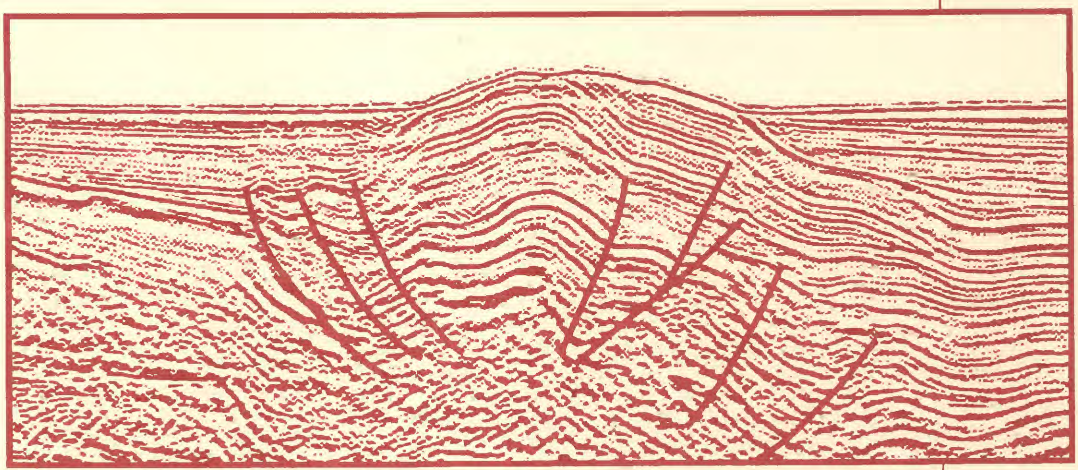
Recognition of Middle Miocene Foraminifers in Highly Indurated Rocks of the Monterey Formation, Coastal Santa Maria Province, Central California



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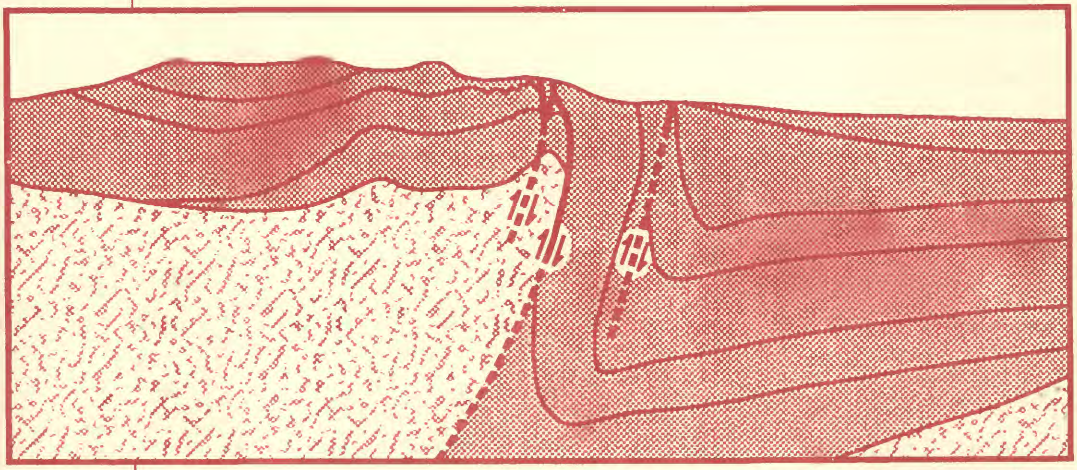

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Chapter L

Recognition of Middle Miocene Foraminifers in Highly Indurated Rocks of the Monterey Formation, Coastal Santa Maria Province, Central California

By KENNETH L. FINGER

U.S. GEOLOGICAL SURVEY BULLETIN 1995

EVOLUTION OF SEDIMENTARY BASINS/ONSHORE OIL AND GAS INVESTIGATIONS—
SANTA MARIA PROVINCE

Edited by Margaret A. Keller

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1995

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Library of Congress Cataloging in Publication Data

Finger, Kenneth L.
Recognition of Middle Miocene foraminifers in highly indurated rocks of the Monterey Formation, coastal Santa Maria Province, central California / by Kenneth L. Finger.
p. cm.--(Evolutlon of sedimentary basins/onshore oil and gas investigations--Santa Maria Province; L) (U.S. Geological Survey Bulletin: 1995)
Includes b1bilographica1 references (p. -).
Supt. of Docs. no.; I 19.3:1995-L
1. Foraminifera, Fossil--California--Santa Maria basin. 2. Paleontology--Miocene. 3. Monterey Formation (Calif.) I. Title. II. Series. III. Serles: Evolution of sedimentary basins/onshore oil and gas investigatlons--Santa Maria Provlnce: ch. L.
QE75.B9 no. 1995-L
[QE772]
557.3 s--dc20
[563'.12'09794] 95-22276
CIP

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Recognition of Middle Miocene Foraminifers in Highly Indurated Rocks of the Monterey Formation, Coastal Santa Maria Province, Central California

By Kenneth L. Finger[1]

ABSTRACT

Investigations were undertaken to identify and interpret foraminiferal assemblages in six outcrop sections of the Monterey Formation in the onshore Santa Maria basin, Calif.—Mussel Rock, Lions Head, Point Pedernales, Rodeo Canyon, Sweeney Road, and Manville Quarry. The purpose of this study was to complement existing lithostratigraphic and siliceous microfossil data from these sections with traditional benthic foraminiferal stage correlations. Most of these rocks are devoid of foraminifers, owing to their relatively high diagenetic alteration in which the foraminiferal calcite was converted into dolomite. No foraminifers were recovered from Point Pedernales or within the Manville Quarry, and only one specimen was obtained from Sweeney Road. Most, but not all, of the coastal outcrops at Mussel Rock, Lions Head, and Rodeo Canyon are similarly devoid of foraminifers. The few foraminifer-bearing rocks at these localities are highly indurated, rendering it difficult to isolate specimens by conventional processing techniques. Most specimens freed from the rock matrix are poorly preserved and not easily identified. To compensate for these hindrances, foraminifers were studied in petrographic thin sections. The stage-diagnostic benthic foraminiferal assemblages recognized are those of (1) the Relizian-Luisian for the lower calcareous-siliceous member of the Monterey Formation at Rodeo Canyon, (2) the Relizian-Luisian for the lower part of the phosphatic member of the Monterey Formation at Lions Head, (3) the Luisian for the upper part of the phosphatic member at Lions Head, (4) the Luisian for the lower part of the phosphatic member at Mussel Rock, and (5) the Mohnian for the upper part of the phosphatic member at Mussel Rock.

The assemblages recovered from Mussel Rock and Lions Head contain foraminifers indicative of deposition in the lower middle-bathyal (1,500-2,000 m) zone. The Relizian-Luisian foraminiferal assemblage at Rodeo Canyon occurs in a pelletal phosphorite formed on a sediment-starved bank at a water depth of about 1,500 m and later redeposited as a turbidite on the basin floor. Paleoenvironmental marker species indicate that the Relizian-Luisian, Luisian, and Mohnian foraminiferal assemblages in the calcareous mudstones of the phosphatic member of the Monterey Formation along the Santa Maria coast are bathymetrically mixed associations deposited at lower middle-bathyal (1,500-2,000 m) depths.

This document contains an extensive set of faunal illustrations that will provide paleontologists and petrographers working on the Monterey Formation with an ample visual reference for recognizing similar foraminiferal assemblages in correlative stratigraphic sections.

INTRODUCTION

The purpose of this study of foraminiferal assemblages in the Monterey Formation was to complement a lithostratigraphic study on selected outcrops in Santa Maria basin (fig. 1) and was intended to provide regional correlations that possibly could be extended into the adjacent offshore areas. This report incorporates a slightly updated version (Finger, 1992) of Barron's (1986a, b) biostratigraphic correlation chart for the Neogene of California (fig. 2) and utilizes the lithostratigraphic subdivisions of the Monterey Formation proposed by MacKinnon (1989a) for the Santa Maria basin (fig. 3). Initial biostratigraphic studies were restricted to siliceous microfossils (for example, Akers and others, 1987) because biogenically derived silica is abundant in many of the rocks in the sections investigated. During the course of these studies, it became apparent that siliceous microfossils are generally rare or absent in the calcareous mudstones of the lower part of the Monterey Formation, where foraminifers were more likely to be present. Thus, an investigation of the foraminiferal fauna was undertaken in order to complete the biostratigraphic analysis.

Six sections in western Santa Barbara County were selected for foraminiferal studies—Mussel Rock, Lions Head, Point Pedernales, Rodeo Canyon, Sweeney Road, and Manville Quarry. In the coastal bluffs at Mussel Rock, Lions Head, and Rodeo Canyon, foraminifers are restricted to the Point Sal Formation (equivalent to the lowest part of the Monterey Formation in other regions; Woodring and Bramlette, 1950) and the lower calcareous-siliceous mem-

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Manuscript approved for publication May 3, 1995.

ber and the phosphatic member of the lower part of the Monterey Formation. One other suite of 20 samples collected in the lower part of the Monterey Formation from Point Pedernales yielded no foraminifers. Samples from the overlying upper calcareous-siliceous member (22 samples) and clayey-siliceous member (7 samples) of the upper part of the Monterey Formation and the Sisquoc Formation (15 samples) at Point Pedernales were similarly devoid of foraminifers. Rocks collected from the Sweeny Road section yielded only one specimen from the 50 samples collected in the upper part of the Monterey Formation (see Akers and others, 1987) and none from the 23 samples collected in the Sisquoc Formation. Although there is excellent recovery from the upper part of the Monterey Formation exposed along the access road to the Manville Quarry (Finger, 1992; also Govean and Garrison, 1981; Ingle, 1985), younger Monterey and Sisquoc Formation rocks within the quarry are devoid of foraminifers and rich in siliceous microfossils (Barron, 1975, 1976). When compared to the assemblages recovered from Mussel Rock, Lions Head, and Rodeo Canyon, those from the Manville Quarry access road are younger, better preserved, and characterized by higher abundances and species diversities. I have detailed their faunal succession in another publication (see Finger, 1992). These intrabasinal differences suggest that local variations in depositional and diagenetic processes have been important factors in determining the preservation of foraminifers in these rock units.

The present investigation focuses on the recognition of foraminifers in the coastal sections of Mussel Rock, Lions Head, and Rodeo Canyon. The foraminiferal fauna of the Mussel Rock section was selected for initial study because it yielded the most abundant and best preserved foraminifers of the three sections discussed here. Documentation of this fauna provided a valuable basis for studying the other sections. The foraminifers obtained from the Lions Head section are more difficult to isolate from the rocks and are in much poorer states of preservation. Foraminifers recovered from the Rodeo Canyon section were the most difficult to analyze because they were obscured within a single sample of pelletal. Faced with the challenge of identifying species thin sectioned in petrographic slides without the aid of associated "free" specimens, a reference guide for this mode identifying foraminifers from the Miocene of California had to be developed first. After formulating an efficient method of thin sectioning specimens (Finger and Armstrong, 1984), the identification guide was compiled (Finger, 1990), enabling recognition of the assemblages from Santa Maria basin.

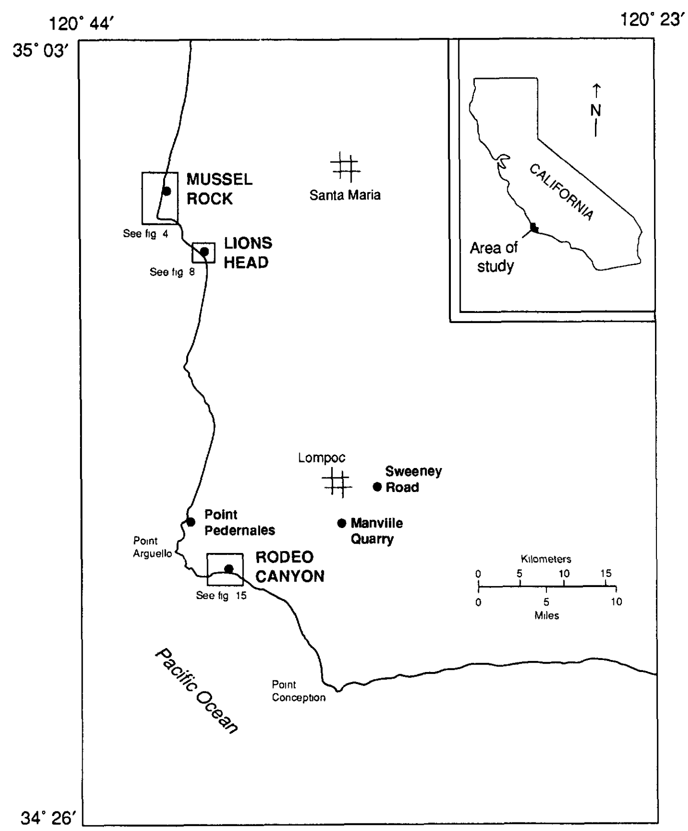


Figure 1. Map showing sampled stratigraphic sections in Santa Maria basin referred to in this study.

ACKNOWLEDGMENTS

This study was undertaken at Chevron Oil Field Research Company, La Habra, Calif. I thank G.L. Armstrong, T.C. MacKinnon, R.J. Navarrette, J.S. Compton, W.H. Akers, and R.E. Marolt for their assistance, contributions, and cooperation throughout various phases of this study. I am also grateful to T.C. MacKinnon, S.R. Jacobson, and P.J. Hoffman for their internal reviews of the manuscript. Chevron Oil Field Research Company kindly granted permission to publish this report. Formal reviews by J.C. Ingle, Jr. (Stanford University), M.B. Lagoe (University of Texas, Austin), and C.M. Isaacs (U.S. Geological Survey, Menlo Park), as well as editorial suggestions by M.A. Keller, S.W. Starratt, and J.W. Hendley (U.S. Geological Survey, Menlo Park), were most beneficial in finalizing this manuscript for publication.

MUSSEL ROCK SECTION

GEOGRAPHIC LOCATION

Mussel Rock is named for the irregularly shaped promontory of seaward-projecting outcrops located west of Guadalupe and Santa Maria on the coastal edge of the Casmalia Hills (fig. 4) and is situated near the midpoint of the stratigraphic section that extends between Rancho Guadalupe Dunes County Park to the north and Point Sal to the south. The term "Mussel Rock" is used herein in reference to this section, not the actual promontory. Overlying the Point Sal ophiolite (Hopson and Frano, 1977), the Mussel Rock section includes the Great Valley sequence (McLean, 1991) and the Lospe, Point Sal, Monterey, and Sisquoc Formations (fig. 5).

PREVIOUS WORK

The Mussel Rock section has been referred to in several reports on the geology of the Santa Maria basin, including Woodring and Bramlette (1950), Pisciotto (1981), Pisciotto and Garrison (1981), and Grivetti (1982). In his comprehensive dissertation on Miocene foraminiferal biostratigraphy of California, R.M. Kleinpell (1938, p. 119) referred to the presence of Relizian strata north of Point Sal but did not specifically mention its fauna. A year later, C.R. Canfield (1939), a paleontologist for Union Oil Company of California, presented a lithostratigraphic framework for the Santa Maria district in which he described the corresponding foraminiferal associations. Wissler and Dreyer (1943), also of Union Oil, named these biostratigraphic zones and related them to the benthic foraminiferal stages of Kleinpell (1938); however, Mussel Rock was not noted among the subject sections in either of these publications.

Woodring and Bramlette (1950, p. 21-22) provided the only previous formal publication on foraminifers in the

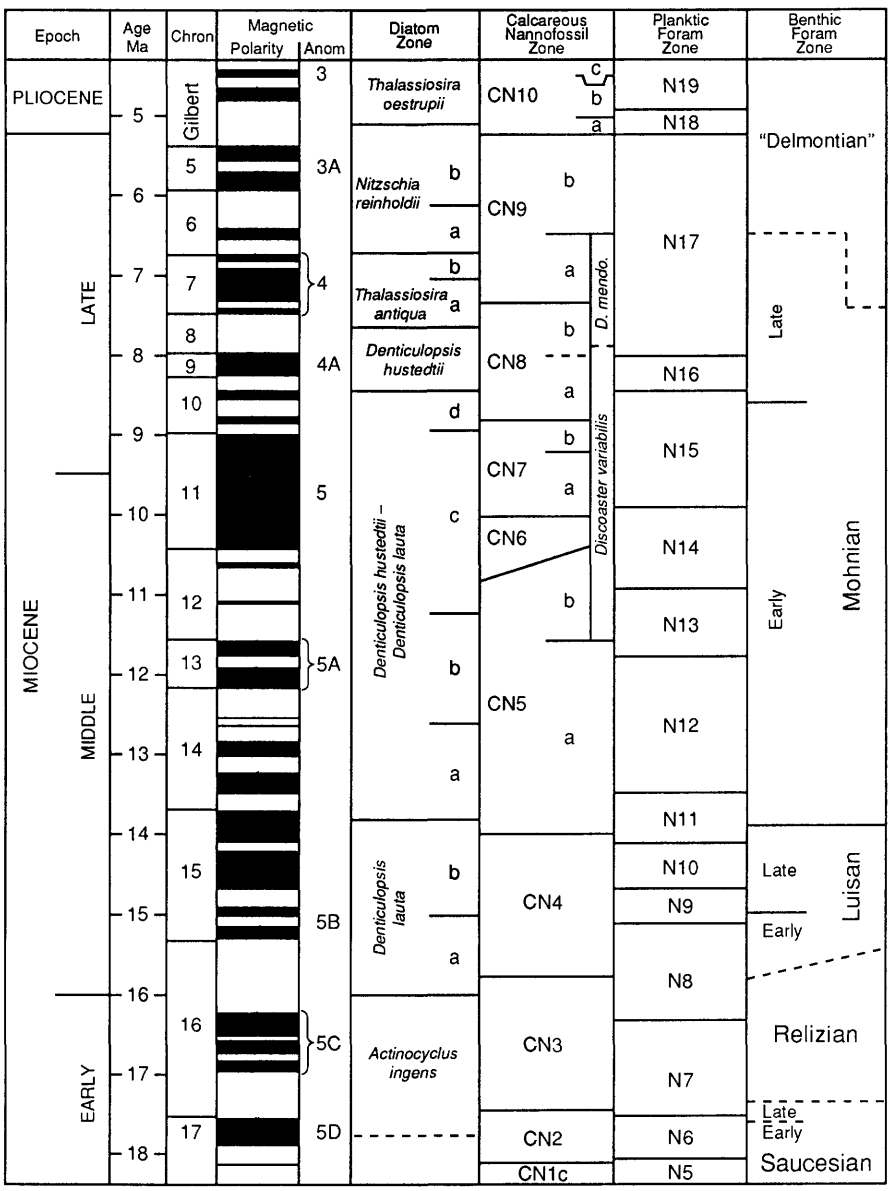


Figure 2. Chronostratigraphic correlation chart for middle Early Miocene to Early Pliocene of California (Finger, 1992, slightly modified from Barron, 1986a, b).

Mussel Rock section. Their foraminiferal checklist is composed of seven assemblages—one from a Mussel Rock locality roughly equivalent to my sample CRC-40398-4 (note CRC indicates samples stored at Chevron Petroleum Technology Center (formerly Chevron Oil Field Research Company), La Habra, Calif.), three from Lions Head, and three from Casmalia Hills. In discussing the Point Sal Formation between Point Sal and Mussel Rock, Woodring and Bramlette (1950, p. 17) noted that "Much of the mudstone contains Foraminifera, generally poorly preserved." It is probably for this reason that they did not include a corresponding species list in their report.

Ingle (1985) and Rider (1985) included analyses of foraminifers and siliceous microfossils, respectively, from the Mussel Rock section in their papers. Ingle (1985) discussed the relationship between the depositional history of

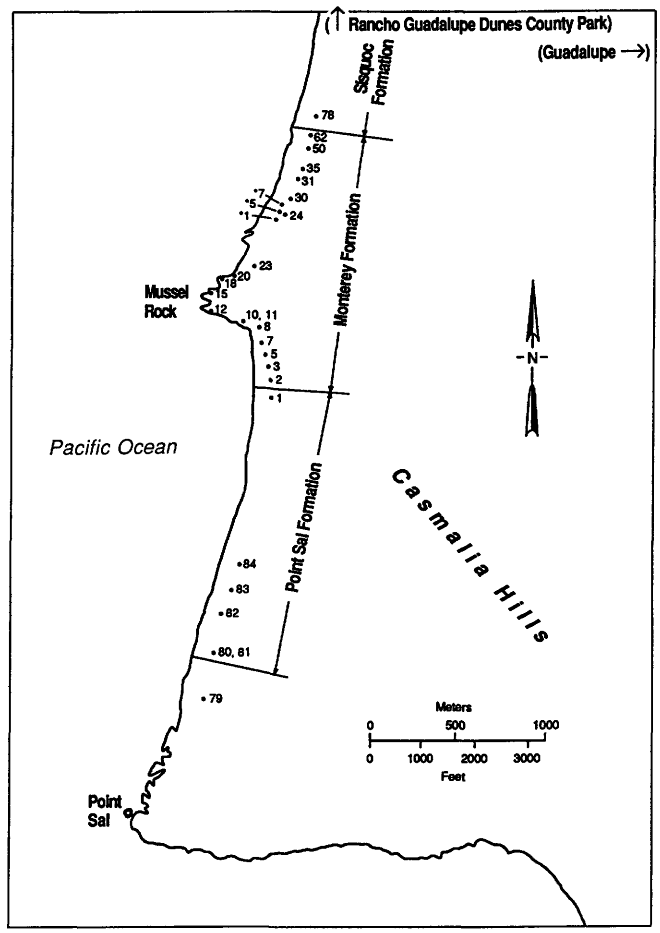
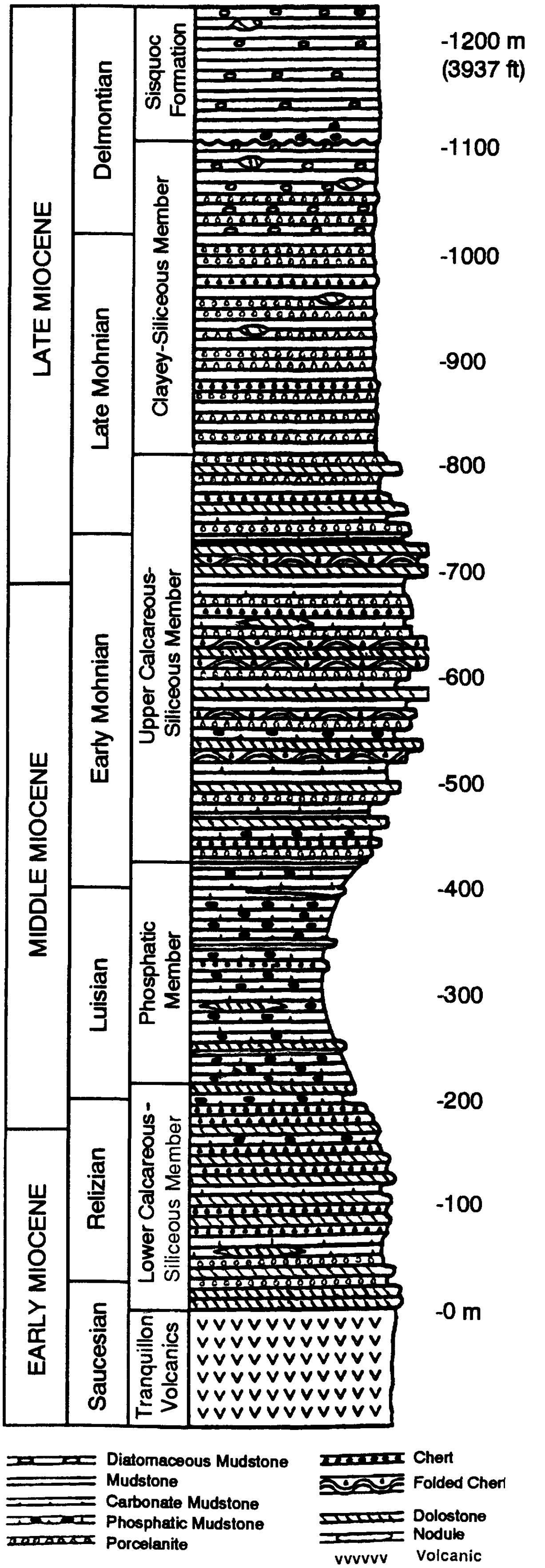


Figure 4. Sample locality map of Mussel Rock section. Sample numbers refer to CRC-3098 collection, except those preceded by asterisk, which denotes CRC-43156 collection. Some intermediate numbers not plotted for clarity. See figure 1 for section location.



◀ **Figure 3.** Composite geologic column of Monterey Formation in Santa Maria basin (from MacKinnon, 1989a).

the Mussel Rock section and that of Santa Maria basin in the context of regional and global Neogene paleoceanography. Additional findings on the diatom biostratigraphy of this section was provided by White and others (1992).

COLLECTIONS

In May 1982, W.H. Akers and G.L. Armstrong collected 77 samples (CRC-40398 collection) at Mussel Rock, mostly from the Monterey and Sisquoc Formations, for siliceous microfossil studies (Armstrong, oral commun., 1982). Another seven samples (CRC-43156 collection) were obtained from the Mussel Rock section by myself, G.L. Armstrong, and R.E. Marolt in July 1984 (figs. 4 and 5). This supplementary collection was obtained from outcrops of the Monterey Formation exposed by interim storms. Lithologic descriptions of all the samples and designation of those (primarily mudstones) selectively processed for foraminifers are given in appendix A.

RECOVERY AND PRESERVATION

Foraminifers are present in only 4 of 31 samples processed from the Monterey Formation at Mussel Rock, with recovery restricted to the phosphatic member. In contrast, five of the six processed samples from the Point Sal Formation yield foraminifers. This selective preservation and differential recovery is similar to that reported by Woodring and Bramlette (1950).

The foraminifers illustrated as scanning electron micrographs in plates 1 to 5 are among the better preserved

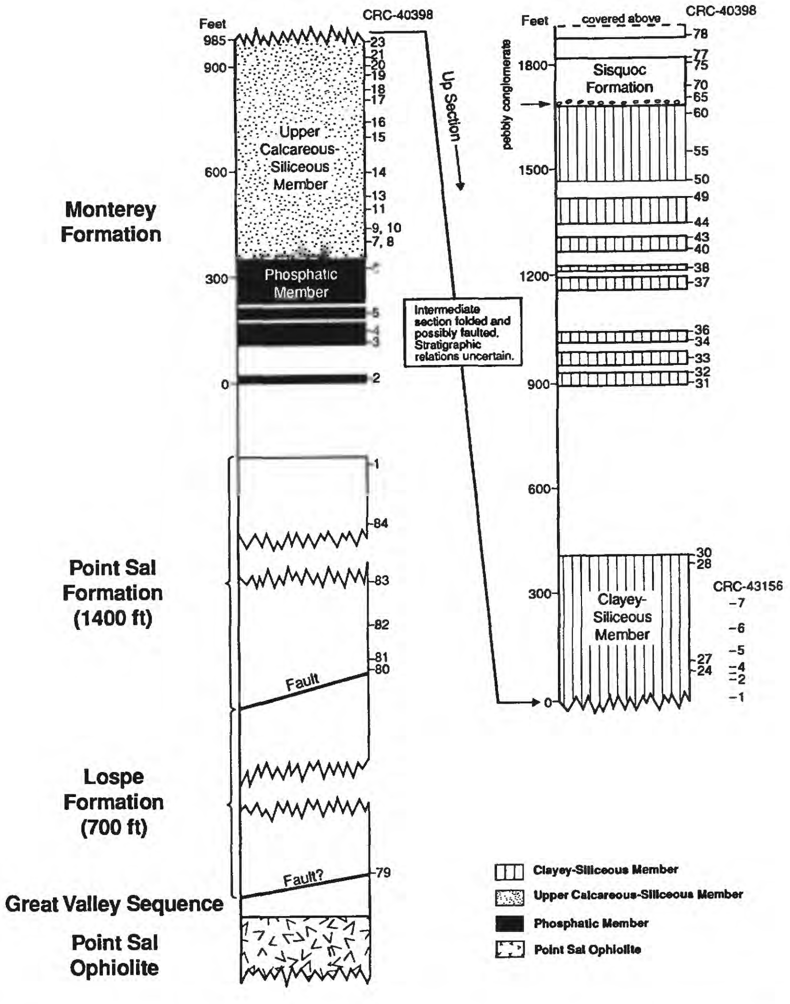


Figure 5. Stratigraphic column of Mussel Rock section denoting positions of collected samples (CRC-40398 and CRC-43156 collections). Some intermediate numbers not plotted for clarity. Great Valley sequence (McLean, 1991) and Point Sal ophiolite (Hopson and Frano, 1977) names not adopted by U.S. Geological Survey.

specimens isolated from the Monterey Formation at Mussel Rock; their condition is atypical of the total assemblage—most specimens are poorly preserved. Partial dissolution is probably responsible for the frosting of test surfaces and the thinning of test walls, which render the foraminifers susceptible to further destruction. Replacement by phosphate or silica is not evident (fig. 6); infillings of calcite (fig. 7) probably encouraged the preservation of these eroded tests, which might have otherwise disintegrated.

FAUNAL ASSEMBLAGES

Combining conventional free-specimen viewing with my thin-section study (pls. 6-19) improved the ability to identify and quantify taxa. The samples of the Monterey and Point Sal Formations from Mussel Rock yielded 75 benthic and 8 planktic species of Foraminifera (table 1); this composite assemblage has more than five times the number of species recorded by Woodring and Bramlette (1950) from the Mussel Rock section. The tally of foraminifers collected from the Point Sal Formation (table 1) is composed of 35 benthic and 6 planktic species, most of which are also found in the superjacent Monterey Formation. Both formations' assemblages actually contain more species, as poorly preserved specimens of apparently different indeterminate species are lumped by genera because it was impossible to consistently differentiate them. Also, the many indeterminate taxa observed in thin section have been excluded from these lists.

BIOSTRATIGRAPHY

Foraminiferal biostratigraphy in the Miocene of California has been based almost exclusively on the benthic fauna because associated diagnostic planktic foraminifers are rarely encountered. For nearly half a century, the main source of referral has been the extensive framework of benthic foraminiferal successions described by Kleinpell

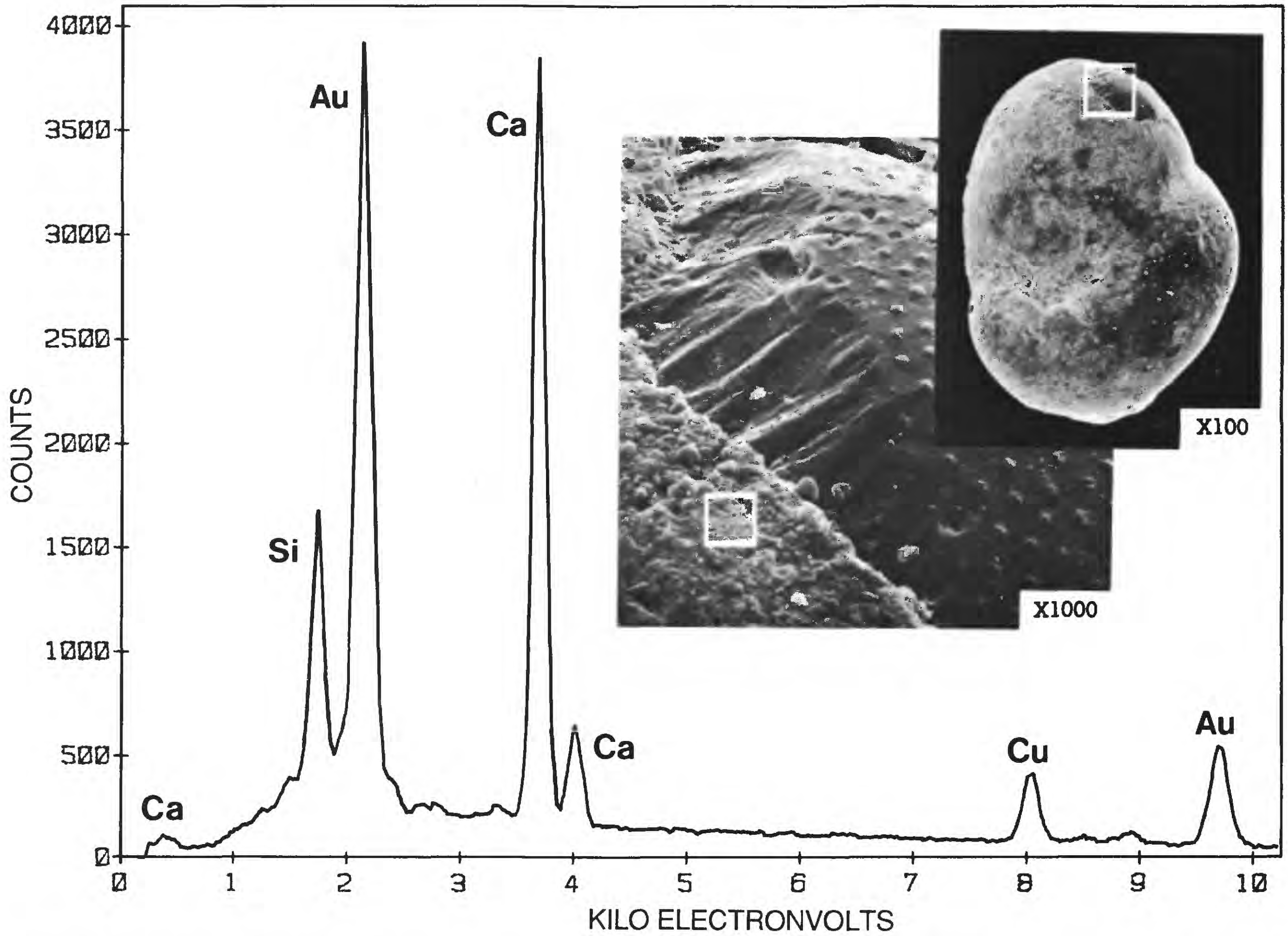


Figure 6. Chemical analysis of outer test wall of *Valvulineria robusta* specimen from Mussel Rock section, sample CRC-40398-3. Test is composed of calcite, indicated by Ca peaks. Other element peaks represent sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

(1938). It has been increasingly evident that Kleinpell's pioneering subdivision of the Miocene of California was based on much diachronous and geographically limited data, as expected from benthic foraminiferal distributions in a heterogeneous array of coastal basins. I interpret benthic foraminiferal zones as local biostratigraphic units and refrain from correlating the Mussel Rock section with Kleinpell's composite zonation. Regional application of Kleinpell's Miocene stages is less problematic because these larger biostratigraphic units reflect more widespread faunal changes. Their time-transgressive nature, and the basis for recognizing them, however, is in need of careful scrutiny.

The inadequate taxonomic base about which Kleinpell (1938) constructed his biostratigraphic framework has led to much confusion about the Miocene of California. In his "revisit," Kleinpell (1980) criticizes the interim work of others for their species misidentifications, impossible associations, and lack of useful faunal illustrations. Among those taken to task are Woodring and Bramlette (1950) for having presented "conflicting" evidence in six of their seven assemblages checklisted from their lower member of the Monterey Formation in the western Santa Maria district. In response to the apparent need for clarification of his species concepts, Kleinpell (1980) supplemented his comments with 26 plates of California Miocene foraminifers. Nevertheless, his appended gallery remains incomplete and its use is hindered by many ambiguous or invalid species concepts. If analyzed on the basis of the species ranges determined by Kleinpell (1938, 1980), the Mussel Rock assemblages documented in this report would fall into his category of "impossible associations" because of their "discordant" species.

The discrepancies in size and content between my sample CRC-40398-4 (table 1) and Woodring and Bramlette's (1950, p. 21-22) sample 9 probably are attributable to sampling of different strata and subjective identifications. If both samples happened to be from precisely the same stratigraphic horizon (a most unlikely coincidence, particularly after nearly half a century of coastal erosion), the coeval assemblages would represent separate thanatotopes. For comparative purposes, Woodring and

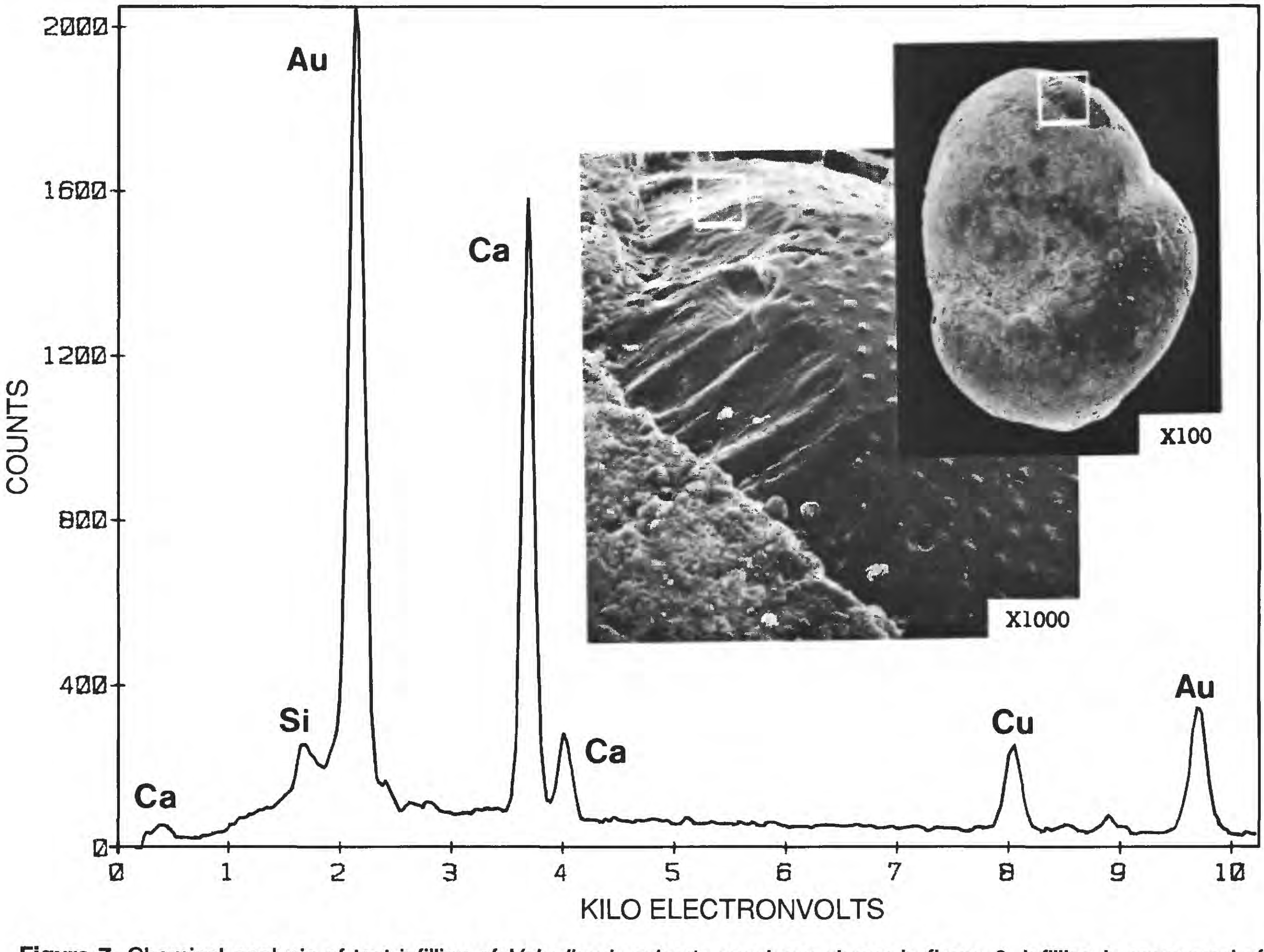


Figure 7. Chemical analysis of test infilling of *Valvulineria robusta* specimen shown in figure 6. Infilling is composed of calcite, indicated by Ca peaks. Other element peaks represent sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

FORAMINIFERA SPECIES	Point Sal Fm.					Monterey Fm.			
BENTHICS	80	81	82	83	84	2	3	4	5
Ambitropus evax						VR			
Anomalinoides salinasensis							A	C	
Baggina californica							R	F	VR
Bolivina advena		A	A	C	A		A		
Bolivina advena ornata							C		
Bolivina alata						R			
Bolivina blakei					F				
Bolivina brevior					A	F			
Bolivina californica					F	F	C	F	VR
Bolivina churchi							A		
Bolivina imbricata						F			
Bolivina modeloensis						R			R
Bolivina parva		F		A	A	F			
Bolivina pseudospissa						R			
Bolivina spp. indet.	F	R	R			VR	A	R	A
Buccella oregonensis					F	F			
Bulimina subcalva								R	
Buliminella elegantissima				R	F				
Buliminella subfusiformis	A	A	A	A	A	F	F		C
Cibicides spp.					R	C	VR	VR	
Cibicidoides mckannai					R				
Concavella gyroidinaformis									F
Dentalina pseudoobliqua								F	
Elphidium granti					F	R			
Fursenkoina sp.									VR
Gavelinopsis sp.					R				
Globocassidulina neomargareta					F				
Guttulina sp.					VR				
Gyroidina healdi									R
Gyroidina rosaformis					VR		C	R	
Hansenisca rotundimargo						F		VR	F
Hanzawaia depaoloi	VR				F	R	VR	R	
Haplophragmoides sp.		F							
Holmanella baggi					F	VR	F		
Islandiella modeloensis			VR	VR	R	F	A	C	A
Kleinpella californiensis		R	A	R	R		VR	VR	
Lagena apiopleura						VR			
Lenticulina douglasi								VR	F
Lenticulina reedi							F		C
Lenticulina smileyi							F		
Marginulinopsis beali							F	R	R
Megastomella capitanensis									VR
Nodogenerina advena					R		R		
Nodogenerina irregularis							VR		
Nodogenerina sagrinensis							C		
Nodosaria ewaldi							R	VR	
Nodosaria spp.?							F	R	F
Oolina melo						VR			
Oolina sp.					VR				
Parafissurina sp.				VR					
Parafrondicularia miocenica					F				
Protoglobobulimina pseudotorta							VR	C	F
Proxifrons vaughani							VR		
Pseudononion costiferum		C	VR	VR					
Pseudononion incisum							VR		
Pseudononion sp.					VR				
Pseudoparrella subperuviana			VR	A	A	F	F	R	
Pullenia miocenica							C	F	
Rectuvigerina branneri						VR	A	F	
Rutherfordoides californiensis								VR	
Saracenaria schencki									VR
Siphonodosaria montereyana							C	R	
Sphaeroidina chilostomata									R
Suggrunda kleinpelli	F								VR
Trifarina fluens					R	R			VR
Uvigerina hannai									A
Uvigerina hootsi						R			
Uvigerina subperegrina					F				
Uvigerina spp.			VR		R				
Uvigerinella californica								R	
Uvigerinella californica ornata								VR	
Valvulineria californica						R	F	VR	
Valvulineria miocenica	VR	A	F	C	A				
Valvulineria robusta		R		VR		VR		R	
Valvulineria sp.						R			
Genus and species indeterminate		R		VR		R			
PLANKTICS	80	81	82	83	84	2	3	4	5
Globigerina bulloides	F	F	A	A	A	A	C	F	
Globigerina pseudociperoensis	C	A	C		C	F	F	R	
Globigerina quinqueloba				R	F	F			
Globigerina sp.				F		VR			
Globigerinella pseudobesa	A		A			VR	VR		
Globigerinita uvula						VR			
Globorotalia praescitula						F			
Tenuitellinata angustiumbilicata		R	A	F	C	A	F		

◀ **Table 1.** Foraminifera species checklist for Point Sal and Monterey Formations (CRC-40398 collection), Mussel Rock section

[Abundance Key: A, abundant; C, common; F, few; R, rare; VR, very rare]

Bramlette's (1950) assemblage data are listed below with my table 1 synonymies bracketed (see table 1 for frequency abbreviations noted below in parentheses):

Bolivina californica Cushman (F)
Bolivina imbricata Cushman (C)
Bolivina parva Cushman & Galliher (C) [=?*Bolivina* spp. indet.]
Bolivina salinasensis Kleinpell (F) [=?*Bolivina* spp. indet.]
Bulimina pseudoaffinis Kleinpell (R) [*Protoglobobulimina pseudotorta* (Cushman)]
Buliminella subfusiformis Cushman (C)
Cibicides cf. *C. altamiraensis* Kleinpell (C) [=?*Cibicides* sp. or *Cibicidoides mckannai* (Galloway and Wissler)]
Cibicides relizensis Kleinpell (F) [not seen]
Entosolenia sp. (F) [=?*Fissurina* sp.; not seen]
Globigerina bulloides d'Orbigny (A)
Lagena acuticosta Reuss of Kleinpell (C) [=*L. apiopleura* Loeblich and Tappan]
Lagena sp. (R) [not seen]
Pulvinulinella subperuviana Cushman (F) [=*Pseudoparrella*]
Siphogenerina branneri Cushman (F) [=*Rectuvigerina branneri* (Bagg)]
Uvigerinella californica Cushman (F)
Valvulineria californica var. *obesa* Cushman (R) [var. not distinguished]

In reference to their list of assemblages from Mussel Rock, Lions Head, and Casmalia Hills, Woodring and Bramlette (1950, p. 21) deduced, "The large foraminiferal fauna of the lower member of the Monterey shale represents the upper part of Kleinpell's Relizian stage and all of his Luisian stage. *Siphogenerina* is a conspicuous genus of the fauna, *S. branneri* being common in the lower part of the member and *S. collomi* in the upper part." However, they did not provide zonal assignments for these assemblages, probably because they could not relate them more specifically to Kleinpell's (1938) biostratigraphy. On this point, Kleinpell (1980, p. 28, 33) insinuated the problem lies with Woodring and Bramlette's (1950) misidentification of species.

I am reluctant to rely on the *Siphogenerina* biostratigraphy proposed by Kleinpell (1938) and modified by Kleinpell and Tipton (in Kleinpell, 1980) because the designated species appear to be gradational ecophenotypes of what is most likely a single polyphenotypic species. Referral to type descriptions, type figures, and the many illustrations included in Kleinpell's (1980) "revisit" reveals an incomprehensible methodology. To illustrate the complications of employing the criteria of Kleinpell (1938) and Kleinpell and Tipton (1980), my recording of *S. hughesi* Cushman in the phosphatic member of the Monterey Formation at Mussel Rock would indicate that the unit is of early Relizian age. Kleinpell (1980) may have defended his system by suggesting that my forms are reworked *S. hughesi* or worn specimens of a younger costate species. My discussion below illustrates that, for other reasons, the foraminifers present in the phosphatic member at Mussel Rock cannot be assigned to lower Relizian strata.

Because California Miocene *Siphogenerina* have evaded taxonomically consistent usage, I have adopted the first of the California Miocene species named in the literature, *Rectuvigerina branneri* (Bagg), to designate a large portion of the plexus. The *overall* composition of single and composite assemblages should be analyzed, with less emphasis placed on the absolute first and last appearances of those species designated by Kleinpell (1938, 1980) as markers. Because many of these marker species are difficult to differentiate and their biostratigraphic ranges extend beyond those documented by Kleinpell (1938, 1980), careful attention should be paid to their acmes. In some cases, species acmes, derived from the semiquantitative ranges tabulated by Kleinpell (1938, table 18) and Finger (1992), might be more widespread and reliable for age dating than first and last occurrence datums. Relative abundances of species are often the only criterion useful in analyzing isolated samples or brief stratigraphic sections, where subjacent and superjacent data on the faunal succession are lacking.

I prefer to correlate California Miocene sections on as local a basis as possible. In general, this approach improves accuracy and provides a more sound interpretation. Prior to publication and general acceptance of Kleinpell's (1938) regional synthesis, localized biostratigraphies were commonplace. Unfortunately, these local basin frameworks were put aside by subsequent workers who incorrectly presumed that Kleinpell's was the definitive reference for the California Miocene. In fact, the original local biostratigraphic scheme formulated by Canfield (1939) and Wissler and Dreyer (1943) is still very useful in correlating sequences in the Santa Maria basin.

Canfield (1939) designated the lowest and thickest unit of the Monterey Formation as the Siltstone and Shell zone, adding in a footnote that the name Point Sal Formation would be proposed. He noted that its "local silty facies foraminiferal fauna" is characterized by *Buliminella subfusiformis* Cushman, *Valvulineria ornata* Cushman, and *Uvigerinella obesa* Cushman. My samples from the Point Sal Formation match Canfield's (1939) lithologic and paleontologic descriptions of the Siltstone and Shell zone fairly well. Wissler and Dreyer (1943) referred to their corresponding biostratigraphic unit as Foram zone 7, the *Valvulineria ornata-Uvigerinella obesa* zone, which they assigned to the Relizian stage. The predominance of *Bolivina advena* Cushman s.s. in my samples is also typical of Relizian thanatofacies (Kleinpell, 1938, 1980).

Similar Relizian assemblages encountered elsewhere in the Santa Maria district are documented by Woodring and Bramlette (1950). In reference to a species of benthic foraminifer present in many of these assemblages, Woodring and others (1943, p. 1344) stated, "The variety of *Siphogenerina hughesi*, which shows numerous very fine costae, is associated elsewhere with the typical noncostate form of that species." Thus, they correlated the Point Sal Formation with Kleinpell's (1938) *Siphogenerina hughesi* Zone, or the lower part of the Relizian stage. This deduction was retained almost verbatim in the report by Woodring and Bramlette (1950, p. 17). The only other occurrence I know of where *Siphogenerina* populations predominantly consist of the finely costate form (= *Rectuvigerina loeblichi* Finger and Lipps) is in the "classic" Relizian section along Graves Creek, near Atascadero in the Salinas basin (Finger and others, 1990). Recovery of this species in the adjacent Santa Maria basin suggests that these occurrences may be coeval. Using a hand lens, I perused the Point Sal Formation north of Point Sal in search of strata bearing *Rectuvigerina*, but none were observed nor were any recovered later from the processed samples.

Mussel Rock sample localities CRC-40398-2, -3, and -4 in the phosphatic member of the Monterey Formation yielded a composite benthic foraminiferal assemblage, which includes the characteristic Luisian association of *Anomalinoides salinasensis, Bolivina advena ornata, Marginulinopsis beali, Pullenia miocenica, Rectuvigerina branneri*, and *Valvulineria californica.* Canfield (1939) noted that the association of *Anomalinoides salinasensis* and *Siphogenerina* characterizes his Dark Brown zone. Wissler and Dreyer (1943) subsequently referred to this biostratigraphic unit as Foram zone 5, the *Siphogenerina collomi-Siphogenerina nuciformis* zone, and correlated it with the Luisian stage. The lithology of this zone is described by Canfield (1939) as consisting of "a moderately hard series of fractured fairly interbedded chocolate-brown and buff phosphatic semiplaty foraminiferal shale." The Dark Brown zone derives its name from its common staining by oil saturation.

Sample CRC-40398-2 from the basal exposure of the phosphatic member of the Monterey Formation yielded several specimens of *Globorotalia praescitula* Blow, a planktic foraminifer with a relatively short biostratigraphic range. In the middle latitudes, this species ranges from the *Catapsydrax dissimilis* Zone to the *Globorotalia peripheroronda-peripheroacuta* overlap Zone (Kennett and Srinivasan, 1983), an interval approximately from 20 to 14 Ma (Keller and Barron, 1981; Poore and others, 1981). Sample CRC-40398-2 also yielded *Denticulinopsis lauta* (Bailey) Simonsen and *Coscinodiscus lewisianus* Greville, diatoms which have a concurrent range of 16.0 to 14.6 Ma (R.J. Navarrette, oral commun., 1984), supporting the early middle Miocene age implied by the Luisian benthic foraminifers (see fig. 2). The superjacent foraminifer-bearing rocks did not yield any diagnostic planktic foraminifers or siliceous microfossils.

Sample locality CRC-40398-5, also in the phosphatic member, yielded an assemblage that includes *Baggina californica, Concavella gyroidinaformis,* and *Megastomella capitanensis,* the only three species noted by Canfield (1939) as diagnostic of his Buff and Brown zone. Wissler and Dreyer (1943) referred to their corresponding faunal unit as Foram zone 4, the *Baggina californica* zone (earliest Mohnian). The assignment of my sample to the lowermost Mohnian is supported by its stratigraphic position, the concurrence of the three species noted above, and the absence of the characteristic Luisian association (mentioned for the three subjacent samples) in this otherwise rich and diverse assemblage. Canfield (1939) described the lithology of his Buff and Brown zone as "a series of moderately hard interbedded chocolate-brown semiplaty foraminiferal and buff-colored phosphatic shales."

The Luisian and earliest Mohnian foraminiferal ages determined for the lower part of the Monterey Formation at Mussel Rock are congruous with the younger siliceous microfossil datums recognized in the overlying section. *Cyrtocapsella tetrapera* (Haeckel), a radiolarian with a last appearance datum of about 12.7 to 12.4 Ma (Nigrini and Lombari, 1984), occurs in sample CRC-40398-10 (W.H. Akers, oral commun., 1984), indicating that the lower part of the upper calcareous-siliceous member of the Monterey Formation at Mussel Rock is concurrent with the lower part of the Mohnian.

DEPOSITIONAL PALEOENVIRONMENT

On the basis of its Eocene to Holocene occurrences and associations, "*Siphogenerina*" is considered to be an indicator of warm climatic regions (Kleinpell, 1938). Its last appearance datum in California is accompanied by the disappearance of many other warm-temperate to subtropical taxa at the Luisian-Mohnian boundary and their replacement by cold-temperate to subpolar species. Isotopic studies on deep-sea benthic foraminifers (for example, Savin and others, 1981) provide evidence that a global cooling trend commenced in the middle Miocene.

Paleobathymetries for the Neogene of California are determined from the upper depth limits of benthic foraminifers listed by Ingle (1980, 1985). Several species in my Monterey Formation assemblages indicate basin-floor deposition at lower middle-bathyal depths (1,500-2,000 m)—*Anomalinoides salinasensis, Gyroidina rosaformis, Nodogenerina sagrinensis,* and *Pullenia miocenica.* Although neritic indicators are present, the composite assemblage consists primarily of bathyal species. Mixed associations of this sort are typical in the Monterey Formation and indicate that most of the mudstones that constitute the Monterey Formation are turbidites (see Ingle, 1980, 1985).

Although the rare specimens of *Gyroidina rosaformis* and *Siphonodosaria advena* in the Point Sal Formation suggest deposition at depths similar to that of the Monterey Formation, their associated mixed assemblages predominantly consist of transported shelf species. Thus, the paleoenvironment of deposition for both formations is lower middle bathyal, but their primary sources of sediment differ. In general, proximal turbidite sequences of sand and silt constitute the Point Sal Formation, whereas distal turbidites and hemipelagites constitute the very fine grained sediments of the Monterey Formation. Laminations in most Monterey Formation rocks, including three of the foraminiferal samples from Mussel Rock (CRC-40398-2, -3, -4), are indicative of low-oxygen bottom waters in the depositional basin.

SYNOPSIS

Foraminifers recovered from the Point Sal and Monterey Formations at Mussel Rock provide useful data on the age and depositional history of the Santa Maria basin. Studies of foraminiferal assemblages isolated from the rocks and thin sectioned in petrographic slides indicate that (1) proximal silt and sand turbidites in the Point Sal Formation were deposited at bathyal depths greater than 1,500 m during the Relizian (latest early and earliest middle Miocene) and (2) distal mud turbidites in the phosphatic member of the lower Monterey Formation were deposited at similar bathyal depths during the Luisian (early middle Miocene) and earliest Mohnian (late middle Miocene). These foraminiferal data complement younger siliceous microfossil datums determined from the superjacent strata of the Monterey and Sisquoc Formations.

LIONS HEAD SECTION

GEOGRAPHIC LOCATION

Lions Head is a prominent knoll located 8 km southeast of Point Sal along the coastline southwest of Santa Maria (figs. 1 and 8). The sampled section is located along the beach just south of this knoll (fig. 8) and is within the confines of the Vandenberg Air Force Base. The section is part of the northeast flank of a syncline (Woodring and Bramlette, 1950) and consists of the phosphatic and upper calcareous-siliceous members of the Monterey Formation. Upsection (northwest along the coastline), the basal exposure of the phosphatic member is in fault contact with the Point Sal ophiolite of Hopson and Frano (1977; figs. 8 and 9).

PREVIOUS WORK

The Lions Head section has received mention in other reports on the geology and paleontology of the Santa Maria district, notably Woodring and Bramlette (1950), Pisciotto (1981), Pisciotto and Garrison (1981), Grivetti (1982), Compton and Siever (1984), Wornardt (1986), Dunham and Blake (1987), MacKinnon (1989b), White (1989), and Dunham and Cotton-Thornton (1990).

Although they had studied foraminiferal sequences elsewhere in the Santa Maria basin, neither Kleinpell (1938), Canfield (1939), Wissler and Dreyer (1943), nor Woodring and others (1943) mentioned Lions Head. However, Woodring and Bramlette (1950, p. 21-22 table) provided data on the foraminiferal assemblages in three samples (their 10, 10a, 10b) from the lower section, which they identified as the lower member of the Monterey Formation.

Without presenting any detailed biostratigraphy, Dunham and Blake (1987) identified 13 foraminiferal species in "the lower Monterey section" at Lions Head (the section below the sand-covered section) and correlated them with the late Relizian and upper to middle-bathyal water depths. Although the Luisian is not mentioned in their description of the sequence, they noted that the middle Monterey Formation section (the section above the sand-covered section) is within the *Denticulopsis hustedtii-D. lauta* subzones (c) to (a), indicating an early Mohnian age. In a subsequent paper, Dunham and Cotton-Thornton (1990) presented limited biostratigraphic data for three Lions Head samples: (1) Their oldest age-diagnostic assemblage, which occurs 42 ft above the base of the section, is correlated with the Relizian on the basis of *Siphogenerina branneri* and *Valvulineria robusta*, (2) a foraminiferal assemblage recovered from approximately 35 ft below the top of the lower section is assigned to the Luisian on the basis of occurrences of *Suggrunda kleinpelli, Hemicristellaria beali,* and *Anomalina salinasensis*, and (3) a sparse population of *Uvigerinella californica* from another sample about 120 ft higher in the stratigraphic section is interpreted as possibly Luisian. Although all six of the aforementioned species range into the Saucesian of coastal California (Finger, 1992), M.L. Cotton (oral commun., 1993) confirmed that the ages assigned to these three assemblages are based on strict correlation with the foraminiferal sequences in the stratotypes (see Billman and Hopkins, 1980).

Wornardt (1986; also see Grivetti, 1982) recognized two diatom datums in the upper part of the Lions Head section utilizing the methodology later published by Lagle (1984) for recovering siliceous microfossils (diatoms, radi-

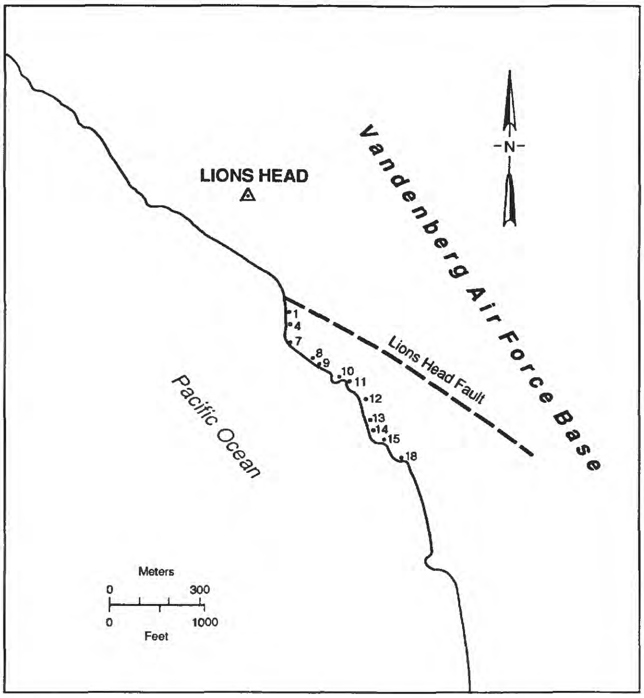


Figure 8. Map of sample localities in the Monterey Formation, Lions Head section. Sample numbers refer to CRC-40471 collection. Some intermediate numbers not plotted for clarity. See figure 1 for section location.

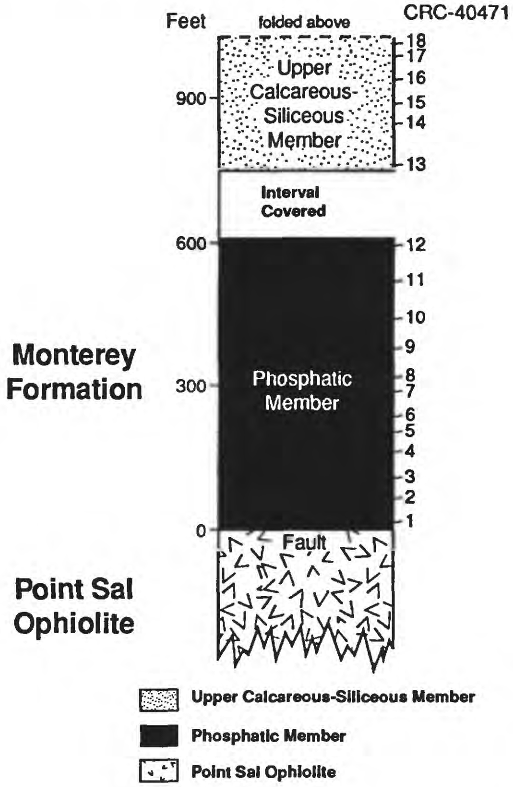


Figure 9. Stratigraphic column of Lions Head section denoting positions of collected samples (CRC-40471 collection).

olarians, and silicoflagellates) from dolostones. White (1989) also identified diatoms in this part of the Lions Head section. Although the laboratory at Chevron Oil Field Research Company attempted similar processing, none of my samples yielded any siliceous microfossils.

COLLECTIONS

In June 1983, G.L. Armstrong and I collected 18 samples (CRC-40471 collection) from the 995-ft stratigraphic section of the Monterey Formation at Lions Head (figs. 8 and 9). Lithologic descriptions of the samples and designation of those selectively processed for foraminifers are given in appendix B. An apparent discrepancy between our stratigraphic measurements and those of Dunham and Blake (1987) has not been resolved.

RECOVERY AND PRESERVATION

Foraminifers are present in all of the thin sections prepared from the phosphatic member of the Monterey Formation at Lions Head. The abundance of foraminifers in these rocks is similar to that evident in the semiquantitative data presented by Woodring and Bramlette (1950).

The foraminifers illustrated in scanning electron micrographs (pl. 20) are typical of those isolated from the Lions Head section by conventional processing. As previously noted, the recovered specimens are very poorly preserved, and most could not be completely freed from the indurated mudstone matrix. Few species are recognizable in this condition. Chemical analyses (figs. 10-14) reveal that the specimens are composed primarily of calcite, although it is questionable whether any of the original shell material remains. The tests appear to be partially dissolved and (or) recrystal-

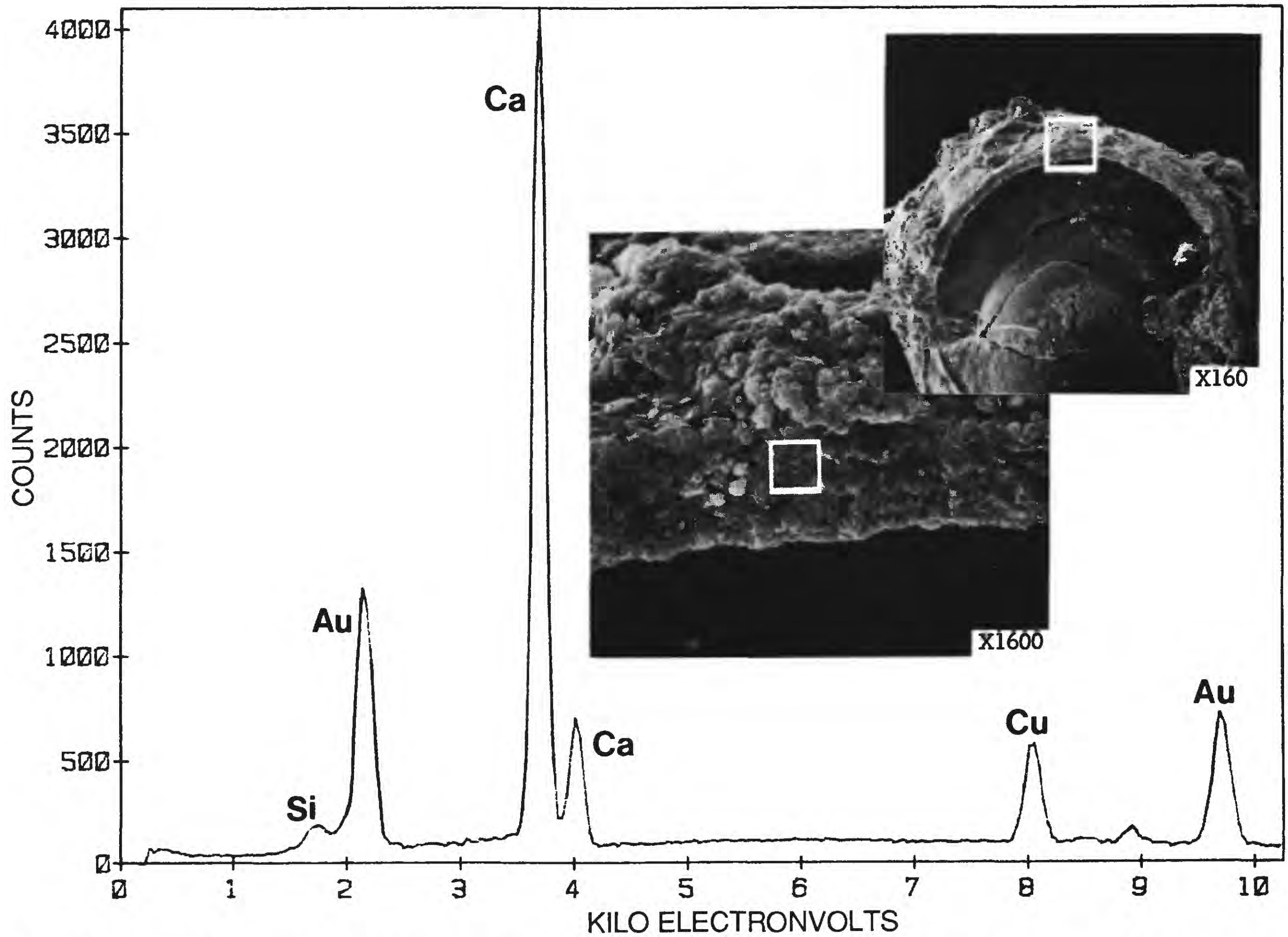


Figure 10. Chemical analysis of test wall of *Pullenia miocenica* specimen from Lions Head section, sample CRC-40471-6. Ca peaks indicate that it is composed of calcite. Other element peaks indicate sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

lized, with infillings mostly of calcite. In some cases, the infillings include aggregates of pyrite framboids (fig. 14).

FAUNAL ASSEMBLAGES

Analysis of the Lions Head fauna is based almost exclusively on the examination of petrographic slides. Twenty-five species of Foraminifera are identified in the present study (table 2). In comparison, Woodring and Bramlette (1950, p. 21-22) listed 33 benthic and 1 planktic species isolated from three samples from this section. Their larger list and recognition of seven bolivinid species suggests that they examined better-preserved assemblages collected from less-indurated strata. Because Woodring and Bramlette list only fossiliferous sample localities, I do not know how many indurated and nonfossiliferous samples may have been excluded from their report.

BIOSTRATIGRAPHY

As noted in the previous discussion of the Mussel Rock section, it appears that Woodring and others (1943) and Woodring and Bramlette (1950) correlated the lower member of the Monterey Formation primarily, if not entirely, on Kleinpell's (1938) *Siphogenerina* biostratigraphy. They similarly interpreted the lower member of the Monterey Formation in the Santa Maria district as late Relizian through Luisian, with "*S. branneri* common in the lower part and *S. collomi* in the upper part," but neither report offered refined ages for individual assemblages. In reference to Woodring and Bramlette's (1950) checklist, Kleinpell (1980, p. 33) noted, "From the lower member of the overlying Monterey (p. 21-22, 100, 137) come seven assemblages, again not stratigraphically allocated but, with only one exception (10b, "not plotted"), showing conflicting evidence." The commas in this statement appear misplaced, for only the 10b assem-

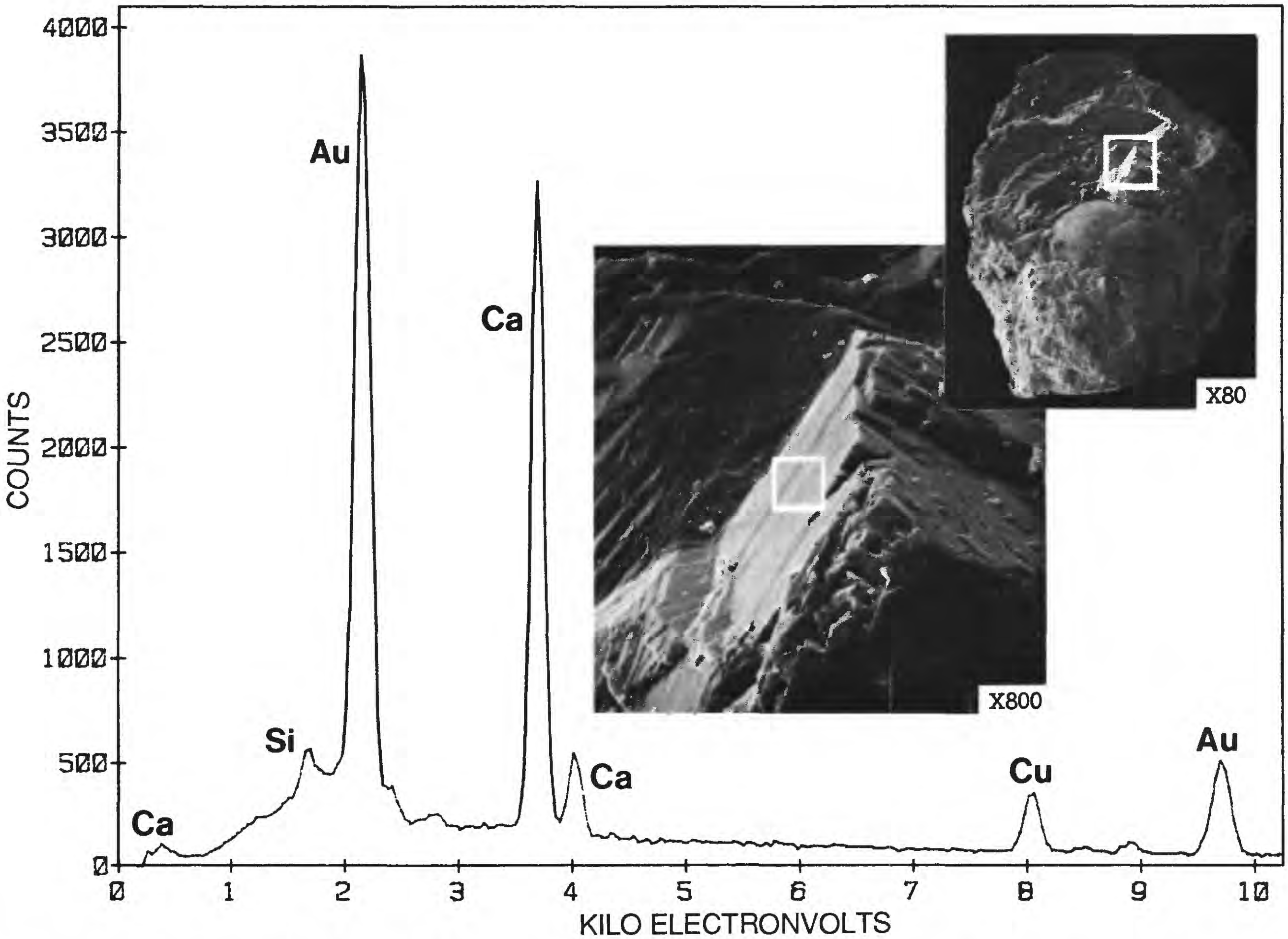


Figure 11. Chemical analysis of infilling of *Rectuvigerina branneri* specimen from Lions Head section, sample CRC-40471-6. Ca peaks indicate that it is composed of calcite. Other element peaks represent sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

blage from Lions Head lists the most obvious conflict of *S. branneri* and *S. collomi*, and Kleinpell (1980, p. 28) refuted the identification of *S. collomi*. Woodring and Bramlette's (1950) checklist included many other species associations that defy Kleinpell's scheme, but Kleinpell did not discuss those taxa nor did he assign specific ages to any of Woodring and Bramlette's (1950) assemblages.

Dominant species in the present study's Lions Head composite assemblage include *Anomalinoides salinasensis*, *Nodogenerina sagrinensis*, and *Pullenia miocenica*. *Rectuvigerina branneri* is less common but nonetheless most conspicuous. The overall fauna is similar to the benthic foraminiferal thanatofacies noted by Woodring and others (1943), Woodring and Bramlette (1950), Dunham and Blake (1987), and Dunham and Cotton-Thornton (1990) for the lower member of the Monterey Formation in this region. Regional biostratigraphic ranges (see Finger, 1990, 1992) indicate that all of the assemblages documented by these authors are characteristic of both the Relizian and Luisian stages; however, when species acmes are considered (see Finger, 1992), the concurrence of *Anomalinoides salinasensis* and *Pullenia miocenica* in the upper part of the lower section at Lions Head (sample localities CRC-40471-6 through -12) suggest a Luisian age. The meager assemblages characteristic of the lower part of the section are less definitive. Woodring and Bramlette's (1950) recovery of *Anomalinoides salinasensis* and *Pullenia miocenica* from all three of their Lions Head samples, including their lowest sample, which they assigned to the lower part of the lower member of the Monterey Formation, may be evidence of a Luisian age for the entire foraminiferal sequence. As noted above, Dunham and Cotton-Thornton (1990) correlated the lower member of the Monterey Formation with the type Relizian, but their adoption of Kleinpell's (1938) method of interbasinal benthic zonation is dubious (see Finger, 1990). Subdividing the Lions Head sequence into substages or biozones would not appear to be possible, let alone meaningful.

On the basis of lithology and paleontology, the phosphatic member of the Monterey Formation at Lions Head

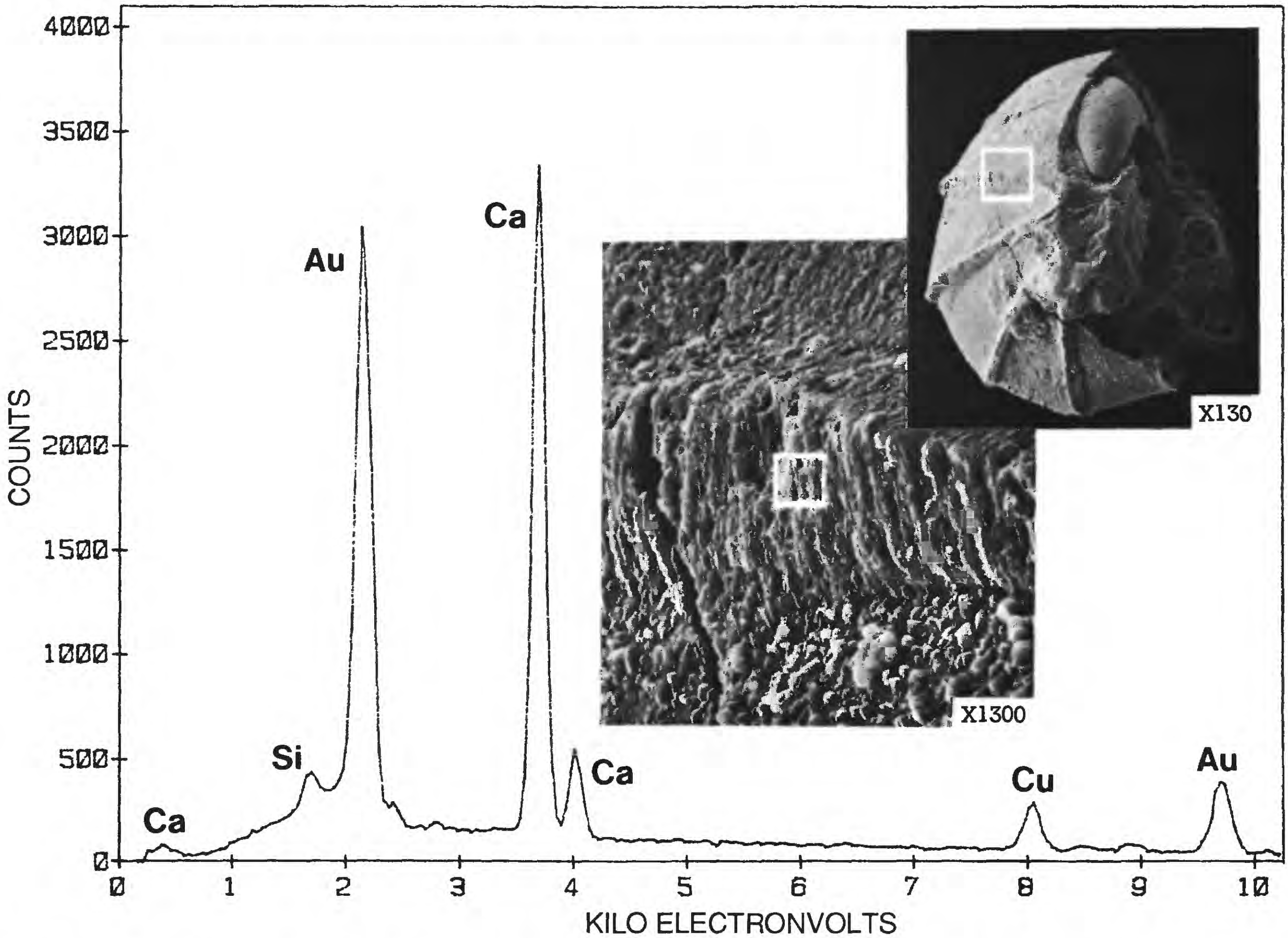


Figure 12. Chemical analysis of test wall of *Lenticulina smileyi* specimen from Lions Head section, sample CRC-40471-6. Ca peaks indicate that it is composed of calcite. Other element peaks represent sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

resembles Canfield's (1939) Dark Brown zone and Wissler and Dreyer's (1943) Foram zone 5, the *Siphogenerina collomi-Siphogenerina nuciformis* Zone, which I correlate with the early Luisian stage and the lower part of the phosphatic member at Mussel Rock. The upper part of the phosphatic member is not exposed at Lions Head; hence, I did not recover the early Mohnian thanatofacies recognized at Mussel Rock. The faunal similarity and close proximity of the Lions Head and correlative Mussel Rock sections suggests that these sediments may have been deposited as part of the same lower middle-bathyal facies that characterized the floor of the Santa Maria basin during the early middle Miocene.

Although Luisian foraminiferal assemblages have been recognized within the latest early to early middle Miocene interval of approximately 17 to 11 Ma on the basis of their associations with calcareous nannofossils (Crouch and Bukry, 1979; Arnal and others, 1980), correlation with the calcareous nannofossil and diatom zonations of its stratotype places the Luisian in the early middle Miocene, about 15.7 to 13.8 Ma. Unfortunately, time-significant planktic foraminifers are rarely encountered in the Miocene of California and the Lions Head section is no exception. By multiplying the thickness of strata by an estimated rate of deposition, Srivastava (1984) calculated that the lower 70 m (210 ft) of the Lions Head section, which yielded "early to middle Miocene" palynomorph assemblages, should date at about 16 to 15 Ma. This age range straddles the Relizian-Luisian boundary.

In Grivetti's (1982) regional study, C.W. Lagle extracted diatoms from two dolostone samples in the 274 to 275-m (899 to 902 ft) interval of the Lions Head section, which W.W. Wornardt identified as the *Denticulinopsis hustedtii-Denticulinopsis lauta* Zone, with the higher sample assigned to subzones (b) and (c). This zonal assignment is supported by White's (1989) analysis of diatoms in the lower 65 m of the upper Lions Head section. In the middle latitudes, subzones (b) and (c) range from 12.6 to 8.9 Ma, within the interval of planktic foraminiferal zones N12 to N15. Therefore, it can be concluded that at least part of the upper

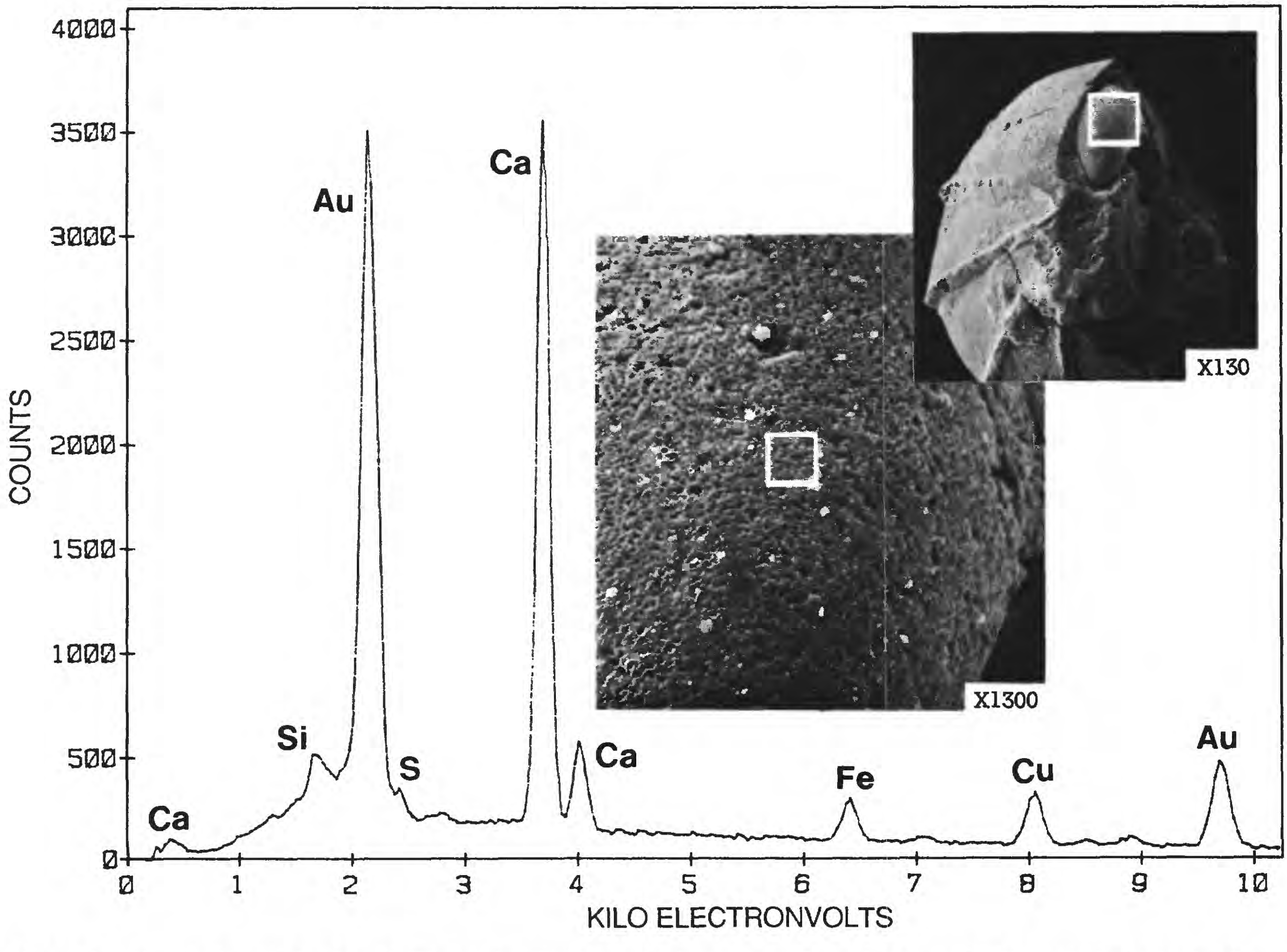


Figure 13. Chemical analysis of test infilling of *Lenticulina smileyi* specimen shown in figure 12. Ca peaks indicate that it is composed of calcite. The small Fe and S peaks indicate pyrite, probably beneath the calcite surface. Other element peaks represent sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

calcareous-siliceous member of the Monterey Formation at Lions Head is late middle Miocene. Although foraminifers were not recovered from these rocks, the diatom horizons correlate with rocks of the lower Mohnian benthic foraminiferal stage. Thus, the Relizian-Luisian age determined for the lower Lions Head section makes stratigraphic sense and the Luisian/Mohnian boundary is buried.

DEPOSITIONAL PALEOENVIRONMENT

According to Ingle (1980, 1985), *Anomalinoides salinasensis, Gyroidina rosaformis, Nodogenerina sagrinensis,* and *Pullenia miocenica* are among the deepest-dwelling paleobathymetric marker species in the Lions Head fauna. As concluded for the correlative part of the Mussel Rock section, most of the phosphatic member of the Monterey Formation at Lions Head was deposited as mud turbidites and hemipelagites at lower middle-bathyal depths (1,500-2,000 m). The Luisian benthic foraminiferal fauna suggests prevailing subtropical to warm-temperate waters. Laminated sediments common throughout much of the Lions Head section indicate that low-oxygen conditions prevailed in the depositional paleoenvironment during the middle and late Miocene.

SYNOPSIS

The phosphatic member of the Monterey Formation at Lions Head contains a relatively warm-water lower middle-bathyal Relizian (upper lower Miocene)? to Luisian (lower middle Miocene) foraminiferal thanatofacies. The composite assemblage is most similar to the Luisian thanatofacies recovered from the lower part of the phosphatic member at Mussel Rock with which it is correlated. The upper part of the phosphatic member is not exposed at Lions Head; therefore, early Mohnian foraminifers similar to those recognized at Mussel Rock were not recovered. The overlying upper calcareous-siliceous member of the

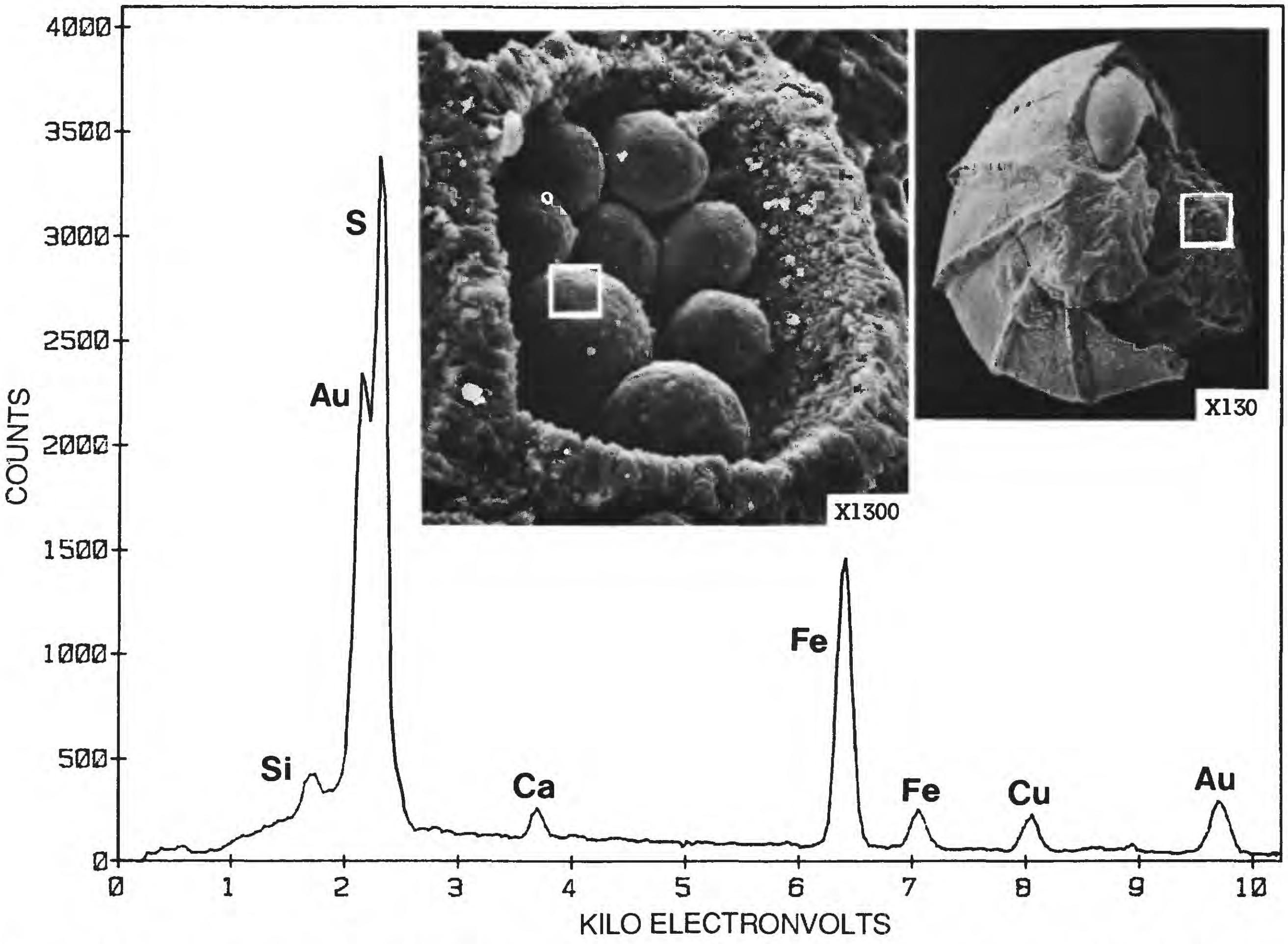


Figure 14. Chemical analysis of pyrite (FeS_2) framboids infilling *Lenticulina smileyi* specimen shown in figure 12. Test is composed of calcite, indicated by Ca peaks. Other element peaks represent sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

Table 2. Foraminifera species checklist, Monterey Formation, Lions Head section (CRC-40471 collection)

[Solid boxes denote presence of species]

FORAMINIFERA SPECIES	1	2	3	4	5	6	9	10	11	12
Anomalinoides salinasensis			■		■		■	■	■	■
Baggina californica		■						■		■
Bolivina advena ornata										■
Bolivina blakei								■		■
Bolivina californica										■
Bulimina subacuminata										■
Buliminella subfusiformis										■
Globigerina bulloides			■							
Gyroidina rosaformis							■	■	■	■
Holmanella baggi									■	
Islandiella modeloensis						■	■	■		
Lenticulina hughesi							■			
Lenticulina miocenica						■				
Lenticulina smileyi						■		■		
Megastomella capitanensis					■					
Nodogenerina sagrinensis						■		■	■	■
Nodosaria ewaldi									■	
Protoglobobulimina pseudotorta			■							
Pseudoparrella subperuviana					■					
Pullenia miocenica						■	■	■		■
Rectuvigerina branneri		■		■		■	■	■		■
Siphonodosaria montereyana						■		■		■
Siphonodosaria quadrulata								■		
Tenuitellinata angustiumbilicata			■							
Valvulineria californica						■	■	■		
Indeterminate fragments	■									

Monterey Formation at Lions Head is devoid of foraminifers, but diatom datums indicate that part of this member is concurrent with the early Mohnian (late middle Miocene).

PREVIOUS WORK

Since the discovery of the Point Arguello Oil Field in 1981 (see Crain and others, 1985), the stratigraphy of the nearby Rodeo Canyon section has been viewed as having particular significance. Until recently, however, the Rodeo Canyon section had rarely been mentioned in the regional literature, perhaps because of its relative inaccessibility and its location on the fringe of the Santa Barbara-Ventura basin. Although Arnold and Anderson (1907, pl. 1) and Dibblee (1950, pl. 1) plot the Monterey Formation along this part of the California coastline on their regional maps, they do not specifically refer to this section in text. Prior to the U.S. Geological Survey Bulletin 1995 series, published studies involving the Rodeo Canyon section included studies on dolomites by Compton and Siever (1984), paleomagnetic stratigraphy by Hornafius (1985) and Hornafius and others (1986), diatom biostratigraphy by Wornardt (1986), and phosphorites and phosphatic rocks by Garrison and others (1987).

Using Lagle's (1984) technique for extracting diatoms from dolomites, Wornardt (1986) determined that two samples in the upper part of the Rodeo Canyon section were within the *Denticulopsis lauta-Denticulopsis hustedtii* Zone, subzones (b) to (d). These subzones range from 12.6 to 8.4 Ma in age and correlate with the lower Mohnian to lowest upper Mohnian benthic foraminiferal stage.

RODEO CANYON SECTION

GEOGRAPHIC LOCATION

This coastal locality is situated on Vandenberg Air Force Base property, 4 km southeast of Point Arguello and about 25 km southwest of Lompoc (fig. 1). The stratigraphic section investigated extends westward from the mouth of Cañada del Rodeo, for which it is named (fig. 15). This section has been also referred to as "Boathouse Beach" because of the building situated at its western end.

Although previous studies included the Rodeo Canyon section within the Santa Maria province, it is probably within the western end of the Santa Barbara embayment. This is because (1) it is situated southeast of the Arguello High (see Fischer, 1976; Isaacs, 1981), (2) the Tranquillon Volcanics (Hornafius and others, 1982) consist here of altered water-lain tuff, whereas at Point Pedernales, just north of Point Arguello, they are composed of welded tuffs and rhyolite agglomerate, and (3) the mudstones of the upper Oligocene-lower Miocene Rincon Formation, which represent the initial deep-water subsidence of the Santa Barbara embayment, are exposed in Cañada del Rodeo (Dibblee, 1950).

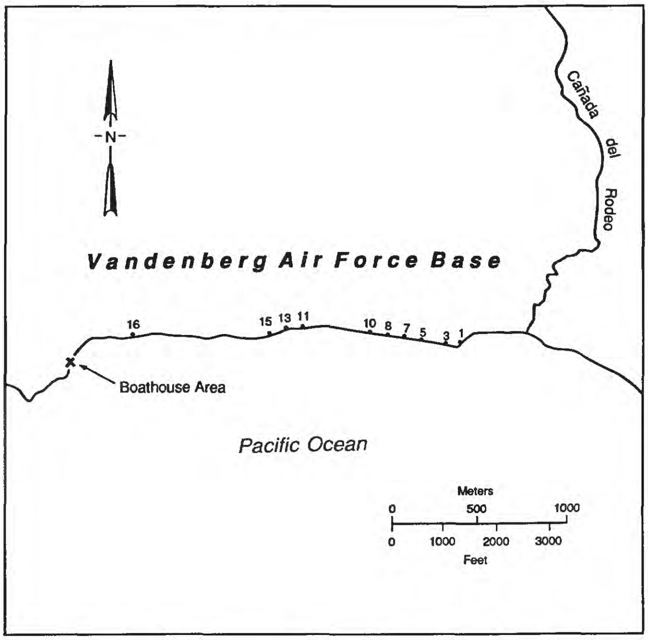


Figure 15. Sample locality map of Rodeo Canyon section. Sample numbers refer to CRC-40661 collection. Some intermediate numbers not plotted for clarity. See figure 1 for section location.

COLLECTIONS

At least 1,038 ft (316 m) of the Monterey Formation disconformably overlies the Tranquillon Volcanics flanking the mouth of Cañada del Rodeo (fig. 16). Complex structure and unexposed intervals render detailed measurement of the superjacent stratigraphic section impossible. Although the lower calcareous-siliceous and upper calcareous-siliceous members of the Monterey Formation are recognizable here, an intermediate interval lacks the diagnostic lithology (for example, predominantly phosphatic mudstones and dolostones) of the phosphatic member and instead has an atypical abundance of porcellanite and chert. Because it is lithologically transitional between the subjacent and superjacent members, this part of the section is instead referred to as the "phosphatic member" interval (fig. 16).

In August 1983, G.L. Armstrong and I collected 15 samples (CRC-40661-1 to -15) from the Rodeo Canyon section and obtained an additional sample (CRC-40661-16) collected by T.C. MacKinnon for microfossil analyses (figs. 15 and 16). Although only the basal sample (CRC-40661-1) revealed foraminifers at low magnification in the field and laboratory, another relatively soft sample (CRC-40661-6) was also selected for processing using the conventional laboratory washing method designed to isolate foraminifers from clastic rocks. Lithologic descriptions of the samples and designation of those selectively processed for foraminifers are given in appendix C.

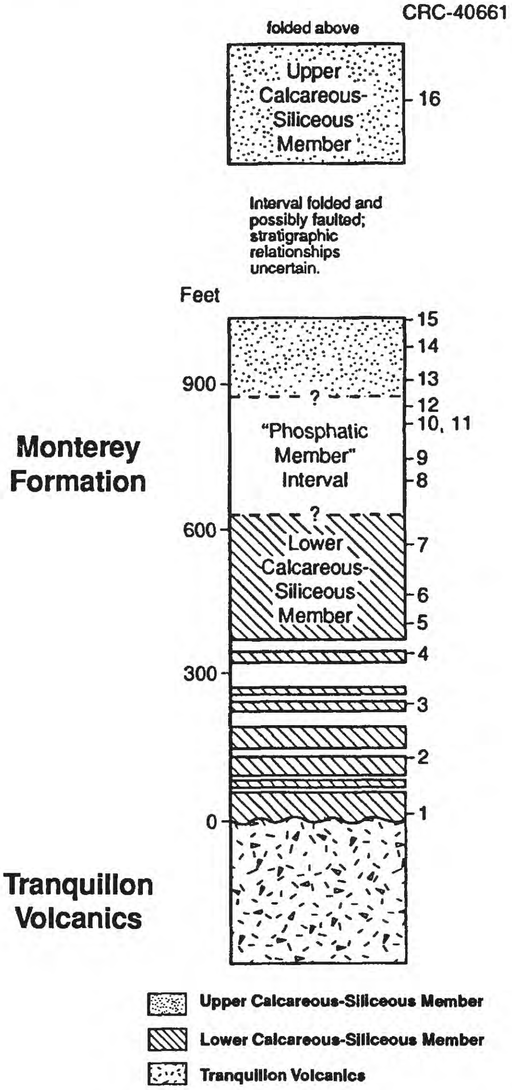


Figure 16. Stratigraphic column of Rodeo Canyon section denoting positions of collected samples (CRC-40661 collection). "Phosphatic member" interval is stratigraphically positioned where the phosphatic member should be, but it is more transitional than distinct from the adjacent members.

RECOVERY AND PRESERVATION

Foraminifers were recovered only from the pelletal phosphorite (sample CRC-40661-1) near the base of the Rodeo Canyon section. The unevenly distributed specimens are obscured by pelletal encasements of collophane or by the phosphatic matrix (fig. 17; pls. 34-37) and the specimens themselves are composed of collophane (fig. 18). Examination of petrographic slides makes it possible to view these hidden specimens (pls. 38-46).

FAUNAL ASSEMBLAGE

Nineteen species of Foraminifera are identified in the eight petrographic slides made from sample CRC-40661-1 (table 3). *Rectuvigerina branneri* and *Protoglobobulimina pseudotorta* dominate the assemblage. Also common are *Anomalinoides salinasensis, Pullenia miocenica,* and *Valvulineria robusta.*

BIOSTRATIGRAPHY

The benthic foraminiferal assemblage recovered from the base of the Rodeo Canyon section is immediately recognizable as part of the warm-temperate to subtropical Relizian to Luisian fauna, particularly by the conspicuous presence of *Rectuvigerina branneri*. The concurrence of *Anomalinoides salinasensis, Cancris baggi, Pullenia miocenica,* and *Valvulineria californica* suggests that this assemblage is Relizian to Luisian in age (Kleinpell, 1938; Finger, 1992). The common occurrence in this association of *Valvulineria robusta,* which most frequently occurs in the Relizian (Kleinpell, 1938; Finger, 1992) and characterizes the Relizian stratotype (Billman and Hopkins, 1980), suggests that the assemblage is of late Relizian age rather than Luisian age. Although Kleinpell's (1938) restriction of

Cancris baggi to the late Relizian would seem to support this, I have recovered both *Valvulineria robusta* and *Cancris baggi* from rocks of Saucesian, Relizian, and Luisian age (Finger, 1992). Overall, the assemblage is very similar to those recovered from the phosphatic member of the Monterey Formation at Mussel Rock and Lions Head, assemblages which are interpreted herein as Luisian in age. Lack of a more complete foraminiferal sequence in the Rodeo Canyon section precludes refining the age determination for the pelletal phosphorite (sample CRC-40661-1), especially because the Relizian and Luisian stages often are difficult to differentiate. Under these circumstances, and for reasons discussed below, I am inclined to place the basal exposure of the Rodeo Canyon section within the late Relizian to early Luisian interval.

Although the sequence of porcelanites and dolostones in the lower part of the Rodeo Canyon section differs from the lithology of Canfield's (1939) Dark Brown zone, which is characterized by phosphatic shales, their respective biofacies are similar. Wissler and Dreyer (1943) biostratigraphically referred to Canfield's (1939) unit as Foram zone 5, the *Siphogenerina collomi-Siphogenerina nuciformis* zone, and correlated it with the Luisian stage. Woodring and others (1943) and Woodring and Bramlette (1950) described similar sections in the Santa Maria basin as part of their lower member of the Monterey Formation, to which they apply an age of late Relizian and Luisian. None of these previous workers in the Santa Maria area, however, included the Rodeo Canyon section in their studies. Pisciotto (1981, fig. 3) correlates the Dark Brown zone with the upper part of his calcareous facies and the lower part of his phosphatic facies. I similarly relate the corresponding faunal zone to the transitional "phosphatic member" (fig. 16).

The Tranquillon Volcanics, which underlie the Monterey Formation at Rodeo Canyon, have an age of 17±1.2 Ma near the Santa Ynez River (Turner, 1970), approximately 32 km to the east. On the basis of adjacent foraminiferal sequences in the Santa Barbara basin, Kleinpell and Weaver (1963, fig. 2) placed the Tranquillon Volcanics

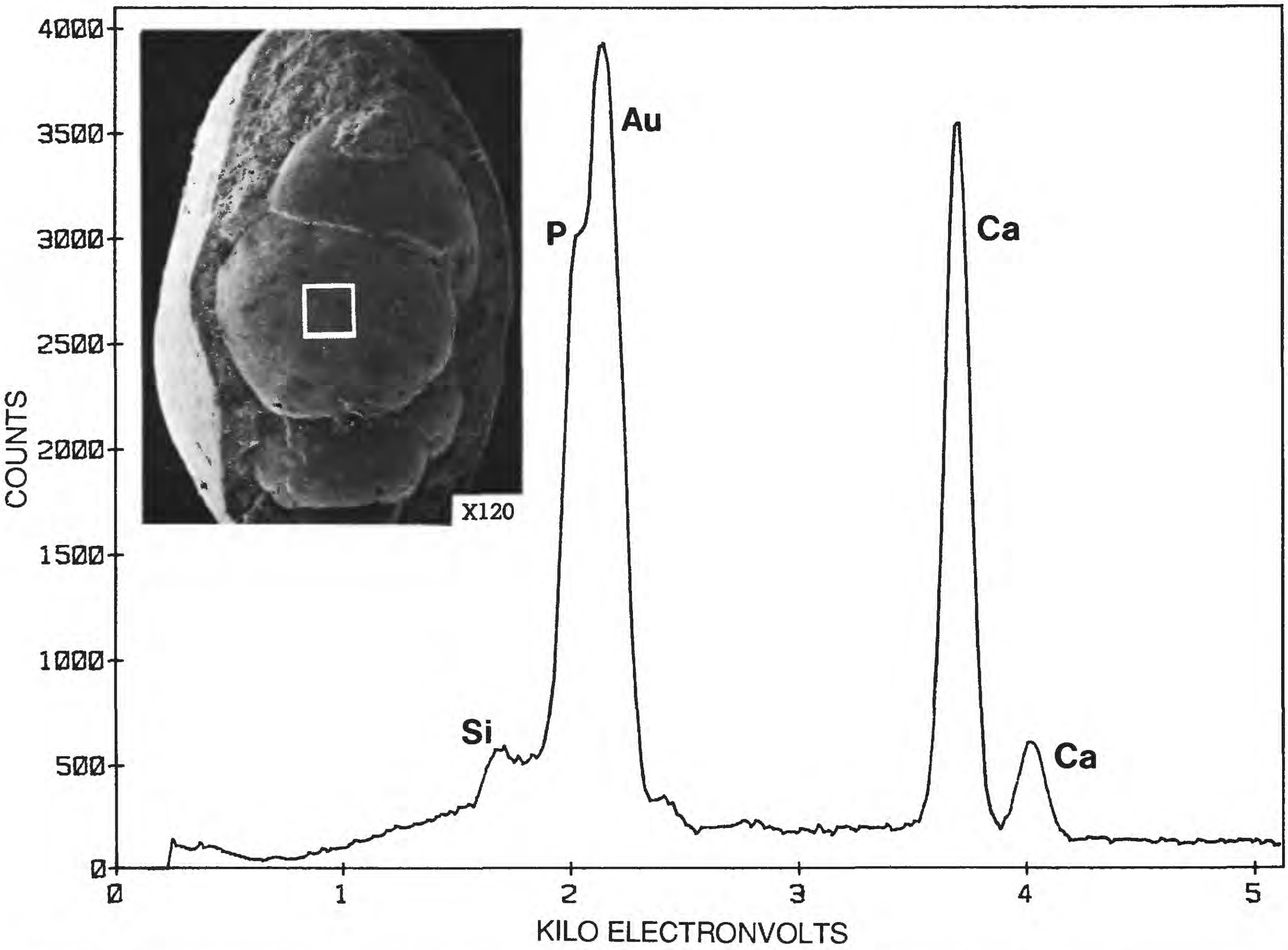


Figure 17. Chemical analysis of outer surface of phosphatic pellet (with foraminifer nucleus) from Rodeo Canyon section, sample CRC-40661-1. Ca and P peaks indicate that pellet is composed of collophane. Other element peaks represent sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

within the late Saucesian, whereas Carson (1965) interpreted it as the Saucesian-Relizian boundary. The latter correlation had been established previously by the Standard Oil Company of California, as noted by Dibblee (1950). More recently, DePaolo and Finger (1991) used high-resolution strontium isotope chronostratigraphy and biostratigraphy to determine that the age of the basal Monterey in the Salinas and Ventura basins is 17.85±0.10 Ma. In the Rodeo Canyon section, however, the contact between the Tranquillon Volcanics and Monterey Formation appears to be erosional, and the superjacent foraminiferal assemblage indicates that a substantial period of depositional time is missing here.

The late Relizian to early Luisian foraminiferal age for the basal part of the exposure at Rodeo Canyon is supported by three diatom datums recognized in overlying strata (R.J. Navarrette, oral commun., 1984). Sample locality CRC-40661-8 in the basal part of the "phosphatic member" is within *Denticulopsis lauta* subzone (b), which has an age range of 15.0 to 13.7 Ma and correlates with the late Luisian. In the superjacent upper calcareous-siliceous member, sample localities CRC-40661-13 and -15 are within *Denticulopsis hustedtii-Denticulopsis lauta* subzones (b) and (c), respectively. This interval has an age range of 13.5 to 11.0 Ma and correlates for the most part with the early Mohnian or late middle Miocene.

DEPOSITIONAL PALEOENVIRONMENT

Although the number of observable specimens and recognizable species are limited by the preservational state of the foraminiferal assemblage recovered from Rodeo Canyon, the recognized taxa appear to be sufficient for an interpretation of the depositional paleoenvironment. *Anomalinoides salinasensis, Gyroidina rosaformis,* and *Pullenia miocenica* are listed by Ingle (1980, 1985) as species with upper-depth limits within the lower middle-bathyal zone (1,500-2,000 m), indicating that they were deposited within this depth interval.

The sedimentology of the pelletal phosphorite has significant implications in the depositional history of the lower Rodeo Canyon section. In the Miocene of California, pelletal

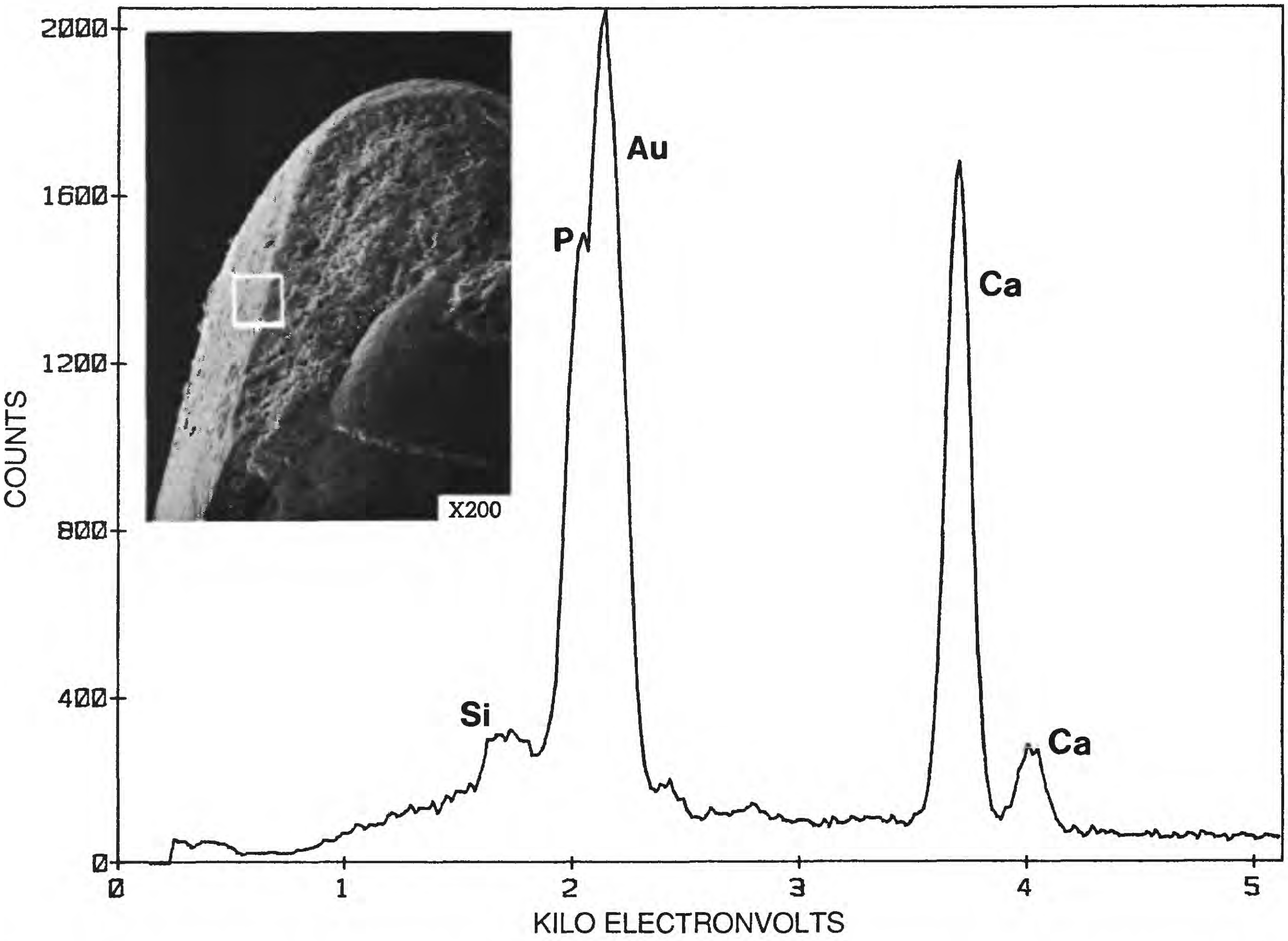


Figure 18. Chemical analysis of internal mold of *Protoglobobulimina pseudoaffinis* specimen encased within phosphatic pellet shown in figure 17. Ca and P peaks indicate that mold is composed of collophane. Other element peaks represent sediment contaminants (Si) and plug (Cu) and coating (Au) used for scanning electron microscopy.

Table 3. Foraminiferal assemblage in pelletal phosphorite sample (CRC-40661-1), Monterey Formation, Rodeo Canyon section

FORAMINIFERA SPECIES
Anomalinoides salinasensis
Bolivina advena?
Buliminella subfusiformis
Cancris baggi
Globigerina bulloides
Globigerina pseudociperoensis
Globigerina sp.?
Gyroidina rosaformis
Islandiella modeloensis
Lenticulina smileyi
Marginulinopsis beali
Praeglobobulimina galliheri
Protoglobobulimina pseudotorta
Pseudoparrella subperuviana
Pullenia miocenica
Rectuvigerina branneri
Siphonodosaria quadrulata
Valvulineria californica
Valvulineria robusta

phosphorite is often present in strata representing the initial downwarping of a basin. Although their internal contents are rarely observed, collophane pellets bearing California Miocene foraminifers as their nuclei have previously been recorded off southern California (Dietz and others, 1942) and in the lowermost Graves Creek section near Atascadero, San Luis Obispo County, Calif. (Graham, 1980). I also have found them in the lower part of the Monterey Formation on San Clemente Island and in the lower Rincon Formation along Los Sauces Creek, Ventura County, Calif. (Finger, 1983).

Although it has been postulated that pelletal phosphorite originates as fecal pellets of indiscriminate deposit feeders (Dietz and others, 1942), the mechanism of its deposition remains unclear (Bentor, 1980; Baturin, 1982). Ingle (1980) states that pelletal phosphorite accumulates at the upper (200-500 m) and lower (1,000-1,500 m) boundaries of the intersection between the oxygen-minimum zone and continental slope or basin sill. Pisciotto and Garrison (1981) and Garrison and others (1987, 1990) noted that veneers of pelletal phosphorite tend to form on sediment-starved isolated bank tops at the fringes of the oxygen-minimum zone and may be redeposited as basin-floor turbidites. Garrison and others (1987) classified the basal lithofacies of the Monterey Formation at Rodeo Canyon as a banktop glaucophosphorite.

The upper-depth limits (see Ingle, 1980, 1985) of the encased foraminifers at Rodeo Canyon suggest that the pellets probably formed near the 1,500-m lower edge of the oxygen-minimum layer. The phosphorite is unsorted and overlain by laminated rocks, implying that it was displaced into the deeper basin by slumping off an adjacent bank. The laminated rocks that predominate above the phosphorite in the Rodeo Canyon section are evidence that low-oxygen (< 0.1 mL/L) bottom conditions existed in the depositional basin (see Ingle, 1980, 1985). These conditions are attributed to the intersection of the oxygen-minimum layer with the basin sill (see Ingle, 1980, 1985; Blake, 1981; Pisciotto and Garrison, 1981). On the basis of field relationships and regional histories (see Ingle, 1980, 1985), the initial subsidence of the basin, the development of low-oxygen bottom waters, and the slumping of bank sediments were almost concurrent events.

SYNOPSIS

At Rodeo Canyon, foraminifers are restricted to a lens of pelletal phosphorite in the basal part of the lower calcareous-siliceous member of the Monterey Formation. Thin-section study and lithostratigraphic correlation reveal that the foraminiferal assemblage is most diagnostic of the late Relizian (latest early and earliest middle Miocene) to early Luisian (early middle Miocene) interval. This conclusion suggests that the Rodeo Canyon assemblage is slightly older than the foraminiferal assemblages recovered from the phosphatic member at Mussel Rock and Lions Head. The lithologic and paleontologic evidence indicates that the phosphorite at Rodeo Canyon formed at a depth of approximately 1,500 m on a bank that was intersected by the oxygen-minimum zone. Paleobathymetric marker species indicate subsequent redeposition in the lower middle-bathyal zone (1,500-2,000 m).

DISCUSSION

Two methods of sample processing were employed in this foraminiferal study. Samples were washed by conventional laboratory techniques through a 200-mesh (75 μm openings) screen to yield a sand residue from which isolated specimens were picked, sorted, and identified. Selected specimens are illustrated as scanning electron micrographs in plates 1 to 5, 20, and 34. Selected indurated mudstones that yielded foraminifers were also thin sectioned because most of the specimens could not be cleanly extracted nor were they well preserved. These samples were sectioned both parallel and perpendicular to bedding. From these, petrographic slides were prepared and then analyzed by comparing observed specimens with reference thin sections prepared by the technique of Finger and Armstrong (1984).

Table 4. Checklist of Monterey Formation Foraminifera species versus plate numbers

[Solid box, scanning electron micrograph; shaded box, thin-section photomicrograph]

FORAMINIFERA SPECIES	Mussel Rock																			Lions Head														Rodeo Canyon												
BENTHICS PLATE:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Ambitropus evax	■																																													
Anomalinoides salinasensis					■	▒	▒	▒	▒				▒				▒								▒	▒	▒																▒	▒		▒
Baggina californica			■									▒								■									▒																	
Bolivina advena																																							▒							
Bolivina advena ornata		■											▒											▒					▒																	
Bolivina blakei																													▒																	
Bolivina brevior		■																																												
Bolivina californica		■																						▒					▒				▒													
Bolivina churchi		■																															▒													
Bolivina imbricata		■												▒																																
Bolivina modeloensis		■																																												
Bolivina sp.																													▒																	
Buccella oregonensis					■																																									
Bulimina subcalva		■																																												
Buliminella subfusiformis			■										▒	▒																			▒												▒	▒
Cancris baggi																																														
Cibicides spp.				■																																					▒					
Cibicidoides mckannai																																														
Concavella gyroidinaformis	■																																													
Elphidium granti			■																																											
Gyroidina rosaformis					■							▒			▒	▒												▒		▒														▒		
Hanzawaia depaoloi				■																																										
Holmanella baggi			■		■																												▒													
Islandiella modeloensis			■												▒		▒											▒	▒												▒				▒	
Kleinpella californiensis				■																																										
Lagena apiopleura	■																																													
Lenticulina douglasi	■																											▒																		
Lenticulina hughesi																												▒																		
Lenticulina miocenica																															▒															
Lenticulina smileyi																				■											▒													▒		
Marginulinopsis beali	■																																	■												
Megastomella capitanensis																														▒																
Nodogenerina advena	■															▒																														
Nodogenerina sagrinensis																▒															▒	▒	▒													
Nodosaria ewaldi															▒	▒																▒														
Praeglobobulimina galliheri		■																																										▒		
Protoglobobulimina pseudotorta		■															▒																▒	■					▒					▒	▒	▒
Proxifrons vaughani																	▒																													
Pseudoparrella subperuviana	■											▒			▒	▒			▒											▒																
Pullenia miocenica			■											▒						■			▒	▒																	▒					
Rectuvigerina branneri		■								▒	▒	▒								■	▒	▒						▒						■				▒	▒	▒				▒		
Rectuvigerina hughesi		■																																												
Saracenaria schencki	■																																													
Siphonodosaria montereyana	■														▒	▒		▒														▒														
Siphonodosaria quadrulata			■																														▒							▒						
Suggrunda kleinpelli			■																																											
Trifarina fluens				■															▒																											
Uvigerina hannai				■					▒									▒	▒																											
Valvulineria californica					■								▒							■								▒																	▒	
Valvulineria robusta	■												▒																					■							▒	▒	▒			
Gen. et sp. indet.																																▒			▒	▒										
PLANKTICS PLATE:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Globigerina bulloides				■																											▒									▒						
Globigerina pseudociperoensis																																								▒						
Globigerina sp.?																																								▒						
Globigerinella pseudobesa				■																																										
Globorotalia praescitula				■																																										
Tenuitellinata angustiumbilicata				■																											▒															

Identifying California Miocene foraminifers in thin section can be particularly difficult at the species level; admittedly, educated guesswork is often involved. Although the "Atlas of California Miocene Foraminifera" (Finger, 1990) enhances one's ability to recognize these species in petrographic thin sections, actual application of the data in the atlas will always be confronted with the problems of differentiating morphologically similar species, as well as specimens that are partially dissolved, distorted, obscured, or fragmented. Minor misidentifications should not significantly affect interpretations if correlations are based primarily on associations of biostratigraphic marker species that are distinct and readily recognizable forms.

Scanning electron micrographs of the best preserved specimens isolated from the rocks and photomicrographs of most of the better preserved specimens recognized in the petrographic slides are shown on plates 1 to 43. This comprehensive set of illustrations enhances the reader's ability to comprehend the condition, composition, and interpretation of the Santa Maria fauna. The table 4 checklist is a convenient index to the 55 species figured on these plates.

SUMMARY

Foraminifers present in some of the highly indurated rocks from the Mussel Rock, Lions Head, and Rodeo Canyon sections can be identified in petrographic slides. Petrographic study reveals foraminiferal associations indicating (1) a Relizian-Luisian age for the lower calcareous-siliceous member of the Monterey Formation at Rodeo Canyon, (2) a Relizian-Luisian age for the lower part of the phosphatic member of the Monterey Formation at Lions Head, (3) a Luisian age for the upper part of the phosphatic member at Lions Head, (4) a Luisian age for the lower part of the phosphatic member at Mussel Rock, and (5) a Mohnian age for the upper part of the phosphatic member at Mussel Rock.

Paleobathymetric marker species indicate that the Luisian and Mohnian assemblages in the calcareous mudstones of the phosphatic member of the Monterey Formation are mixed associations deposited at lower middle-bathyal (1,500-2,000 m) depths. The Relizian assemblage at Rodeo Canyon occurs in a pelletal phosphorite that initially formed on a sediment-starved bank at a water depth of about 1,500 m; it subsequently was redeposited at lower middle-bathyal depths.

The absence of foraminifers in most of the rocks sampled from the Mussel Rock, Lions Head, Point Pedernales, Rodeo Canyon, Sweeney Road, and Manville Quarry sections may be attributable to any or all of the following: (1) an elevated calcium-carbonate compensation depth, (2) early diagenetic dissolution and incorporation of test calcite into dolomite, and (or) (3) outcrop leaching. The lack of foraminifers in the lower Monterey Formation at Point Pedernales is particularly perplexing because several assemblages were recovered from the coeval rocks at Mussel Rock, Lions Head, and Rodeo Canyon. Such local variations may reflect local differences in depositional paleoenvironments and (or) diagenesis.

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APPENDIX A. MUSSEL ROCK SECTION—LITHOLOGIC AND PROCESSING LOG OF SAMPLES

Lithologic descriptions of collected samples examined in the laboratory. Bedding thicknesses are defined as follows: laminated, <3 mm; thin bedded, 3 to 40 mm; massive, neither laminated nor bedded in hand sample and probably thick bedded (>40 mm) in field.

SAMPLES CRC-40398-1 TO -84

Note: Washed residues were prepared from the following samples, all of which were devoid of Foraminifera: 1, 6, 7, 11, 14, 17, 22, 24, 29, 32, 36, 40, 44, 48, 52, 56, 60, 64, 68, 72, 76, 79.

POINT SAL FORMATION (SAMPLE 1)

(1) Top exposure: Massive greenish gray-brown slightly calcareous siltstone.

MONTEREY FORMATION (SAMPLES 2 THROUGH 62)

PHOSPHATIC MEMBER (SAMPLES 2 THROUGH 6)

(2) 0 ft: Light-brown thin-bedded calcareous mudstone. Washed residue and four thin sections prepared.

(3) 112 ft: Light-brown thin-bedded to laminated calcareous mudstone. Washed residue and six thin sections prepared.

(4) 150 ft: Light-brown thin-bedded to laminated calcareous mudstone. Washed residue and four thin sections prepared.

(5) 195 ft: Light-brown thin-bedded to laminated calcareous mudstone. Washed residue and four thin sections prepared.

(6) 325 ft: Buff to dark-brown thin-bedded phosphatic siliceous mudstone and dark-brown dolomitic mudstone or dolostone.

UPPER CALCAREOUS-SILICEOUS MEMBER (SAMPLES 7 THROUGH 23)

(7) 390 ft: Buff to dark-brown thin-bedded phosphatic siliceous mudstone and light-brown thick-bedded porcellanite.
(8) 390 ft: Light-brown thin-bedded to weakly laminated dolomitic siliceous mudstone.
(9) 430 ft: Dark-brown massive to very faintly laminated dolostone or dolomitic porcellanite.
(10) 430 ft: Light-gray-brown poorly laminated to massive dolomitic siliceous mudstone or dolostone and dark-brown very faintly laminated siliceous mudstone.
(11) 480 ft: Medium-brown poorly thin-bedded siliceous mudstone and black laminated chert.
(12) 515 ft: Brown-gray massive medium dolostone.
(13) 530 ft: Medium-brown thin-bedded siliceous dolostone and medium-brown laminated siliceous mudstone.
(14) 590 ft: Buff- to dark-brown very thinly laminated phosphatic siliceous mudstone.
(15) 658 ft: Same as No. 14.
(16) 735 ft: Light-brown chert-laminated siliceous mudstone.
(17) 802 ft: Medium- to light-brown thinly laminated siliceous mudstone.
(18) 840 ft: Light-brown laminated dolomitic siliceous mudstone.
(19) 855 ft: White laminated and medium-brown laminated siliceous mudstone.
(20) 890 ft: Light-brown laminated siliceous mudstone.
(21) 924 ft: Light- to medium-brown laminated siliceous mudstone, light-brown dolomitic siliceous mudstone, and light-brown laminated chert.
(22) 950 ft: Light-brown laminated to thin-bedded siliceous mudstone and light-brown laminated siliceous mudstone.
(23) 975 ft: Same as No. 22 and dark-brown massive dolomitic porcellanite.

CLAYEY-SILICEOUS MEMBER (SAMPLES 24 THROUGH 62)

Owing to the structural discontinuity and complexity of the strata in the interval above sample 23, the following section was measured separately with its base at the cliff north of Mussel Rock (see fig. 5).

Note: Supplementary collection (CRC-43156) of seven samples from the siliceous member logged at end of appendix A.

(24) 85 ft: Same as No. 22.
(25) 95 ft: White and light-brown laminated siliceous mudstone.
(26) 135 ft: Light-brown faintly laminated dolomitic siliceous mudstone.
(27) 145 ft: Light-brown faintly laminated to massive siliceous mudstone, some of which tends toward porcellanite.
(28) 390 ft: Same as No. 27.
(29) 400 ft: Same as No. 27 but highly fractured.
(30) 410 ft: Same as No. 27 but with some porcellanite and asphalt in some fractures.
(31) 903 ft: Buff to light-brown laminated to thin-bedded siliceous mudstone.
(32) 930 ft: Same as No. 31.
(33) 980 ft: Light-gray laminated to thin-bedded porcellanite.
(34) 1020 ft: Light-brown laminated diatomaceous mudstone.
(35) 1030 ft: Medium-brown laminated to thin-bedded diatomaceous mudstone.
(36) 1045 ft: Same as No. 35 but slightly darker brown.
(37) 1185 ft: Same as No. 36.
(38) 1220 ft: Same as No. 36 but greenish gray to medium brown.
(39) 1228 ft: Same as No. 36.
(40) 1270 ft: Same as No. 36 and massive dark-gray to medium-brown diatomaceous mudstone.
(41) 1280 ft: Medium-greenish-brown massive to very faintly thin-bedded mudstone.
(42) 1290 ft: Medium-greenish-brown massive to very faintly thin-bedded mudstone.
(43) 1305 ft: Very faintly greenish-medium-brown laminated diatomaceous mudstone.
(44) 1350 ft: Same as No. 43.
(45) 1362 ft: Same as No. 43.
(46) 1375 ft: Medium-greenish-gray-brown laminated to thin-bedded diatomaceous mudstone.
(47) 1387 ft: Same as No. 43.
(48) 1400 ft: Medium-dark-greenish-brown laminated to thin-bedded diatomaceous mudstone.
(49) 1412 ft: Greenish-gray-brown laminated diatomaceous mudstone.
(50) 1470 ft: Light- to medium-brown laminated diatomaceous mudstone.
(51) 1480 ft: Same as No. 49.
(52) 1490 ft: Light- to medium-brown laminated to thin-bedded diatomaceous mudstone.
(53) 1505 ft: Same as No. 52 but all laminated.
(54) 1525 ft: Same as No. 52 but all medium brown.
(55) 1545 ft: Same as No. 49.
(56) 1565 ft: Greenish-gray-brown faintly laminated to thin-bedded diatomaceous mudstone.
(57) 1585 ft: Medium-brown laminated to thin-bedded diatomaceous mudstone.
(58) 1605 ft: Same as No. 57 but slightly more greenish.
(59) 1625 ft: Light- to medium-brown laminated diatomaceous mudstone.
(60) 1645 ft: Greenish-gray-brown laminated to thin-bedded diatomaceous mudstone.
(61) 1655 ft: Medium-greenish-gray faintly thin-bedded diatomaceous mudstone.
(62) 1663 ft: Light-brown laminated to thin-bedded diatomaceous mudstone.

SISQUOC FORMATION (SAMPLES 63 THROUGH 78)

(63) 1671 ft: Two-foot-thick layer of glazed black 1/4- to 5-in-long phosphatic nodules embedded in grayish-brown diatomaceous mudstone; interior of nodules light-brown to buff with some orange staining.
(64) 1679 ft: Light-gray to buff massive diatomaceous mudstone or muddy diatomite.
(65) 1687 ft: Slightly green medium-gray massive diatomaceous mudstone.
(66) 1696 ft: Same as No. 65 but medium brown.
(67) 1705 ft: Light-brown massive diatomaceous siltstone.
(68) 1720 ft: Medium-greenish-gray massive diatomaceous mudstone.
(69) 1730 ft: Same as No. 68.
(70) 1740 ft: Same as No. 68.
(71) 1750 ft: Dark-greenish-gray massive diatomaceous siltstone.
(72) 1760 ft: Same as No. 71.
(73) 1770 ft: Same as No. 71 but light gray.
(74) 1785 ft: Buff massive diatomaceous(?) siltstone or silty mudstone.
(75) 1800 ft: Light-greenish-tan massive diatomaceous(?) silty mudstone.
(76) 1810 ft: Light-greenish-tan massive diatomaceous(?) silty mudstone.
(77) 1820 ft: Light-greenish-gray massive diatomaceous(?) siltstone.
(78) 1903 ft: Same as No. 77.

LOSPE FORMATION (SAMPLE 79)

(79) 10 ft above fault contact with Espada Formation: Medium-gray massive slightly calcareous mudstone.

POINT SAL FORMATION (SAMPLES 80 THROUGH 84)

Washed residues and two thin sections were prepared from each of these five samples.

(80) Basal exposure, 10 ft above fault contact with Lospe Formation: Medium-brown-gray faintly thin-bedded foraminiferal mudstone.
(81) 40 ft: Same as No. 80, with occasional white laminae and fish scales.
(82) Upsection from No. 81, footage not measured—light-gray shale.
(83) Upsection from No. 82, footage not measured—light-gray shale.
(84) Upsection from No. 83, footage not measured—dark-greenish-gray shale.

SUPPLEMENTARY COLLECTION (SAMPLES CRC-43156-1 THROUGH -7)

MONTEREY FORMATION

CLAYEY-SILICEOUS MEMBER

Washed residues were prepared from each of the seven samples.

(1) 0 ft: Medium-brown faintly thin-bedded slightly dolomitic and slightly phosphatic mudstone.
(2) 43 ft: Dark-brown thin-bedded to laminated to massive slightly dolomitic mudstone with laminae and thin lenses of light-buff phosphate and dark-brown to gray massive dolostone.
(3) 55 to 65 ft: Composite sample of medium- to dark-brown thin-bedded to massive mudstones and medium- to dark-brown massive dolostone.
(4) 76 ft: Medium-brown faintly laminated to thin-bedded mudstone.
(5) 127 ft: Same as No. 4.
(6) 185 ft: Highly fractured medium- to dark-brown very poorly thin-bedded to laminated mudstone.
(7) 261 ft: Medium gray-brown laminated mudstone.

APPENDIX B. LIONS HEAD SECTION—LITHOLOGIC AND PROCESSING LOG OF SAMPLES

Lithologic descriptions of collected samples examined in the laboratory. Bedding thicknesses are defined as follows: laminated, <3 mm; thin bedded, 3 to 40 mm; massive, neither laminated nor bedded in hand sample and probably thick bedded (>40 mm) in field.

SAMPLES CRC-40471-1 TO -18

MONTEREY FORMATION

PHOSPHATIC MEMBER (SAMPLES 1 THROUGH 12)

(1) 22 ft : Alternately light- and medium-brown laminated to thin-bedded to massive slightly dolomitic phosphatic mudstone and buff faintly laminated calcareous silty dolostone; Foraminifera visible in both rock types at 30×. Two thin sections of mudstone prepared.
(2) 65 ft : Alternately light- and dark-brown thin-bedded calcareous phosphatic mudstone with Foraminifera visible at 30× and light-brown massive limestone. Two thin sections of mudstone prepared.

(3) 110 ft : Alternately medium- and dark-brown thin-bedded to massive calcareous phosphatic mudstone and buff massive limestone; Foraminifera visible in both rocks at 30×. Two thin sections of mudstone prepared.
(4) 165 ft : Alternately gray and dark-brown laminated to thin-bedded slightly calcareous phosphatic mudstone and dark-brown faintly laminated slightly calcareous dolostone; Foraminifera visible in both rocks at 30×. Two thin sections of mudstone prepared.
(5) 210 ft : Alternately light- and medium-brown thin-bedded flaggy phosphatic mudstone with Foraminifera visible at 30× and medium-brown laminated to thin-bedded sandy limestone. Washed residue and two thin sections of mudstone prepared.
(6) 240 ft : Alternately light- and dark-brown laminated to thin-bedded calcareous phosphatic mudstone with Foraminifera visible at 30×. Washed residue and two thin sections prepared.
(7) 285 ft : Alternately light- and dark-brown thin-bedded to massive slightly calcareous phosphatic mudstone; Foraminifera not visible at 30×.
(8) 315 ft : Alternately light- and dark-brown laminated to thin-bedded siliceous phosphatic mudstone; Foraminifera not visible at 30×.
(9) 370 ft : Alternately light- and dark-brown laminated to thin-bedded calcareous phosphatic mudstone with Foraminifera visible at 30×. Two thin sections of mudstone prepared.
(10) 435 ft : Alternately light- and medium-brown faintly thin-bedded to massive calcareous phosphatic mudstone with Foraminifera visible at 30×. Washed residue and two thin sections prepared.
(11) 515 ft : Medium-brown faintly thin-bedded to massive calcareous phosphatic mudstone with Foraminifera visible at 30×. Two thin sections prepared.
(12) 590 ft : Alternately light- and medium-brown laminated to thin-bedded calcareous phosphatic mudstone with Foraminifera visible at 30×. Two thin sections prepared.

UPPER CALCAREOUS-SILICEOUS MEMBER (SAMPLES 13 THROUGH 18)

(13) 750 ft : Dark-brown to black faintly laminated to massive siliceous mudstone and light-brown faintly laminated siliceous dolostone; Foraminifera not visible at 30×.
(14) 830 ft : Light-brown faintly laminated siliceous mudstone and indistinctly laminated to thin-bedded black chert; Foraminifera not visible at 30×.
(15) 870 ft : Dark-brown massive but flaggy siliceous mudstone and medium-brown massive dolostone; Foraminifera not visible at 30×.
(16) 920 ft : Light-brown to black faintly laminated to massive siliceous mudstone and black chert with white laminae; Foraminifera not visible at 30×.
(17) 970 ft : Black massive but flaggy siliceous mudstone and medium-gray laminated dolostone; Foraminifera not visible at 30×.
(18) 995 ft : Light-brown laminated siliceous dolostone and black chert with contorted white laminae; Foraminifera not visible at 30×.

APPENDIX C. RODEO CANYON SECTION—LITHOLOGIC AND PROCESSING LOG OF SAMPLES

Lithologic descriptions of collected samples examined in the laboratory. Bedding thicknesses are defined as follows: laminated, <3 mm; thin bedded, 3 to 40 mm; massive, neither laminated nor bedded in hand sample and probably thick bedded (>40 mm) in field.

SAMPLES CRC-40661-1 TO -16

MONTEREY FORMATION (SAMPLES 1 THROUGH 16)

LOWER CALCAREOUS-SILICEOUS MEMBER (SAMPLES 1 THROUGH 7)

(1) 0 ft (base of section): Buff massive pelletal phosphorite with Foraminifera and fish debris common. Washed residue and eight thin-sections prepared.
(2) 130 ft: Buff faintly laminated dolomitic porcellanite with fish debris.
(3) 230 ft: Buff laminated dolomitic porcellanite with some fish debris.
(4) 328 ft: Buff laminated very dolomitic porcellanite with some fish debris.
(5) 421 ft: Buff to gray faintly laminated porcellaneous dolostone.
(6) 484 ft: Buff to brown laminated slightly dolomitic siliceous mudstone and buff porcelaneous dolostone. Washed residue prepared from mudstone.
(7) 565 ft: Buff to brown laminated porcellanite.

"PHOSPHATIC MEMBER" INTERVAL (SAMPLES 8 THROUGH 12)

Note: Recognition of this unit and its boundaries are uncertain.
(8) 715 ft: Buff to brown massive porcelaneous dolostone.
(9) 756 ft: Buff sugary massive dolostone with irregular blebs of brown chert.
(10) 820 ft: Buff sugary massive dolostone.

(Note: The remaining section is structurally complex; thus, sample heights are estimated.)

(11) ~820 ft: Buff to brown laminated to thin-bedded dolostone.
(12) ~858 ft: Buff sugary dolostone poorly laminated with irregular blebs of brown dolomitic chert.

UPPER CALCAREOUS-SILICEOUS MEMBER (SAMPLES 13 THROUGH 16)

(13) ~910 ft: Buff poorly laminated porcelaneous dolostone with lenses of brown chert.
(14) ~980 ft: Buff sugary massive dolostone.
(15) ~1038 ft: Buff faintly laminated porcelaneous dolostone.
(16) Above No. 15 (stratigraphic position uncertain): Buff sugary massive dolostone.

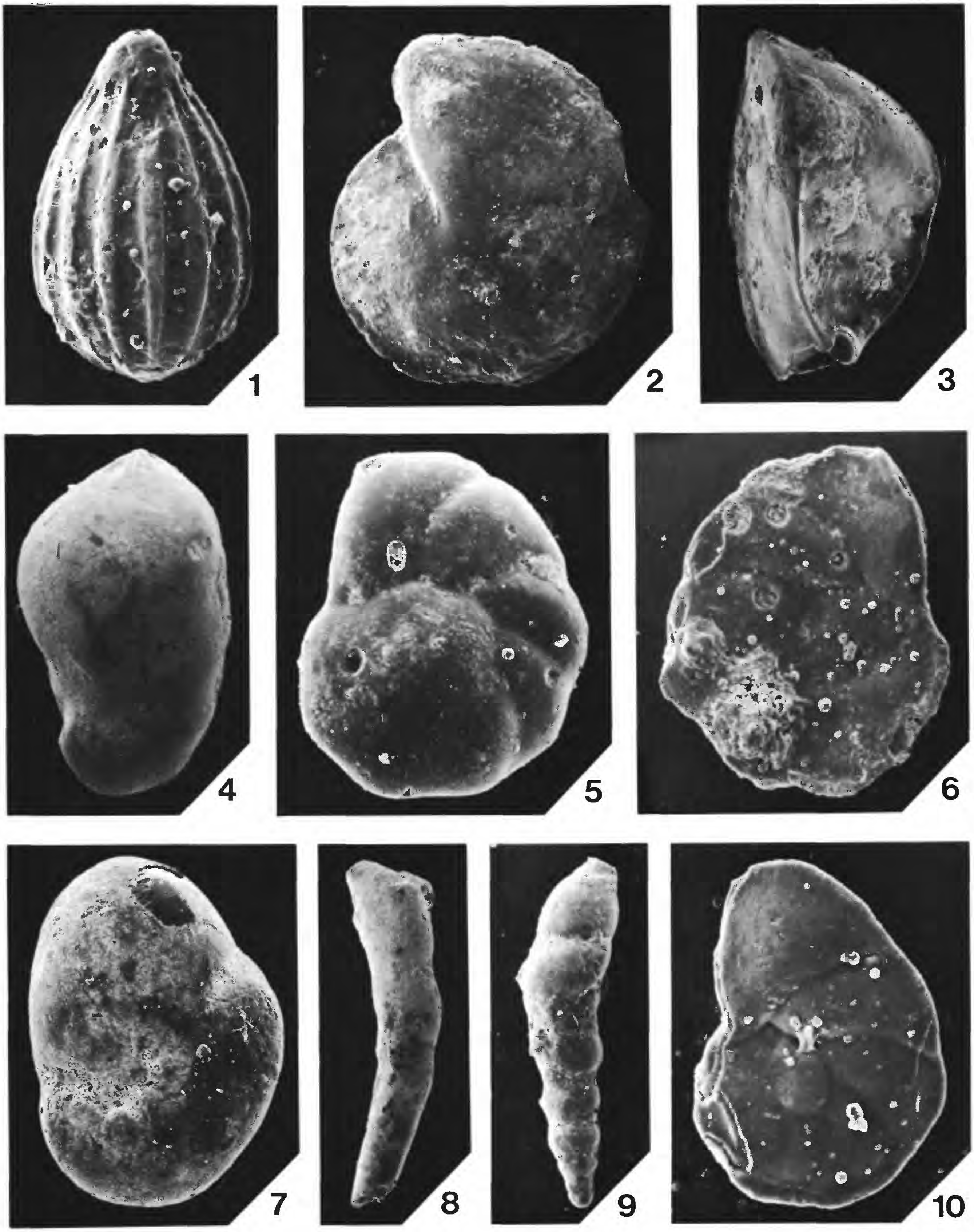
PLATES 1–46

[CRC numbers are samples stored at Chevron Petroleum Technology Company (formerly Chevron Oil Field Research Company), La Habra, Calif.]

PLATE 1

Scanning electron micrographs of foraminifers, Monterey Formation, Mussel Rock section.

Figure 1. *Lagena apiopleura* Loeblich and Tappan, side view, ×240, CRC-40398-2.
2. *Lenticulina douglasi* Finger, side view, ×90, CRC-40398-5.
3. *Saracenaria schencki* Cushman and Hobson, oblique side view, ×80, CRC-40398-5.
4. *Marginulinopsis beali* (Cushman), oblique side view, ×53, CRC-40398-3.
5. *Pseudoparrella subperuviana* (Cushman), spiral view, ×253, CRC-40398-3.
6. *Concavella gyroidinaformis* (Cushman and Goudkoff), spiral view, ×176, CRC-40398-5.
7. *Valvulineria robusta* (Kleinpell), umbilical view, ×90, CRC-40398-2.
8. *Siphonodosaria montereyana* Finger and Lipps, side view, ×33, CRC-40398-3.
9. *Siphonodosaria advena* (Cushman and Laiming), side view, ×93, CRC-40398-3.
10. *Ambitropus evax* (Bandy), spiral view, ×100, CRC-40398-3.

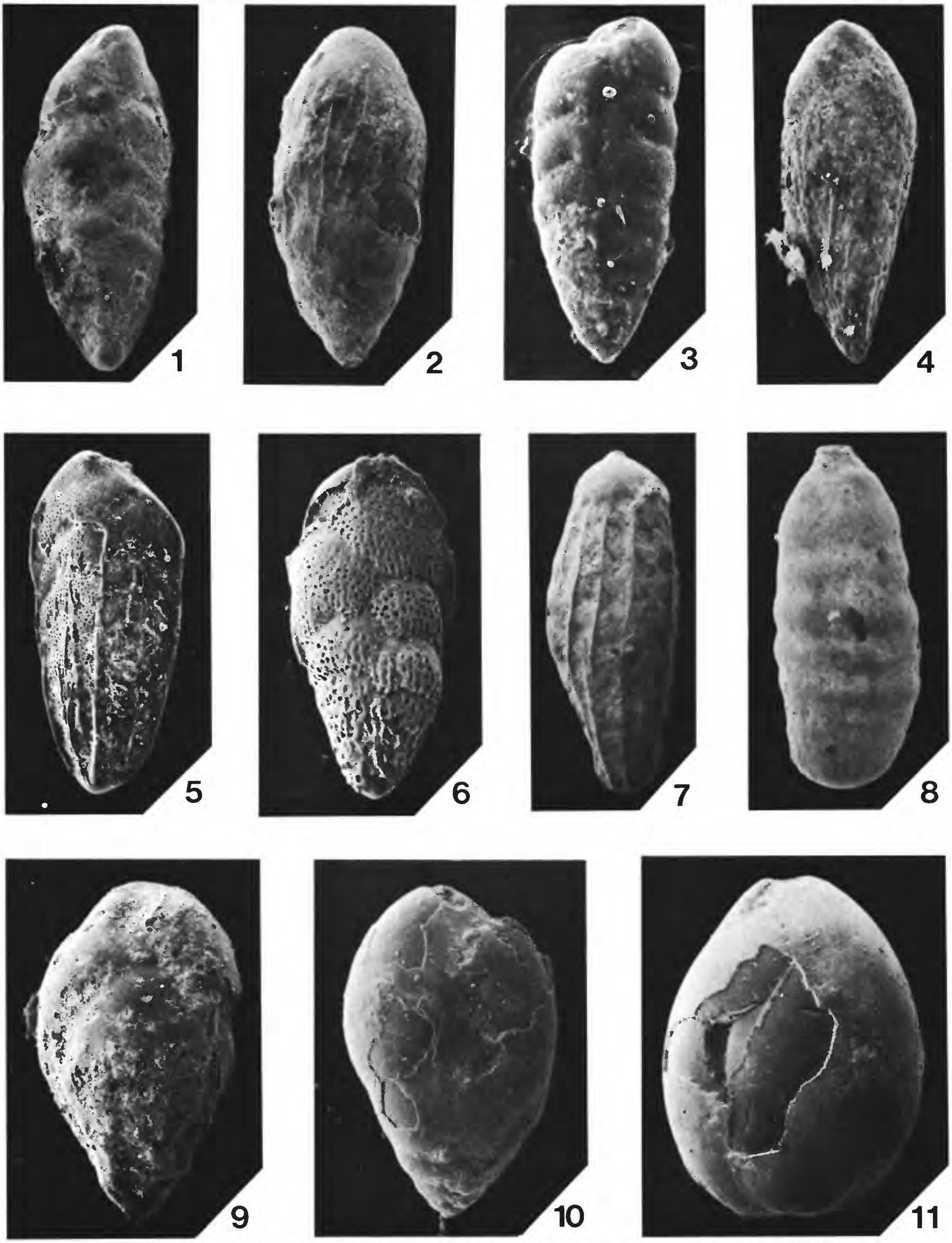


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 2

Scanning electron micrographs of foraminifers, Monterey Formation, Mussel Rock section.

Figure 1. *Bolivina churchi* Kleinpell and Tipton, side view, ×80, CRC-40398-3.
2. *Bolivina californica* Cushman, side view, ×168, CRC-40398-3.
3. *Bolivina brevior* Cushman var., side view, ×238, CRC-40398-2.
4. *Bolivina advena ornata* Cushman, side view, ×160, CRC-40398-3.
5. *Bolivina imbricata* Cushman, side view, ×130, CRC-40398-2.
6. *Bolivina modeloensis* Cushman and Kleinpell, side view, ×130, CRC-40398-2.
7. *Rectuvigerina branneri* (Cushman), side view, ×35, CRC-40398-3.
8. *Rectuvigerina hughesi* (Cushman), side view, ×60, CRC-40398-3.
9. *Bulimina subcalva* Cushman and K.C. Stewart, side view, ×130, CRC-40398-4.
10. *Protoglobobulimina pseudotorta* (Cushman), side view, ×92, CRC-40398-3.
11. *Praeglobobulimina galliheri* (Kleinpell), side view, ×63, CRC-40398-5.

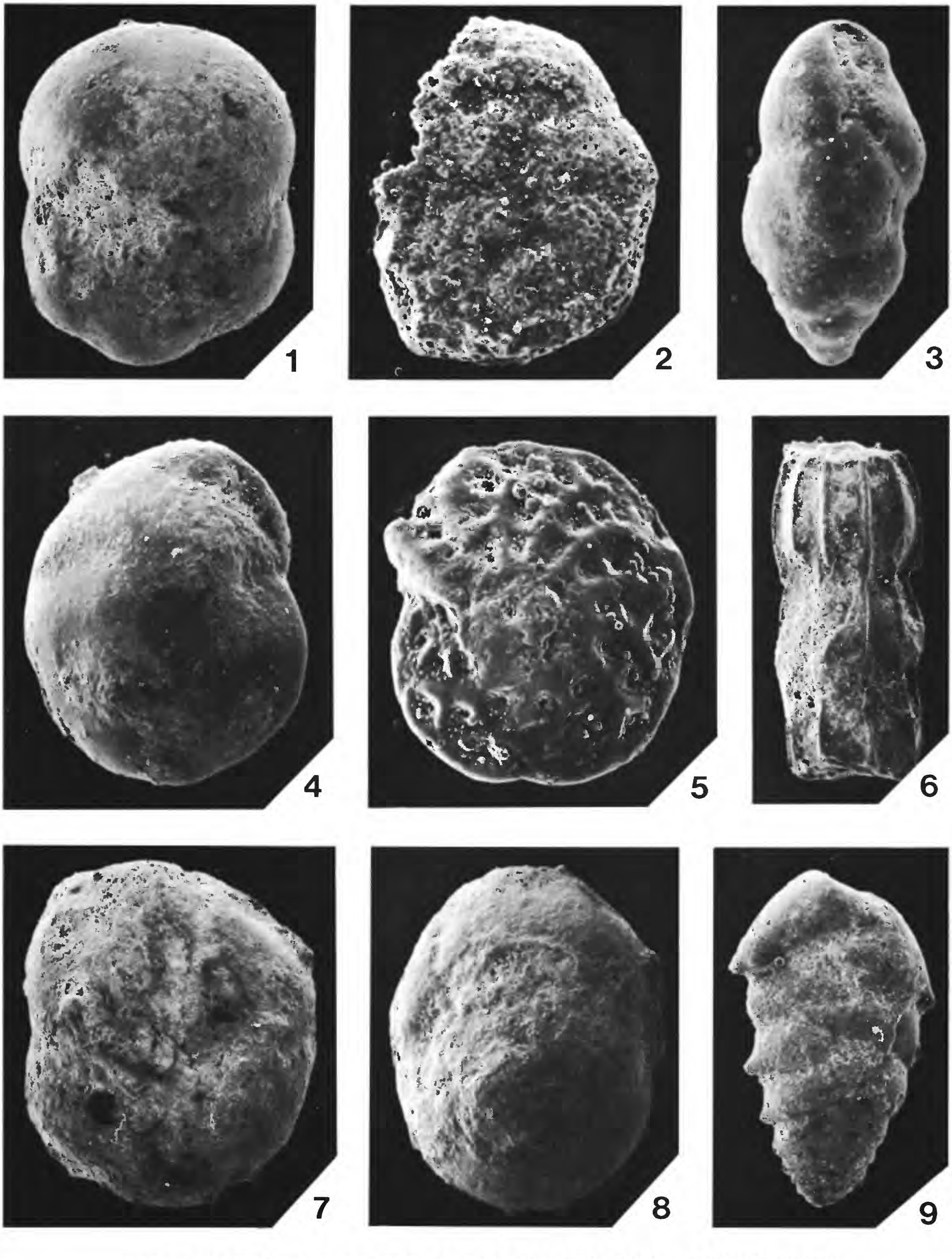


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 3

Scanning electron micrographs of foraminifers, Monterey Formation, Mussel Rock section.

Figure 1. *Baggina californica* Cushman, umbilical view, ×80, CRC-40398-3.
2. *Holmanella baggi* (Kleinpell), side view, ×184, CRC-40398-2.
3. *Buliminella subfusiformis* Cushman, side view, ×147, CRC-40398-3.
4. *Islandiella modeloensis* (Rankin), side view, ×146, CRC-40398-3.
5. *Elphidium granti* Kleinpell, side view, ×220, CRC-40398-2.
6. *Siphonodosaria quadrulata* (Cushman and Laiming), side view of segment, ×130, CRC-40398-5.
7,8. *Pullenia miocenica* Kleinpell, ×110, CRC-40398-5: 7, side view; 8, edge view.
9. *Suggrunda kleinpelli* Bramlette, side view, ×170, CRC-40398-5.

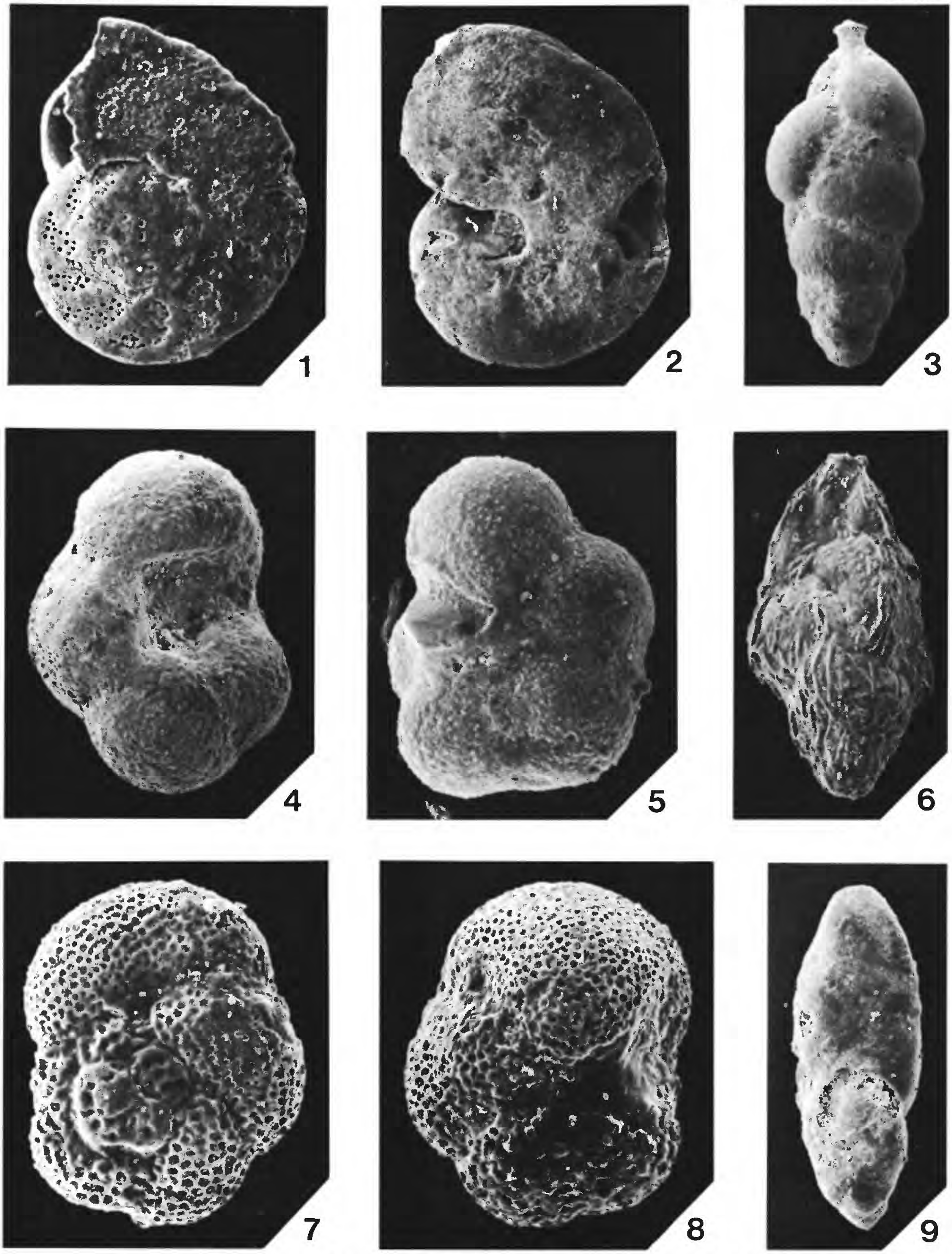


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 4

Scanning electron micrographs of foraminifers, Monterey Formation, Mussel Rock section.

Figure 1. *Cibicidoides mckannai* Galloway and Wissler, spiral view, ×190, CRC-40398-2.
2. *Hanzawaia depaoloi* Finger and Lipps, umbilical view, ×140, CRC-40398-2.
3. *Uvigerina hannai* Kleinpell, side view, ×83, CRC-40398-5.
4. *Globigerina pseudobesa* (Salvatorini), umbilical view, ×116, CRC-40398-3.
5. *Tenuitellinata angustiumbilicata* (Bolli), umbilical view, ×327, CRC-40398-3.
6. *Trifarina fluens* (Cushman and McCulloch?), side view, ×130, CRC-40398-2.
7,8. *Globorotalia praescitula* Blow, ×260, CRC-40398-2: 7, spiral view; 8, umbilical view.
9. *Kleinpella californiensis* (Cushman), side view, ×150, CRC-40398-3.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 5

Scanning electron micrographs of foraminifers, Monterey Formation, Mussel Rock section.

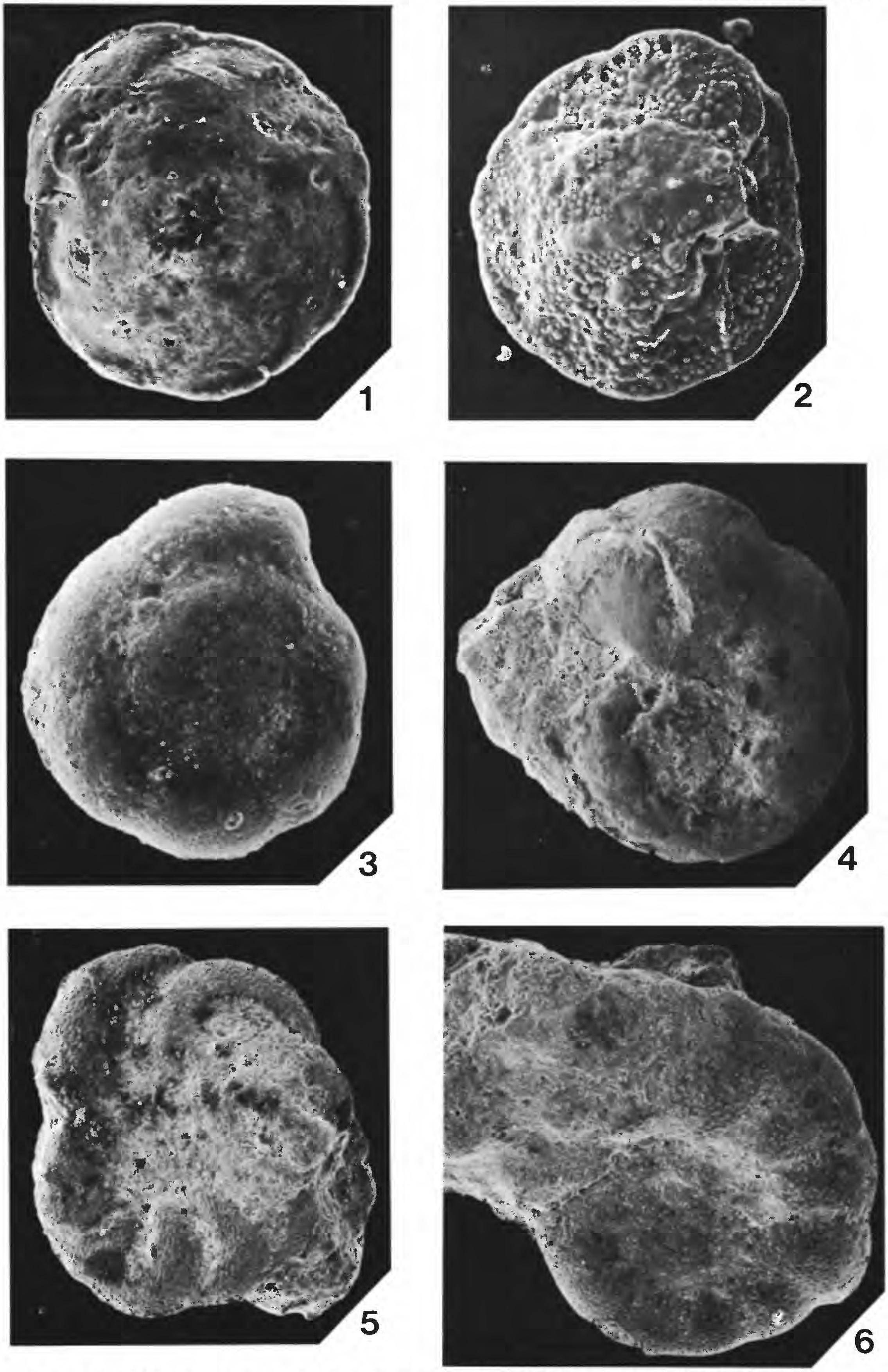
Figures 1,2. *Buccella oregonensis* (Cushman, Stewart, and Stewart), ×240, CRC-40398-2: 1, side view; 2, umbilical view.

3. *Gyroidina rosaformis* (Cushman and Kleinpell), spiral view, ×263, CRC-40398-3.

4. *Valvulineria californica* Cushman, umbilical view, ×80, CRC-40398-3.

5. *Holmanella baggi* (Kleinpell), side view, ×80, CRC-40398-3.

6. *Anomalinoides salinasensis* (Kleinpell), spiral view, ×90, CRC-40398-3.

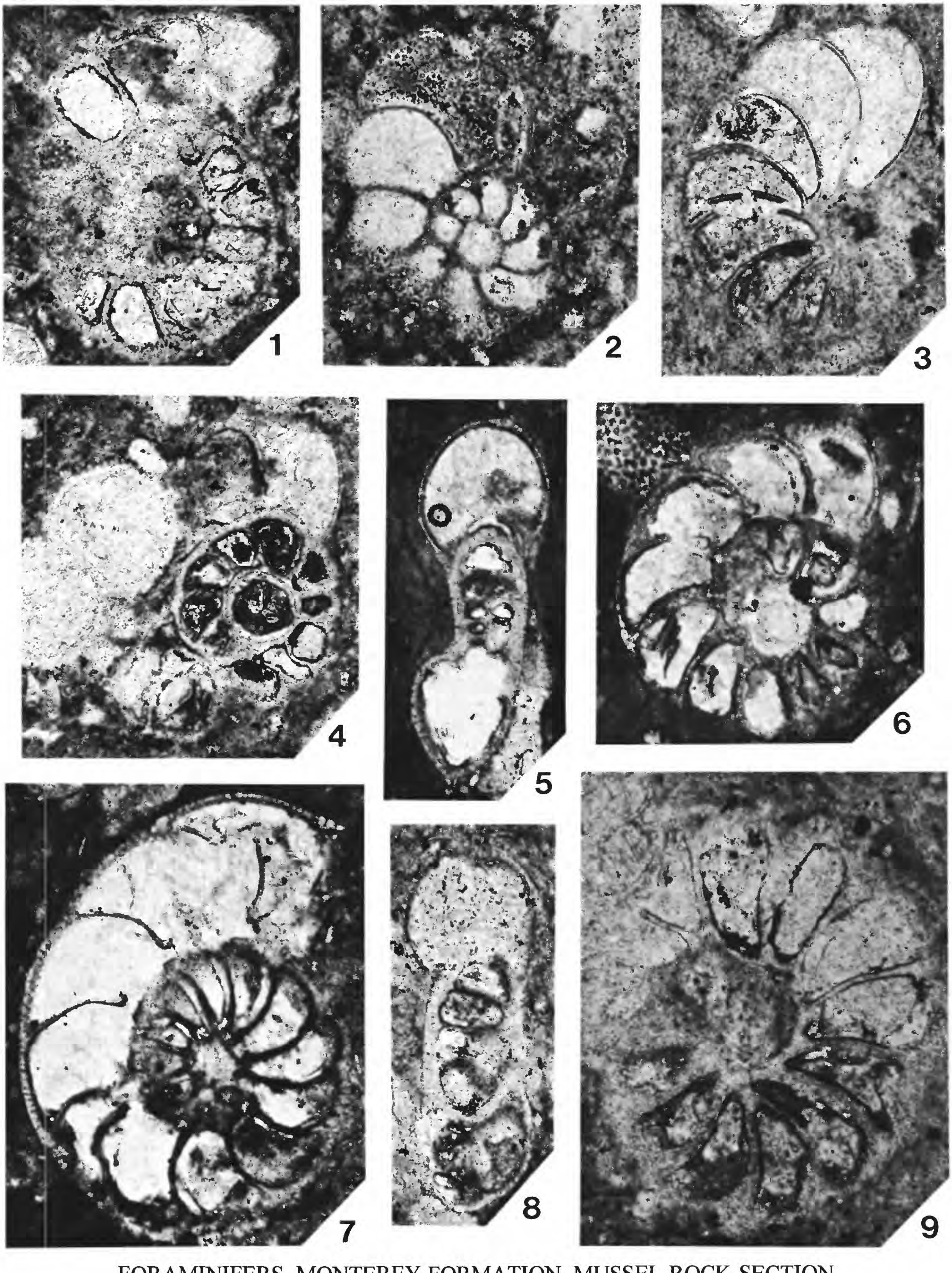


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 6

Photomicrographs of *Anomalinoides salinasensis* (Kleinpell) in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1. ×128, CRC-40398-3, slide no. 3-5, parallel to bedding.
2. ×128, CRC-40398-2, slide no. 3-2, parallel to bedding.
3. ×128, CRC-40398-4, slide no. 3-9, parallel to bedding.
4. ×128, CRC-40398-3, slide no. 3-7, parallel to bedding.
5. ×128, CRC-40398-3, slide no. 3-8, perpendicular to bedding.
6. ×200, CRC-40398-4, slide no. 3-9, parallel to bedding.
7. ×128, CRC-40398-4, slide no. 3-9, parallel to bedding.
8. ×128, CRC-40398-4, slide no. 3-9, parallel to bedding.
9. ×200, CRC-40398-3, slide no. 3-6, parallel to bedding.

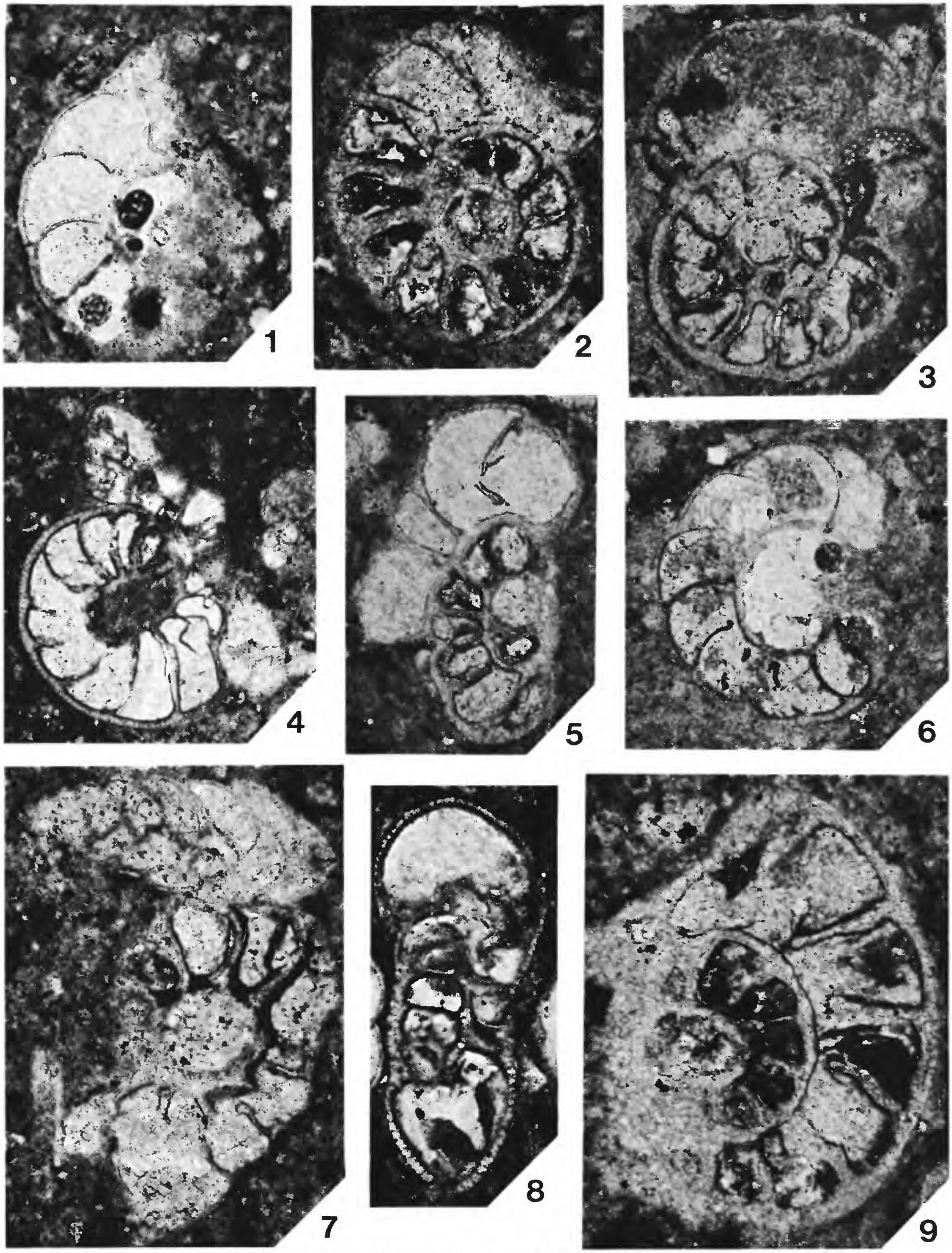


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 7

Photomicrographs of *Anomalinoides salinasensis* (Kleinpell) in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1. ×80, CRC-40398-4, slide no. 3-9, parallel to bedding.
2. ×128, CRC-40398-3, slide no. 3-7, parallel to bedding.
3. ×128, CRC-40398-3, slide no. 3-5, parallel to bedding.
4. ×80, CRC-40398-3, slide no. 3-7, parallel to bedding.
5. ×128, CRC-40398-3, slide no. 3-7, parallel to bedding.
6. ×80, CRC-40398-4, slide no. 3-9, parallel to bedding.
7. ×200, CRC-40398-3, slide no. 3-7, parallel to bedding.
8. ×128, CRC-40398-4, slide no. 3-9, parallel to bedding.
9. ×200, CRC-40398-3, slide no. 3-5, parallel to bedding.

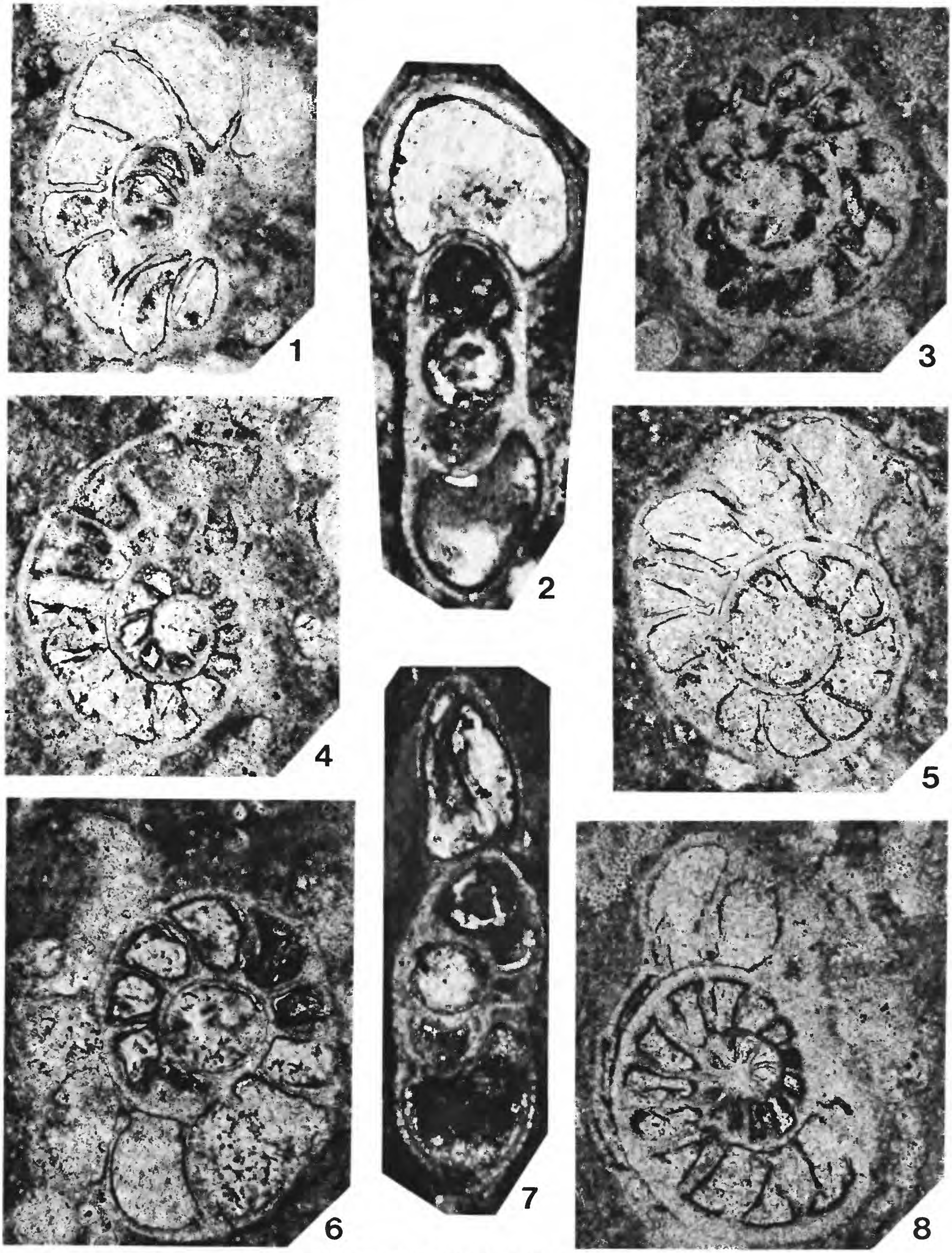


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 8

Photomicrographs of *Anomalinoides salinasensis* (Kleinpell) in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1. ×128, CRC-40398-3, slide no. 3-7, parallel to bedding.
2. ×200, CRC-40398-3(3V), perpendicular to bedding.
3. ×128, CRC-40398-3, slide no. 3-5, parallel to bedding.
4. ×128, CRC-40398-3, slide no. 3-5, parallel to bedding.
5. ×128, CRC-40398-3, slide no. 3-5, parallel to bedding.
6. ×128, CRC-40398-3, slide no. 3-7, parallel to bedding.
7. ×200, CRC-40398-3(3V), perpendicular to bedding.
8. ×128, CRC-40398-3, slide no. 3-7, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 9

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1. *Anomalinoides salinasensis* (Kleinpell), ×80, CRC-40398-4, slide no. 3-9, parallel to bedding.

2. *Anomalinoides salinasensis* (Kleinpell), ×80, CRC-40398-4, slide no. 3-9, parallel to bedding.

3. *Anomalinoides salinasensis* (Kleinpell), ×200, CRC-40398-3, slide no. 3-7, parallel to bedding.

4. *Anomalinoides salinasensis* (Kleinpell), ×128, CRC-40398-3, slide no. 3-6, parallel to bedding.

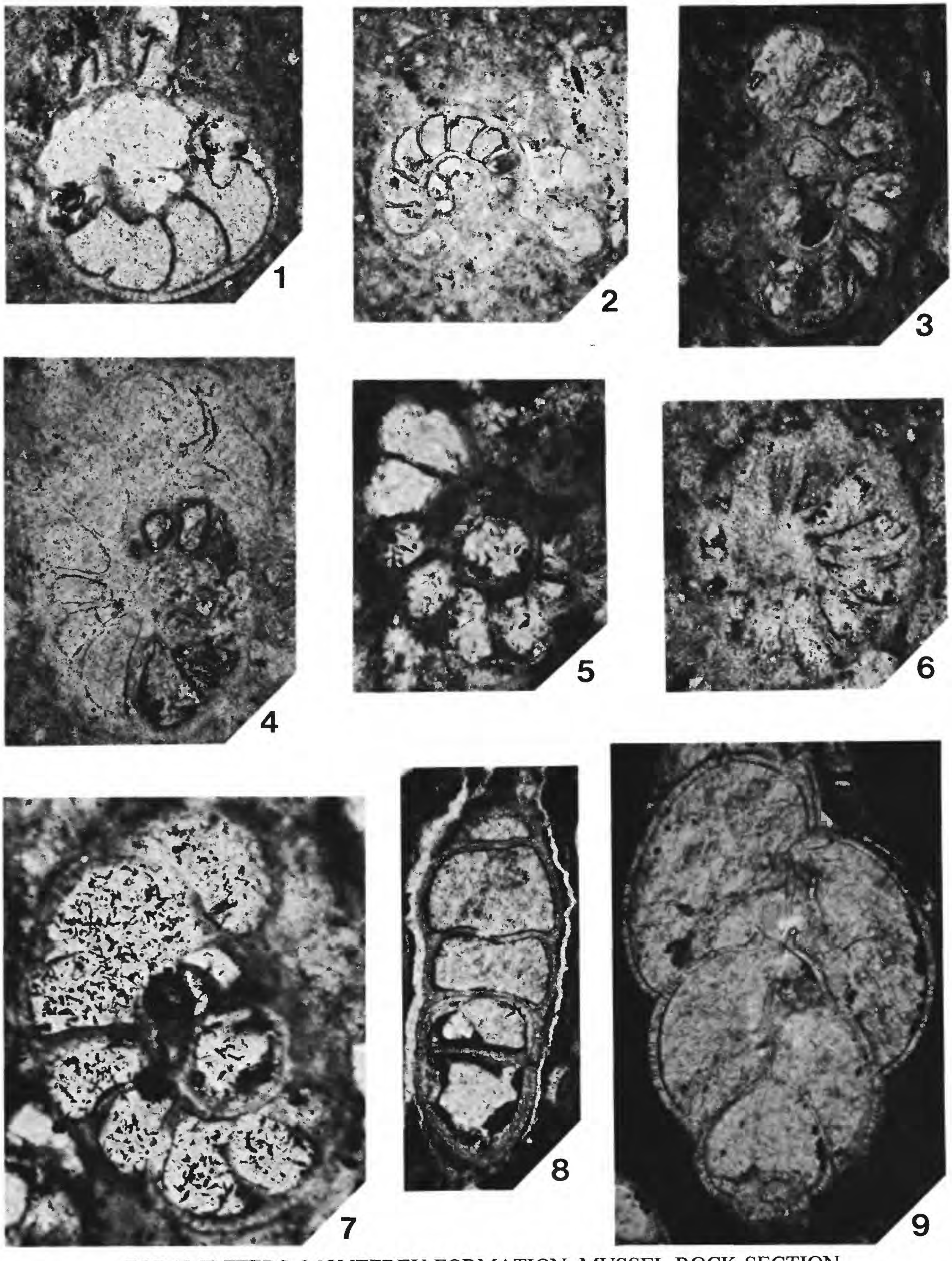
5. *Anomalinoides salinasensis* (Kleinpell), ×200, CRC-40398-3(3H), parallel to bedding.

6. *Anomalinoides salinasensis* (Kleinpell), ×128, CRC-40398-3, slide no. 3-5, parallel to bedding.

7. *Anomalinoides salinasensis* (Kleinpell), ×200, CRC-40398-3(3H), parallel to bedding.

8. *Anomalinoides salinasensis* (Kleinpell), ×128, CRC-40398-3, slide no. 3-8, perpendicular to bedding.

9. *Uvigerina hannai* Kleinpell, ×200, CRC-40398-5, slide no. 3-16, perpendicular to bedding.

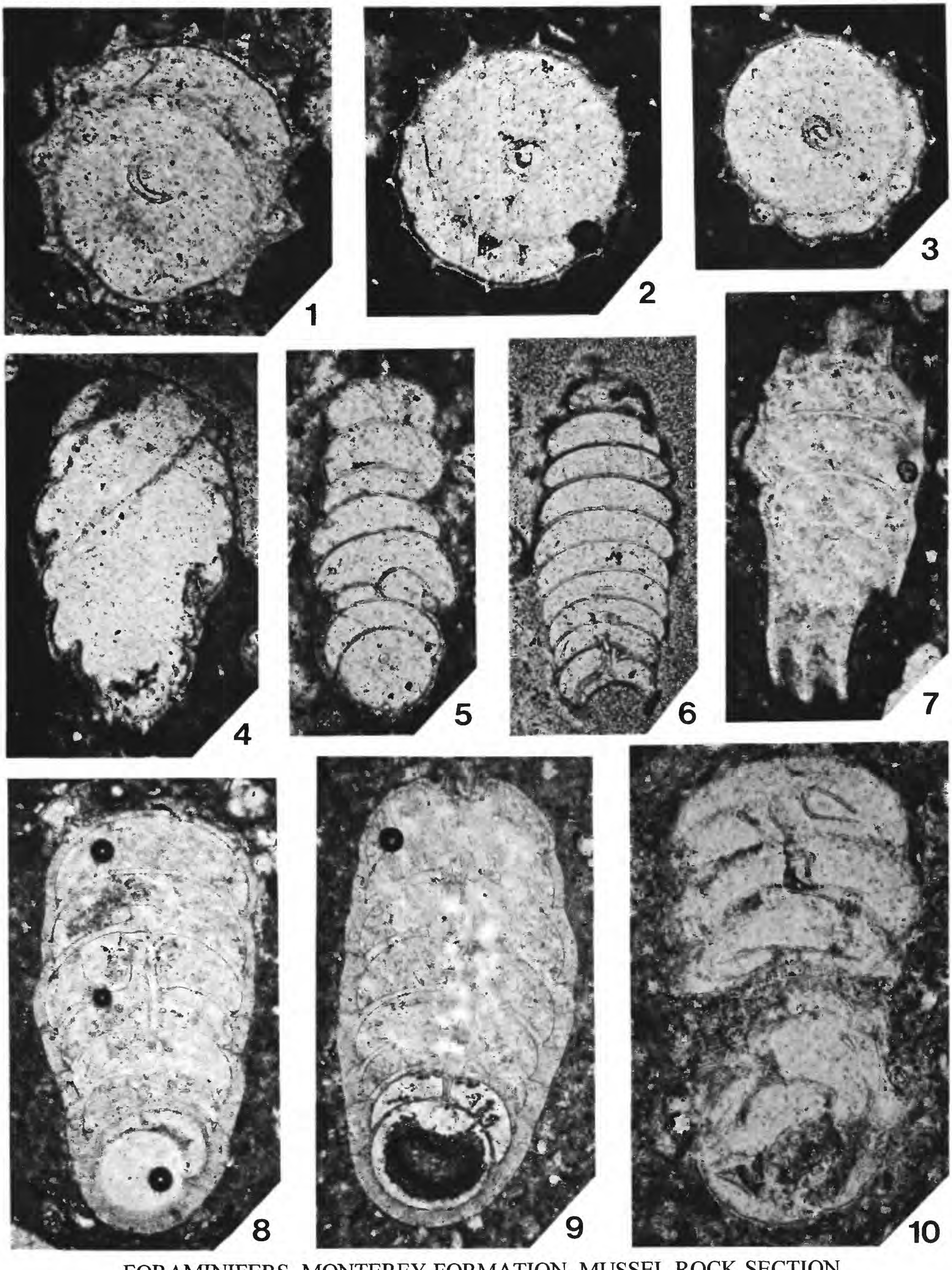


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 10

Photomicrographs of *Rectuvigerina branneri* (Bagg) in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1. ×128, CRC-40398-3(3V), perpendicular to bedding.
2. ×80, CRC-40398-3(3V), perpendicular to bedding.
3. ×80, CRC-40398-3(3V), perpendicular to bedding.
4. ×80, CRC-40398-3(3H), parallel to bedding.
5. ×80, CRC-40398-3(3H), parallel to bedding.
6. ×50, CRC-40398-3(3H), parallel to bedding.
7. ×80, CRC-40398-3, slide no. 3-7, parallel to bedding.
8. ×80, CRC-40398-4, slide no. 3-9, parallel to bedding.
9. ×80, CRC-40398-4, slide no. 3-9, parallel to bedding.
10. ×128, CRC-40398-3, slide no. 3-2, parallel to bedding.

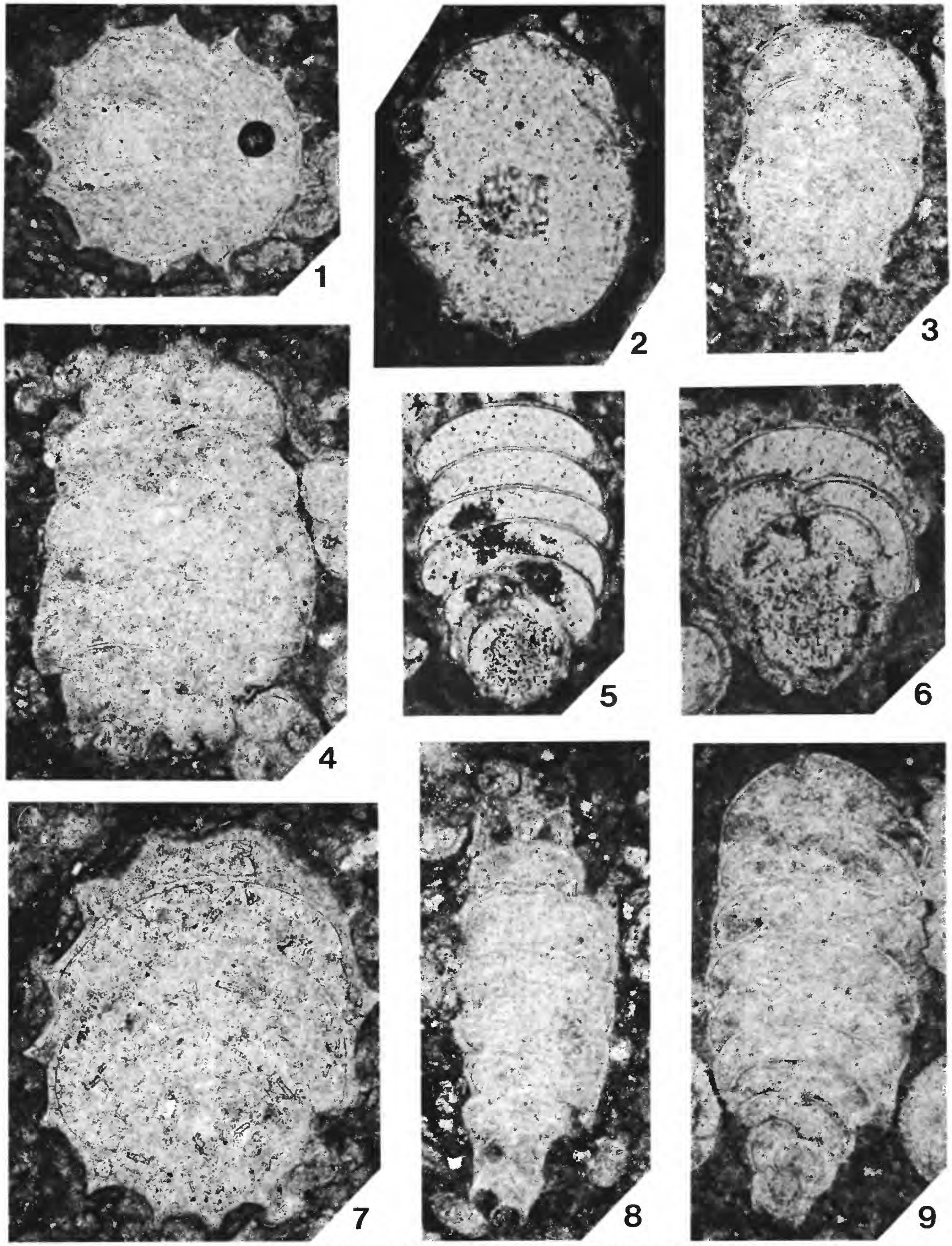


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 11

Photomicrographs of *Rectuvigerina branneri* (Bagg) in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1. ×80, CRC-40398-3, slide no. 3-8, perpendicular to bedding.
2. ×200, CRC-40398-3(3V), perpendicular to bedding.
3. ×80, CRC-40398-3, slide no. 3-5, parallel to bedding.
4. ×80, CRC-40398-3, slide no. 3-5, parallel to bedding.
5. ×80, CRC-40398-3(3H), parallel to bedding.
6. ×128, CRC-40398-3(3H), parallel to bedding.
7. ×128, CRC-40398-3, slide no. 3-8, perpendicular to bedding.
8. ×80, CRC-40398-3, slide no. 3-5, parallel to bedding.
9. ×80, CRC-40398-3, slide no. 3-5, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 12

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figures 1,2. *Gyroidina rosaformis* (Cushman and Kleinpell), ×128, CRC-40398-4, slide no. 3-9, parallel to bedding, and ×320, CRC-40398-3, slide no. 3-7, parallel to bedding, respectively.

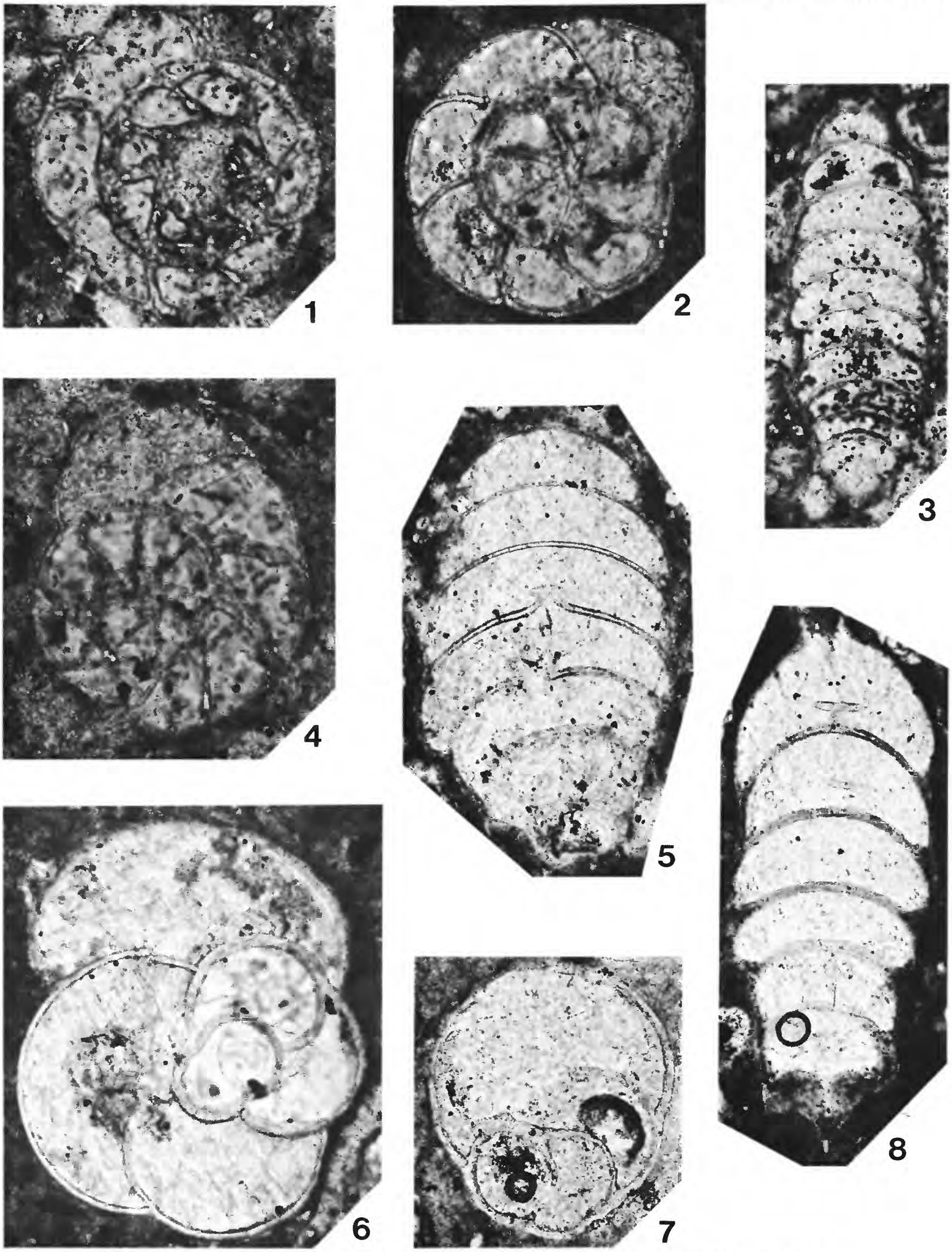
3. *Rectuvigerina branneri* (Bagg), ×50, CRC-40398-3(3H), parallel to bedding.

4. *Pseudoparrella subperuviana* (Cushman): ×320, CRC-40398-3, slide no. 3-5, parallel to bedding.

5. *Rectuvigerina branneri* (Bagg), ×80, CRC-40398-3(3H), parallel to bedding.

6,7. *Baggina californica* Cushman, ×200, CRC-40398-4, slide no. 3-9, parallel to bedding, and ×128, CRC-40398-4, slide no. 3-9, parallel to bedding, respectively.

8. *Rectuvigerina branneri* (Bagg), ×80.4, CRC-40398-3(3H), parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 13

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

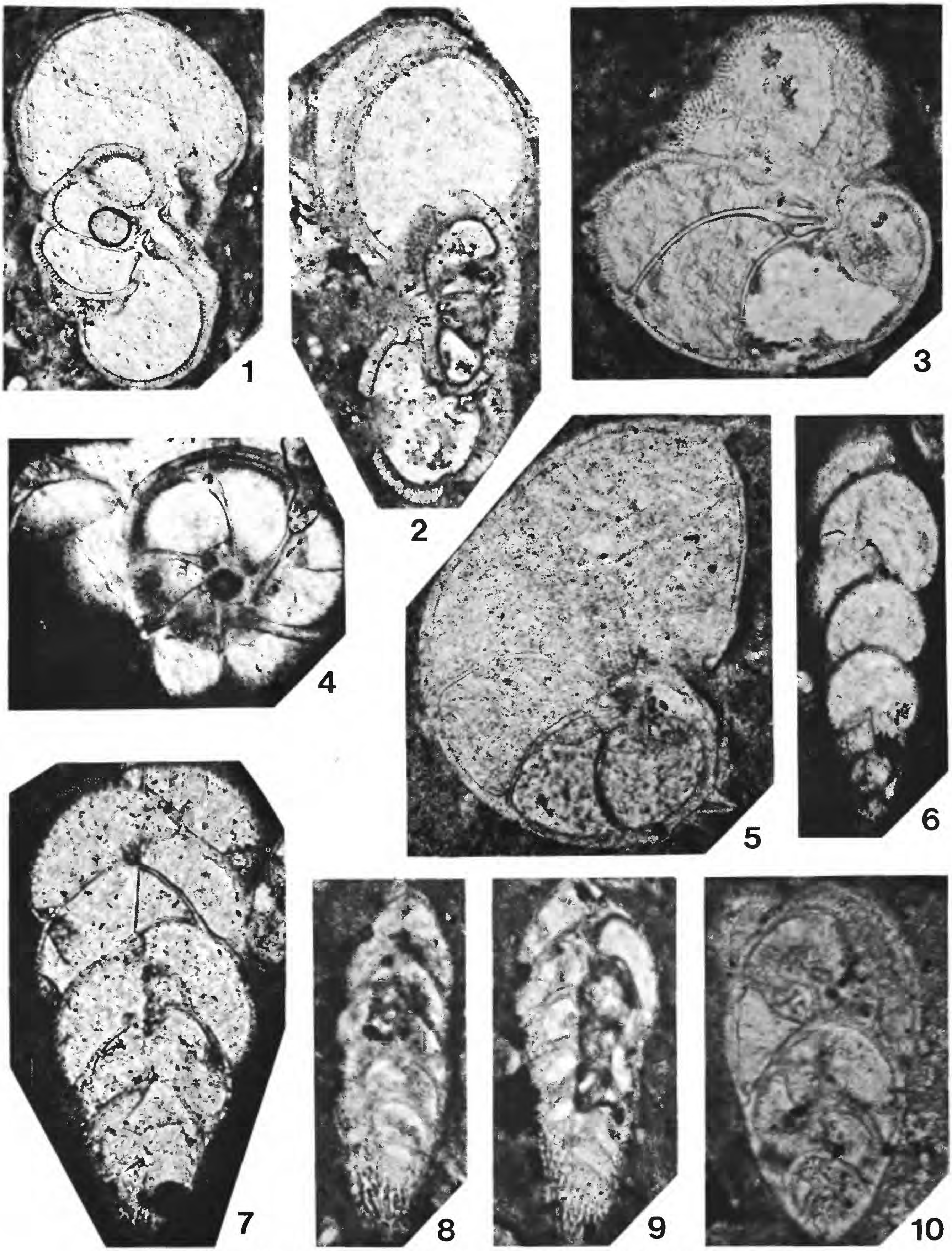
Figure 1. *Valvulineria californica* Cushman, ×80, CRC-40398-3(3V), perpendicular to bedding.

2. *Anomalinoides salinasensis* (Kleinpell), ×128, CRC-40398-4, slide no. 3-9, parallel to bedding.

3-5. *Valvulineria robusta* (Kleinpell): **3**, ×128, CRC-40398-4, slide no. 3-9, parallel to bedding; **4**, ×80, CRC-40398-4(3-10; **5**, ×200, CRC-40398-4, slide no. 3-9, parallel to bedding.

6-9. *Bolivina advena ornata* Cushman: **6**, ×128, CRC-40398-5, slide no. 3-16, perpendicular to bedding; **7**, ×200, CRC-40398-3(3H), parallel to bedding; **8**, ×200, CRC-40398-4, slide no. 3-9, parallel to bedding; **9**, ×200, CRC-40398-4, slide no. 3-9, parallel to bedding.

10. *Buliminella subfusiformis* Cushman, ×320, CRC-40398-4, slide no. 3-9, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 14

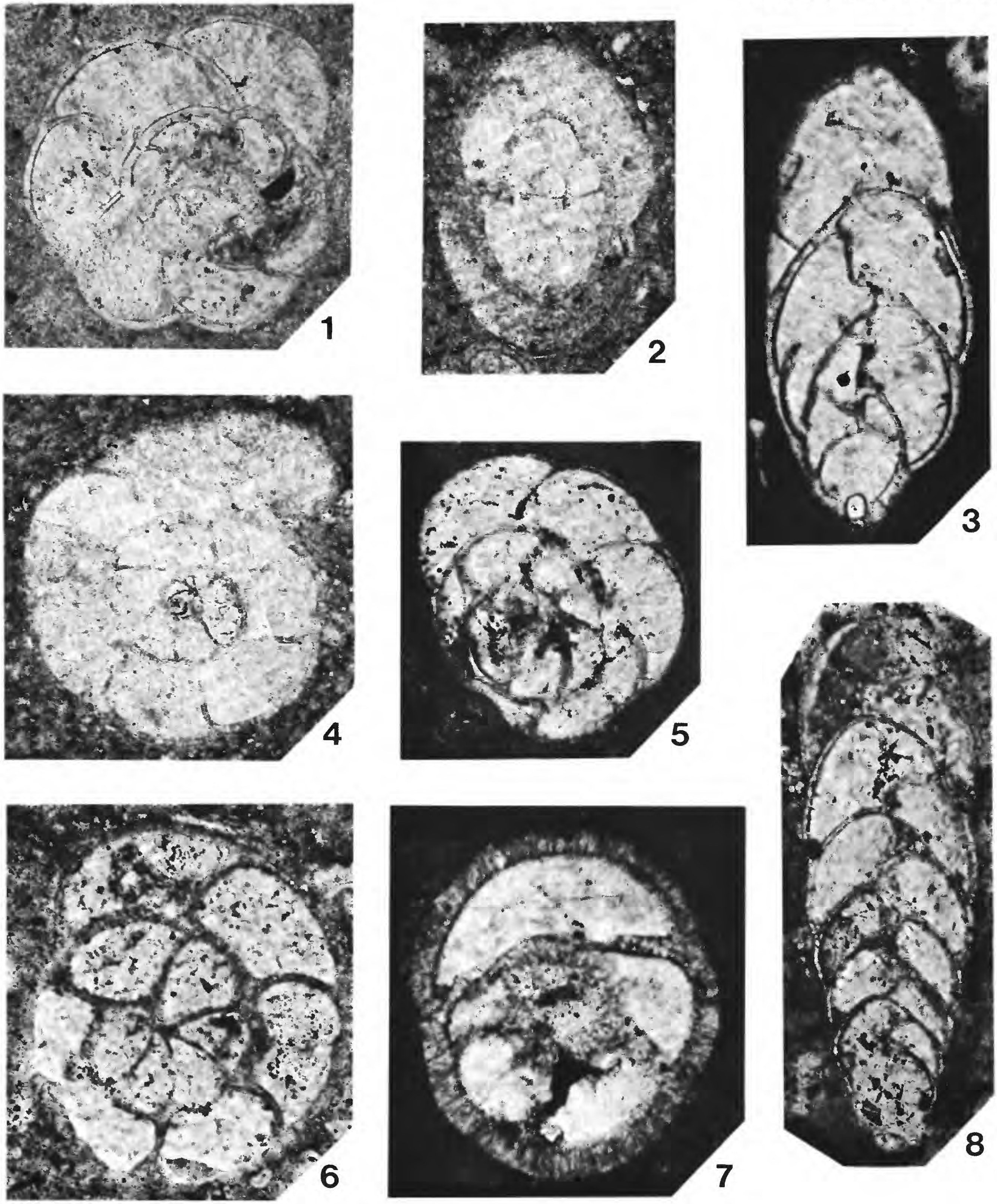
Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figures 1,2. *Pullenia miocenica* Kleinpell, ×200, CRC-40398-5, slide no. 3-14, parallel to bedding, and ×80, CRC-40398-4, slide no. 3-9, parallel to bedding, respectively.

3. *Buliminella subfusiformis* Cushman, ×200, CRC-40398-5, slide no. 3-16, perpendicular to bedding.

4-7. *Pullenia miocenica* Kleinpell: **4**, ×200, CRC-40398-4, slide no. 3-9, parallel to bedding; **5**, ×200, CRC-40398-3(3V), perpendicular to bedding; **6**, ×200, CRC-40398-4, slide no. 3-9, parallel to bedding; **7**, ×320, CRC-40398-4, slide no. 3-10, parallel to bedding.

8. *Bolivina imbricata* Cushman, ×200, CRC-40398-3(3H), parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 15

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1. *Islandiella modeloensis* (Rankin), ×128, CRC-40398-4, slide no. 3-9, parallel to bedding.

2. *Gyroidina rosaformis* (Cushman and Kleinpell), ×320, CRC-40398-4, slide no. 3-10, parallel to bedding.

3,4. *Islandiella modeloensis* (Rankin), ×128, CRC-40398-5, slide no. 3-16, perpendicular to bedding, and ×200, CRC-40398-3(3V), perpendicular to bedding, respectively.

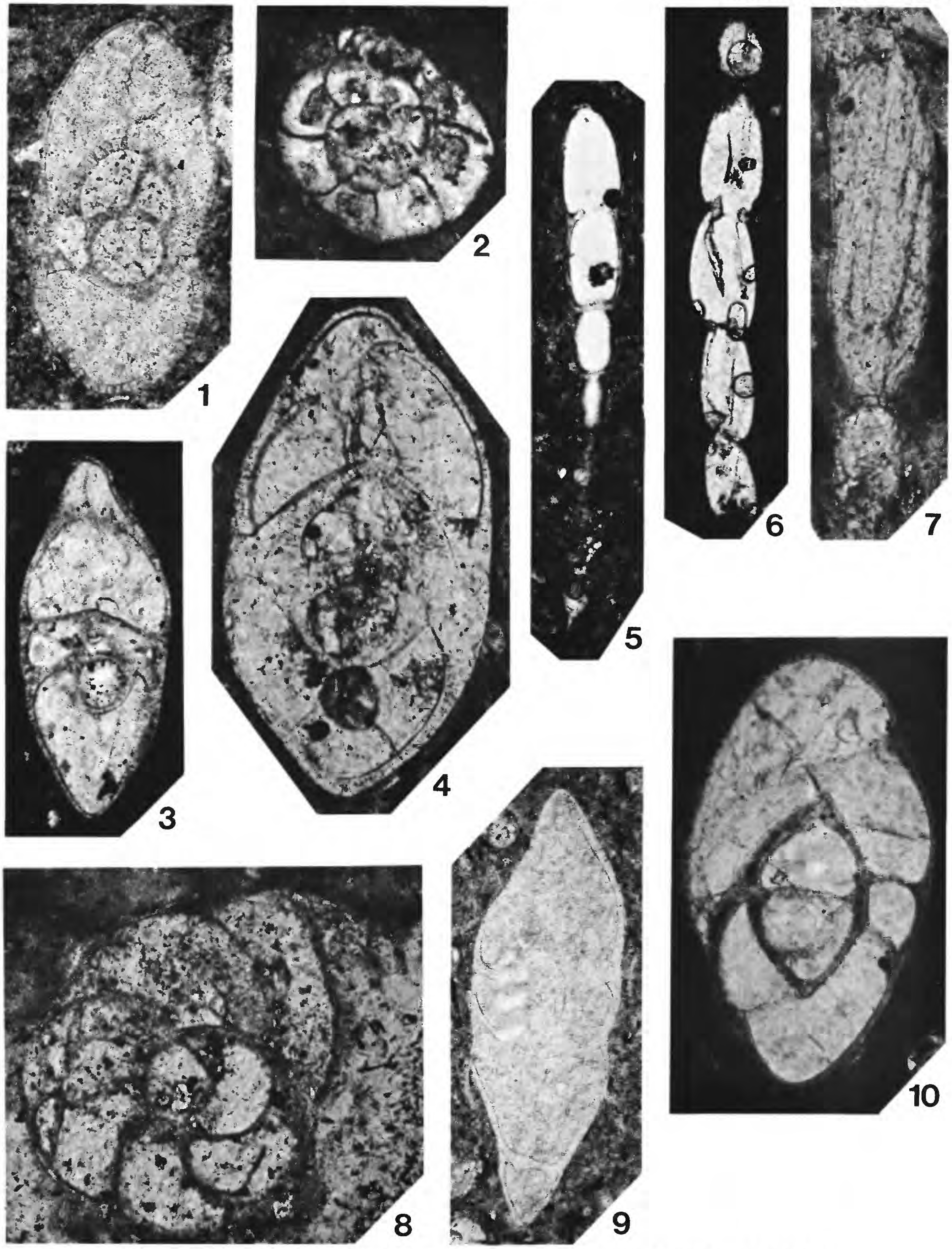
5,6. *Siphonodosaria montereyana* Finger and Lipps, ×50, CRC-40398-4, slide no. 3-10, parallel to bedding, and ×50, CRC-40398-4, slide no. 3-10, parallel to bedding, respectively.

7. *Nodosaria ewaldi* Reuss, late segment, ×200, CRC-40398-3(3H), parallel to bedding.

8. *Pseudoparrella subperuviana* (Cushman), ×200, CRC-40398-3(3H), parallel to bedding.

9. *Islandiella modeloensis* (Rankin), ×80, CRC-40398-4, slide no. 3-9, parallel to bedding.

10. *Islandiella modeloensis* (Rankin), ×128, CRC-40398-5, slide no. 3-16, perpendicular to bedding.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 16

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1. *Pseudoparrella subperuviana* (Cushman), ×128, CRC-40398-3(3H), parallel to bedding.

2,3. *Gyroidina rosaformis* (Cushman and Kleinpell), ×200, CRC-40398-3(3V), perpendicular to bedding, and ×128, CRC-40398-3(3H), parallel to bedding, respectively.

4. *Siphonodosaria advena* (Cushman and Laiming), ×128, CRC-40398-5, slide no. 3-16, perpendicular to bedding.

5. *Nodogenerina sagrinensis* (Bagg), ×128, CRC-40398-3, slide no. 3-5, parallel to bedding.

6. *Nodosaria ewaldi* Reuss, ×50, CRC-40398-4, slide no. 3-10, parallel to bedding.

7. *Siphonodosaria montereyana* Finger and Lipps, ×32, CRC-40398-4, slide no. 3-10, parallel to bedding.

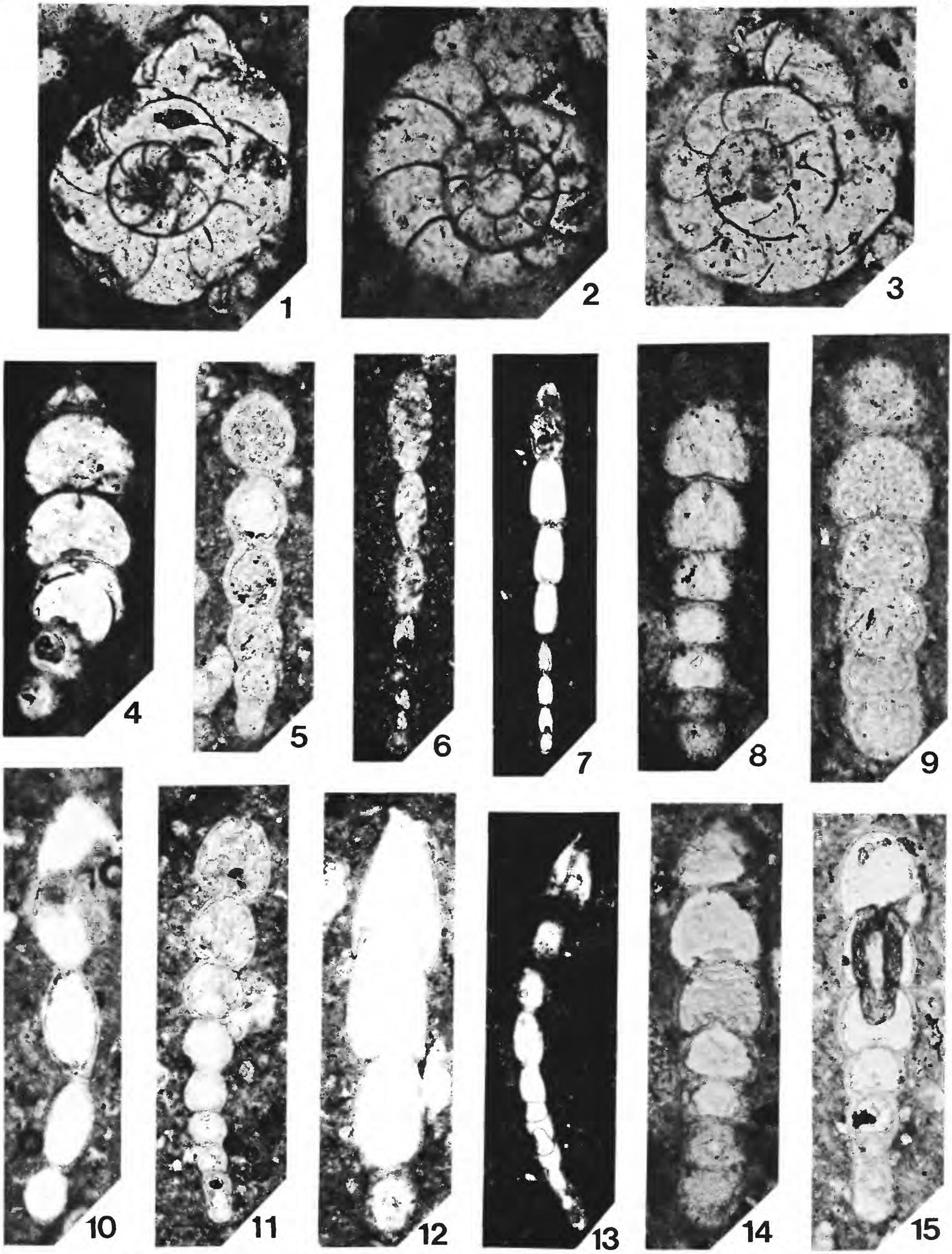
8,9. *Nodogenerina sagrinensis* (Bagg), ×200, CRC-40398-4, slide no. 3-10, parallel to bedding, and ×128, CRC-40398-3, slide no. 3-7, parallel to bedding, respectively.

10. *Nodosaria ewaldi* Reuss, ×80, CRC-40398-3, slide no. 3-9, parallel to bedding.

11. *Nodogenerina sagrinensis* (Bagg), ×50, CRC-40398-4, slide no. 3-9, parallel to bedding.

12,13. *Siphonodosaria montereyana* Finger and Lipps, ×50, CRC-40398-3, slide no. 3-9, parallel to bedding, and ×32, CRC-40398-4, slide no. 3-10, parallel to bedding, respectively.

14,15. *Nodogenerina sagrinensis* (Bagg), ×128, CRC-40398-4, slide no. 3-9, parallel to bedding, and ×80, CRC-40398-4, slide no. 3-9, parallel to bedding, respectively.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 17

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figure 1-4. *Protoglobobulimina pseudotorta* (Cushman): **1**, ×128, CRC-40398-3(3H), parallel to bedding; **2**, ×80, CRC-40398-3(3H), parallel to bedding; **3**, ×128, CRC-40398-3(3H), parallel to bedding; **4**, ×128, CRC-40398-3(3H), parallel to bedding.

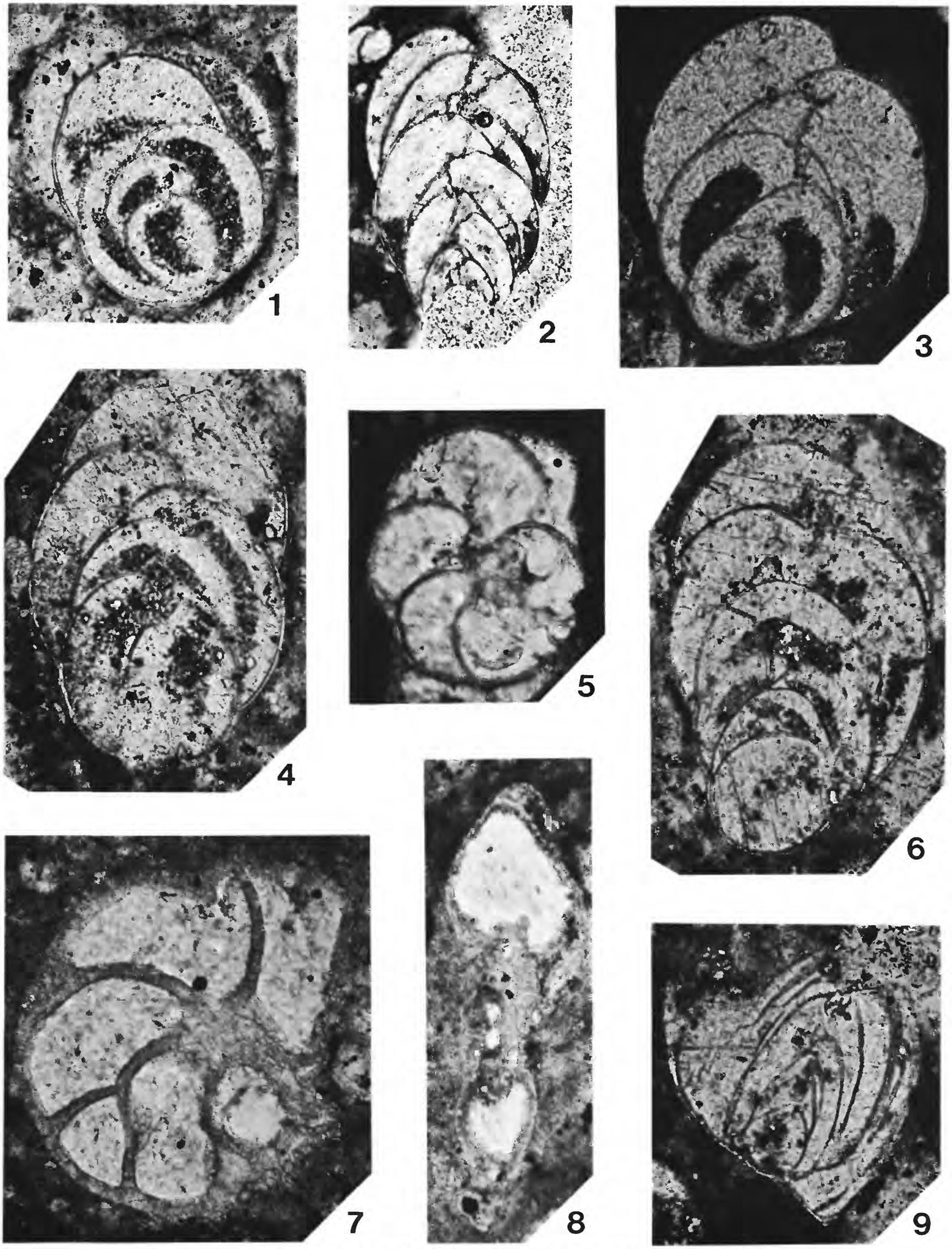
5. *Islandiella modeloensis* (Rankin), ×200, CRC-40398-5, slide no. 3-16, perpendicular to bedding.

6. *Protoglobobulimina pseudotorta* (Cushman), ×128, CRC-40398-3(3H), parallel to bedding.

7. *Islandiella modeloensis* (Rankin), ×200, CRC-40398-4, slide no. 3-9, parallel to bedding.

8. *Anomalinoides salinasensis* (Kleinpell), ×200, CRC-40398-4, slide no. 3-9, parallel to bedding.

9. *Proxifrons vaughani* (Cushman), ×128, CRC-40398-3(3H), parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

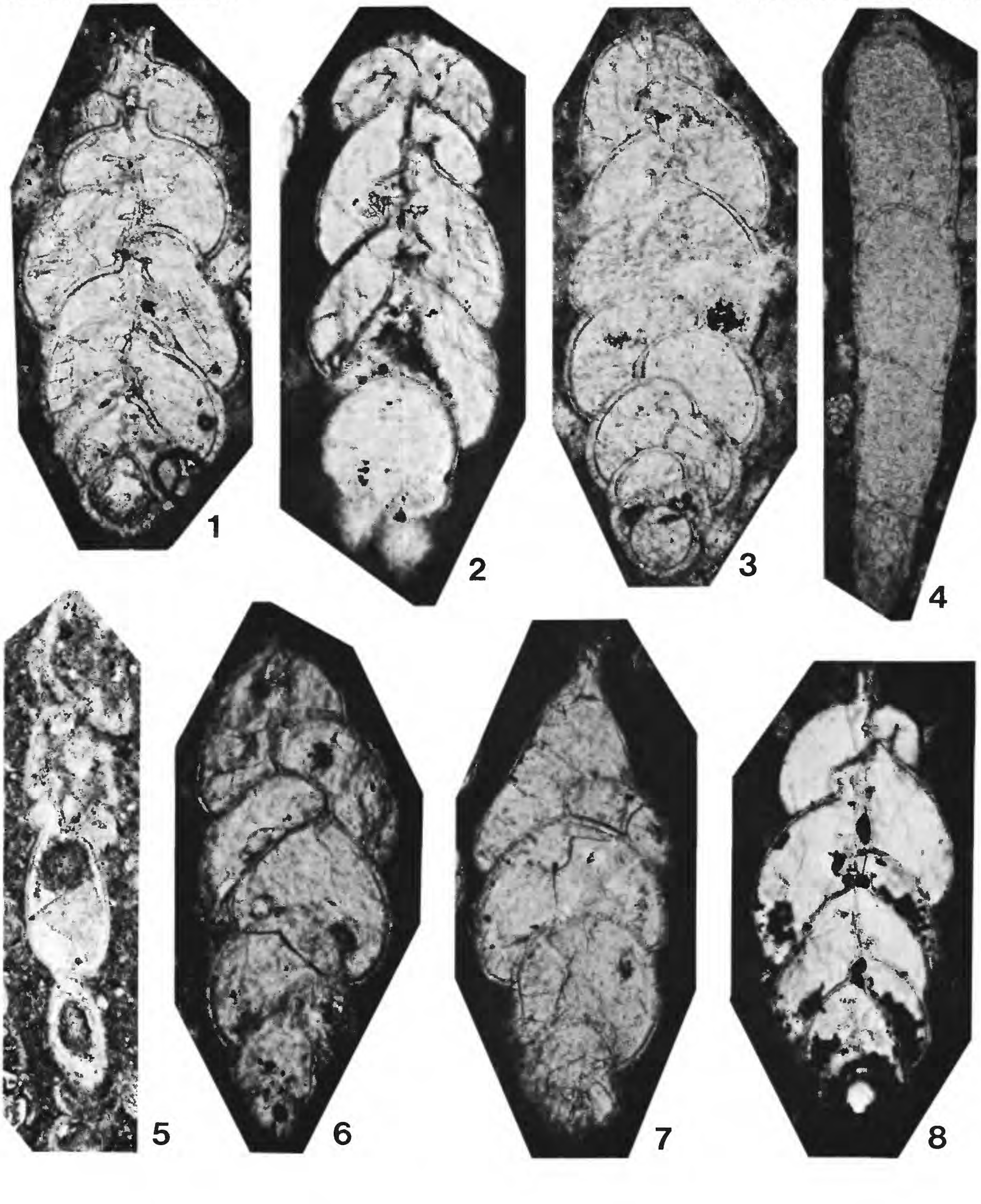
PLATE 18

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figures 1-3. *Uvigerina hannai* Kleinpell: **1,** ×200, CRC-40398-5, slide no. 3-14, parallel to bedding; **2,** ×200, CRC-40398-5, slide no. 3-14, parallel to bedding; **3,** ×200, CRC-40398-5, slide no. 3-14, parallel to bedding.

4,5. *Siphonodosaria montereyana* Finger and Lipps, ×80, CRC-40398-3, slide no. 3-7, parallel to bedding, and ×50, CRC-40398-4, slide no. 3-9, parallel to bedding, respectively.

6-8. *Uvigerina hannai* Kleinpell: **6,** ×200, CRC-40398-5, slide no. 3-14, parallel to bedding; 7, ×128, CRC-40398-5, slide no. 3-16, perpendicular to bedding; **8,** ×200, CRC-40398-5, slide no. 3-14, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 19

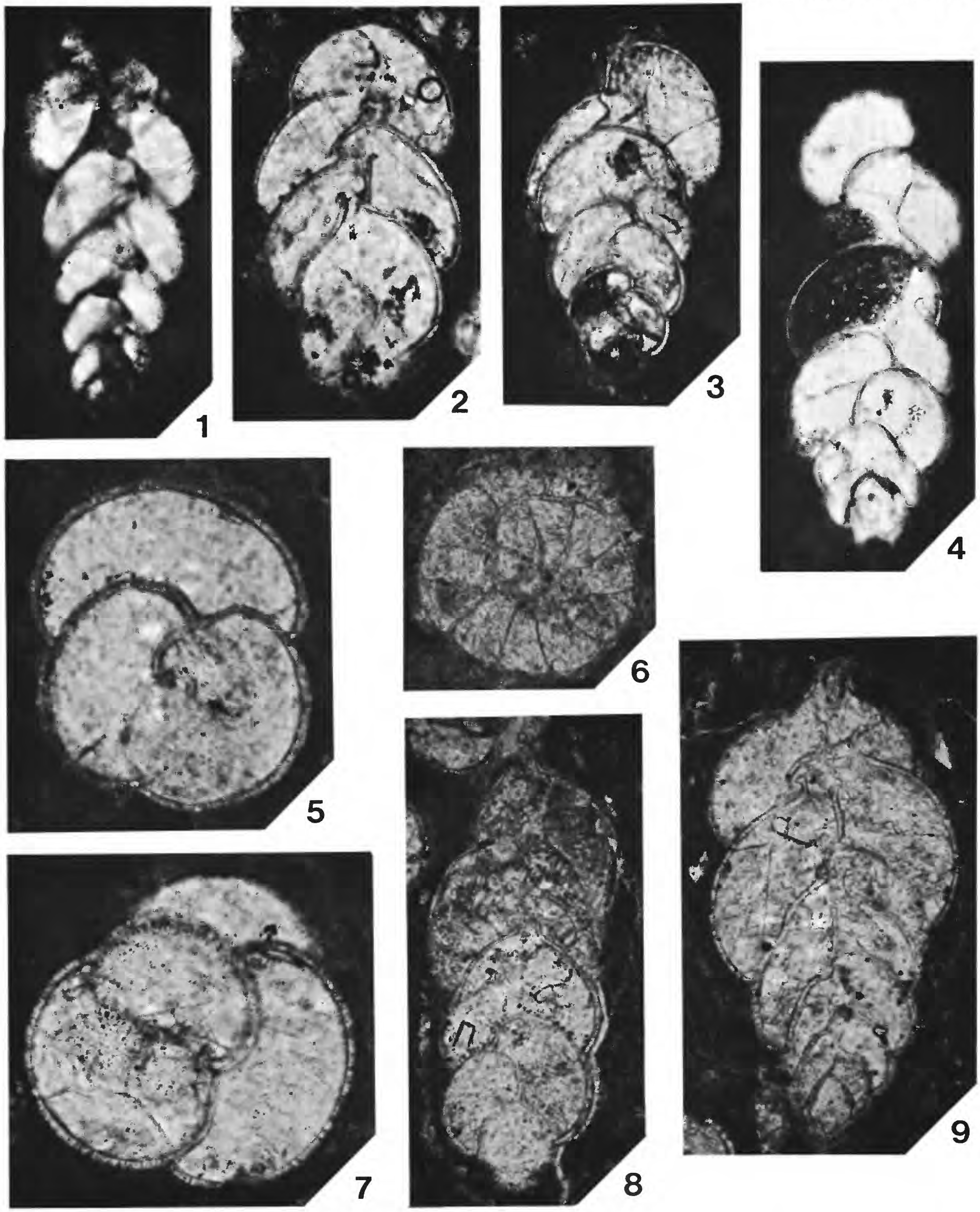
Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Mussel Rock section.

Figures 1-5. *Uvigerina hannai* Kleinpell: **1**, ×200, CRC-40398-5, slide no. 3-14, parallel to bedding; **2**, ×200, CRC-40398-5, slide no. 3-14, parallel to bedding; **3**, ×200, CRC-40398-5, slide no. 3-14, parallel to bedding; **4**, ×200, CRC-40398-5, slide no. 3-14, parallel to bedding; **5**, ×200, CRC-40398-5, slide no. 3-16, perpendicular to bedding.

6. *Pseudoparrella subperuviana* (Cushman), ×200, CRC-40398-3, slide no. 3-7, parallel to bedding.

7. *Trifarina fluens* (Todd), ×200, CRC-40398-5, slide no. 3-16, perpendicular to bedding.

8,9. *Uvigerina hannai* Kleinpell, ×128, CRC-40398-5, slide no. 3-16, perpendicular to bedding, and ×200, CRC-40398-5, slide no. 3-16, perpendicular to bedding, respectively.

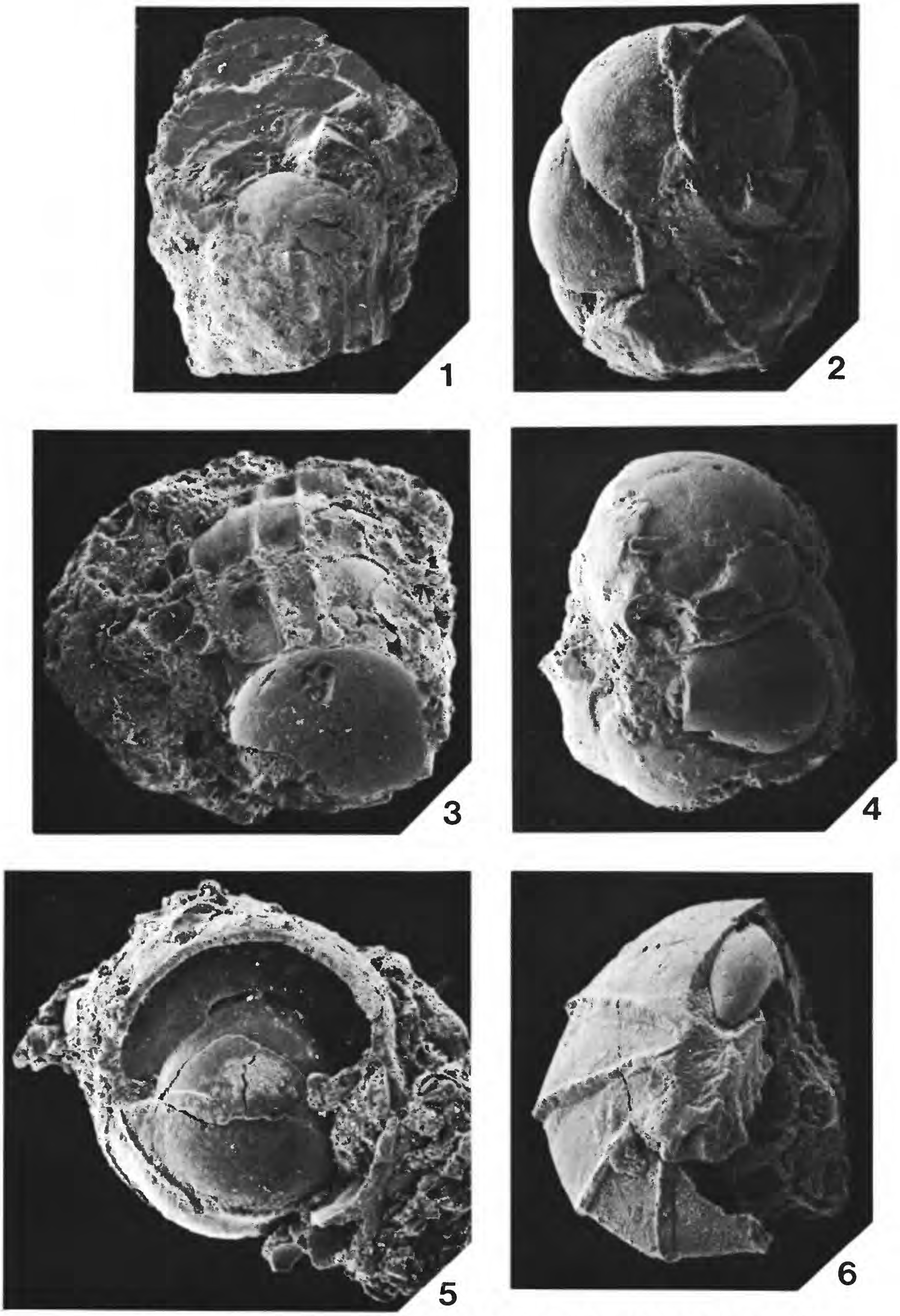


FORAMINIFERS, MONTEREY FORMATION, MUSSEL ROCK SECTION

PLATE 20

Scanning electron micrographs of foraminifers from phosphatic member (CRC-40471-6), Monterey Formation, Lions Head section.

Figure 1. *Rectuvigerina branneri* (Bagg), ×90.
2. *Valvulineria californica* Cushman, ×130.
3. *Rectuvigerina branneri* (Bagg), ×100.
4. *Baggina californica* Cushman, ×120.
5. *Pullenia miocenica* Kleinpell, ×160.
6. *Lenticulina smileyi* (Kleinpell), ×150.

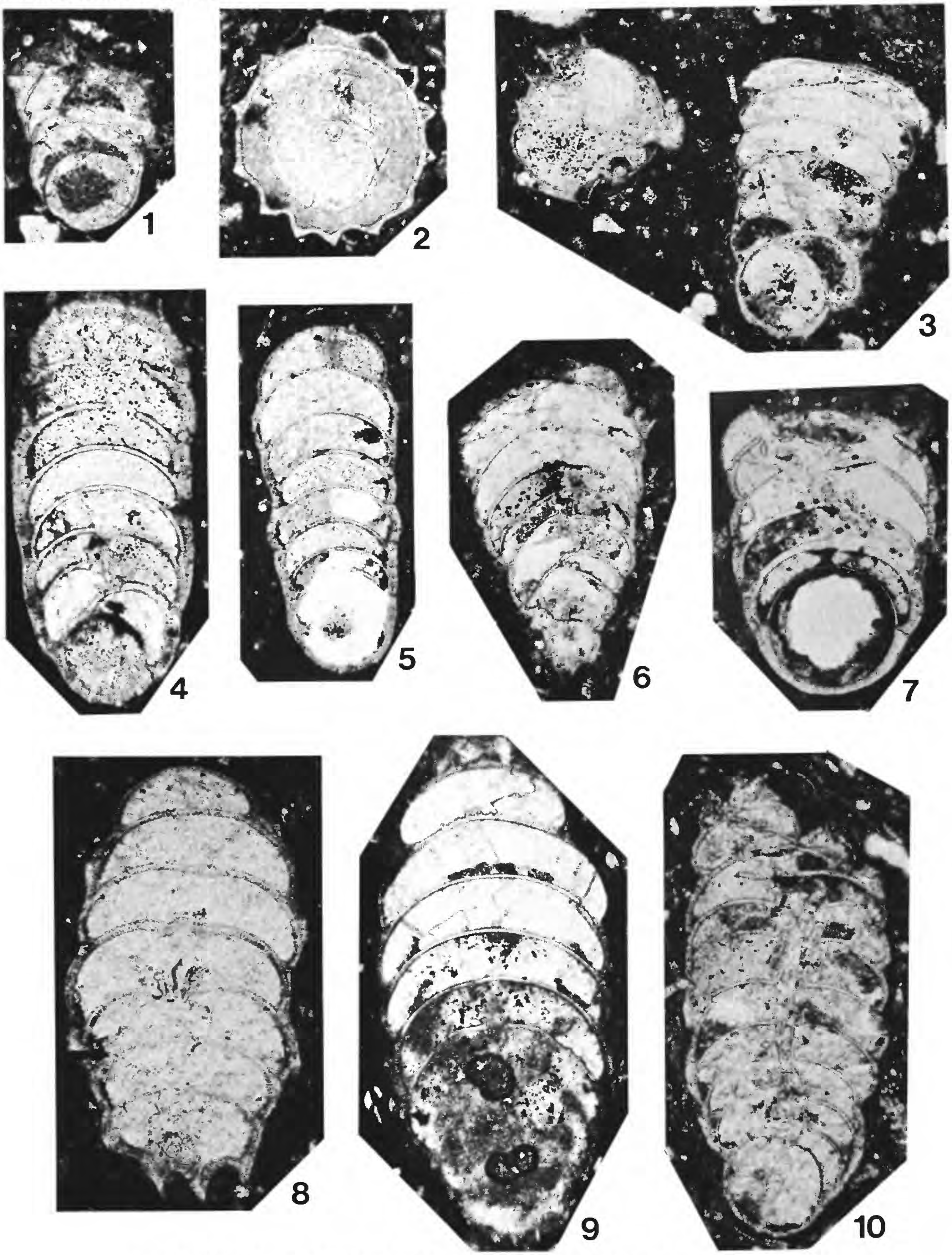


FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 21

Photomicrographs of *Rectuvigerina branneri* (Bagg) in petrographic thin sections, Monterey Formation, Lions Head section.

Figure 1. ×80, CRC-40471-2, slide no. 12, parallel to bedding.
2. ×80, CRC-40471-9, slide no. 7, perpendicular to bedding.
3. ×80, CRC-40471-9, slide no. 17, parallel to bedding.
4. ×80, CRC-40471-12, slide no. 20, parallel to bedding.
5. ×50, CRC-40471-12, slide no. 10, perpendicular to bedding.
6. ×80, CRC-40471-9, slide no. 17, parallel to bedding.
7. ×80, CRC-40471-12, slide no. 20, parallel to bedding.
8. ×80, CRC-40471-10, slide no. 8, perpendicular to bedding.
9. ×80, CRC-40471-6, slide no. 6, perpendicular to bedding.
10. ×80, CRC-40471-9, slide no. 7, perpendicular to bedding.

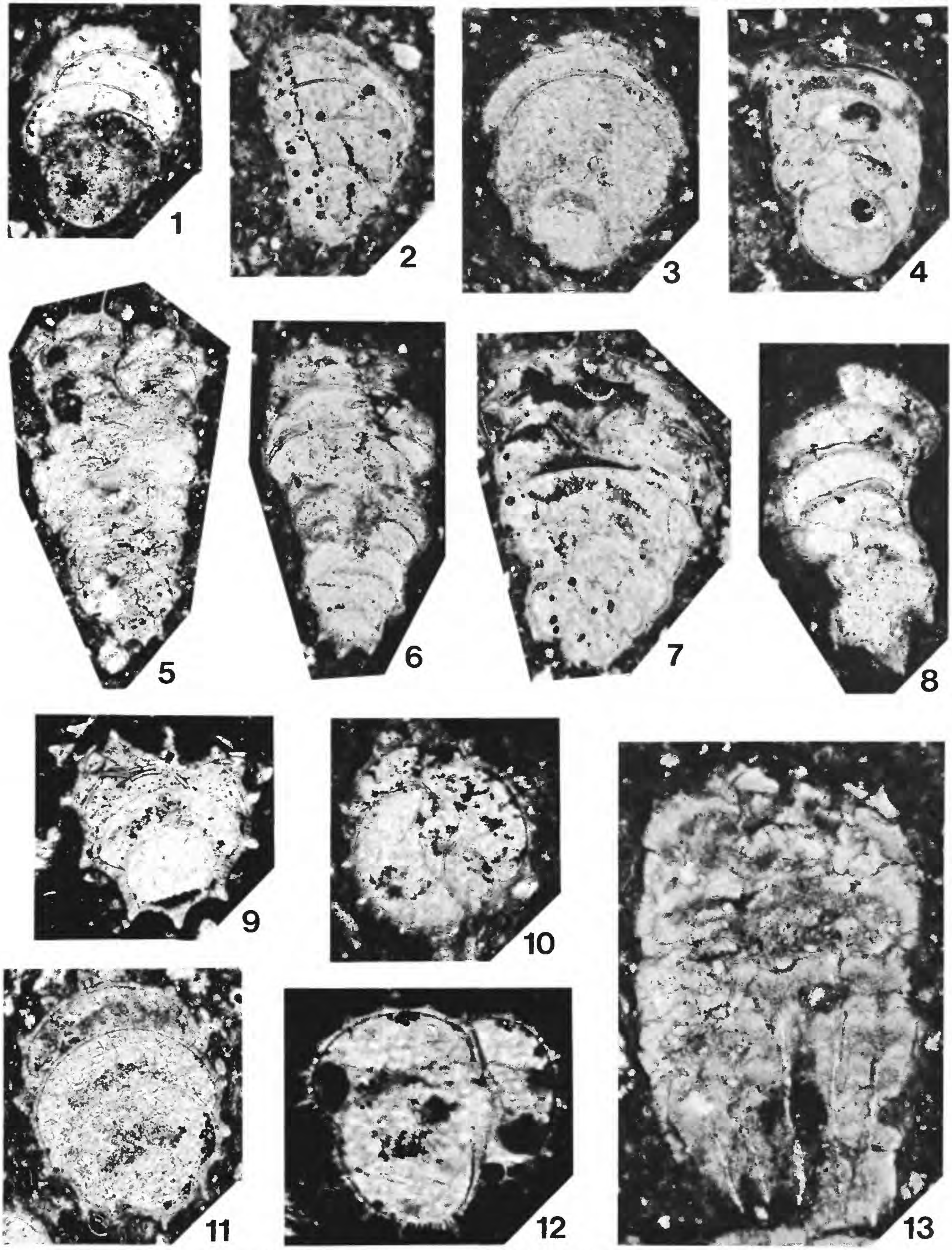


FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 22

Photomicrographs of *Rectuvigerina branneri* (Bagg) in petrographic thin sections, Monterey Formation, Lions Head section.

Figure 1. ×80, CRC-40471-4, slide no. 4, perpendicular to bedding.
2. ×80, CRC-40471-2, slide no. 12, parallel to bedding.
3. ×80, CRC-40471-9, slide no. 7, perpendicular to bedding.
4. ×80, CRC-40471-2, slide no. 12, parallel to bedding.
5. ×80, CRC-40471-2, slide no. 12, parallel to bedding.
6. ×50, CRC-40471-9, slide no. 17, parallel to bedding.
7. ×50, CRC-40471-9, slide no. 17, parallel to bedding.
8. ×80, CRC-40471-9, slide no. 17, parallel to bedding.
9. ×80, CRC-40471-9, slide no. 7, perpendicular to bedding.
10. ×128, CRC-40471-4, slide no. 4, perpendicular to bedding.
11. ×80, CRC-40471-9, slide no. 7, perpendicular to bedding.
12. ×80, CRC-40471-9, slide no. 7, perpendicular to bedding.
13. ×200, CRC-40471-12, slide no. 10, perpendicular to bedding.

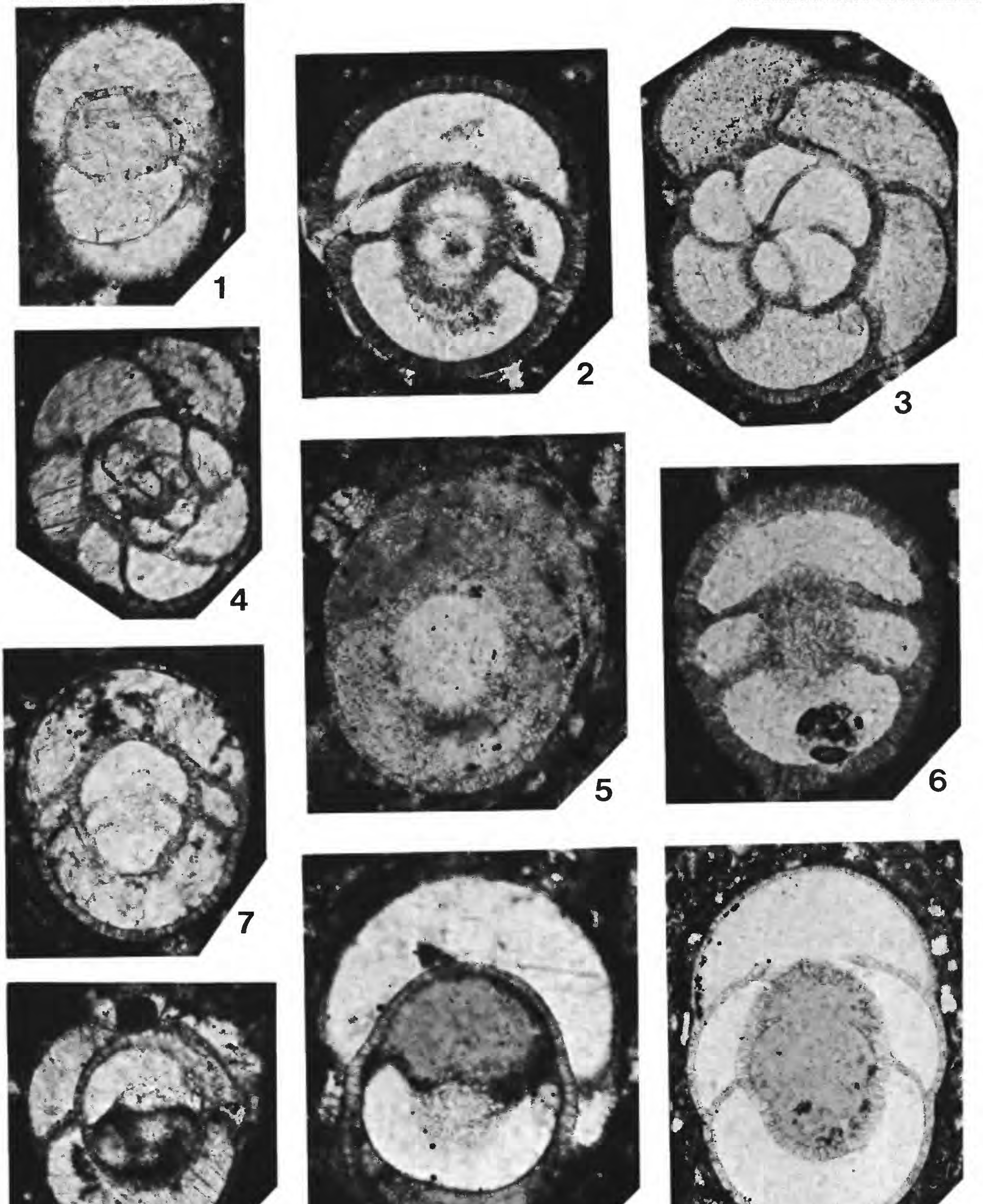


FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 23

Photomicrographs of *Pullenia miocenica* Kleinpell in petrographic thin sections, Monterey Formation, Lions Head section.

Figure 1. ×200, CRC-40471-9, slide no. 17, parallel to bedding.
2. ×128, CRC-40471-12, slide no. 20, parallel to bedding.
3. ×128, CRC-40471-9, slide no. 17, parallel to bedding.
4. ×80, CRC-40471-9, slide no. 17, parallel to bedding.
5. ×200, CRC-40471-10, slide no. 18, parallel to bedding.
6. ×200, CRC-40471-12, slide no. 10, perpendicular to bedding.
7. ×200, CRC-40471-12, slide no. 10, perpendicular to bedding.
8. ×200, CRC-40471-12, slide no. 20, parallel to bedding.
9. ×200, CRC-40471-10, slide no. 18, parallel to bedding.
10. ×128, CRC-40471-9, slide no. 7, perpendicular to bedding.



FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

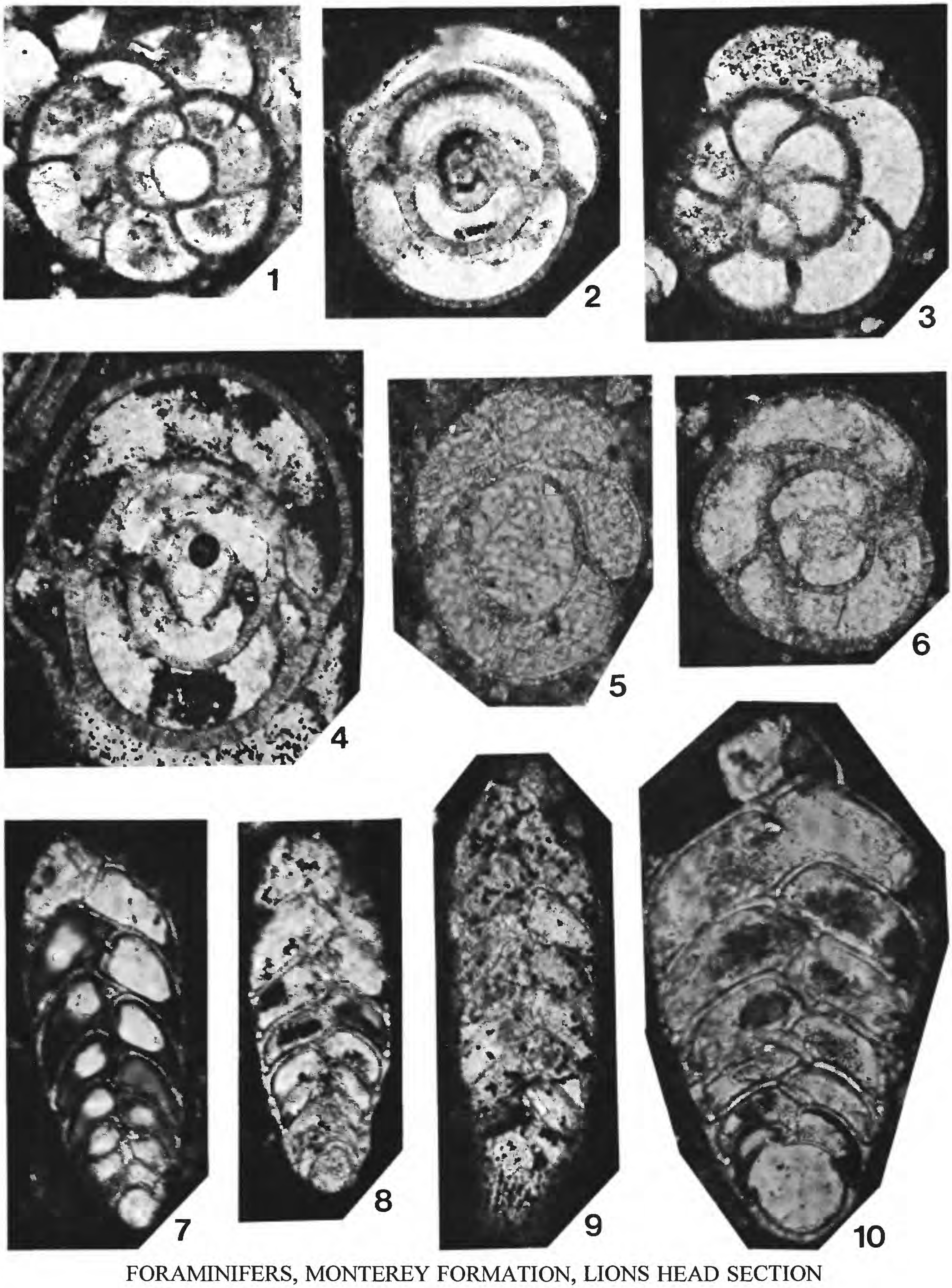
PLATE 24

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Lions Head section.

Figures 1-6. *Pullenia miocenica* Kleinpell: **1**, ×128, CRC-40471-6, slide no. 6, perpendicular to bedding; **2**, ×128, CRC-40471-12H, parallel to bedding; **3**, ×128, CRC-40471-12H, parallel to bedding; **4**, ×200, CRC-40471-12V, perpendicular to bedding; **5**, ×200, CRC-40471-10H, parallel to bedding; **6**, ×200, CRC-40471-12H, parallel to bedding.

7-9. *Bolivina advena ornata* Cushman: **7**, ×320, CRC-40471-12H, parallel to bedding; **8**, ×200, CRC-40471-12H, parallel to bedding; **9**, ×200, CRC-40471-12H, parallel to bedding.

10. *Bolivina californica* Cushman, ×320, CRC-40471-12H, parallel to bedding.

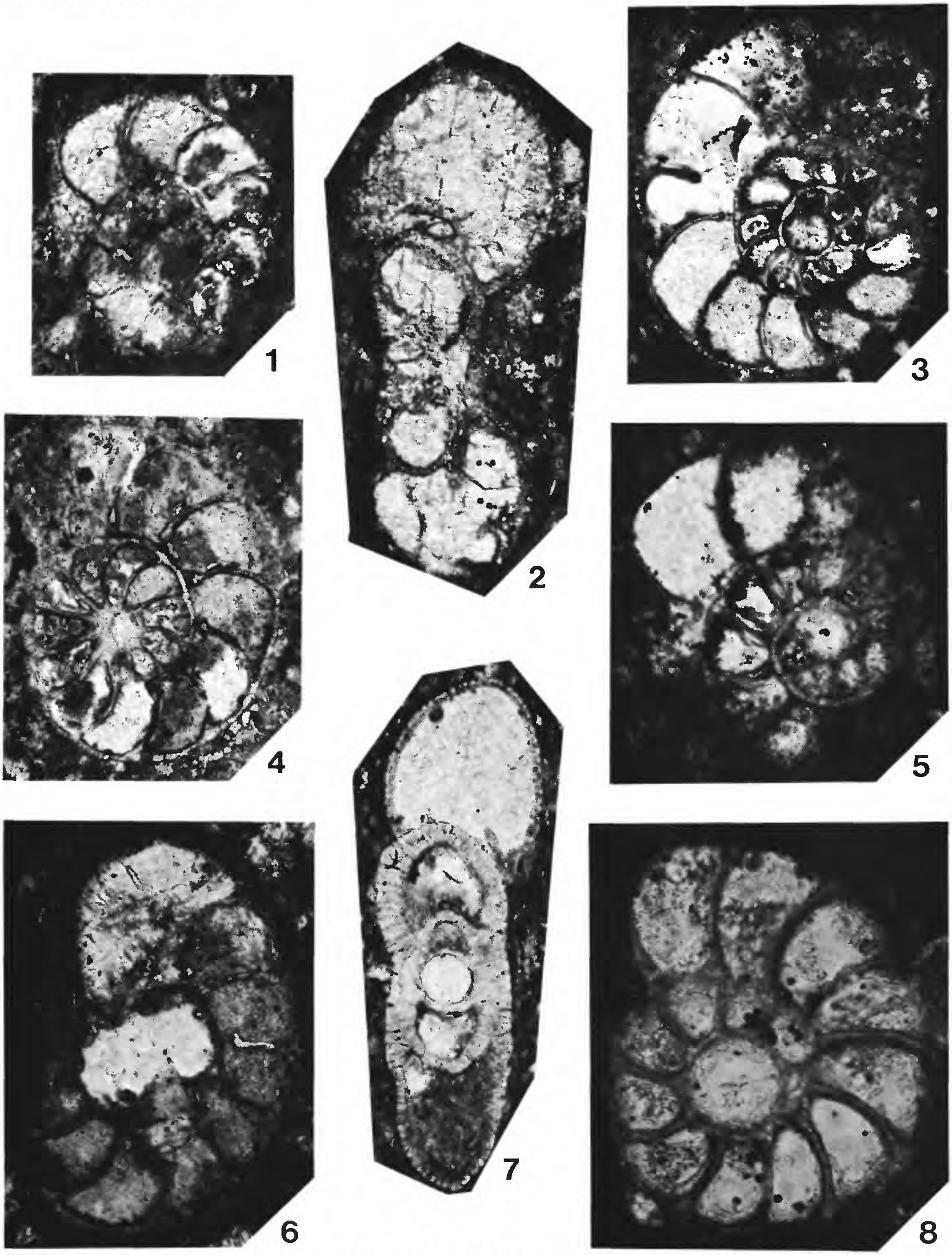


FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 25

Photomicrographs of *Anomalinoides salinasensis* (Kleinpell) in petrographic thin sections, Monterey Formation, Lions Head section.

Figure 1. ×200, CRC-40471-11, slide no. 9, perpendicular to bedding.
2. ×200, CRC-40471-11, slide no. 9, perpendicular to bedding.
3. ×128, CRC-40471-12, slide no. 20, parallel to bedding.
4. ×128, CRC-40471-10, slide no. 18, parallel to bedding.
5. ×200, CRC-40471-12, slide no. 20, parallel to bedding.
6. ×200, CRC-40471-11, slide no. 19, parallel to bedding.
7. ×128, CRC-40471-10, slide no. 8, perpendicular to bedding.
8. ×320, CRC-40471-12, slide no. 20, parallel to bedding.

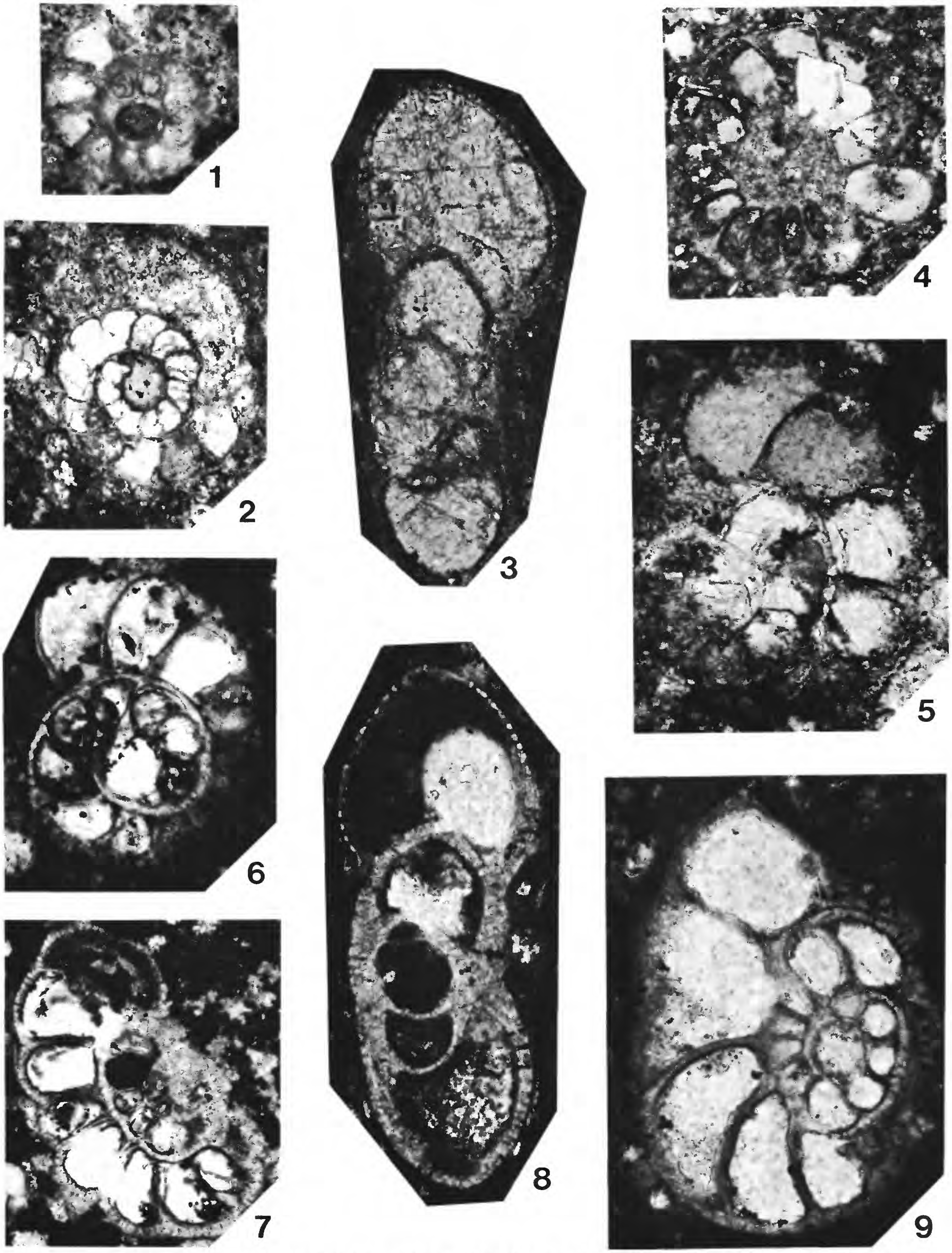


FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 26

Photomicrographs of *Anomalinoides salinasensis* (Kleinpell) in petrographic thin sections, Monterey Formation, Lions Head section.

Figure 1. ×320, CRC-40471-3, slide no. 13, parallel to bedding.
2. ×80, CRC-40471-10, slide no. 18, parallel to bedding.
3. ×80, CRC-40471-11, slide no. 19, parallel to bedding.
4. ×200, CRC-40471-11, slide no. 9, perpendicular to bedding.
5. ×200, CRC-40471-11, slide no. 19, parallel to bedding.
6. ×200, CRC-40471-12, slide no. 20, parallel to bedding.
7. ×128, CRC-40471-10, slide no. 18, parallel to bedding.
8. ×200, CRC-40471-12, slide no. 10, perpendicular to bedding.
9. ×200, CRC-40471-12, slide no. 20, parallel to bedding.

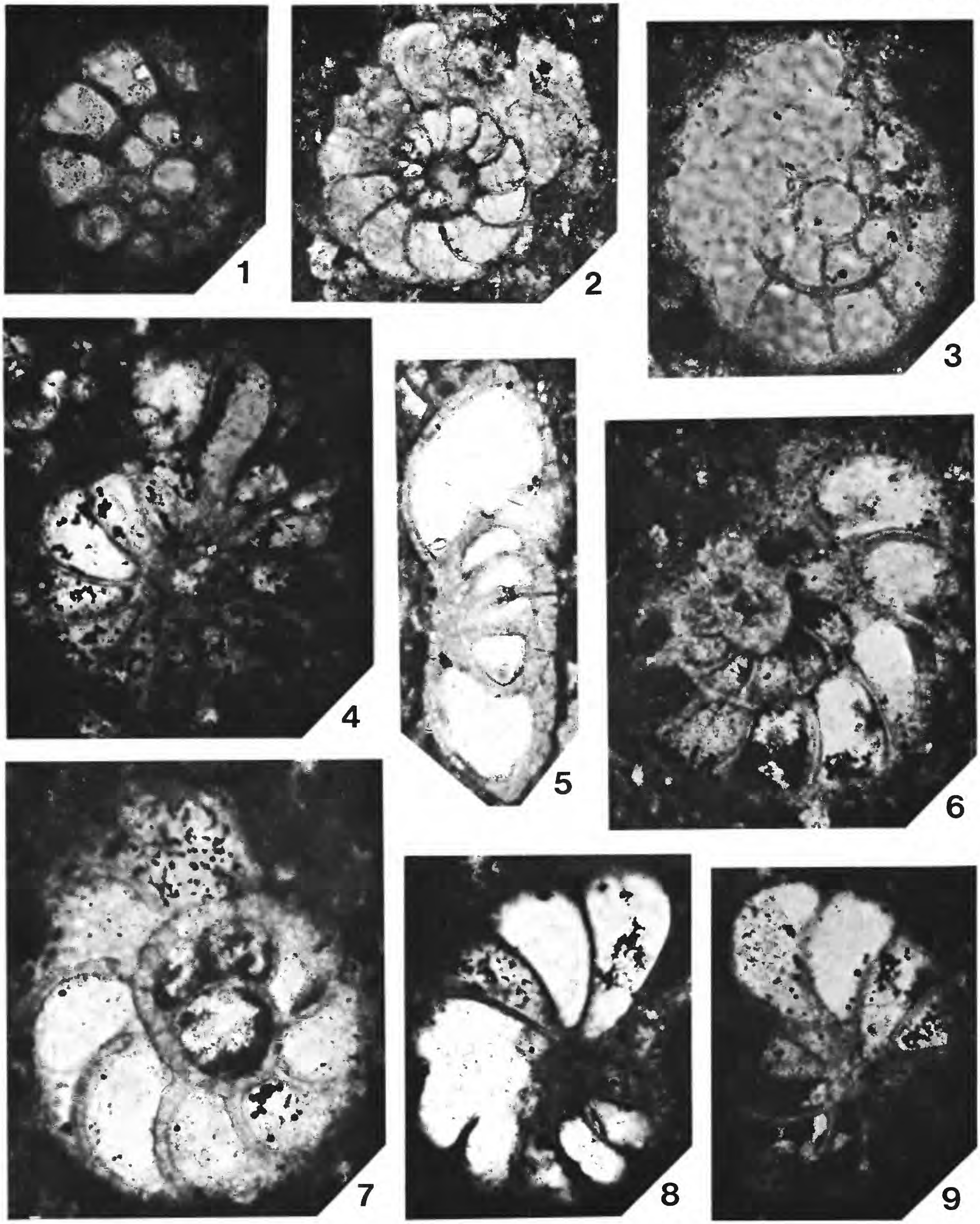


FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 27

Photomicrographs of *Anomalinoides salinasensis* (Kleinpell) in petrographic thin sections, Monterey Formation, Lions Head section.

Figure 1. ×320, CRC-40471-5, slide no. 15, parallel to bedding.
2. ×80, CRC-40471-11, slide no. 19, parallel to bedding.
3. ×320, CRC-40471-10, slide no. 18, parallel to bedding.
4. ×200, CRC-40471-12, slide no. 20, parallel to bedding.
5. ×200, CRC-40471-9, slide no. 7, perpendicular to bedding.
6. ×200, CRC-40471-12, slide no. 20, parallel to bedding.
7. ×320, CRC-40471-12, slide no. 20, parallel to bedding.
8. ×200, CRC-40471-12, slide no. 20, parallel to bedding.
9. ×200, CRC-40471-12, slide no. 20, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 28

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Lions Head section.

Figures 1,2. *Islandiella modeloensis* (Rankin), ×200, CRC-40471-9, slide no. 17, parallel to bedding, and ×200, CRC-40471-9, slide no. 17, parallel to bedding, respectively.

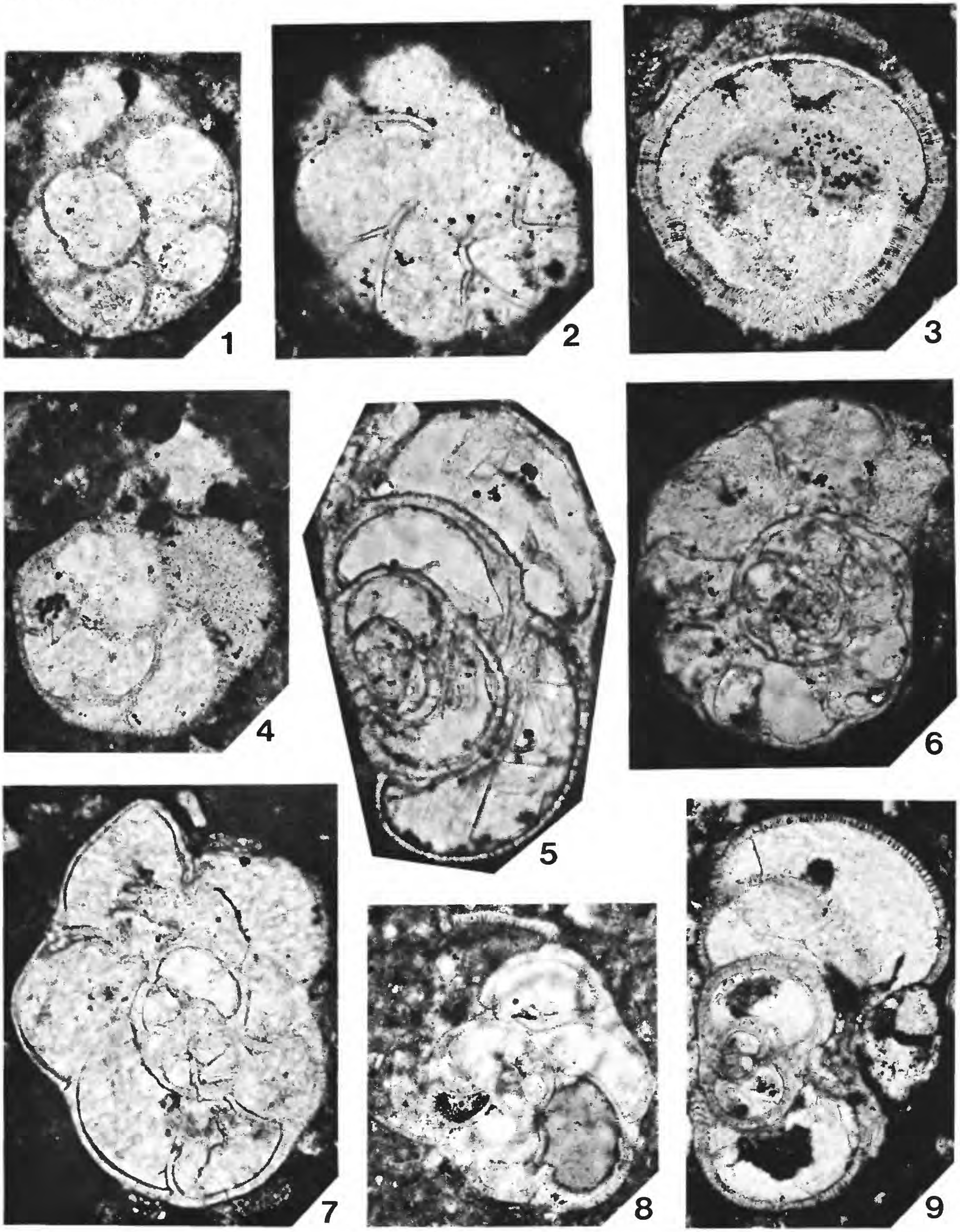
3. *Rectuvigerina branneri* (Bagg), ×128, CRC-40471-12, slide no. 10, perpendicular to bedding.

4. *Islandiella modeloensis* (Rankin), ×200, CRC-40471-10, slide no. 18, parallel to bedding.

5. *Gyroidina rosaformis* (Cushman and Kleinpell), ×320, CRC-40471-9, slide no. 17, parallel to bedding.

6. *Islandiella modeloensis* (Rankin), ×320, CRC-40471-9, slide no. 17, parallel to bedding.

7-9. *Valvulineria californica* Cushman: **7**, ×200, CRC-40471-9, slide no. 17, parallel to bedding; **8**, ×80, CRC-40471-10, slide no. 18, parallel to bedding; **9**, ×128, CRC-40471-6, slide no. 6, perpendicular to bedding.



FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 29

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Lions Head.

Figure 1. *Baggina californica* Cushman, ×200, CRC-40471-10, slide no. 18, parallel to bedding.

2. *Islandiella modeloensis*? (Rankin), ×128, CRC-40471-6, slide no. 6, perpendicular to bedding.

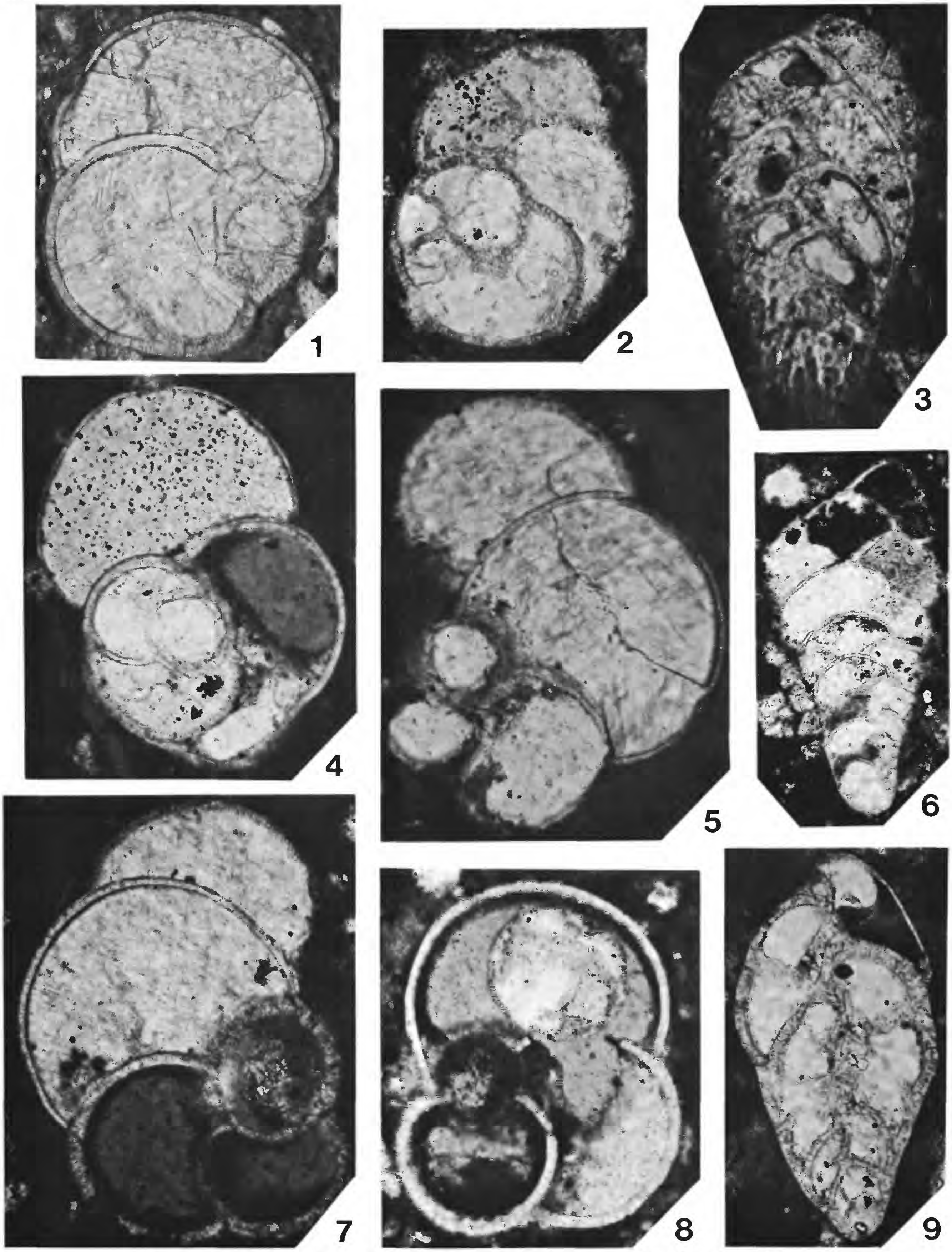
3. *Bolivina advena ornata* Cushman, ×320, CRC-40471-12, slide no. 20, parallel to bedding.

4,5. *Baggina californica* Cushman, ×200, CRC-40471-12, slide no. 20, parallel to bedding, and ×200, CRC-40471-12, slide no. 20, parallel to bedding, respectively.

6. *Bolivina blakei* Finger and Lipps, ×128, CRC-40471-10, slide no. 18, parallel to bedding.

7,8. *Baggina californica* Cushman, ×200, CRC-40471-12, slide no. 20, parallel to bedding, and ×200, CRC-40471-10, slide no. 18, parallel to bedding, respectively.

9. *Bolivina californica* Cushman, ×200, CRC-40471-12, slide no. 20, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 30

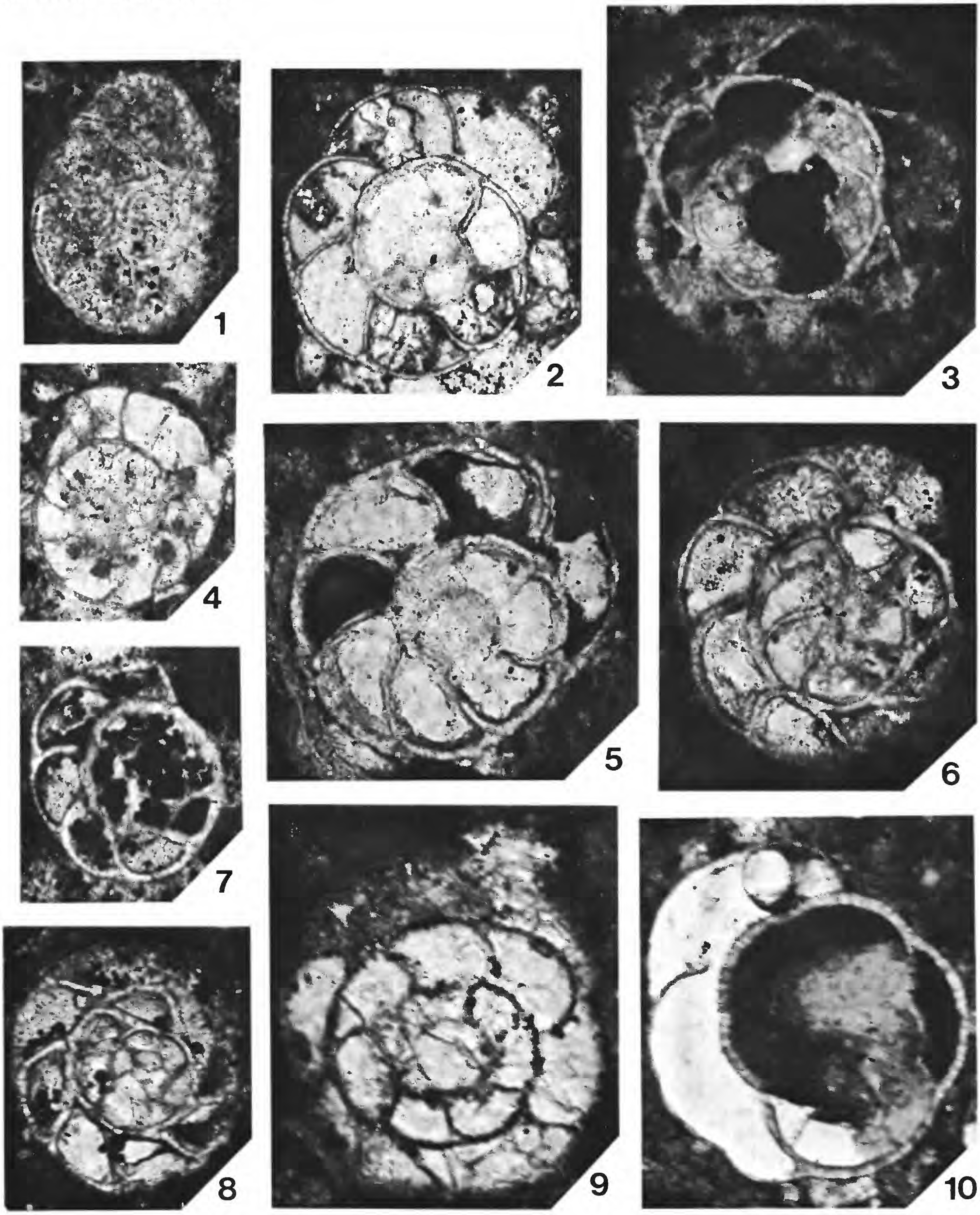
Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Lions Head section.

Figure 1. *Megastomella capitanensis* (Cushman and Kleinpell), ×320, CRC-40471-5, slide no. 15, parallel to bedding.

2,3. *Gyroidina rosaformis* (Cushman and Kleinpell), ×200, CRC-40471-9, slide no. 17, parallel to bedding, and ×320, CRC-40471-10, slide no. 18, parallel to bedding, respectively.

4. *Pseudoparrella subperuviana* (Cushman), ×128, CRC-40471-5, slide no. 15, parallel to bedding.

5-10. *Gyroidina rosaformis* (Cushman and Kleinpell): **5**, ×320, CRC 40471-12, slide no. 20, parallel to bedding; **6**, ×320, CRC-40471-12, slide no. 20, parallel to bedding; **7**, ×320, CRC-40471-10, slide no. 18, parallel to bedding; **8**, ×320, CRC-40471-12, slide no. 20, parallel to bedding; **9**, ×320, CRC-40471-11, slide no. 19, parallel to bedding; **10**, ×200, CRC-40471-12, slide no. 20, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 31

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Lions Head section.

Figure 1. *Nodogenerina sagrinensis* (Bagg), ×80, CRC-40471-6, slide no. 6, perpendicular to bedding.

2,3. *Tenuitellinata angustiumbilicata* (Bolli), ×320, CRC-40471-3, slide no. 13, parallel to bedding, and ×320, CRC-40471-3, slide no. 13, parallel to bedding, respectively.

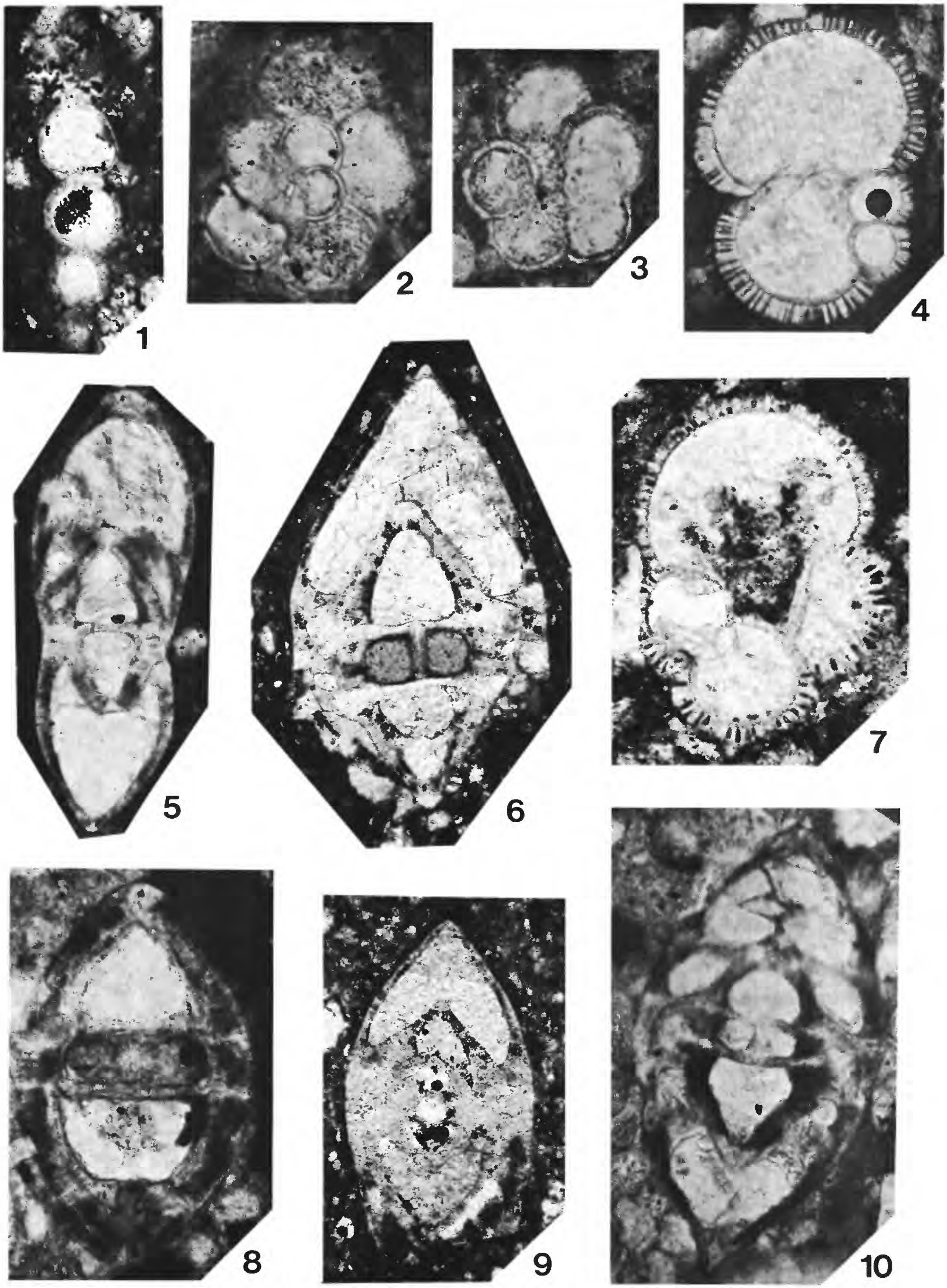
4. *Globigerina bulloides* d'Orbigny, ×200, CRC-40471-3, slide no. 3, perpendicular to bedding.

5. *Lenticulina miocenica* (Chapman), ×200, CRC-40471-6, slide no. 6, perpendicular to bedding.

6. *Lenticulina smileyi* (Kleinpell), ×80, CRC-40471-10, slide no. 8, perpendicular to bedding.

7. *Globigerina bulloides* d'Orbigny, ×200, CRC-40471-3, slide no. 13, parallel to bedding.

8-10. *Lenticulina smileyi* (Kleinpell): **8**, ×200, CRC-40471-6, slide no. 6, perpendicular to bedding; **9**, ×50, CRC-40471-10, slide no. 18, parallel to bedding; **10**, ×128, CRC-40471-6, slide no. 6, perpendicular to bedding.



FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 32

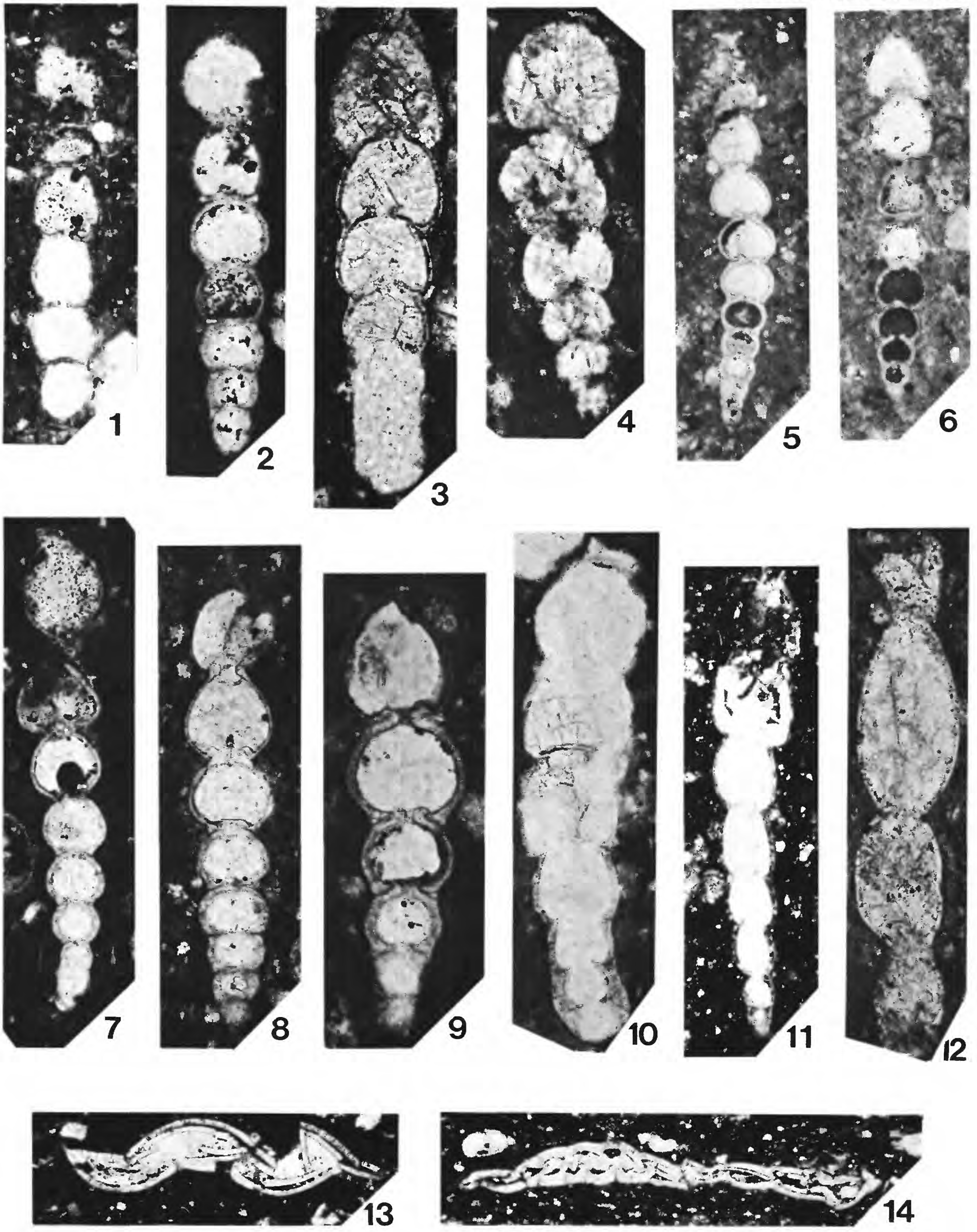
Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Lions Head.

Figures 1-10. *Nodogenerina sagrinensis* (Bagg): **1**, ×80, CRC-40471-10, slide no. 18, parallel to bedding; **2**, ×128, CRC-40471-12, slide no. 20, parallel to bedding; **3**, ×128, CRC-40471-11, slide no. 9, perpendicular to bedding; **4**, ×128, CRC-40471-11, slide no. 19, parallel to bedding; **5**, ×80, CRC-40471-12, slide no. 20, parallel to bedding; **6**, ×80, CRC-40471-10, slide no. 18, parallel to bedding; **7**, ×200, CRC-40471-12, slide no. 10, perpendicular to bedding; **8**, ×128, CRC-40471-12, slide no. 20, parallel to bedding; **9**, ×200, CRC-40471-12, slide no. 20, parallel to bedding; **10**, ×128, CRC-40471-10, slide no. 18, parallel to bedding.

11. *Siphonodosaria montereyana* Finger and Lipps, ×32, CRC-40471-12, slide no. 20, parallel to bedding.

12. *Nodosaria ewaldi* Reuss, ×128, CRC-40471-11, slide no. 9, perpendicular to bedding.

13,14. Typical examples of crushed foraminifers, ×80, CRC-40471-12, slide no. 10, perpendicular to bedding, and ×50, CRC-40471-12, slide no. 10, perpendicular to bedding, respectively.



FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 33

Photomicrographs of foraminifers in petrographic thin sections, Monterey Formation, Lions Head.

Figure 1. *Bulimina* cf. *B. subacuminata* Cushman and R.E. Stewart, ×128, CRC-40471-12, slide no. 10, perpendicular to bedding.

2. *Siphonodosaria quadrulata* (Cushman and Parker), ×200, CRC-40471-10, slide no. 18, parallel to bedding.

3-6. *Nodogenerina sagrinensis* (Bagg): **3**, ×80, CRC-40471-10, slide no. 18, parallel to bedding; **4**, ×200, CRC-40471-12, slide no. 20, parallel to bedding; **5**, ×200, CRC-40471-12, slide no. 20, parallel to bedding; **6**, ×80, CRC-40471-11, slide no. 19, parallel to bedding.

7,8. *Siphonodosaria quadrulata* (Cushman and Parker), ×80, CRC-40471-10, slide no. 18, parallel to bedding, and ×80, CRC-40471-10, slide no. 18, parallel to bedding, respectively.

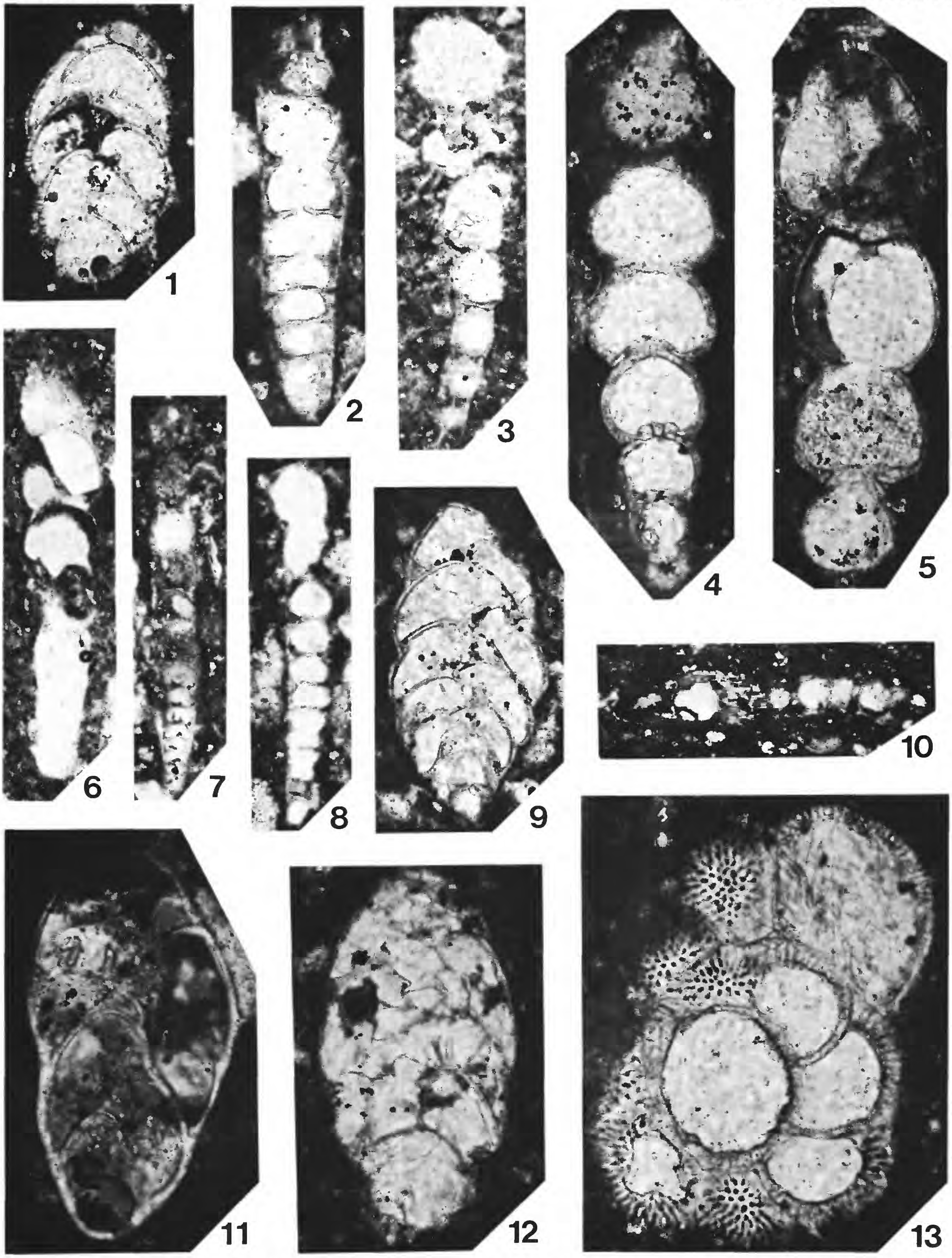
9. *Bolivina californica* Cushman, ×200, CRC-40471-2, slide no. 12, parallel to bedding.

10. *Nodogenerina sagrinensis* (Bagg), ×50, CRC-40471-10, slide no. 8, perpendicular to bedding.

11. *Buliminella subfusiformis* Cushman, ×320, CRC-40471-12, slide no. 20, parallel to bedding.

12. *Protoglobobulimina pseudotorta*? (Cushman), ×200, CRC-40471-3, slide no. 13, parallel to bedding.

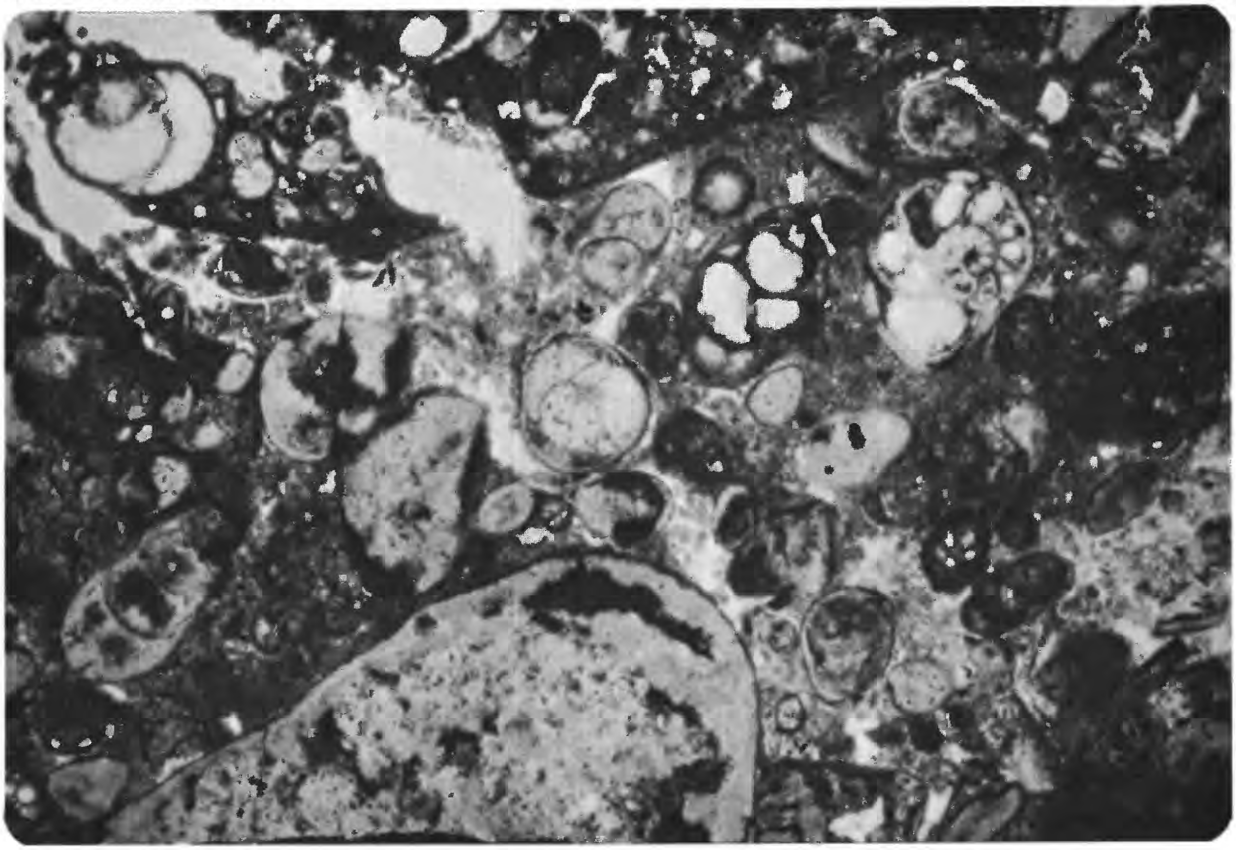
13. *Holmanella baggi* (Kleinpell), ×200, CRC-40471-12, slide no. 20, parallel to bedding.

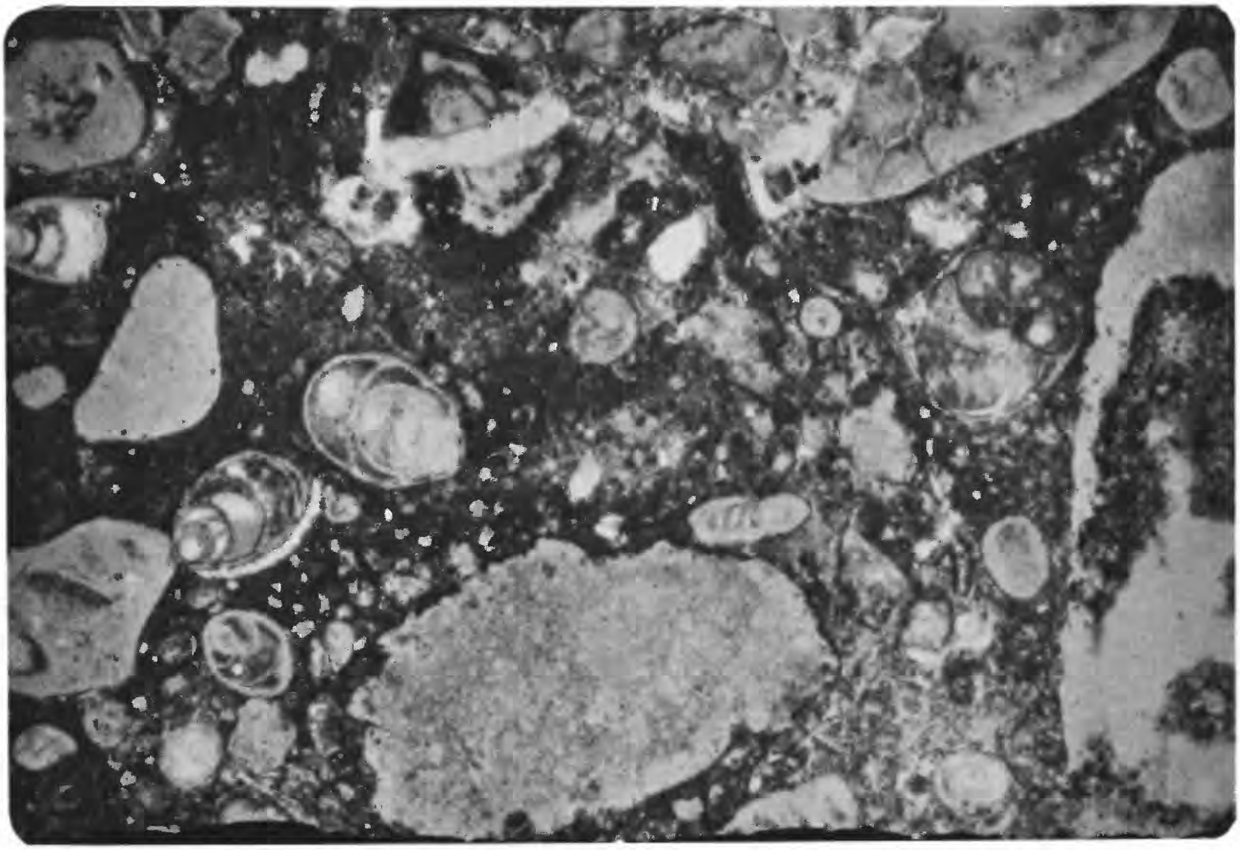


FORAMINIFERS, MONTEREY FORMATION, LIONS HEAD SECTION

PLATE 34

Photomicrographs (×25) of foraminiferal pelletal phosphorite in petrographic thin section CRC-40661-1, slide no. 1-12, parallel to bedding, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

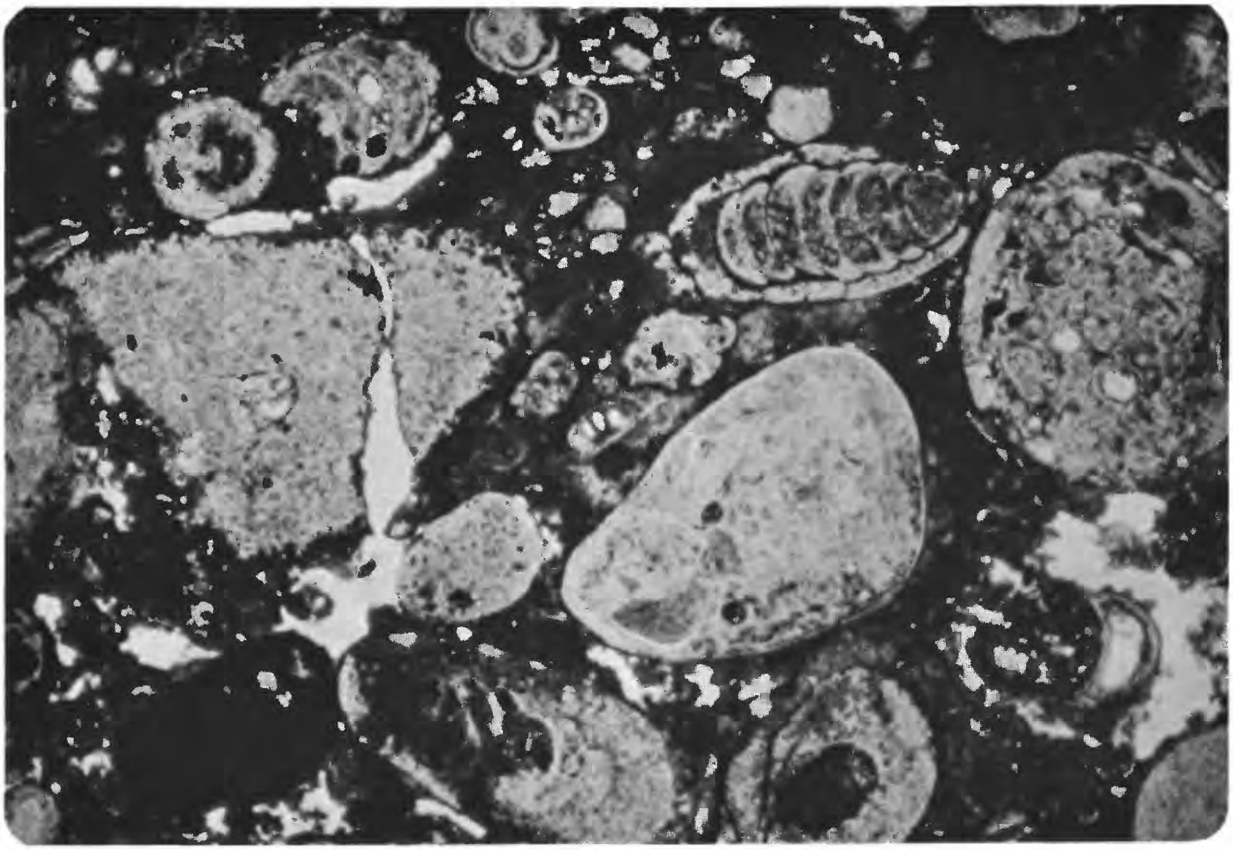


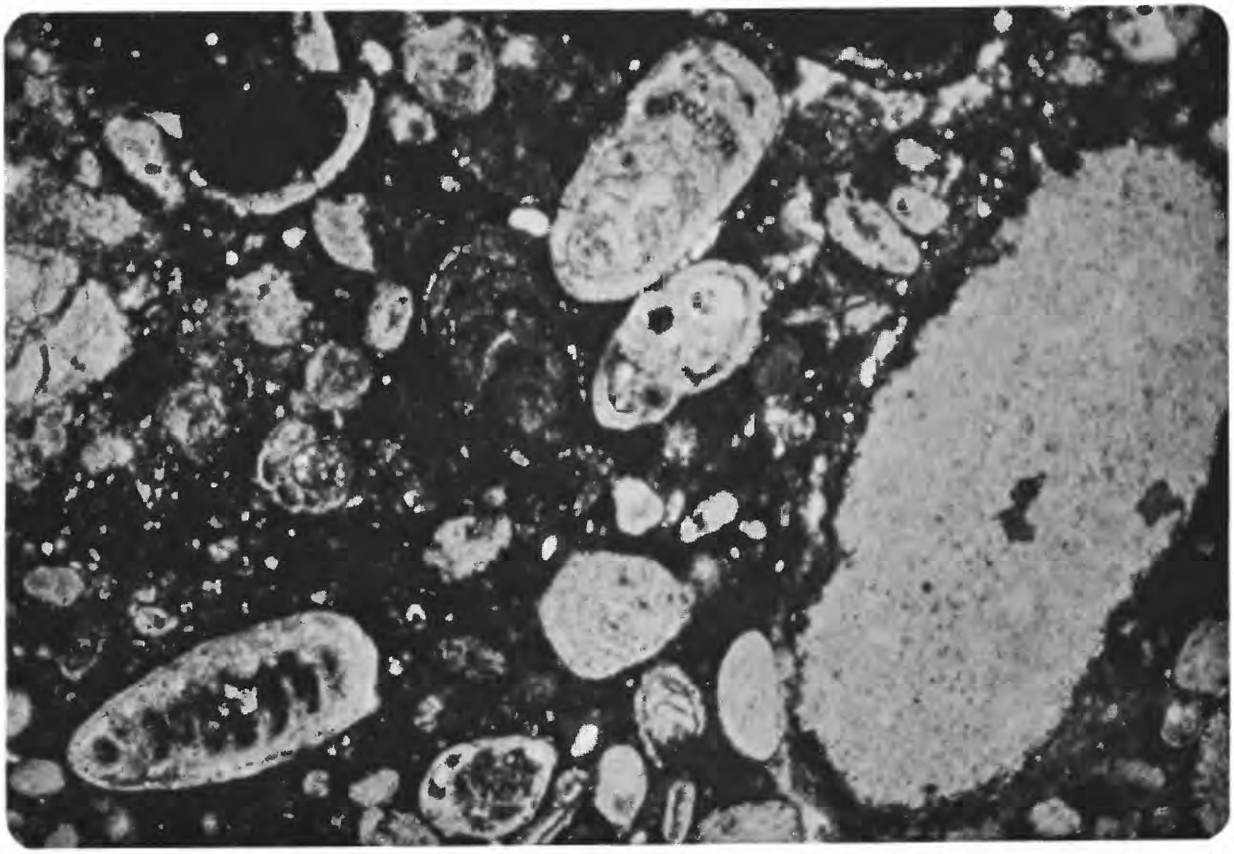


FORAMINIFERAL PELLETAL PHOSPHORITE, MONTEREY FORMATION,
RODEO CANYON SECTION

PLATE 35

Photomicrographs (×25) of foraminiferal pelletal phosphorite in petrographic thin section CRC-40661-1, slide no. 1-7, parallel to bedding, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

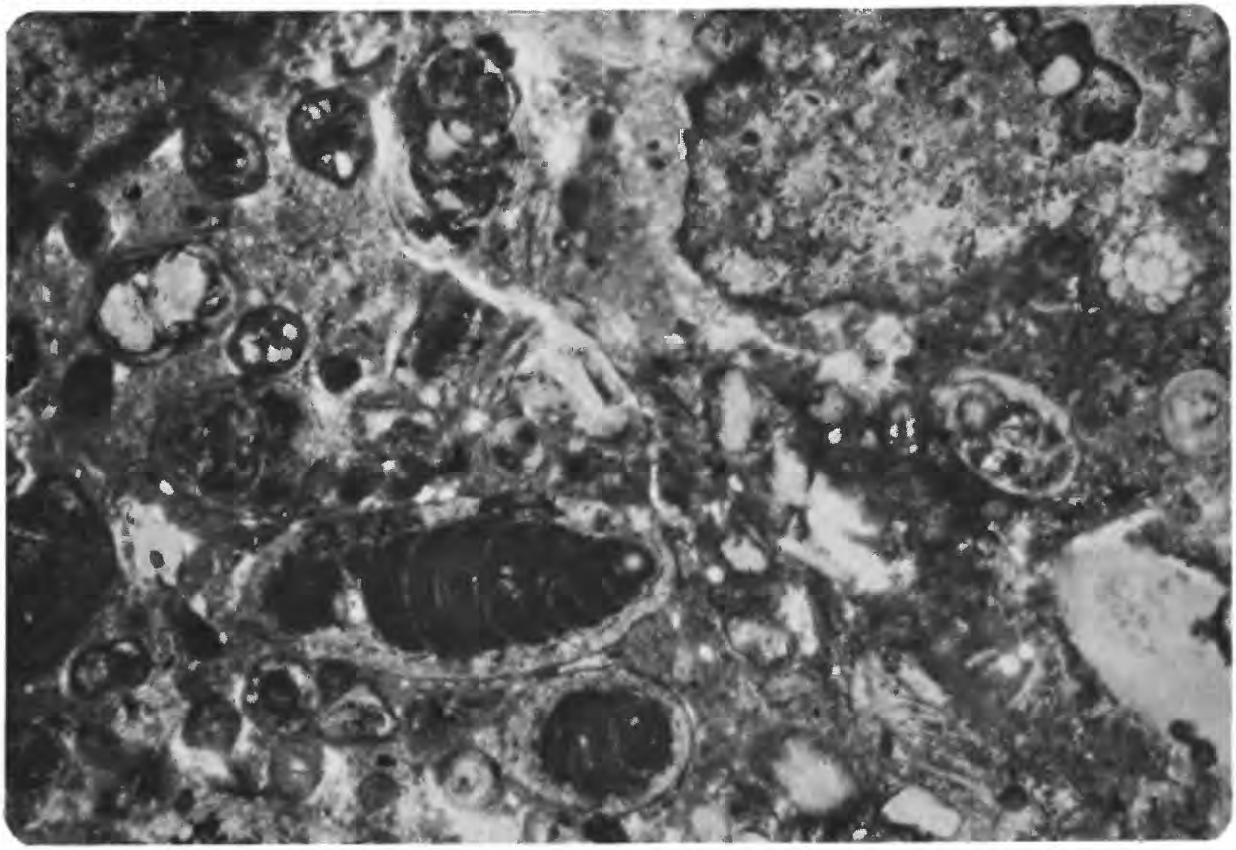


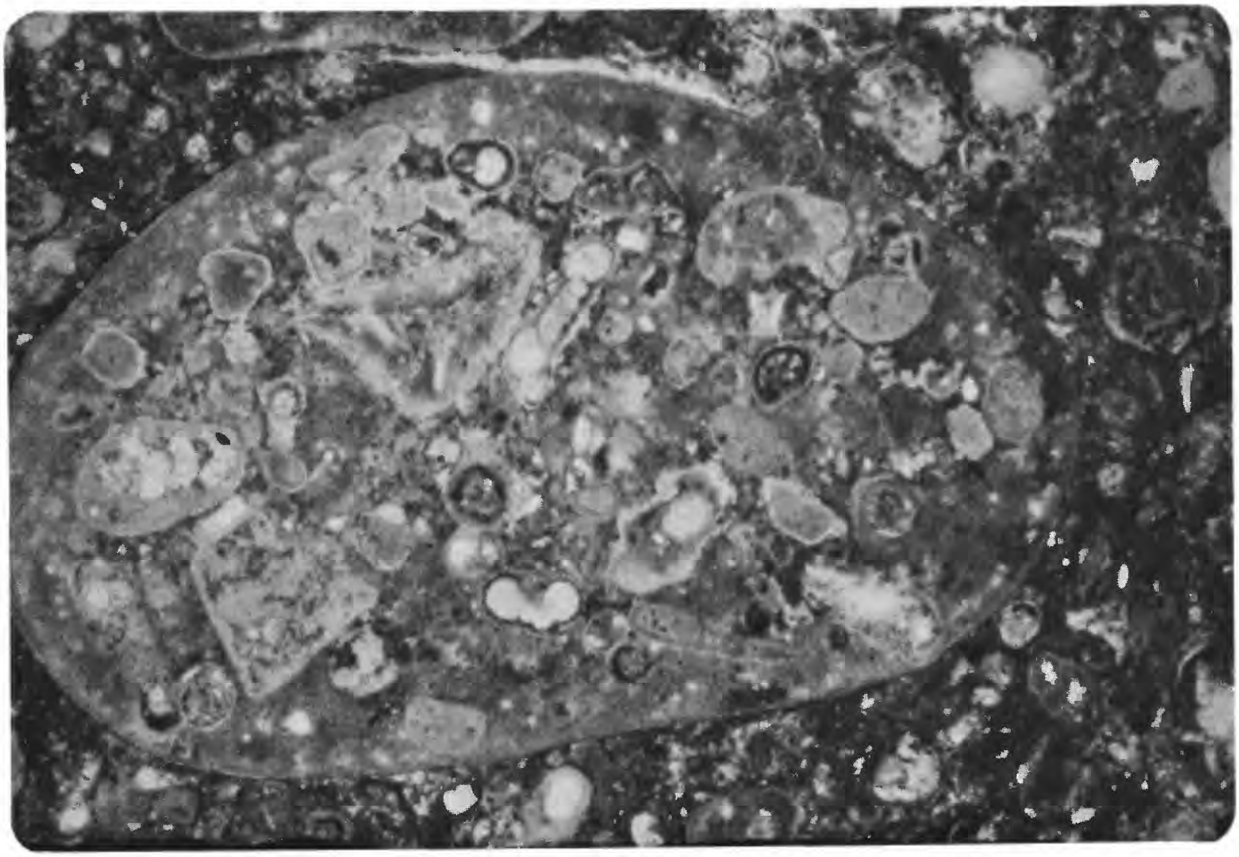


FORAMINIFERAL PELLETAL PHOSPHORITE, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 36

Photomicrographs (×25) of foraminiferal pelletal phosphorite in petrographic thin sections CRC-40661-1, slide no. 1-9, parallel to bedding (top photomicrograph) and CRC-40661-1, slide no. 1-9, parallel to bedding (bottom photomicrograph), basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.



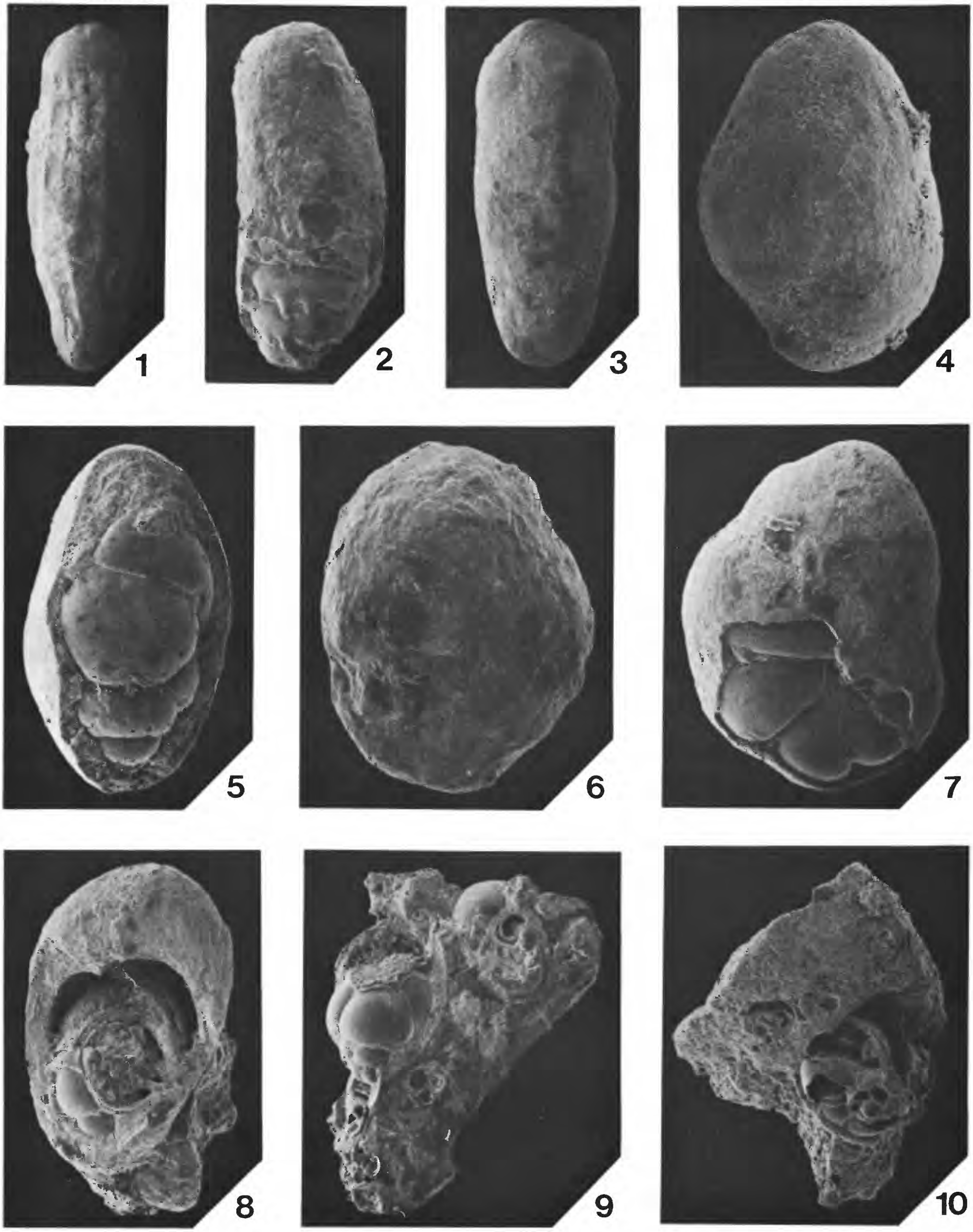


FORAMINIFERAL PELLETAL PHOSPHORITE, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 37

Scanning electron micrographs of internal molds of foraminifers from pelletal phosphorite (CRC-40660-1), basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figure 1. *Rectuvigerina branneri* (Bagg), side view, ×50.
2. *Rectuvigerina branneri* (Bagg), side view, ×60.
3. *Rectuvigerina branneri* (Bagg), side view, ×50.
4. *Marginulinopsis beali* (Cushman), side view, ×100.
5. *Protoglobobulimina pseudotorta* (Cushman), side view, ×80.
6. *Valvulineria robusta* (Kleinpell), side view, ×70.
7. *Valvulineria robusta* (Kleinpell), side view, ×90.
8. *Valvulineria robusta* (Kleinpell), side view, ×70.
9. *Protoglobobulimina pseudotorta* (Cushman) and *Valvulineria robusta* (Kleinpell), side views, ×60.
10. *Valvulineria robusta* (Kleinpell), side view, ×60.

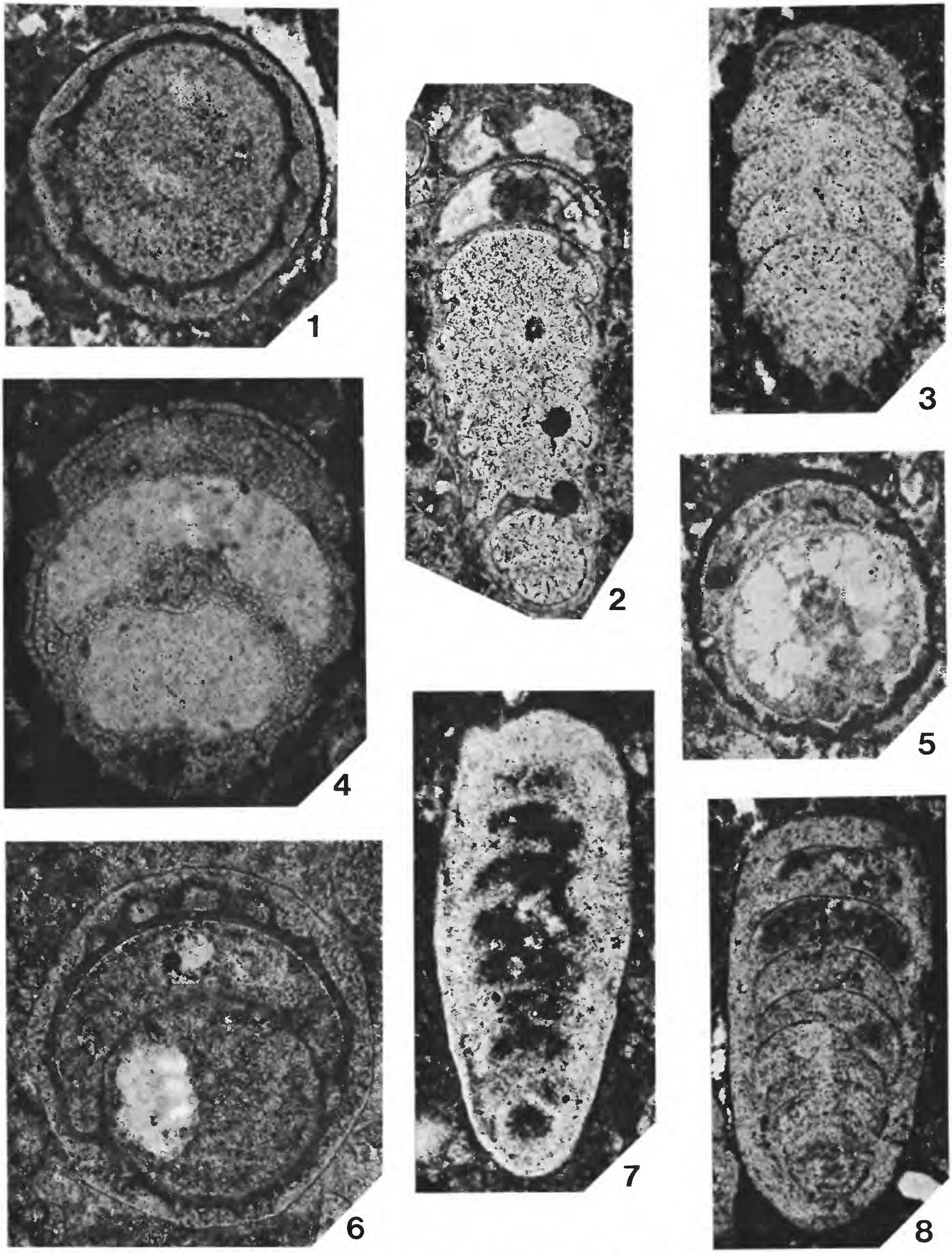


FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 38

Photomicrographs of *Rectuvigerina branneri* (Bagg) in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figure 1. ×128, CRC-40661-1, slide no. 1-7, parallel to bedding.
2. ×80, CRC-40661-1, slide no. 1-6, parallel to bedding.
3. ×80, CRC-40661-1, slide no. 1-6, parallel to bedding.
4. ×128, CRC-40661-1, slide no. 1-5, parallel to bedding.
5. ×80, CRC-40661-1, slide no. 1-5, parallel to bedding.
6. ×128, CRC-40661-1, slide no. 1-7, parallel to bedding.
7. ×80, CRC-40661-1, slide no. 1-7, parallel to bedding.
8. ×80, CRC-40661-1, slide no. 1-7, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

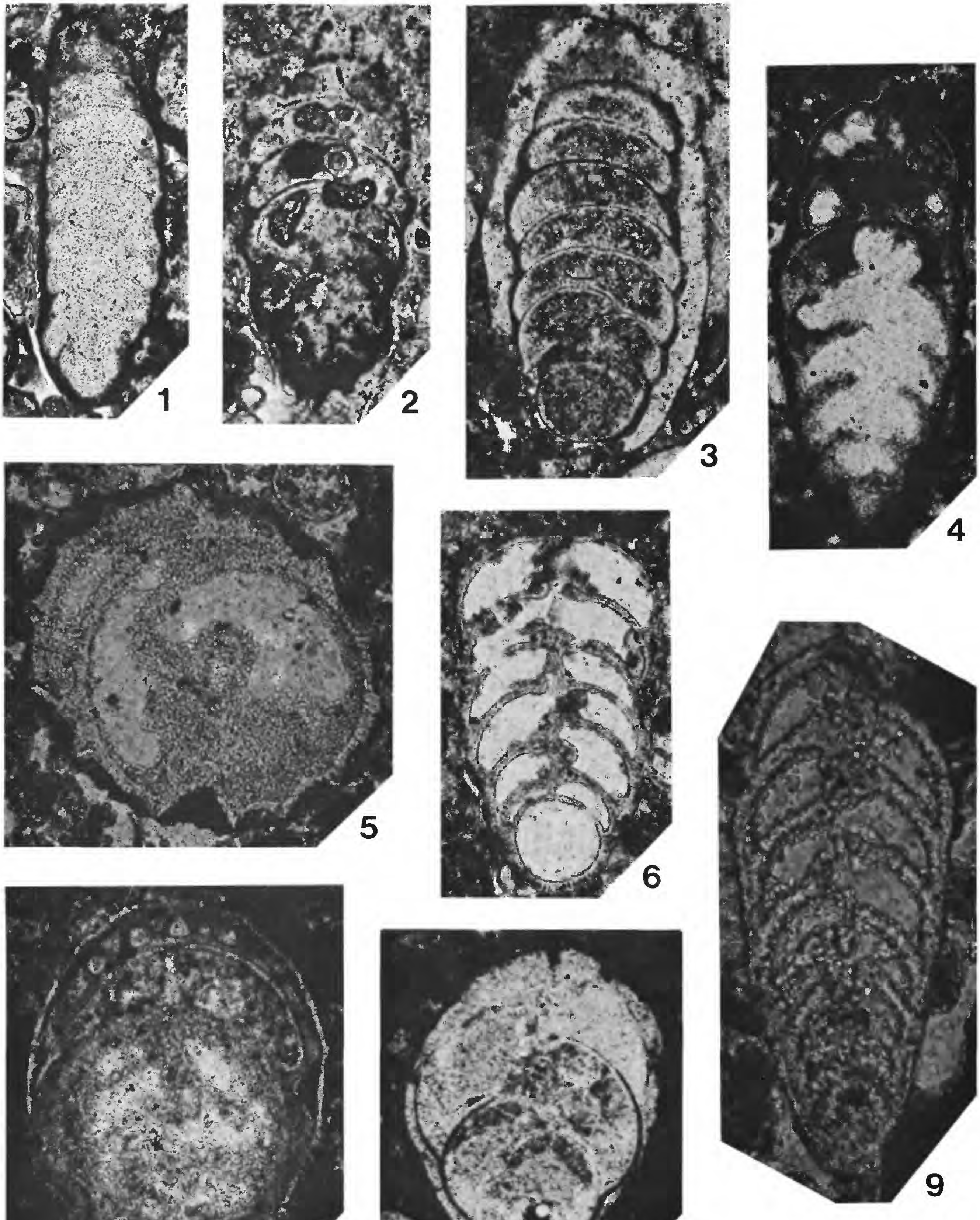
PLATE 39

Photomicrographs of foraminifers in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figures 1-7. *Rectuvigerina branneri* (Bagg): **1**, ×50, CRC-40661-1, slide no. 1-6, parallel to bedding; **2**, ×50, CRC-40661-1, slide no. 1-6, parallel to bedding; **3**, ×50, CRC-40661-1, slide no. 1-6, parallel to bedding; **4**, ×50, CRC-40661-1, slide no. 1-6, parallel to bedding; **5**, ×50, CRC-40661-1, slide no. 1-6, parallel to bedding; **6**, ×50, CRC-40661-1, slide no. 1-6, parallel to bedding; **7**, ×50, CRC-40661-1, slide no. 1-6, parallel to bedding.

8. *Protoglobobulimina pseudotorta* (Cushman), ×80, CRC-40661-1, slide no. 1-7, parallel to bedding.

9. *Bolivina advena*? Cushman, ×320, CRC-40661-1, slide no. 1-6, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 40

Photomicrographs of foraminifers in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

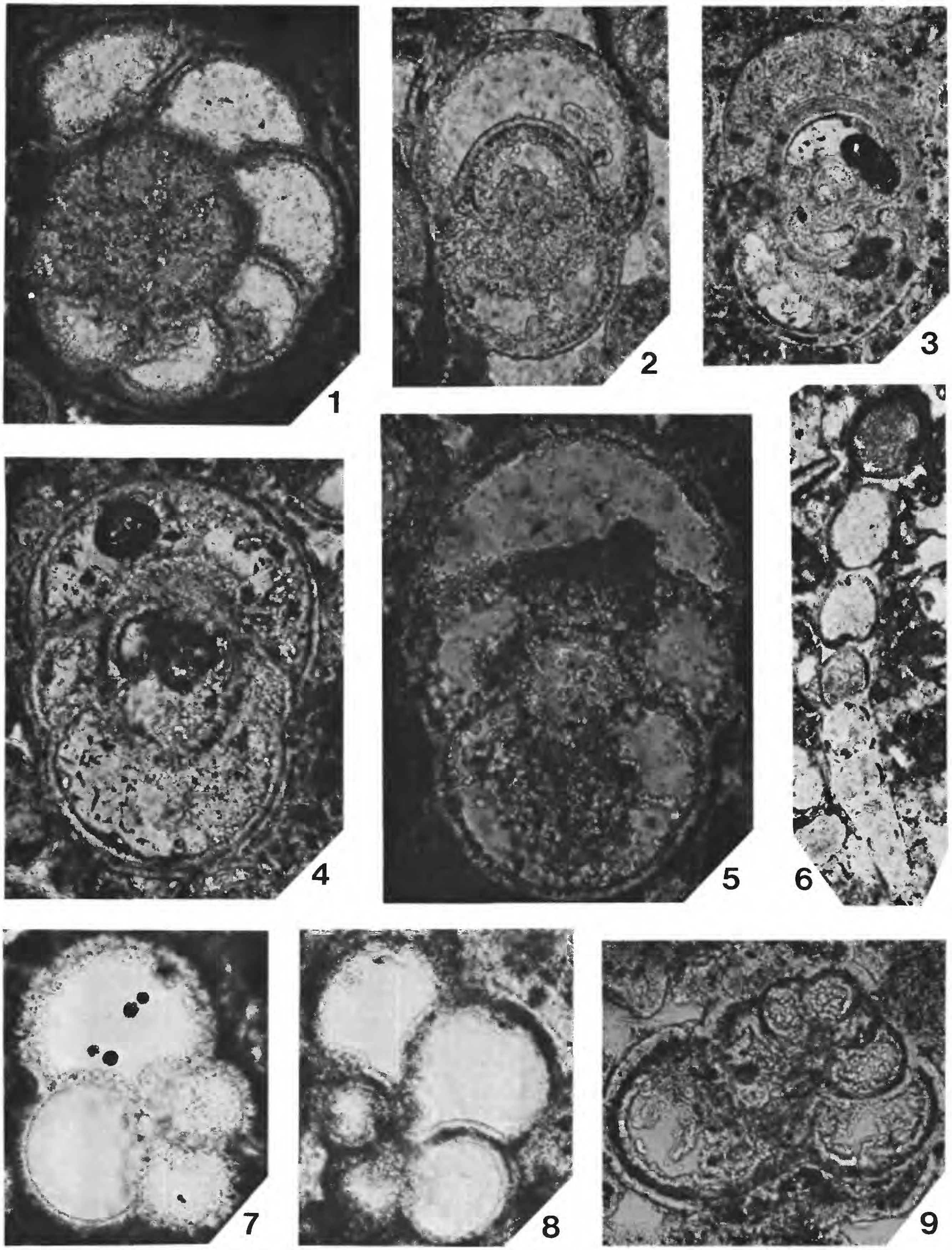
Figures 1-5. *Pullenia miocenica* Kleinpell: **1**, ×200, CRC-40661-1, slide no. 1-7, parallel to bedding; **2**, ×200, CRC-40661-1, slide no. 1-6, parallel to bedding; **3**, ×128, CRC-40661-1, slide no. 1-7, parallel to bedding; **4**, ×200, CRC-40661-1, slide no. 1-7, parallel to bedding; **5**, ×320, CRC-40661-1, slide no. 1-6, parallel to bedding.

6. *Siphonodosaria quadrulata* (Cushman and Laiming), ×50, CRC-40661-1, slide no. 1-6, parallel to bedding.

7. *Globigerina bulloides* d'Orbigny, ×250, CRC-40661-1, slide no. 1-9, parallel to bedding.

8. *Globigerina pseudociperoensis* Blow, ×250, CRC-40661-1, slide no. 1-9, parallel to bedding.

9. *Globigerina* sp.?, ×250, CRC-40661-1, slide no. 1-9, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 41

Photomicrographs of foraminifers in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figures 1,2. *Pullenia miocenica* Kleinpell, ×200, CRC-40661-1, slide no. 1-9, parallel to bedding, and ×250, CRC-40661-1, slide no. 1-12, parallel to bedding, respectively.

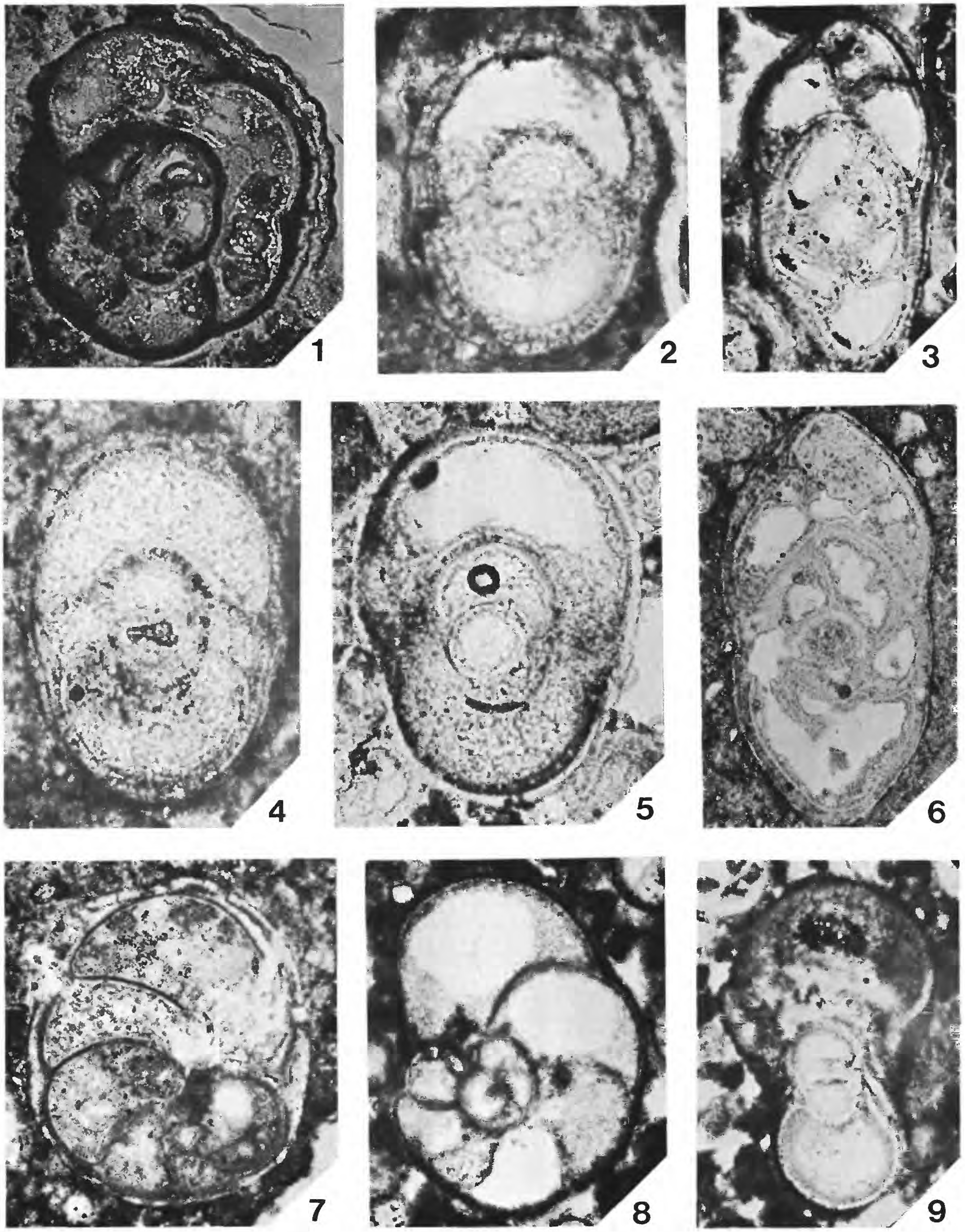
3. *Islandiella modeloensis* (Rankin), ×128, CRC-40661-1, slide no. 1-12, parallel to bedding.

4,5. *Pullenia miocenica* Kleinpell, ×320, CRC-40661-1, slide no. 1-12, parallel to bedding, and ×250, CRC-40661-1, slide no. 1-12, parallel to bedding, respectively.

6. *Islandiella modeloensis* (Rankin), ×128, CRC-40661-1, slide no. 1-9, parallel to bedding.

7. *Cancris baggi* Cushman and Kleinpell, ×100, CRC-40661-1, slide no. 1-12, parallel to bedding.

8,9. *Valvulineria robusta* (Kleinpell), ×128, CRC-40661-1, slide no. 1-12, parallel to bedding, and ×100, CRC-40661-1, slide no. 1-11, parallel to bedding, respectively.



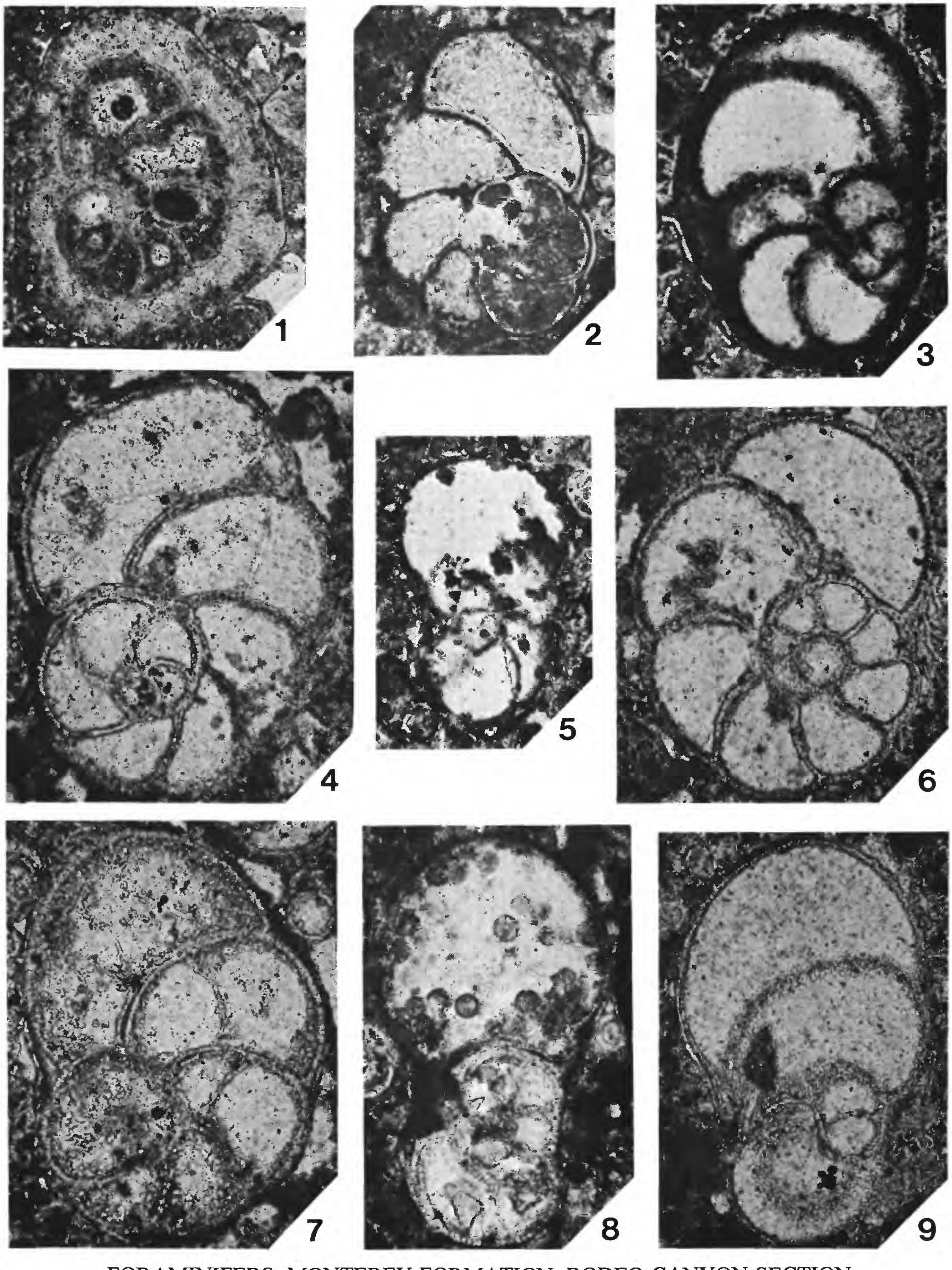
FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 42

Photomicrographs of *Valvulineria robusta* (Kleinpell) in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figure

1. ×80, CRC-40661-1, slide no. 1-6, parallel to bedding.
2. ×80, CRC-40661-1, slide no. 1-5, parallel to bedding.
3. ×128, CRC-40661-1, slide no. 1-7, parallel to bedding.
4. ×128, CRC-40661-1, slide no. 1-6, parallel to bedding.
5. ×80, CRC-40661-1, slide no. 1-6, parallel to bedding.
6. ×128, CRC-40661-1, slide no. 1-6, parallel to bedding.
7. ×128, CRC-40661-1, slide no. 1-6, parallel to bedding.
8. ×128, CRC-40661-1, slide no. 1-5, parallel to bedding.
9. ×128, CRC-40661-1, slide no. 1-6, parallel to bedding.



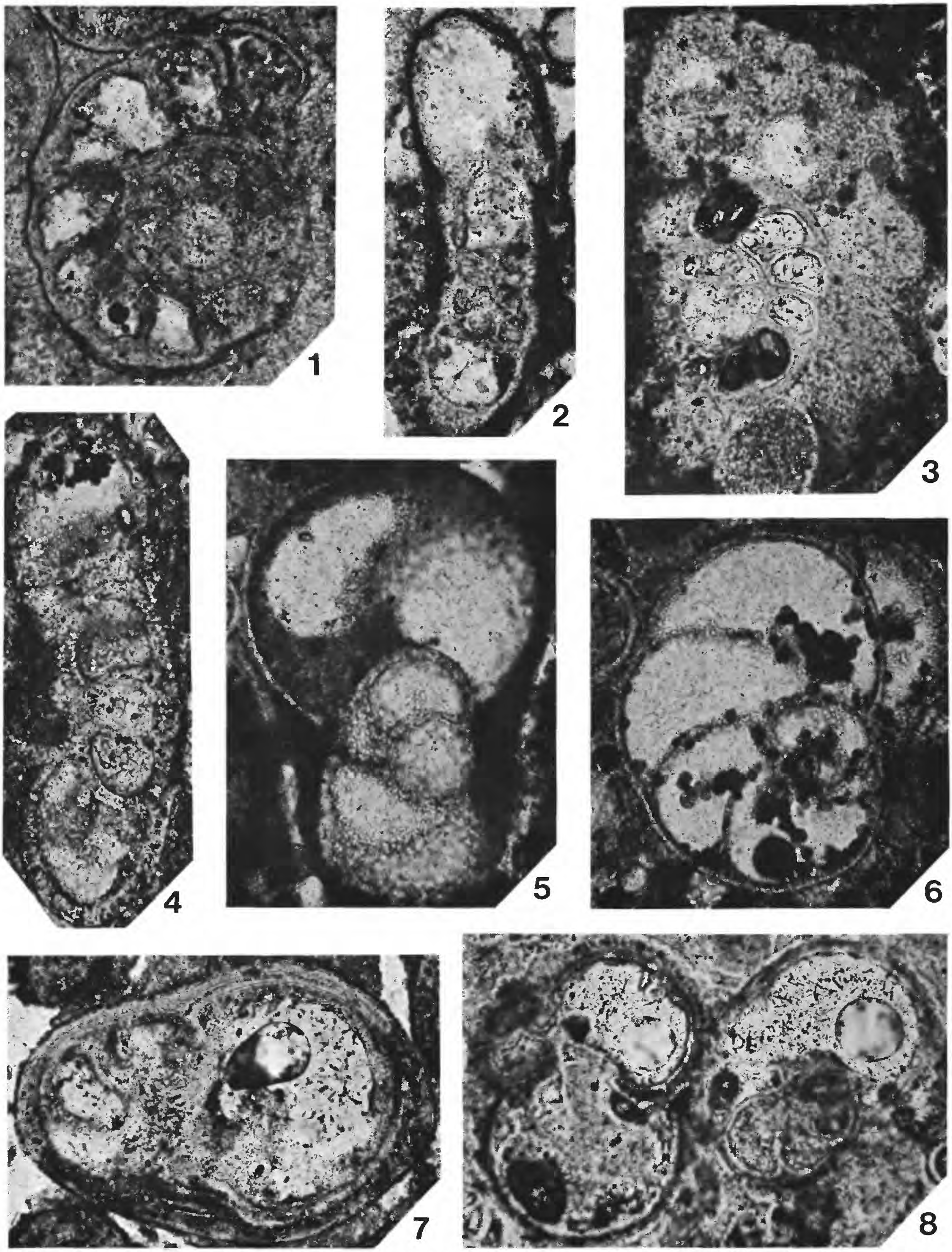
FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 43

Photomicrographs of foraminifers in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figures 1-4. *Anomalinoides salinasenis* (Kleinpell): **1**, ×200, CRC-40661-1, slide no. 1-6, parallel to bedding; **2**, ×128, CRC-40661-1, slide no. 1-5, parallel to bedding; **3**, ×128, CRC-40661-1, slide no. 1-6, parallel to bedding; **4**, ×200, CRC-40661-1, slide no. 1-5, parallel to bedding.

5-8. *Valvulineria robusta* (Kleinpell): **5**, ×200, CRC-40661-1, slide no. 1-7, parallel to bedding; **6**, ×128, CRC-40661-1, slide no. 1-7, parallel to bedding; **7**, ×128, CRC-40661-1, slide no. 1-7, parallel to bedding; **8**, ×128, CRC-40661-1, slide no. 1-7, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 44

Photomicrographs of foraminifers in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figures 1-3. *Anomalinoides salinasenis* (Kleinpell): **1**, ×200, CRC-40661-1, slide no. 1-12, parallel to bedding; **2**, ×128, CRC-40661-1, slide no. 1-9, parallel to bedding; **3**, ×128, CRC-40661-1, slide no. 1-6, parallel to bedding.

4. *Rectuvigerina branneri* (Bagg), ×40, CRC-40661-1, slide no. 1-11, parallel to bedding.

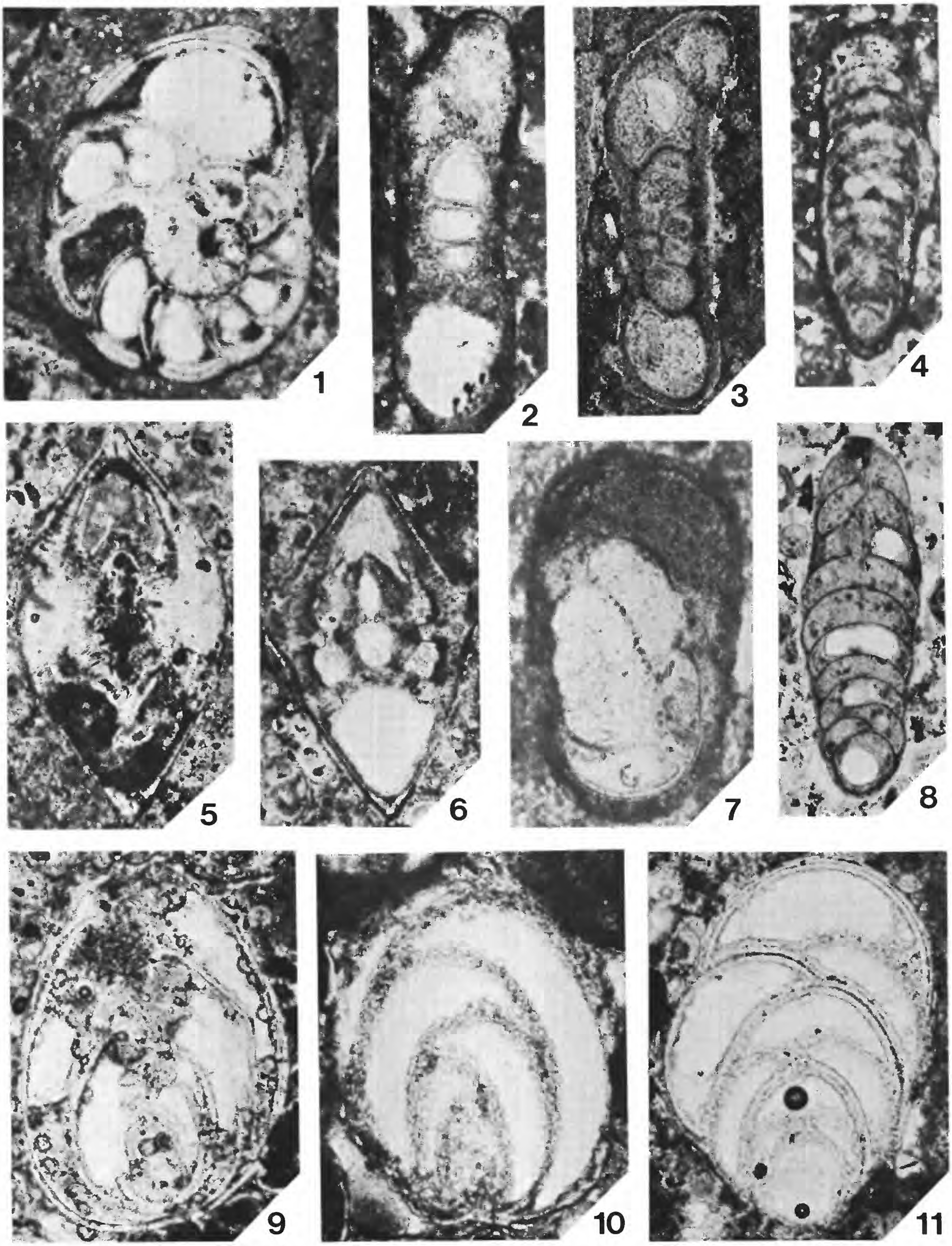
5,6. *Lenticulina smileyi* (Kleinpell) ×100, CRC-40661-1, slide no. 1-8, parallel to bedding, and ×100, CRC-40661-1, slide no. 1-11, parallel to bedding, respectively.

7. *Gyroidina rosaformis* (Cushman and Kleinpell), ×200, CRC-40661-1, slide no. 1-12, parallel to bedding.

8. *Rectuvigerina branneri* (Bagg), ×51, CRC-40661-1, slide no. 1-11, parallel to bedding.

9,10. *Praeglobobulimina galliheri* (Kleinpell), ×160, CRC-40661-1, slide no. 1-12, parallel to bedding, and ×160, CRC-40661-1, slide no. 1-12, parallel to bedding, respectively.

11. *Protoglobobulimina pseudotorta* (Cushman), ×128, CRC-40661-1, slide no. 1-10, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

PLATE 45

Photomicrographs of foraminifers in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figure 1. *Valvulineria californica* Cushman, ×80, CRC-40661-1, slide no. 1-7, parallel to bedding.

2. *Buliminella subfusiformis* Cushman, ×320, CRC-40661-1, slide no. 1-6, parallel to bedding.

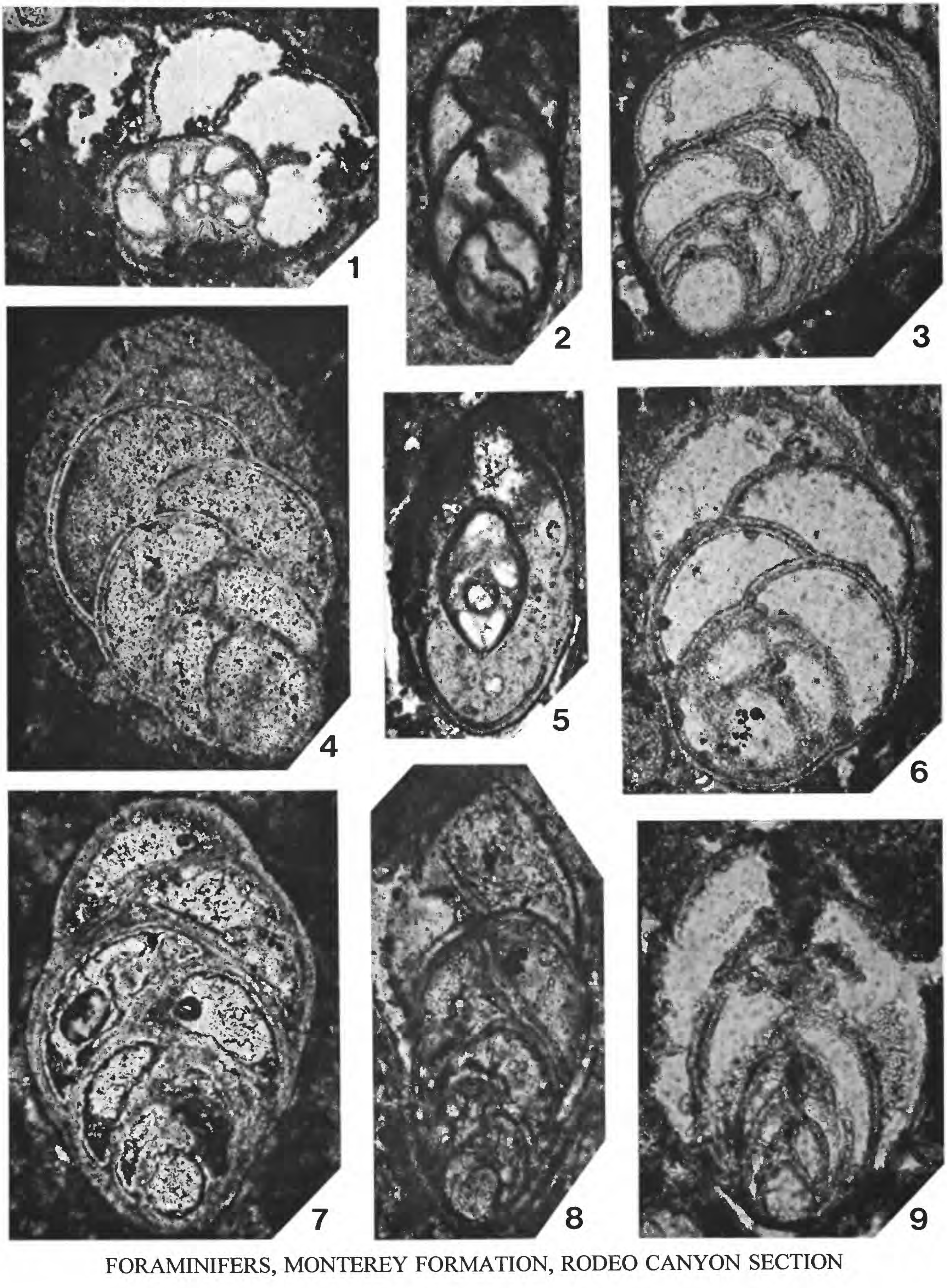
3,4. *Protoglobobulimina pseudotorta* (Cushman), ×128, CRC-40661-1, slide no. 1-7, parallel to bedding, and ×128, CRC-40661-1, slide no. 1-7, parallel to bedding, respectively.

5. *Islandiella modeloensis* (Rankin), ×80, CRC-40661-1, slide no. 1-7, parallel to bedding.

6,7. *Protoglobobulimina pseudotorta* (Cushman), ×128, CRC-40661-1, slide no. 1-6, parallel to bedding, and ×128, CRC-40661-1, slide no. 1-7, parallel to bedding, respectively.

8. *Buliminella subfusiformis* Cushman, ×320, CRC-40661-1, slide no. 1-6, parallel to bedding.

9. *Protoglobobulimina pseudotorta* (Cushman), ×200, CRC-40661-1, slide no. 1-7, parallel to bedding.



FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

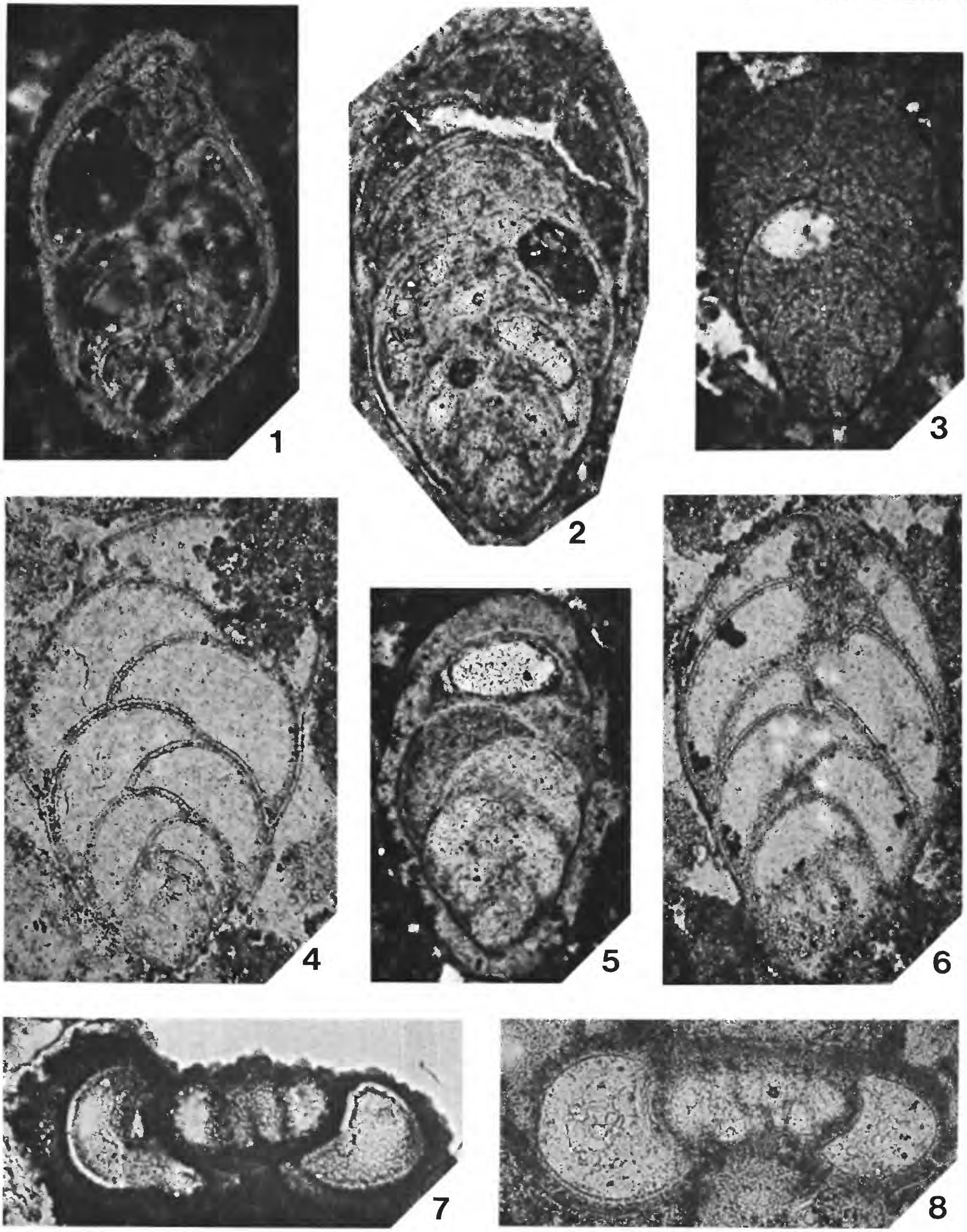
PLATE 46

Photomicrographs of foraminifers in petrographic thin sections, basal lower calcareous-siliceous member, Monterey Formation, Rodeo Canyon section.

Figure 1. *Buliminella subfusiformis* Cushman, ×320, CRC-40661-1, slide no. 1-7, parallel to bedding.

2-6. *Protoglobobulimina pseudotorta* (Kleinpell): **2**, ×128, CRC-40661-1, slide no. 1-7, parallel to bedding; **3**, ×128, CRC-40661-1, slide no. 1-7, parallel to bedding; **4**, ×128, CRC-40661-1, slide no. 1-5, parallel to bedding; **5**, ×80, CRC-40661-1, slide no. 1-7, parallel to bedding; **6**, ×128, CRC-40661-1, slide no. 1-5, parallel to bedding.

7,8. *Anomalinoides salinasensis* (Kleinpell), ×250, CRC-40661-1, slide no. 1-9, parallel to bedding, and ×200, CRC-40661-1, slide no. 1-9, parallel to bedding, respectively.



FORAMINIFERS, MONTEREY FORMATION, RODEO CANYON SECTION

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