–530	490–510	470–490	450–470	430–450	410–430	390–410	370–390	350–370	330–350	270–290	250–270	230–250
1. *Bolivina advena* var.	×																	
2. *Valvulineria depressa*	\																	
3. *Cassidulina* cf. *C. panzana*	\		\							·								
4. *Bolivina advena* var. *striatella*	○	⊖	†	●	⊕	\			†	○					⊖		\	
5. *Bolivina* cf. *B. pseudospissa*	×																	
6. *Buliminella curta*	●	○	×		×	†	\	†			⊕	⊕					×	†
7. *Epistominella relizensis*	×		\			○				·		†	†	⊖			·	†
8. *Globigerina bulloides*	×			†	†	×	◑	†	†	⊕	●	⊕	×	†	○	×	†	
9. *Buliminella subfusiformis*		○	⊕	○	⊕	⊕	⊕	⊠	⊠	◑			†		○	×	×	
10. *Valvulineria californica* var. *obesa*		◑	○	⊕	⊖			\		\	○							
11. *Uvigerina subperegrina*		×	⊖		·					·					†	·	○	\
12. *Valvulineria miocenica*		×		×	†	†	○	†	×									
13. *Nonion costiferum*		\	\	·	·					·								
14. *Bolivina* cf. *B. vaughani*			\		†	◑	⊖						×		◑	◑	⊕	●
15. *Pullenia miocenica* var. *globula*			×	†	†													
16. *Gyroidina rotundimargo*			\	·	\				\?		\		†			\	·	
17. *Baggina californica*				·								\			†		·	
18. *Dentalina obliqua*				·	·													
19. *Hemicristellaria beali*				·														
20. *Robulus smileyi*				·														
21. *Siphogenerina collomi*				·	·													
22. *Epistominella subperuviana*					†													
23. *Eponides rosaformis*					\							×	†	†				
24. *Bolivina rankini*						†	\	×	×	○		⊕	⊕	⊕				
25. *Bolivina marginata* var. *gracillima*							\	\										
26. *Virgulina californiensis*							\	×	†	\					†			
27. *Suggrunda kleinpelli*										×							\	\
28. *Bolivina tumida*											○					·		
29. "*Uvigerinella*" *californica*											\							
30. *Bolivina decurtata*												†	×		○	◑	⊖	◑
31. *Uvigerina hootsi*												×	†	⊖	×			
32. *Epistominella gyroidinaformis*												†						
33. *Bolivina sinuata* var. *alisoensis*													†					
34. *Bulimina carnerosensis*													†					
35. *Buliminella ecuadorana*													○	⊖				
36. *Cassidulina cushmani*													·			·		
37. *Bulimina ovula*														\				
38. *Bolivina woodringi*																\		
39. *Epistominella thalmanni*																†	·	
40. *Bolivina* cf. *B. pisciformis*																	○	
41. *Bolivina brevior*																	\	
42. *Angulogerina?* sp																	\	
Total population (rounded)	29	390	7,400	6,000	37,000	14,000	16,000	18,000	6,200	120,000	880	1,800	1,800	4,000	26	15,000	17,000	9,600

TABLE 8.—*Distribution of Foraminifera in Monterey shale from the area west of Oso Creek*

[Numbers indicate percent of total population of locality: ·, <1; \, 1-3; †, 4-6; ×, 7-10; ○, 11-15; ⊖, 16-20; ⊗, 21-30; ◑, 31-40; ●, 41-60; ⊠, 61-80; ■, 80-100, cf., see p. 464]

Species (arranged in order of lowest occurrence)	Localities (arranged in approximate stratigraphic order)																
	Middle Miocene																Upper Miocene
	Lower Luisian stage			Upper Luisian stage													Mohnian stage
	m40	m41	m56 [1]	m42	m43	m44	m45	m46	m47	m48	m49	m50	m51	m52	m53	m54	m55
1. *Cassidulina williami*	\																
2. *Valvulineria depressa*	×	\	†													×cf.	
3. *Robulus smileyi*	\				\		·	\	\	\						\	
4. *Bulimina ovula*	\					\					\						
5. *Nonionella miocenica*	×			\										×			
6. *Valvulineria californica*	\	×		\			·	\	×		†	†				○	
7. *Virgulina californiensis*	●	\		◑	\		⊖	⊗	○		\	⊖	◑	⊖	×	○	
8. *Bolivina advena* var. *striatella*	×			\		×	\	⊖	†	×	⊖	⊖	○		†	⊗	
9. *Nonion costiferum*	\		\	†					\	†	\		†		\	\	
10. *Suggrunda kleinpelli*	\						·		\					\	\		○
11. *Pullenia miocenica*	\	×	\				×			\							\
12. *Epistominella relizensis*	†	†		\		\	○	\		\	†				\	\	†
13. *Bolivina tumida*	\	\	\	⊗		⊗	×	\	\		†	○		×		\	×
14. *Globigerina bulloides*	○		◑			†	\	†	⊗		\	†		⊖	\	\	†
15. *Valvulineria californica* var. *obesa*		◑	×		⊠	\	×	\		⊠	⊗		○	○	⊖		
16. *Bolivina californica*		†					·				×				†	\	
17. *Bolivina marginata* var. *gracillima*		○						†						×		\	
18. *Buliminella subfusiformis*		×	⊖	×		×	×	×	○		†	◑	⊖	⊖	⊖		
19. *Bolivina salinasensis*		\						\								\	
20. *Hemicristellaria beali*		\		\	\		·			†	\				\	\	
21. *Baggina californica*		\					·				\	\				\	
22. *Siphogenerina collomi*		\	†		\											×	
23. *Dentalina obliqua*		\	\		\		·			\	\		\		\	\	
24. *Valvulineria miocenica*			\			×	\	\	×	\	\	†	\	†	\	\	
25. *Bolivina imbricata*			\	×	\	⊗	†	○	×								
26. *Buliminella curta*			×	†					†			×		○	†	\	○
27. *Bulimina montereyana*			\		⊖	\	⊖	\					\				
28. *Uvigerina subperegrina*			\			×	\	†						\		\	\
29. "*Uvigerinella*" *californica* var.			\														
30. *Bolivina sinuata* var. *alisoensis*			\														
31. *Bolivina* cf. *B. rhomboidalis*				\	\	\	·	\	×				\				
32. *Planularia luciana*					\		·										
33. *Cancris baggi*					\												
34. *Gyroidina rotundimargo*							\	\		\	×					\	
35. *Pullenia miocenica* var. *globula*								\						×		\	
36. *Bolivina subadvena*									\								
37. *Eponides rosaformis*											†			†			
38. *Anomalina salinasensis*										·	\	†					
39. *Robulus* aff. *R. simplex*													\				
40. *Bulimina pupoides*													\				
41. *Bolivina brevior*														\	\		
42. *Epistominella subperuviana*															\		
43. *Bolivina* cf. *B. vaughani*															\		
44. *Bolivina woodringi*																	⊗
45. *Bolivina decurtata*																	⊗
46. *Discorbinella valmonteensis*																	\
Total population (rounded)	1,400	270,000	24,000	15,000	29,000	18,000	66,000	88,000	4,400	5,800	110,000	200,000	200,000	51,000	85,000	250,000	15,000

[1] Stratigraphic position unknown.

sible in stratigraphic order based on a detailed structure section across the area. The base of this section (samples m40, m41) is referred to the *Siphogenerina reedi* zone of the Luisian stage, as is sample m56, and contains *Valvulineria depressa*. Samples m42 to m54 exhibit superb development of the *Siphogenerina collomi* zone. Mohnian Foraminifera were found at only one surface locality (m55) in the Monterey shale west of Oso Creek. Upper(?) Mohnian Foraminifera are found in the Capistrano formation which unconformably overlies the Monterey shale.

Table 9 is a list of Foraminifera of the Monterey shale from Shell Oil Co.'s Moulton contraflush No. 32 (well 10, table 1). Each sample represents a composite 30-foot section.

The interval from 543 feet to 303 feet is Luisian, probably all *Siphogenerina collomi* zone.

No forms characteristic of either the Luisian or the Mohnian stage occur in the interval from 303 feet to 183 feet, but the absence of the *Valvulineria* fauna indicates that the rocks are Mohnian in age. Above 183 feet, the samples contain *Epistominella gyroidinaformis* and a form closely related to *Bulimina uvigerinaformis*, indicating that the strata belong to the *Bulimina uvigerinaformis* zone of the Mohnian stage.

FAUNAL SUMMARY

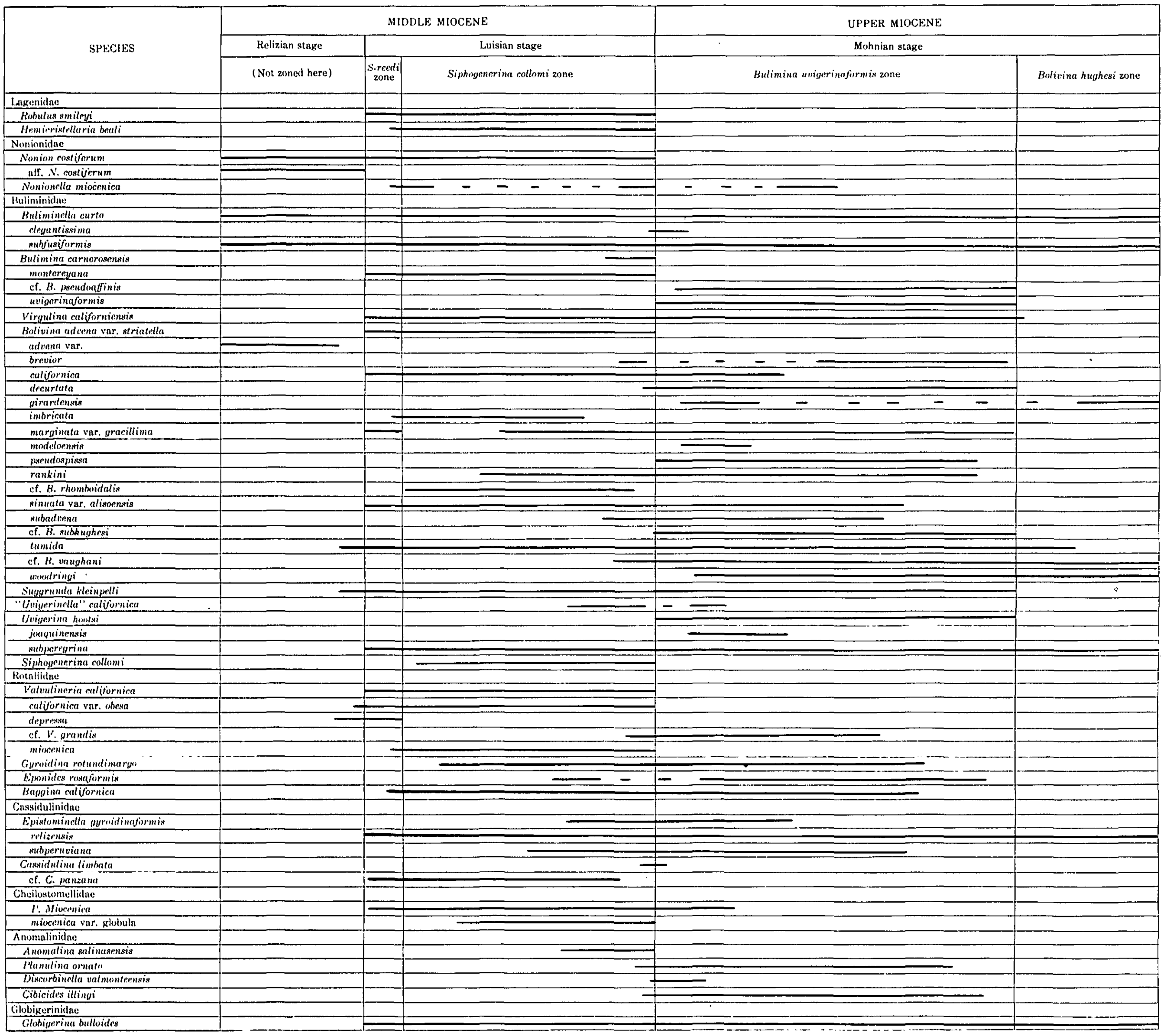
The stratigraphic ranges of the more important and abundant species have been compiled from all seven distribution charts onto a range chart (table 10).

TABLE 9.—*Distribution of Foraminifera in Monterey shale from Shell Oil Co.'s Moulton contraflush No. 32*

[Numbers indicate percent of total population in sample: ·, <1; \, 1-3; †, 4-6; ×, 7-10; ○, 11-15; ⊖, 16-20; ⊗, 21-30; ◑, 31-40; ●, 41-60; ⊠, 61-80; ■, 81-100, cf., see p. 464]

Species (arranged in order of lowest occurrence)	Core samples (depth interval in feet)												
	Middle Miocene							Upper Miocene					
	Upper(?) Luisian stage							Lower(?) Mohnian stage					
	513–543	483–513	453–483	423–453	393–423	363–393	303–333	273–303	243–273	213–243	183–213	153–183	123–153
1. *Valvulineria miocenica* Cushman	⊗	\	\	†	---	---	\	---	---	---	---	---	---
2. *Valvulineria californica* var. *obesa*	\	×	⊖	\	⊗	⊗	†	---	---	---	---	---	---
3. *Bolivina imbricata*	⊗	⊖	\	×	\	---	---	---	---	---	---	---	---
4. *Bolivina advena* var. *striatella*	×	---	---	⊗	⊖	---	○	---	---	---	---	---	---
5. *Siphogenerina collomi*	\	\	\	---	\	†	---	---	---	---	---	---	---
6. *Bolivina tumida*	\	○	---	---	---	†	---	---	---	\	---	---	---
7. *Uvigerina subperegrina*	○	\	---	\	---	†	---	---	\	---	\	---	†
8. *Buliminella curta*	○	\	⊖	⊗	○	×	⊗	⊗	○	⊖	⊖	---	⊗
9. *Buliminella subfusiformis*	\	○	○	○	\	×	○	---	●	×	\	---	---
10. *Gyroidina rotundimargo*	\ cf.	\	---	\	†	\	·	---	---	---	\	---	†
11. *Epistominella subperuviana*	\	---	---	---	†	---	---	---	---	---	---	†	---
12. *Globigerina bulloides*	†	⊖	⊗	---	○	○	⊖	●	---	●	◑	---	---
13. *Bolivina* cf. *B. vaughani*	---	○	⊗	×	†	\	○	⊖	---	---	---	---	---
14. *Bulimina montereyana*	---	\	\	\	---	---	---	---	---	---	---	---	---
15. *Pullenia miocenia* var. *globula*	---	\	---	---	†	×	\	---	---	---	---	---	---
16. *Cancris baggi*	---	\	---	---	---	---	---	---	---	---	---	---	---
17. *Robulus smileyi*	---	\	---	---	---	·	·	---	---	---	---	---	---
18. *Bolivina rhomboidalis*	---	---	\	\	---	---	---	---	---	---	---	---	---
19. *Bolivina rankini*	---	---	\	\	---	---	†	×	⊗	×	⊗	⊗	⊖
20. *Bulimina ovula*	---	---	\	---	---	---	---	---	---	---	---	---	---
21. *Virgulina californiensis*	---	---	---	†	---	---	---	---	---	\	\	---	---
22. *Valvulineria* cf. *V. ornata*	---	---	---	\	\	---	---	---	---	---	---	---	---
23. *Nonion costiferum*	---	---	---	\	\	·	·	---	---	---	---	---	---
24. *Dentalina obliqua*	---	---	---	---	\	---	·	---	---	---	\	---	\
25. *Bolivina subadvena*	---	---	---	---	---	·	---	---	×	\	○	---	---
26. *Epistominella relizensis*	---	---	---	---	---	×	\	---	---	---	---	---	×
27. *Baggina californica*	---	---	---	---	---	·	---	---	---	---	---	---	---
28. *Hemicristellaria beali*	---	---	---	---	---	·	---	---	---	---	---	---	---
29. *Nodosaria* sp	---	---	---	---	---	·	---	---	---	---	---	---	\
30. *Bulimina carnerosensis*	---	---	---	---	---	---	·	---	---	---	---	---	---
31. *Bolivina marginata* var. *gracillima*	---	---	---	---	---	---	---	×	---	---	---	---	---
32. *Valvulineria araucana*	---	---	---	---	---	---	---	\	†	\	---	×	†
33. *Cibicides illingi*	---	---	---	---	---	---	---	---	† cf.	---	---	---	·
34. "*Uvigerinella*" *californica*	---	---	---	---	---	---	---	---	\	·	---	---	---
35. *Bolivina pisciformis*	---	---	---	---	---	---	---	---	---	·	---	---	\
36. *Suggrunda kleinpelli*	---	---	---	---	---	---	---	---	---	\	---	---	---
37. *Angulogerina*? sp	---	---	---	---	---	---	---	---	---	\	---	---	---
38. *Uvigerina hootsi*	---	---	---	---	---	---	---	---	---	---	\	⊖	†
39. *Bolivina* cf. *B. decussata*	---	---	---	---	---	---	---	---	---	---	---	†	\
40. *Buliminella ecuadorana*	---	---	---	---	---	---	---	---	---	---	---	⊗	---
41. *Virgulina californiensis* var. *grandis*	---	---	---	---	---	---	---	---	---	---	---	\	---
42. *Epistominella gyroidinaformis*	---	---	---	---	---	---	---	---	---	---	---	×	○
43. *Bulimina uvigerinaformis*	---	---	---	---	---	---	---	---	---	---	---	---	†
44. *Cassidulina cushmani*	---	---	---	---	---	---	---	---	---	---	---	---	\
Total population (rounded)	900	35,000	36,000	44,000	25,000	50,000	46,000	1,600	6,800	24,000	6,200	84	1,600

TABLE 10.—*Geologic ranges of more important Foraminifera*



Species are listed systematically, with geologic ranges indicated by a bar graph.

This chart brings out many features of the middle and upper Miocene faunas: There is an obvious change in fauna at the end of Luisian time from a generically diverse assemblage to one composed predominantly of Buliminidae. A great many genera die out at the end of Luisian time, and relatively few are introduced at the beginning of Mohnian time. The Lagenidae, Nonions, Siphogenerinas, and the robust Valvulinerias all die out at the end of the middle Miocene. A few new genera are introduced at the beginning of Mohnian time, such as the group of Anomalinidae listed, but most of the new forms which appear in the Mohnian are new species of *Bolivina* and *Bulimina*.

A striking thing about the entire group of faunas is the absence of Miliolidae and of arenaceous Foraminifera. The absence of these two groups was also noted by Kleinpell (1938, p. 16) in his section of the Monterey from the Reliz Canyon area, California. Woodring, Bramlette, and Kew (1946, p. 13–40) list only one arenaceous form (*Bathysiphon?* sp.) and no miliolids from the Monterey shale of the Palos Verdes Hills, Calif. This is a very interesting feature of the faunas, and is deserving of closer study.

CORRELATION OF FORMATIONS AND STAGES

Figure 157 consists of four columnar sections, one from each of the four previously described areas of the Santa Ana Mountains-San Juan Capistrano area. These columns are compiled from measured surface sections or from core holes. As shown in this figure, the columns differ greatly from one another in thickness of strata assigned to various rock and time-rock units.

A tentative Relizian age is assigned to most of the upper part of the widespread Topanga formation, which is present in most of the Santa Ana Mountains and San Juan Capistrano area. The faunas of the Topanga formation of Burruel Ridge are similar to those of the Topanga formation in the San Joaquin Hills, west of the area shown on figure 156. A cursory examination of the faunas from the San Joaquin Hills revealed the presence of *Nonion* aff. *N. costiferum*, *Buliminella subfusiformis*, *Bolivina advena* var., and also *Valvulineria depressa*.

The rocks of the Topanga formation (Relizian(?) stage) are overlain by rocks assigned to several different zones and stages. On the west limb of the Capistrano syncline (core hole No. 14 and surface samples) rocks of the *Siphogenerina reedi* zone of the Luisian stage lie on the older rocks. Here, this zone grades upward into a thick section of the Monterey shale assigned to the *Siphogenerina collomi* zone.

On Burruel Ridge, the El Modeno volcanics (*Siphogenerina collomi* zone) are apparently comformable on the underlying Topanga formation and are overlain unconformably by the Puente formation. No other rocks belonging to the Luisian stage are exposed in the northern Santa Ana Mountains. Late Luisian time is presumably represented by the unconformity.

The Luisian stage is best represented in the Monterey shale in the Capistrano syncline. The Monterey rocks of Luisian age are more than 400 feet thick in the area west of Oso Creek and less than 100 feet thick in the area east of Oso Creek.

Rocks of Mohnian age are widespread in the Santa Ana Mountains and San Juan Capistrano area. In the Santa Ana Mountains the Mohnian stage is represented by a maximum of about 3,000 feet of sandstone and siltstone of the Puente formation. In the area west of Oso Creek, the Mohnian part of the Monterey shale is about 200 feet thick while in the area east of Oso Creek it is more than 1,000 feet thick.

CONCLUSIONS

From figure 157 it can be seen that lateral changes in the thickness of strata assigned to the Mohnian and Luisian stages within the Monterey shale and Puente formation are considerable. A rather striking example of these changes is shown in the Monterey shale in the San Juan Capistrano area. Unconformably overlying the Topanga formation in the area east of Oso Creek, rocks of the Monterey assigned to the Luisian stage are less than 100 feet thick, and rocks of the Monterey assigned to the Mohnian stage are about 1,200 feet thick. The contact with the overlying Capistrano formation is gradational. In the area west of Oso Creek the Monterey shale unconformably overlies San Onofre breccia and is unconformably overlain by the Capistrano formation. The part of the Monterey shale assigned to the Luisian stage is about 400 feet thick; the part assigned to the Mohnian stage is less than 200 feet thick.

There is not only a change in thickness of these strata, but also a change in their relations. In the San Juan Capistrano area, strata of Luisian age grade upward without lithologic change into strata of Mohnian age. In the Santa Ana Mountains, as typified by Burruel Ridge, rocks of Luisian age are almost totally missing, and rocks of Mohnian age lie unconformably on older rocks.

Such variations can be explained in two ways: (1) Areas of deposition changed, with the result that sediments were not deposited simultaneously over the entire region. Unconformities at the base and top of the Monterey shale represent large gaps in the geologic record. The changes in fauna are not due to lateral ecologic variations, such as lateral change in depth or temperature. (2) Most of the region underwent simultaneous deposition; unconformities at the base and top of the Monterey shale and Puente formation represent insignificant gaps in the geologic record. Luisian and Mohnian faunas were actually contemporaneous, one indicating a deeper water facies than the other.

The second possibility requires that faunas of Luisian age indicate a different depth facies from those of Mohnian age and that Luisian and Mohnian faunas grade laterally into one another. In the Ventura basin, faunas considered to be early Pliocene in age have been found to grade laterally into faunas considered to be late Pliocene in age (E. L. Winterer and D. L. Durham, written communication).

Natland (1933) and Bandy (1953a,b) have shown that changes in the faunas of Recent sediments off the Pacific coast of southern California from deeper to shallower water correspond to changes in faunas from the early Pliocene to Pleistocene in the sediments of the Los Angeles and Ventura basins. The deep-water (5,000 feet +) forms *Nonion pompilioides* and *Bulimina rostrata* are considered characteristic forms of the early Pliocene. *Bulimina subacuminata* (now living around 3,000 feet) is characteristic of middle Pliocene, and *Epistominella pacifica*, *Uvigerina peregrina*, and *Bolivina spissa* (now living around 2,000 feet) are characteristic of late Pliocene. Species which now live

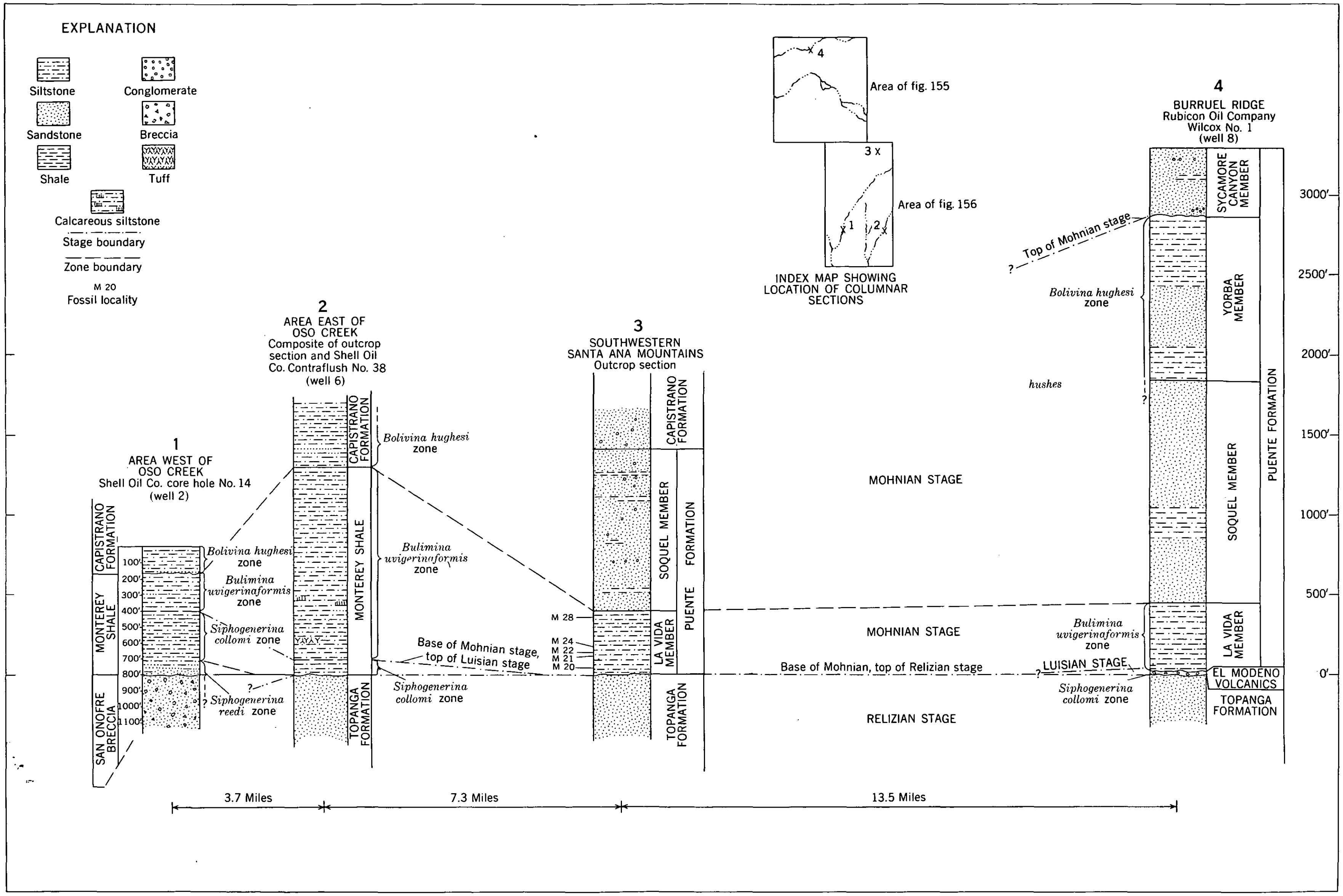


FIGURE 157.—Columnar sections of rocks of middle and late Miocene age in the Santa Ana Mountains and the San Juan Capistrano area, showing relative thicknesses of rock included in the Miocene stages and zones described by Kleinpell (1938).

in the neritic zone (400 feet ±) characterize the early Pleistocene sediments of these basins. There are only a few Pliocene species that are now extinct.

Thus it appears that in the Pliocene, faunal changes were due to changes in depth of water, or to changes in temperature of the water, or other factors that accompany changes in depth. It is difficult to discover whether similar faunal changes occurred in the Miocene, for most Miocene forms are now extinct, and it is necessary to work with "close living relatives" and with purely generic affinities.

There are, however, some forms now living which are present in both Luisian and Mohnian faunas. These forms indicate several depths of water (Natland, 1933; Bandy, 1953a):

Gyroidina rotundimargo	Abyssal (3,000 feet or greater)
Buliminella subfusiformis	Bathyal (600 to 3,000 feet)
Epistominella subperuviana	Bathyal
Planulina ornata	Bathyal
Uvigerina (costate)	Bathyal
Buliminella elegantissima	Neritic (180 to 300 feet)
Nonionella miocenica	Neritic

All these forms occur in faunas of both the Luisian and Mohnian stages. This indicates that both these stages include the same faunal depth-facies.

The presence of similar depth assemblages in both stages indicates that the difference between the Luisian and Mohnian faunas is not primarily one of depth. There is no evidence that the two faunas represent ecologic facies which grade laterally into one another.

The foregoing evidence indicates that the variation in thickness of the Luisian and Mohnian stages within the Monterey shale and Puente formation is due to shifting areas of deposition. The change from early to late Luisian faunas in the lowest part of the Monterey shale and to Mohnian faunas in the lowest part of the Puente formation toward the north and east is a result of progressive onlap in those directions. This change in fauna actually represents a change in the age of the base of the Monterey and Puente. The change in thickness of rocks of Mohnian age within the Monterey shale is due to differential erosion before the deposition of the Capistrano formation. A thick section of the Monterey shale of Mohnian age was present in the area west of Oso Creek, but much of it was removed by erosion before deposition of the Capistrano formation. Such changes in area of deposition and erosion are not unexpected in a region as tectonically active as this one. Geologic mapping in the Santa Ana Mountains and San Joaquin Hills shows the existence of numerous Miocene faults and unconformities.

If, as indicated, there is an abrupt change in faunas at the end of Luisian time, it must be due to some ecologic factor other than depth of water, which does not appear to have changed. Perhaps this factor is a gross change in temperature due to a change in climate. The forms mentioned above which lived from the Miocene to the present (*Buliminella subfusiformis*, *Epistominella subperuviana*, and costate forms of *Uvigerina*) have a fairly wide temperature tolerance. This is not true of the Luisian costate Siphogenerinas, which appear to resist only small changes in temperature (Kleinpell, 1938, p. 14). At the present time, costate Siphogenerinas occur most commonly in tropical seas, especially the Indo-Pacific area (Kleinpell, 1938, p. 14).

This evidence suggests that the sharp faunal break at the end of the Luisian stage over most of the area of this report was caused by a change from a tropical middle Miocene sea to a temperate late Miocene sea. Further indication that this may be true is the fact that in the nearby Palos Verdes Hills, a sandstone sequence equivalent to or older than the rocks of the *Siphogenerina reedi* zone contain tropical molluscan migrants which are absent in younger beds (Woodring and others, 1946).

It seems possible that a temperature drop of only a few degrees Fahrenheit at the end of Luisian time may have been enough either to kill off the characteristic Luisian species of *Siphogenerina* and *Valvulineria* and associated forms, or to drive them elsewhere and to cause the influx of the typical Mohnian Buliminidae.

SYSTEMATIC CATALOG

On the following pages is a systematic catalog listing all the forms referred to in this paper and giving the original reference and other selected references. Species were compared with primary types in the U.S. National Museum, Washington, D.C., and at Stanford University. For those few species whose primary types were not available, careful comparison was made with original illustrations and with plesiotypes of the subsequent references mentioned in the synonomies.

Species descriptions also include the stratigraphic occurrence of each species in the Santa Ana Mountains and San Juan Capistrano area. The numerical position of each species on each table of distribution is indicated by the number of the table and then the species number, as table 4 (42).

Specimens of each species are deposited in the U.S. National Museum.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

Robulus miocenicus (Chapman)

Cristellaria miocenica Chapman, 1900: California Acad. Sci. Proc., 3d ser., (Geology), v. 1, p. 250, pl. 30, figs. 1, 1A.

Robulus miocenicus (Chapman). Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 199, pl. 15, fig. 9.

This form is much like Chapman's but appears slightly thicker through the umbilicus. It is proportionally longer in side view than that figured by Kleinpell.

Occurrence: upper Luisian; table 6 (14).

Robulus aff. R. simplex (d'Orbigny)

These specimens cannot be assigned definitely to d'Orbigny's species because poor preservation obscures details.

Occurrence: upper Luisian; table 8 (39).

Kleinpell (1938, p. 202, pl. 8, fig. 1) refers a figured specimen to d'Orbigny's species and reports its occurrence in the Zemorrian, Saucesian, and Relizian stages.

Robulus smileyi Kleinpell

Robulus smileyi Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 202, 203, pl. 15, fig. 14*A*,*B*.

Occurrence: lower Luisian to Mohnian; tables 4 (40), 6 (15), 7 (20), 8 (3), 9 (17).

Genus PLANULARIA Defrance, 1824

Planularia luciana Kleinpell

Planularia luciana Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 207, 208, pl. 9, fig. 25*A*,*B*.

No types available but appears very similar to Kleinpell's figures.

Occurrence: upper Luisian; table 8 (32).

Genus HEMICRISTELLARIA Stache, 1864

Hemicristellaria beali (Cushman)

Cristellaria beali Cushman, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 24, 25, pl. 4, figs. 6–13.

Hemicristellaria beali (Cushman). Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 206, 207, pl. 11, figs. 10–12, and pl. 12, figs. 15, 16.

Occurrence: lower to upper Luisian; tables 6 (9), 7 (19), 8 (20), 9 (28).

Genus DENTALINA d'Orbigny, 1826

Dentalina obliqua (Linne)

Nautilus obliquus Linne, 1758, Systematic Naturae: ed. 10, p. 711.

Dentalina obliqua (Linne). Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 212, pl. 11, fig. 7.

Occurrence: lower to upper Luisian; tables 6 (16), 7 (18), 8 (23), 9 (24).

Family NONIONIDAE

Genus NONION Montfort, 1808

Nonion costiferum (Cushman)

Nonionina costifera Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 1, p. 90, pl. 13, figs. 2*A*–*C*.

Nonion costiferum (Cushman). Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 229–231, pl. 15, figs. 13*A*,*B*.

Occurrence: Relizian(?) to upper Luisian; tables 3 (3), 4 (10), 5 (2), 6 (8), 7 (13), 8 (9), 9 (23).

Nonion cf. N. costiferum (Cushman)

These specimens are small and may be immature specimens of *N. costiferum*. They are listed separately from the typical form because they are so abundant.

Occurrence: Mohnian, in Shell Oil Co.'s contraflush No. 38, at 513–543 feet; table 6 (19).

Nonion aff. N. costiferum (Cushman)

Plate 58, figures 5 and 6

This form is very similar to *N. costiferum*, but differs from it in several respects. The dorsal side is partly evolute, and the ventral is completely involute. It also has a more rounded periphery than *N. costiferum*.

Occurrence: Relizian(?); table 3 (2).

Nonion pizarrensis W. Berry

Nonion pizarrensis W. Berry, 1928: Jour. Paleontology, v. 1, p. 269, figs. 1–3.

Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 4, pl. 1, fig. 9*A*,*B*.

Kleinpell, 1938; Miocene stratigraphy of California: Tulsa, Okla., p. 234–235.

Sutures are less oblique than in the specimens figured by Berry or by Cushman and Kleinpell.

Occurrence: upper Luisian to lower Mohnian; table 3 (16).

Genus NONIONELLA Cushman, 1926

Nonionella miocenica Cushman

Nonionina auris (d'Orbigny). Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 1, p. 91, pl. 13, fig. 4*A*–*C*.

Nonionella miocenica Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 64.

Occurrence: lower Luisian, lower Mohnian; tables 3 (41), 5 (3), 8 (5).

Family BULIMINIDAE

Genus BULIMINELLA Cushman, 1911

Buliminella curta Cushman

Buliminella curta Cushman, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 33, pl. 5, fig. 13.

Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 248, 249, pl. 7, fig. 3; pl. 15, fig. 4; and pl. 16, fig. 8.

Occurrence: Relizian(?) to upper Mohnian; tables 3 (4), 4 (13), 5 (7), 6 (6), 7 (6), 8 (26), 9 (8).

Buliminella ecuadorana Cushman and Stevenson

Plate 58, figures 1 and 2

Buliminella ecuadorana Cushman and Stevenson, 1948: Cushman Lab. Foram. Research Contr., v. 24, p. 57, pl. 9, figs. 19 and 20.

Occurrence: Luisian to lower Mohnian; tables 3 (21), 4 (33), 6 (17), 7 (35), 9 (40).

Buliminella elegantissima (d'Orbigny)

Bulimina elegantissima d'Orbigny, 1839, Voyage dans l'Amerique Meridionale: v. 5, pt. 5, Foraminifères, p. 51, pl. 7, figs. 13 and 14.

Buliminella elegantissima (d'Orbigny). Barbat and Johnson, 1934; Jour. Paleontology, v. 8, p. 12, figs. 12, 13.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 249, 250, pl. 16, fig. 10.

Occurrence: Mohnian; table 5 (22).

Buliminella subfusiformis Cushman

Buliminella subfusiformis Cushman, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 33, pl. 5, fig. 12.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 251, 252, pl. 9, fig. 8.

Occurrence: Relizian(?) to upper Mohnian; tables 3 (5), 4 (12), 5 (4), 7 (9), 8 (18), 9 (9).

Genus BULIMINA d'Orbigny, 1826

Bulimina carnerosensis Cushman and Kleinpell

Plate 58, figures 3 and 4

Bulimina carnerosensis Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 5, pl. 1, figs. 12*A*,*B*.

Occurrence: upper Luisian; tables 5 (6), 7 (34), 9 (30).

This species is smaller than *B. uvigerinaformis* Cushman and Kleinpell (p. ——, this report), has finer, more nearly continuous, and more numerous costae, and has a subterminal aperture. Kleinpell (1938, p. 259) discusses a form related to *B. uvigerinaformis* that is probably *B. carnerosensis* and states that the fauna associated with it is probably upper Luisian in age.

B. carnerosensis var. *mahonyi* Cushman and Kleinpell (op. cit., p. 5, pl. 1, fig. 13) is not distinguished by the author from *B. carnerosensis* s. s.

Bulimina delreyensis Cushman and Galliher

Bulimina delreyensis Cushman and Galliher, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 25, pl. 4, fig. 8.

Occurrence: lower Mohnian; table 3 (28).

Bulimina montereyana Kleinpell

Bulimina montereyana Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 254, 255, pl. 12, fig. 13.

Occurrence: lower to upper Luisian; tables 3 (13), 5 (1), 8 (27), 9 (14).

Bulimina cf. B. montereyana Kleinpell

Test shorter than typical, more sharply tapering toward initial end, and poorly preserved.
Occurrence: lower Mohnian; table 3 (13).

Bulimina ovula d'Orbigny

Bulimina ovula d'Orbigny, 1839, Voyage dans l'Amerique Meridionale: v. 5, pt. 5, Foraminifères, p. 51, pl. 1, figs. 10, 11.
Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 55, pl. 7, fig. 2.

This form has less-inflated chambers than that figured by Kleinpell (1938, p. 256, 257, pl. 7, fig. 2).

Occurrence: lower Luisian to Mohnian; tables 5 (30), 7 (37), 8 (4), 9 (20).

Bulimina cf. B. pseudoaffinis Kleinpell

Plate 57, figures 7 and 8

This form, extremely abundant in certain localities in the La Vida member of the Puente formation, differs from the species described by Kleinpell (1938, p. 257, 258, pl. 9, fig. 9) in having a more lobulate periphery, and a greater length-to-width ratio. In samples m12 to m12d, it becomes costate and somewhat resembles *B. uvigerinaformis* Cushman and Kleinpell (below, this report). However, it has a more regular chamber arrangement and is much wider than that species.

It differs from *Bulimina delreyensis* Cushman and Galliher (below, this report) in having more inflated later chambers, and in having costae, when present, less prominent.
Occurrence: lower Mohnian; tables 3 (29), 5 (27).

Bulimina pupoides d'Orbigny

Bulimina pupoides d'Orbigny, 1846, Foraminifères Fossiles du bassin tertiaire de Vienne: p. 185, pl. 11, figs. 11, 12.
Cushman and Parker, 1946: U.S. Geol. Survey Prof. Paper 210–D, p. 105, 106, pl. 25, figs. 3–7.

Test tapers sharply to initial end.
Occurrence: upper Luisian; table 8 (40).

Bulimina uvigerinaformis Cushman and Kleinpell

Bulimina uvigerinaformis Cushman and Kleinpell, 1934; Cushman Lab. Foram. Research Contr., v. 10, p. 5, pl. 1, fig. 14*A*,*B*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 259, 260.

Occurrence: lower Mohnian; tables 3 (27), 4 (38), 5 (28), 9 (43).

Bulimina (Desinobulimina) sp.

This form may be related to *Bulimina auriculata* Bailey (Cushman and Parker, 1946, p. 129, pl. 29, figs. 22–24.)
Occurrence: Mohnian; table 5 (26).

Genus VIRGULINA d'Orbigny, 1826

Virgulina californiensis Cushman

Virgulina californiensis Cushman, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 32, pl. 5, fig. 11*A*–*C*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 261, 262, pl. 8, fig. 4.

Occurrence: lower Luisian to lower Mohnian; tables 3 (26), 4 (11), 5 (15), 7 (26), 8 (7), 9 (21).

Virgulina californiensis Cushman var. grandis Cushman and Kleinpell

Virgulina californiensis Cushman var. *grandis* Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 9, pl. 1, figs. 15, 16.

Occurrence: lower Mohnian; table 9 (41).

Genus BOLIVINA d'Orbigny, 1839

Bolivina advena Cushman var. striatella Cushman

Bolivina advena Cushman var. *striatella* Cushman, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 30, pl. 5, fig. 3*A*,*B*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 266, pl. 15, fig. 1.

Occurrence: lower Luisian to upper Luisian; tables 4 (4), 6 (2), 7 (4), 8 (8), 9 (4).

Bolivina advena Cushman var.

Plate 57, figures 3 and 4

Abundant in the Topanga formation in the Burruel Ridge area. Differs from the typical *B. advena* Cushman (1925: Cushman Lab. Foram. Research Contr., v. 1, p. 29, pl. 5, fig. 1) in its greater roundness in cross section and in having the peripheries of the last-formed chambers produced into blunt spines.

Dimensions: figured specimen: length, 0.37 mm, breadth, 0.19 mm. thickness, 0.15 mm. Other specimens: length, 0.37–0.49 mm, breadth, 0.19–0.22 mm, thickness, 0.13–0.15 mm.

Occurrence: Relizian(?) to lower Luisian; tables 3 (1), 7 (1).

Bolivina barbarana Cushman and Kleinpell

Bolivina barbarana Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 11, pl. 2, fig. 5*A*,*B*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 267.

Occurrence: lower Mohnian; tables 3 (43), 4 (25).

Bolivina cf. B. barbarana Cushman and Kleinpell

This form is more tapering at the apertural end than is the typical form.

Occurrence: Luisian(?); table 4 (25).

Bolivina brevior Cushman

Bolivina brevior Cushman, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 31, 32, pl. 5, fig. 8*A*,*B*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 268, pl. 7, fig. 5.

Occurrence: upper Luisian to lower Mohnian; tables 3 (42), 5 (42), 7 (41), 8 (41).

Bolivina californica Cushman

Bolivina californica Cushman, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 32, pl. 5, fig. 10*A*,*B*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 273, 274, pl. 12, figs. 4*A*,*B*, and 5.

Occurrence: lower Luisian to lower Mohnian; tables 3 (33), 5 (17), 8 (16).

Bolivina decurtata Cushman

Plate 57, figures 5 and 6

Bolivina decurtata Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 44, pl. 6, fig. 7.

Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 270, 271, pl. 21, figs. 3, 8.

Occurrence: uppermost Luisian to lower Mohnian; tables 3 (9), 4 (6), 5 (31), 7 (30), 8 (45).

Bolivina cf. B. decurtata Cushman

Usually broken, but apparently lacking nodes on later chambers which distinguish Cushman's species (1926: Cushman Lab. Foram. Research Contr., v. 2, p. 44, pl. 6, fig. 7*A*,*B*).

Occurrence: Luisian(?) to upper Mohnian; tables 3 (20), 4 (34), 5 (20).

Bolivina cf. B. decussata H. B. Brady

Test twisted, quadrate in cross section, sutures noded; wall hyaline, coarsely perforate; it definitely appears related to Brady's species (Cushman, 1937: Cushman Lab. Foram. Research Spec. Pub. No. 9, p. 125, 126, pl. 16, figs. 7–9).

Occurrence: lower Mohnian; table 9 (39).

Bolivina girardensis Rankin

Bolivina girardensis Rankin *in* Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 17, pl. 3, fig. 7*A*,*B*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 272.

Occurrence: lower to upper Mohnian; table 3 (36).

Bolivina imbricata Cushman

Bolivina imbricata Cushman, 1925: Cushman Lab. Foram Research Contr., v. 1, p. 31, pl. 5, fig. 7*A*,*B*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 273, 274, pl. 12, figs. 4*A*,*B*, and 5.

Occurrence: lower to upper Luisian; tables 8 (25), 9 (3).

Bolivina interjuncta Cushman var. bicostata Cushman

Bolivina costata d'Orbigny var. *bicostata* Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 42.
Bolivina interjuncta Cushman var. *bicostata* Cushman, 1937: Cushman Lab. Foram. Research Spec. Pub. no. 9, p. 116, pl. 22, fig. 23.

Occurrence: Luisian(?) to lower Mohnian; tables 3 (46), 4 (19), 5 (23), 6 (32).

Bolivina marginata Cushman var. gracillima Cushman

Bolivina marginata Cushman var. *gracilis* Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 10, pl. 2, fig. 3.
Bolivina marginata Cushman var. *gracillima* Cushman, 1938: Cushman Lab. Foram. Research Contr., v. 14, p. 29.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 277.

Specimens in sample m25 (table 4) are poorly preserved and are only questionably referred to this species.

Occurrence: lower Luisian to lower Mohnian; tables 3 (19), 4 (5), 5 (14), 7 (25), 8 (17), 9 (31).

Bolivina modeloensis Cushman and Kleinpell

Bolivina modeloensis Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 10, pl. 2, fig. 4*A*,*B*.

Occurrence: lower Mohnian; table 3 (37).

Bolivina obliqua Barbat and Johnson

Bolivina obliqua Barbat and Johnson, 1934; Jour. Paleontology, v. 8, p. 15, pl. 1, fig. 20.

Occurrence: Luisian(?) to upper Mohnian; tables 3 (35), 4 (7).

Bolivina pisciformis Galloway and Morrey

Bolivina pisciformis Galloway and Morrey, 1929: Am. Paleontology Bull., v. 15, No. 55, p. 36, pl. 5, fig. 10.

Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 279, pl. 4, fig. 10.

The forms in sample taken at 250–270 feet, in Shell Oil Co.'s core hole 14, have a less spinose periphery than the typical forms.

Occurrence: lower Mohnian; tables 7 (40), 9 (35).

Bolivina pseudospissa Kleinpell

Bolivina pseudospissa Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 279–280, pl. 21, fig. 6.

In the lower Luisian in Shell Oil Co.'s core hole 14 occur forms which resemble *B. pseudospissa*. They are poorly preserved and cannot be identified with certainty.

Occurrence of typical form: lower Mohnian; tables 3 (38), 4 (41), 5 (32), 6 (22), 7 (5).

Bolivina rankini Kleinpell

Bolivina rankini Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 280, pl. 22, figs. 4, 9.

Occurrence: upper Luisian to lower Mohnian; tables 4 (31), 5 (18), 6 (26), 7 (24), 9 (19).

Bolivina cf. B. rhomboidalis (Millett)

Plate 57, figures 13 and 14

This form was compared with Millett's figures of *Textularia rhomboidalis* (1899: Jour. Roy. Micr. Soc., p. 559, pl. 7, fig. 4) and was found to be very similar. It was also compared with plesiotypes from the Marshall Islands, which show a wide range of variation.

This Miocene form is characterized by its rectangular cross section, strongly overlapping chambers, and very coarse perforations.

Occurrence: upper Luisian; tables 8 (31), 9 (18).

Bolivina salinasensis Kleinpell

Bolivina salinasensis Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 280, 281, pl. 9, fig. 6, pl. 15, fig. 3.

Occurrence: lower to upper Luisian; table 8 (19).

Bolivina cf. B. salinasensis Kleinpell

Sutures more curved than those of form figured by Kleinpell.

Occurrence: lower Mohnian; table 3 (24).

Bolivina cf. B. seminuda Cushman

The chambers of this rare form are lower than those of the typical *B. seminuda* (Cushman, 1937: Cushman Lab. Foram. Research Spec. Pub. No. 9, p. 142, pl. 18, figs. 13–15).

Occurrence: Mohnian; table 5 (41).

Bolivina sinuata Galloway and Wissler var. alisoensis Cushman and Adams

Bolivina sinuata Galloway and Wissler var. *alisoensis* Cushman and Adams, 1935: Cushman Lab. Foram. Research Contr., v. 11, p. 19, 20, pl. 3, fig. 5.

Occurrence: lower Luisian to lower Mohnian; tables 3 (12), 4 (27), 5 (12), 6 (13), 7 (33), 8 (30).

Bolivina subadvena Cushman

Bolivina subadvena Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 44, pl. 6, fig. 6*A*,*B*.

Occurrence: upper Luisian to lower Mohnian; tables 8 (36), 9 (25).

Bolivina cf. B. subadvena Cushman

Sutures appear straighter and less oblique than those of the typical *B. subadvena*.

Occurrence: Relizian(?) to lower Mohnian; table 3 (10).

Bolivina cf. B. subhughesi Kleinpell

Plate 57, figures 11 and 12

Test twisted, nearly round in cross section; later chambers greatly inflated. This form is common in the La Vida member of the Puente formation and closely resembles Kleinpell's species (Kleinpell, 1938, p. 283, 284, pl. 21, figs. 7, 12).

Occurrence: lower Mohnian; table 3 (25).

Bolivina tumida Cushman

Bolivina tumida Cushman, 1925: Cushman Lab. Foram Research Contr., v. 1, p. 32, pl. 5, fig. 9*A*,*B*.

Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 284, 285, pl. 9, fig. 4.

Occurrence: Relizian(?) to upper Mohnian; tables 3 (8), 4 (8), 5 (13), 7 (28), 8 (13), 9 (6).

Bolivina cf. B. vaughani Natland

Plate 58, figures 7 and 8

Bolivina vaughani Natland. Crouch, 1952: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 830, pl. 3, fig. 10.

Not *Bolivina vaughani* Natland, 1938: Scripps Inst. Oceanography Tech. Ser., Bull., v. 4, p. 146, pl. 5, fig. 11.

These Miocene forms are much larger than Natland's Recent forms. Also they are more tapering toward the apertural end. Upper Luisian specimens occasionally develop costae on the early part of the test.

Occurrence: upper Luisian to upper Mohnian; tables 3 (18), 4 (37), 5 (33), 6 (28), 7 (14), 8 (43), 9 (13).

Bolivina woodringi Kleinpell

Bolivina woodringi Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 285, 286, pl. 21, figs. 4, 5, 1938.

Occurrence: Mohnian; tables 3 (40), 5 (39), 7 (38), 8 (44).

Bolivina cf. B. woodringi Kleinpell

Plate 57, figures 9 and 10

Occurring in a number of samples from the southern Santa Ana Mountains are specimens of *Bolivina* which closely resemble Kleinpell's species. They differ chiefly in their more acute, sometimes keeled periphery and broader test.

Occurrence: Luisian(?) to upper Mohnian; tables 3 (40), 4 (22), 5 (39).

Genus SUGGRUNDA Hoffmeister and Berry, 1937

Suggrunda kleinpelli Bramlette

Suggrunda kleinpelli Bramlette,, *in* Woodring and Bramlette, 1950: U.S. Geol. Survey Prof. Paper 222, p. 58, 59, pl. 23, figs. 4, 5, 9.

Occurrence: Relizian(?) to lower Mohnian; tables 3 (7), 4 (20), 5 (19), 6 (35), 7 (27), 8 (10), 9 (36).

Genus UVIGERINA d'Orbigny, 1828

Subgenus UVIGERINELLA Cushman, 1926

The apertural characteristics which distinguish this subgenus appear to be somewhat variable, even when good examples are found. Also, species assigned to it appear to belong to other genera; that is, *Uvigerinella californica* var. *gracilis* appears close to *Angulogerina.*

"Uvigerinella" californica Cushman

Uvigerina (Uvigerinella) californica Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 58, pl. 8, figs. 2*A*,*B*, and 5.

Uvigerinella californica Cushman. Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 287, 288, pl. 7, fig. 9 and pl. 9, fig. 13.

Occurrence: Luisian to lower Mohnian; tables 4 (32), 6 (10), 7 (29), 9 (34).

"Uvigerinella" californica Cushman var.

Forms with faint costae on all or on early part of test. Well preserved forms have three carinae on later part of test. May be *Angulogerina* sp.

Occurrence: lower Luisian to Mohnian; tables 4 (9), 5 (10), 8 (29).

Genus UVIGERINA sensu stricto

Uvigerina hootsi Rankin

Uvigerina hootsi Rankin, *in* Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 22, pl. 3, figs. 8 and 9.

Occurrence: lower Mohnian; tables 5 (38), 6 (21), 7 (31), 9 (38). The specimens in the interval from 193 to 233 feet in the Shell Oil Co.'s contraflush No. 38 (table 6 (21)) are poorly preserved, and are only doubtfully referred to this species.

Uvigerina joaquinensis Kleinpell

Plate 57, figures 1 and 2

Uvigerina joaquinensis Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 296, pl. 17, figs. 6, 10, 11.

Occurrence: upper Luisian to lower Mohnian; tables 3 (39), 4 (36), 5 (9).

Uvigerina subperegrina Cushman and Kleinpell

Uvigerina subperegrina Cushman and Kleinpell, 1934: Cushman Lab. Foram. Research Contr., v. 10, p. 12, pl. 2, figs. 9–11.

Occurrence: lower Luisian to upper Mohnian; tables 3 (30), 4 (23), 5 (34), 6 (7), 7 (11), 8 (28), 9 (7).

Genus HOPKINSINA Howe and Wallace, 1933

Hopkinsina magnifica Bramlette

Hopkinsina magnifica Bramlette, *in* Woodring and Bramlette, 1950: U.S. Geological Survey Prof. Paper 222, p. 59, 60, pl. 22, figs. 1–3, 5.

Occurrence: Upper Mohnian; table 3 (48).

Genus SIPHOGENERINA Schlumberger, emend. Mathews, 1945

Siphogenerina collomi Cushman

Siphogenerina collomi Cushman, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 2, pl. 4, fig. 3.

Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 300, pl. 15, fig. 11.

?*Siphogenerina nuciformis* Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 303, pl. 15, figs. 10, 12.

Primary types of *S. collomi* were examined and were identical with these specimens. No primary types of *S. nuciformis* were examined, but plesiotypes assigned by Kleinpell to this species appear to be within the range of variation of *S. collomi.* Therefore, *S. nuciformis* is questionably included in the synonomy of *S. collomi.*

Occurrence: lower to upper Luisian; tables 6 (1), 7 (21), 8 (22), 9 (5).

Genus ANGULOGERINA Cushman, 1927

Angulogerina(?) sp.

These forms are nearly always broken, but better preserved specimens have three carinae on later part of test. These may be the same form as "*Uvigerinella*" *californica* Cushman var. (see to left).

Occurrence: Mohnian; tables 3 (47), 4 (39), 7 (42), 9 (37).

Family ROTALIIDAE

Genus VALVULINERIA Cushman, 1926

Valvulineria araucana (d'Orbigny)

Rosalina araucana d'Orbigny, 1839: Voyage dans l' Amerique Meridionale: v. 5, pt. 5, Foraminifères, p. 44, pl. 6, figs. 16–18.

Valvulineria araucana (d'Orbigny). Cushman, 1927: Scripps Inst. Oceanography Tech. Ser., Bull., v. 1, p. 160, pl. 4, figs. 7, 8.

Occurrence: lower Mohnian; tables 6 (23), 9 (32).

Valvulineria californica Cushman

Plate 59, figures 4–6

Valvulineria californica Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 60, pl. 9, fig. 1*A–C*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 308, 309, pl. 13, fig. 6*A–C*.

Occurrence: Luisian; tables 5 (11), 6 (4), 8 (6).

Valvulineria californica Cushman var. obesa Cushman

Valvulineria californica Cushman var. *obesa* Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 61, pl. 9, fig. 2*A–C*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 310, 311, pl. 14, fig. 12*A–C*.

Occurrence: lower to upper Luisian; tables 3 (14), 4 (2), 6 (5), 7 (10), 8 (15), 9 (2).

Valvulineria depressa Cushman

Plate 59, figures 10–12

Valvulineria miocenica Cushman var. *depressa* Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 61, pl. 9, fig. 7*A–C*.
Valvulineria depressa Cushman. Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 311, 312, pl. 9, fig. 22*A–C* and pl. 13, fig. 5*A–C*.

Occurrence: Relizian(?) to lower Luisian; tables 3 (11), 7 (2), 8 (2).

Valvulineria cf. V. depressa Cushman

Specimens poorly preserved, may be *V. araucana* (d'Orbigny).

Occurrence: Mohnian; table 8 (2).

Valvulineria cf. V. grandis Cushman and Galliher

Plate 59, figures 13–15

This form differs from *V. grandis* Cushman and Galliher (1934: Cushman Lab. Foram. Research Contr., v. 10, p. 26, pl. 4, fig. 12*A–C*) in having a more involute ventral side and raised sutures. Because only the holotype of *V. grandis* is available in the U.S. National Museum, the affinity of these forms could be neither proved or disproved.

Occurrence: upper Luisian to lower Mohnian; tables 3 (22), 4 (3), 5 (36).

Valvulineria cf. *V. grandis* is apparently related to *V. californica* Cushman (p. 486, pl. 4, figs. 10–12) from which it can easily be distinguished by its oblique, raised, sigmoid-curved sutures. It appears at the end of the Luisian, and its range extends into the Mohnian after the true *V. californica* has disappeared. It seems to represent the last flourishing of the *californica*-type Valvulinerias in this region.

Valvulineria cf. *V. grandis* rather closely resembles *V. scintillans* Coryell and Mossman (1942: Jour. Paleontology, v. 16, p. 236, pl. 36, figs. 13–15), but it is much fatter and has a more rounded periphery than that species. Types of *V. scintillans* were unavailable at Columbia University.

It can be distinguished from *V. miocenica* Cushman (below, pl. 59, figs. 7–9) by its smaller number of chambers, less limbate ventral sutures, and its aperture.

Immature forms of *V.* cf. *V. grandis* resemble the form described by Kleinpell (1938, p. 325, 326, pl. 11, fig. 8*A–C*) as *Baggina robusta.*

Valvulineria miocenica Cushman

Plate 59, figures 7–9

Valvulineria miocenica Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 61, pl. 8, figs. 9, 10, pl. 9, fig. 3*A–C*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 313, pl. 16, fig. 1*A–C*.

Occurrence: lower to upper Luisian: tables 6 (3), 7 (12), 8 (24), 9 (1).

Valvulineria cf. V. miocenica Cushman

Poorly preserved specimens resembling *Valvulineria miocenica.*

Occurrence: Luisian(?) to lower Mohnian; table 6 (24).

Valvulineria cf. V. ornata Cushman

These forms resemble *Valvulineria miocenica* Cushman but are more equally biconvex than that species, and have wider clear areas around sutures. They are fatter than the typical *V. ornata* (1926: Cushman Lab. Foram. Research Contr., v. 2, p. 61, pl. 9, fig. 4*A–C*).

Occurrence: upper Luisian; table 9 (22).

Valvulineria williami Kleinpell

Valvulineria williami Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 315, fig. 14*A–C*.

Occurrence: Luisian(?); table 4(1).

Genus GYROIDINA d'Orbigny, 1826

Gyroidina rotundimargo R. E. and K. C. Stewart

Plate 59, figures 1–3

Gyroidina soldanii d'Orbigny var. *rotundimargo* R. E. and K. C. Stewart, 1930: Jour. Paleontology, v. 4, p. 68, pl. 9, fig. 3*A–C*.

Occurrence: upper Luisian to lower Mohnian; tables 3 (49), 4 (24), 5 (37), 6 (31), 7 (16), 8 (34), 9 (10).

Gyroidina sp.

Too poorly preserved to be assignable to any species, but does not appear to be *G. rotundimargo* R. E. and K. C. Stewart.

Occurrence: lower Mohnian; table 3 (23).

Genus EPONIDES Montfort, 1808

Eponides rosaformis Cushman and Kleinpell

Eponides rosaformis Cushman and Kleinpell, 1934: Cushman Lab. Foram Research Contr., v. 10, p. 14, pl. 2, fig. 18*A–C*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 321.

Occurrence: upper Luisian to lower Mohnian; tables 3 (32), 5 (29), 6 (29), 7 (23), 8 (37).

Genus CANCRIS Montfort, 1808

Cancris baggi Cushman and Kleinpell

Cancris baggi Cushman and Kleinpell, 1934: Cushman Lab. Foram Research Contr., v. 10, p. 15, pl. 3, fig. 2*A–C*.

Occurrence: upper Luisian: tables 8 (33), 9 (16).

Genus BAGGINA Cushman, 1926

Baggina californica Cushman

Baggina californica Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 64, pl. 9, fig. 8*A–C*.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 324, pl. 13, fig. 3*A–C*.

Occurrence: lower Luisian to lower Mohnian; tables 3 (45), 4 (26), 5 (35), 6 (11), 7 (17), 8 (21), 9 (27).

Family CASSIDULINIDAE

Genus EPISTOMINELLA Husezima and Maruhasi, 1944

Epistominella gyroidinaformis (Cushman and Goudkoff)

Pulvinulinella gyroidinaformis Cushman and Goudkoff, 1938: Cushman Lab. Foram. Research Contr., v. 14, p. 1, 2, pl. 1, figs. 1, 2.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 328, pl. 18, figs. 17–19.

Occurrence: upper Luisian to lower Mohnian; tables 3 (15), 4 (28), 5 (5), 6 (20), 7 (32), 9 (42).

Epistominella pacifica (Cushman)

Plate 58, figures 12–14

Pulvinulinella pacifica Cushman, *in* Cushman, Stewart, and Stewart, 1930: San Diego Soc. Nat. History Trans., v. 6, p. 73, pl. 6, fig. 5.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 328, 329.

Occurrence: Mohnian; tables 4 (29), 6 (25).

Epistominella relizensis (Kleinpell)

Pulvinulinella relizensis Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 329, 330, pl. 10, fig. 10*A–C*.
Natland, 1950: Geol. Soc. America Mem. 43, pt. 4, p. 33, pl. 9, fig. 4*A–C*.

Primary types of this species were not examined, but comparison with Kleinpell's figures and descriptions indicates that these specimens should be referred to *E. relizensis*.

Occurrence: lower Luisian to upper Mohnian; tables 3 (17), 4 (14), 5 (21), 6 (27), 7 (7), 8 (12), 9 (26).

Kleinpell states that the range of his species is upper Saucesian to upper Luisian. Its occurrence here in the Mohnian represents an upward extension of its range.

Epistominella subperuviana (Cushman)

Pulvinulinella subperuviana Cushman, 1926: Cushman Lab. Foram. Research Contr., v. 2, p. 63, pl. 9, fig. 9*A–C*.

Occurrence: upper Luisian to lower Mohnian; tables 4 (35), 5 (16), 6 (18), 7 (22), 8 (42), 9 (11).

Epistominella thalmanni (Stainforth and Stevenson)

Plate 58, figures 9–11

Palmerinella thalmanni Stainforth and Stevenson, 1946: Jour. Paleontology, v. 20, p. 563, pl. 86, figs. 7–10.
Pseudoparella thalmanni (Stainforth and Stevenson). Cushman and Stevenson, 1948: Cushman Lab. Foram. Research, v. 24, p. 66, pl. 10, figs. 26, 27.

Specimens from California were compared with Stainforth and Stevenson's lower Miocene forms and were found identical.

Occurrence: Mohnian; Table 7 (39).

This form is very close to *Epistominella evax* Bandy (1953a, p. 179, pl. 23, fig. 1) from the Recent off the Pacific coast of California. It is flatter, and the dorsal sutures are straighter. The periphery is less lobulate, with moderately wide carina.

Genus CASSIDULINA d'Orbigny, 1826

Cassidulina cushmani R. E. and K. C. Stewart

Cassidulina cushmani R. E. and K. C. Stewart, 1930: Jour. Paleontology, v. 4, p. 71, pl. 9, fig. 5.

Occurrence: lower Mohnian; tables 3 (44), 5 (25), 7 (36), 9 (44).

Cassidulina limbata Cushman and Hughes

Cassidulina limbata Cushman and Hughes, 1925: Cushman Lab. Foram. Research Contr., v. 1, p. 12, pl. 2, fig. 2A–C.
Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 333, pl. 9, fig. 21.

Occurrence: Luisian (?); table 4 (16).

Cassidulina cf. C. margareta Karrer

Thinner test than that figured by Kleinpell (1938, p. 333, 334, pl. 8, fig. 10); periphery subacute.

Occurrence: Luisian (?); table 4 (17).

Cassidulina cf. C. panzana Kleinpell

Differs from the form described by Kleinpell (1938, p. 335, pl. 8, fig. 19) in presence of clear umbilical area. Possibly related to *C. translucens* Cushman and Hughes (1925: Cushman Lab. Foram. Research Contr., v. 1, p. 15, pl. 2, fig. 5) in shorter chambers, straighter sutures, and subacute periphery.

Occurrence: Luisian; tables 6 (12), 7 (3).

Cassidulina williami Kleinpell

Cassidulina williami Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 337, pl. 14, fig. 5, pl. 17, figs. 7, 8.

Occurrence: lower Luisian; table 8 (1).

Family CHILOSTOMELLIDAE

Genus PULLENIA Parker and Jones, 1862

Pullenia miocenica Kleinpell

Pullenia miocenica Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 338, 339, pl. 14, fig. 6.

Occurrence: lower Luisian to lower Mohnian; table 8 (11).

Pullenia miocenica Kleinpell var. globula Kleinpell

Pullenia miocenica Kleinpell var. *globula* Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 340, pl. 16, fig. 2*A*,*B*.

Occurrence: upper Luisian; tables 7 (15), 8 (35), 9 (15).

Family GLOBIGERINIDAE

Genus GLOBIGERINA d'Orbigný, 1826

Globigerina bulloides d'Orbigny

Globigerina bulloides d'Orbigny. Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 343, 344, pl. 7, fig. 17.

Occurrence: lower Luisian to upper Mohnian; tables 3 (31), 4 (18), 5 (24), 6 (30), 7 (8), 8 (14), 9 (12).

Family ANOMALINIDAE

Genus ANOMALINA d'Orbigny, 1826

Anomalina salinasensis Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 347, pl. 13, fig. 1*A–C*.

Occurrence: upper Luisian; table 8 (38).

Genus PLANULINA d'Orbigny, 1826

Planulina ornata (d'Orbigny)

Truncatulina ornata d'Orbigny, 1839, Voyage dans l'Amerique Meridionale: v. 5, pt. 5, Foraminifères, p. 40, pl. 6, figs. 7–9.

Planulina ornata (d'Orbigny). Cushman, 1927, Scripps Inst. Oceanography, Tech. Ser. Bull., v. 1, p. 176, pl. 6, fig. 12.

Occurrence: Luisian(?) to lower Mohnian; tables 3 (34), 4 (15), 5 (40), 6 (34).

Genus DISCORBINELLA Cushman and Martin, 1935

Discorbinella valmonteensis Kleinpell

Discorbinella valmonteensis Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 350, 351, pl. 21, figs. 14–16.

Occurrence: lower Mohnian; table 8 (46).

Genus CIBICIDES Montfort, 1808

Cibicides sp.

Rare, nondescript form.

Occurrence: Luisian(?); table 4 (21).

Cibicides illingi (Nuttall)

Cibicides illingi (Nuttall). Kleinpell, 1938, Miocene stratigraphy of California: Tulsa, Okla., p. 354, pl. 19, fig. 10, pl. 20, figs. 18–20.

This form was compared with Kleinpell's types and found to be identical.

Occurrence: upper Luisian to lower Mohnian; tables 4 (30), 5 (8), 6 (33), 9 (33).

Foraminifera localities in the Miocene series, Santa Ana Mountains and San Juan Capistrano area, California

No. used in this report	USGS permanent No.	Field No.	Collector	Description of locality
			Topanga formation	
m1	f11413	Y8b	D. M. Kinney, R. F. Yerkes	36,700 ft south and 6,275 ft west of northeast corner of Orange quadrangle; elevation 710 ft. Between Panorama Heights and Peters Canyon.
m2	f11414		D. M. Kinney	35,600 ft south and 7,050 ft west of northeast corner Orange quadrangle; elevation 720 ft. Between Panorama Heights and Peters Canyon.
m3	f11415		do	17,300 ft south and 11,950 ft west of northeast corner Orange quadrangle; elevation 620 ft. Between Walnut Canyon and Cerro Villa Heights.
m4	f11416			18,775 ft south and 24,250 ft west of northeast corner Orange quadrangle. McKee-Kokx Community 8-1 well, core sample from2, 354 to 2,360 ft.
			El Modeno volcanics	
m5	f11417	Y6a	R. F. Yerkes	17,575 ft south and 950 ft west of northeast corner of Orange quadrangle; elevation 1,130 ft. Near divide between Walnut Canyon and Weir Canyon.
			Puente formation	
m6	f11418	Y5e	R. F. Yerkes	35,550 ft south and 37,500 ft west of northeast corner Black Star Canyon quadrangle; elevation 720 ft. Near Santiago Canyon Road and BM 791.
m7	f11419	S344	J. E. Schoellhamer	35,350 ft south and 18,575 ft west of northeast corner Orange quadrangle; elevation 290 ft. Road cut near La Paloma.
m8	f11420		do	18,200 ft south and 18,575 ft west of northeast corner Orange quadrangle; elevation 440 ft. Road cut on Mesa Drive near Cerro Villa Heights.
m8a			do	17,550 ft south and 20,450 ft west of northeast corner Orange quadrangle; elevation 400 ft. Between Burruel Point and Cerro Villa Heights.

Foraminifera localities in the Miocene series, Santa Ana Mountains and San Juan Capistrano area, California—Continued

No. used in this report	USGS permanent No.	Field No.	Collector	Description of locality
Puente formation—Continued				
m9	f11421	S193	D. M. Kinney, J. E. Schoellhamer.	150 ft north and 32,750 ft west of northeast corner of Black Star Canyon quadrangle; elevation 335 ft. In Santa Ana River bottom.
m10	f11422	Y5d	D. M. Kinney, J. E. Schoellhamer, R. F. Yerkes.	34,650 ft south and 1,900 ft west of northeast corner Orange quadrangle; elevation 620 ft. Near Peters Canyon Reservoir.
m11	f11423	S67	J. E. Schoellhamer	3,325 ft south and 31,000 ft west of northeast corner of Black Star Canyon quadrangle; elevation 600 ft. Old road cut above Santa Ana Canyon road and west of Gypsum Canyon.
m12	f11424	S366	do	39,250 ft south and 30,200 ft west of northeast corner of Black Star Canyon quadrangle; elevation 820 ft. Road cut near south shore of Irvine Lake.
m12a		S367	do	Same as m12, but 6 ft stratigraphically higher.
m12b		S370	do	Same as m12, but 35 ft stratigraphically higher.
m12c	f11425	S371	do	Same as m12, but 48.5 ft stratigraphically higher.
m12d		S374	do	Same as m12, but 81.5 ft stratigraphically higher.
m14	f11426	S236	do	40,600 ft south and 36,900 ft west of northeast corner Black Star Canyon quadrangle; elevation 1,160 ft. Near divide between Peters Canyon and Santiago Canyon road.
m16	f11428	S2	do	4,200 ft south and 32,500 ft west of northeast corner Black Star Canyon quadrangle; elevation 660 ft. Near Santa Ana Canyon road west of Gypsum Canyon.
m17	f11429		do	16,500 ft south and 19,400 ft west of northwest corner Orange quadrangle; elevation 560 ft. Between Burruel Point and Cerro Villa Heights.
Monterey shale				
m18	f11430	S259a	J. E. Schoellhamer	20,950 ft south and 26,250 ft west of northeast corner El Toro quadrangle; elevation 470 ft. Ditch on south side of Lambert Reservoir.
m19	f11431	S259	do	Same locality as m18; about 20 ft higher stratigraphically.
m20	f11432	Y78a	J. E. Schoellhamer, R. F. Yerkes.	21,675 ft south and 5,550 ft west of northeast corner El Toro quadrangle; elevation 1,450 ft. Near head of Serrano Creek.
m21	f11433	Y78b	do	21,875 ft south and 5,525 ft west of northeast corner El Toro quadrangle; elevation 1,420 ft. Near head of Serrano Creek.
m22	f11434	Y78c	do	21,950 ft south and 5,525 ft west of northeast corner El Toro quadrangle; elevation 1,410 ft. Near head of Serrano Creek.
m23	f11435	Y79e	do	19,500 ft south and 10,600 ft west of the northeast corner of the El Toro quadrangle; elevation 1,140 ft. Near head of Borrego Canyon.
m24	f11436	Y78d	do	22,025 ft south and 5,600 ft west of northeast corner El Toro quadrangle; elevation 1,400 ft. Near head of Serrano Creek.
m25	f11437	Y79d	do	19,650 ft south and 10,600 ft west of northeast corner El Toro quadrangle; elevation 1,180 ft. Near head of Borrego Canyon.
m26	f11438	Y79c	do	19,750 ft south and 10,700 ft west of northeast corner El Toro quadrangle; elevation 1,200 ft. Near head of Borrego Canyon.
m27	f11439	Y79b	do	19,850 ft south and 10,800 ft west of northeast corner El Toro quadrangle; elevation 1,210 ft. Near head of Borrego Canyon.
m28	f11440	Y78f	do	22,525 ft south and 5,600 ft west of northeast corner El Toro quadrangle; elevation 1,320 ft. Near head of Serrano Creek.
m29	f11441	S289	J. E. Schoellhamer	40,600 ft south and 325 ft west of northeast corner of the El Toro quadrangle; elevation 980 ft. Between Oso Creek and Arroyo Trabuco.
m30	f11442	S287a	do	40,550 ft south and 2,775 ft west of northeast corner El Toro quadrangle; elevation 820 ft. Between Oso Creek and Arroyo Trabuco.
m31	f11443	S307	do	12,700 ft south and 2,250 ft west of northeast corner San Juan Capistrano quadrangle; elevation 500 ft. In Arroyo Trabuco near junction with Tijeras Canyon.
m32	f11444	V102	J. G. Vedder	33,400 ft south and 775 ft west of northeast corner San Juan Capistrano quadrangle; elevation 580 ft. Between Horno Creek and San Juan Creek.

Foraminifera localities in the Miocene series, Santa Ana Mountains and San Juan Capistrano area, California—Continued

No. used in this report	USGS permanent No.	Field No.	Collector	Description of locality
			Monterey shale—Continued	
m33	f11445	V101	J. G. Vedder	34,400 ft south and 1,025 ft west of northeast corner San Juan Capistrano quadrangle; elevation 420 ft. Between Horno Creek and San Juan Creek.
m34	f11446	S305	J. E. Schoellhamer	17,200 ft south and 5,300 ft west of northeast corner San Juan Capistrano quadrangle; elevation 460 ft. West side of Arroyo Trabuco.
m35	f11447	Y66d	R. F. Yerkes	18,100 ft south and 5,450 ft west of northeast corner San Juan Capistrano quadrangle; elevation 480 ft. West side Arroyo Trabuco.
m36	f11448	S300	J. E. Schoellhamer	9,875 ft south and 7,425 ft west of northeast corner San Juan Capistrano quadrangle; elevation 465 ft. Between Oso Creek and Arroyo Trabuco.
m37	f11449	S301	do	10,100 ft south and 6,950 ft west of northeast corner San Juan Capistrano quadrangle; elevation 520 ft. Between Oso Creek and Arroyo Trabuco.
m38	f11450	S302	do	11,075 ft south and 6,150 ft west of northeast corner San Juan Capistrano quadrangle; elevation 550 ft. Between Oso Creek and Arroyo Trabuco.
m39	f11451	Y69b	R. F. Yerkes	32,000 ft south and 4,425 ft west of northeast corner San Juan Capistrano quadrangle; elevation 300 ft. Near head of Horno Creek.
m40	f11452	B115a	P. B. Smith	14,175 ft south and 32,500 ft west of northeast corner San Juan Capistrano quadrangle; elevation 560 ft. Near ranch road between Aliso Creek and Niguel Road.
m41	f11453	V10	J. G. Vedder	23,150 ft south and 32,650 ft west of northeast corner San Juan Capistrano quadrangle; elevation 340 ft. Between Wood Canyon and Aliso Creek.
m42	f11454	B115c	P. B. Smith	14,200 ft south and 31,500 ft west of northeast corner San Juan Capistrano quadrangle; elevation 440 ft. Near ranch road between Aliso Creek and Niguel Road.
m43	f11455	V5	J. G. Vedder	Same locality as m42, but contains a different fauna. Stratigraphic relation to m42 is unknown.
m44	f11456	B115e	P. B. Smith	14,800 ft south and 31,250 ft west of northeast corner San Juan Capistrano quadrangle; elevation 390 ft. Between Aliso Creek and Niguel Road.
m45	f11457	B115b	do	14,100 ft south and 31,800 ft west of northeast corner San Juan Capistrano quadrangle; elevation 480 ft. Between Aliso Creek and Niguel Road.
m46	f11458	B116a	do	14,850 ft south and 31,075 ft west of northeast corner San Juan Capistrano quadrangle; elevation 380 ft. Between Aliso Creek and Niguel Road.
m47	f11459	B116b	P. B. Smith	15,100 ft south and 30,875 ft west of northeast corner San Juan Capistrano quadrangle; elevation 360 ft. Between Aliso Creek and Niguel Road.
m48	f11460	V12	J. G. Vedder	4,800 ft south and 29,375 ft west of northeast corner San Juan Capistrano quadrangle; elevation 360 ft. On Niguel Road near intersection with U.S. Highway 101.
m49	f11461	B116c	P. B. Smith	14,975 ft south and 30,350 ft west of northeast corner San Juan Capistrano quadrangle; elevation 420 ft. Between Niguel Road and Aliso Creek.
m50	f11462	B116d	do	16,025 ft south and 29,250 ft west of northeast corner San Juan Capistrano quadrangle; elevation 340 ft. Between Niguel Road and Aliso Creek.
m51	f11463	V42	J. G. Vedder	6,175 ft south and 25,425 ft west of northeast corner San Juan Capistrano quadrangle; elevation 350 ft. Near intersection of Niguel Road and U.S. Highway 101.
m52	f11464	B116f	P. B. Smith	16,725 ft south, 27,875 ft west of northeast corner San Juan Capistrano quadrangle; elevation 255 ft. Between Niguel Road and Aliso Creek.
m53	f11465	B116e	do	16,350 ft south and 28,575 ft west of northeast corner San Juan Capistrano quadrangle; elevation 300 ft. Between Aliso Creek and Niguel Road.
m54	f11466	V43	J. G. Vedder	7,500 ft south and 24,625 ft west of northeast corner San Juan Capistrano quadrangle; elevation 360 ft. Aliso Creek near U.S. Highway 101.
m55	f11467	V65	do	21,600 ft south and 27,500 ft west of northeast corner San Juan Capistrano quadrangle; elevation 240 ft. East side of Aliso Creek.
m56	f11468	V13	do	38,400 ft south and 28,900 ft west of northeast corner San Juan Capistrano quadrangle; elevation 460 ft. Between Niguel Hill and Arroyo Salada.

REFERENCES

Bandy, O. L., 1953a, Ecology and paleoecology of some California Foraminifera—Part I. The frequency distribution of Recent Foraminifera off California: Jour. Paleontology, v. 27, p. 161–182.

——— 1953b, Ecology and paleoecology of some California Foraminifera—Part II. Foraminiferal evidence of subsidence rate in the Ventura Basin: Jour. Paleontology, v. 27, p. 200–203.

Cushman, J. A., 1937, A monograph of the subfamily Virgulininae of the foraminiferal family Buliminidae: Cushman Lab. Foram. Research Spec. Pub. No. 9.

Cushman, J. A., and Galliher, E. W., 1934, Additional new Foraminifera from the Miocene of California: Cushman Lab. Foram. Research Contr., v. 10, p. 24–26.

Cushman, J. A., and Kleinpell, R. M., 1934, New and unrecorded Foraminifera from the California Miocene: Cushman Lab. Foram. Research. Contr., v. 10, p. 1–23.

Cushman, J. A., and Parker, F. L., 1946, *Bulimina* and related foraminiferal genera: U.S. Geol. Survey Prof. Paper 210–D.

Kleinpell, R. M., 1938, Miocene stratigraphy of California: Am. Assoc. Petroleum Geologists, Tulsa, Okla., 450 p.

Natland, M. L., 1933, Temperature- and depth-distribution of some Recent and fossil Foraminifera in the southern California region: Scripps Inst. Oceanography, Tech. Ser. Bull., v. 3, p. 225–230.

Otto, G. H., 1933, Comparative tests of several methods of sampling heavy mineral concentrates: Jour. Sed. Petrology, v. 3, p. 30–39.

Pierce, R. L., 1956, Mohnian Foraminifera and fish from Benedict Canyon, Sherman Oaks, California: Jour. Paleontology, v. 30, p. 1288–1314.

Reed, R. D., and Hollister, J. S., 1936, Structural evolution of southern California: Am. Assoc. Petroleum Geologists, Tulsa, Okla., 157 p.

Schoellhamer, J. E., Kinney, D. M., Yerkes, R. F., and Vedder, J. G., 1954, Geologic map of the Santa Ana Mountains, Orange and Riverside Counties, California: U.S. Geol. Survey Oil and Gas Inv. Ser. Map OM 154.

Vedder, J. G., Yerkes, R. F., and Schoellhamer, J. E., 1957, Geologic map of the San Joaquin Hills and San Juan Capistrano Area, Orange County, California: U.S. Geol. Survey Oil and Gas Inv. Ser. Map OM 193.

Woodford, A. O., Schoellhamer, J. E., Vedder, J. G., and Yerkes, R. F., 1955, Geology of the Los Angeles Basin: *in* Calif. Div. Mines Bull. 170, chap. 2, p. 65–81.

Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., 1946, Geology and paleontology of Palos Verdes Hills, California: U.S. Geol. Survey Prof. Paper 207, 145 p.

Yerkes, R. F., 1957, Volcanic rocks of the El Modeno area, Orange County, California: U.S. Geol. Survey Prof. Paper 274–K.

INDEX

[Italic numbers indicate catalog mention]

PLATES 57–59

PLATE 57

FIGURES 1, 2. *Uvigerina joaquinensis* Cushman and Kleinpell (p. 485).
1. **Apertural view, slightly oblique. 2. Side view. ×140. USNM 624900.**

3, 4. *Bolivina advena* Cushman var. (p. 483).
3. **Apertural view. 4. Side view. ×186. USNM 624860.**

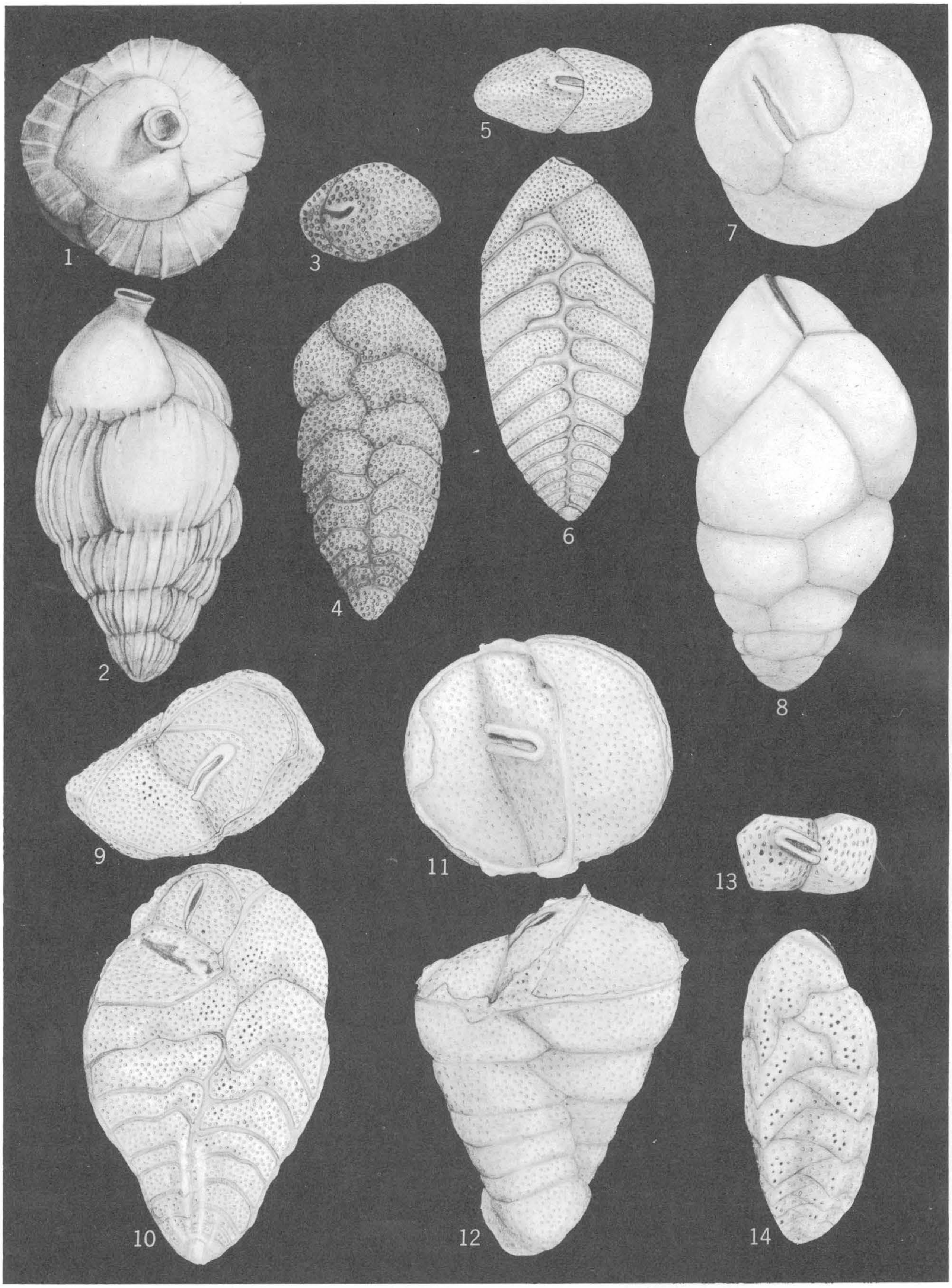
5, 6. *Bolivina decurtata* Cushman (p. 483).
5. **Apertural view. 6. Side view. ×140. USNM 624881.**

7, 8. *Bulimina* cf. *B. pseudoaffinis* Kleinpell (p. 482).
7. **Apertural view. 8. Side view. ×140. USNM 624848.**

9, 10. *Bolivina* cf. *B. woodringi* Kleinpell (p. 485).
9. **Apertural view. 10. Side view. ×186. USNM 624891.**

11, 12. *Bolivina* cf. *B. subhughesi* Kleinpell (p. 484).
11. **Apertural view. 12. Side view. ×186. USNM 624886.**

13, 14. *Bolivina* cf. *B. rhomboidalis* (Millett) (p. 484).
13. **Apertural view. 14. Side view. ×186. USNM 624875.**



FORAMINIFERA OF THE MONTEREY SHALE AND PUENTE FORMATION

PLATE 58

FIGURES 1, 2. *Buliminella ecuadorana* Cushman and Stevenson (p. 481).

1. Apertural view. 2. Side view. ×140. USNM 548920.

3, 4. *Bulimina carnerosensis* Cushman and Kleinpell (p. 482).

3. Apertural view. 4. Side view. ×186. USNM 624852.

5, 6. *Nonion* aff. *N. costiferum* (Cushman) (p. 481).

5. Side view. 6. Peripheral view. ×186. USNM 548915.

7, 8. *Bolivina* cf. *B. vaughani* Natland (p. 484).

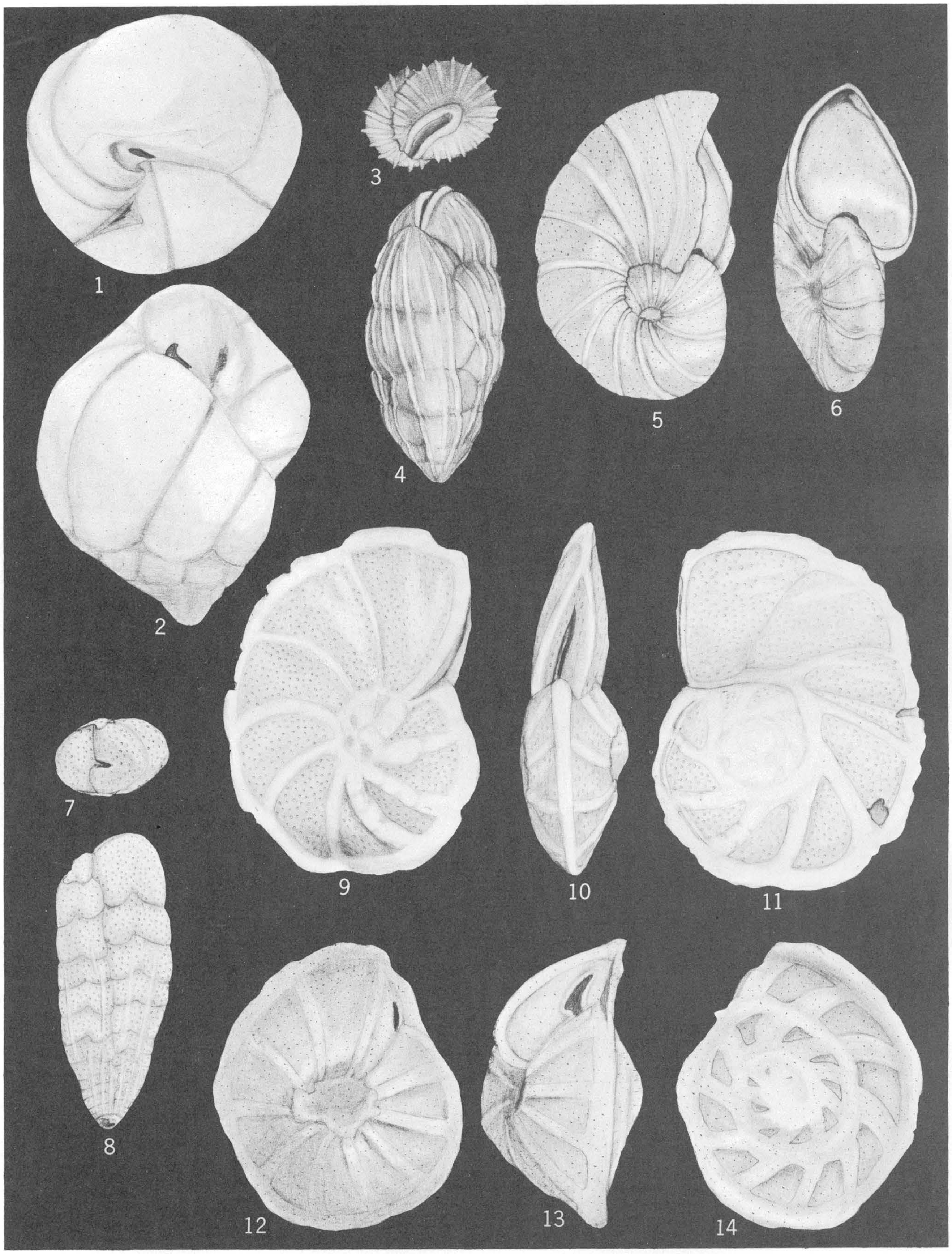
7. Apertural view. 8. Side view. ×186. USNM 624889.

9–11. *Epistominella thalmanni* (Stainforth and Stevenson) (p. 487).

9, 11. Side views. 10. Peripheral view. ×186. USNM 624843.

12–14. *Epistominella pacifica* (R. E. and K. C. Stewart) (p. 487).

12, 14. Side views. 13. Peripheral view. ×186. USNM 624921.



FORAMINIFERA OF THE MONTEREY SHALE AND PUENTE FORMATION

PLATE 59

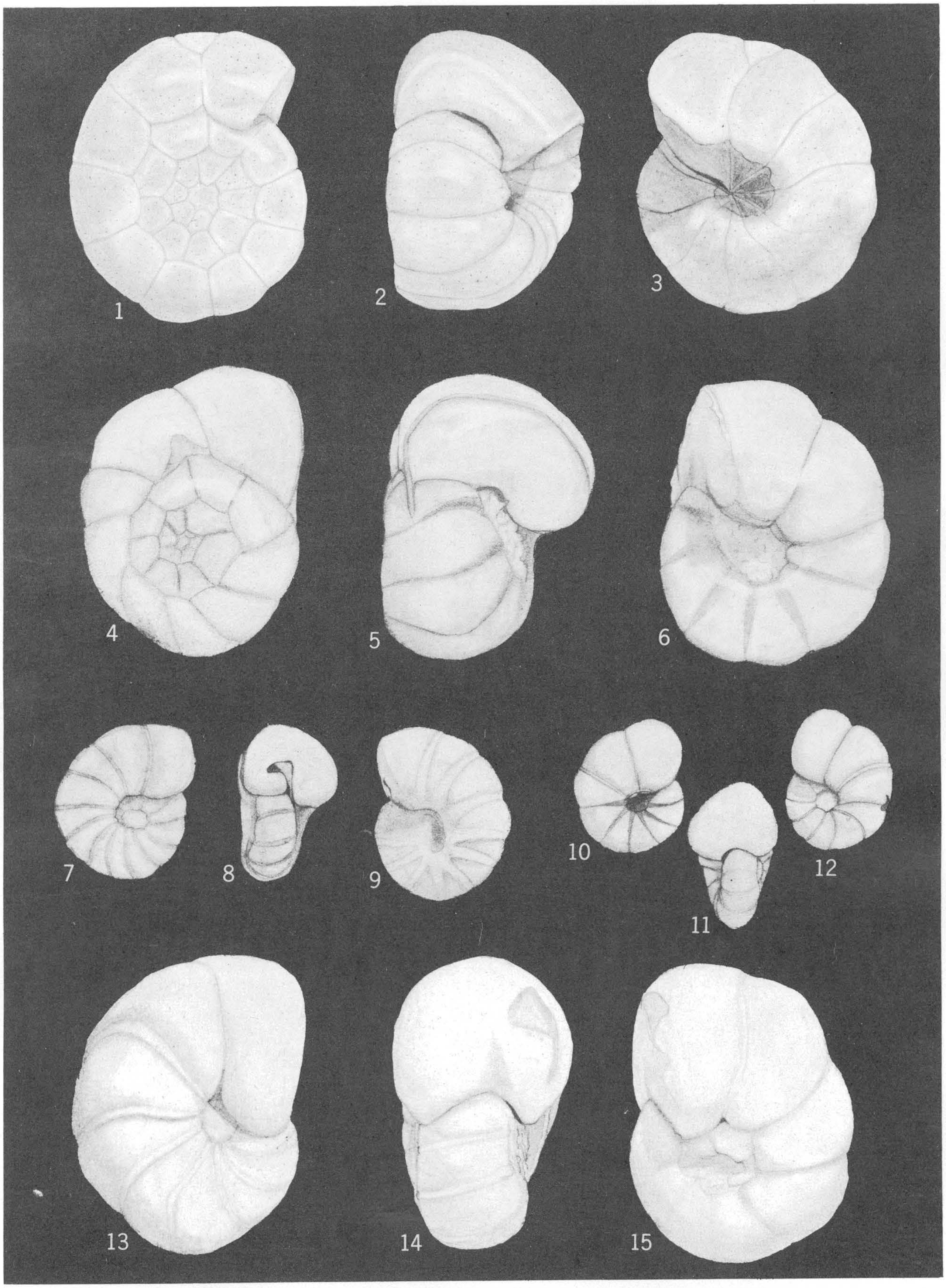
FIGURES 1–3. *Gyroidina rotundimargo* R. E. and K. C. Stewart (p. 486).
1, 3. Side views. 2. Peripheral view. ×186. USNM 624912.

4–6. *Valvulineria californica* Cushman (p. 486).
4, 6. Side views. 5. Peripheral view. ×70. USNM 624905.

7–9. *Valvulineria miocenica* Cushman (p. 486).
7, 9. Side views. 8. Peripheral view. ×70. USNM 624909.

10–12. *Valvulineria depressa* Cushman (p. 486).
10, 12. Side views. 11. Peripheral view. ×70. USNM 624907.

13–15. *Valvulineria* cf. *V. grandis* Cushman and Galliher (p. 486).
13, 15. Side views. 14. Peripheral view. ×70. USNM 624917.



FORAMINIFERA OF THE MONTEREY SHALE AND PUENTE FORMATION