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FORAMINIFERAL RESEARCH

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FOR FORAMINIFERAL RESEARCH  
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360. A STRATIGRAPHIC SEQUENCE OF BENTHONIC SMALLER  
FORAMINIFERA FROM THE LA BOCA FORMATION,  
PANAMA CANAL ZONE\*

GUSTAVO BLACUT<sup>1</sup> AND R. M. KLEINPELL<sup>2</sup>

INTRODUCTION

The siltstones, mudstones, and dark clay of the La Boca Formation, early middle Tertiary of the Panama Canal Zone, have long held more than ordinary interest for students of American middle Tertiary foraminifers. The type locality of *Siphogenerina transversa* Cushman is in the La Boca formation. Geographically widespread, this species occurs stratigraphically near the horizons of supposed boundary between the Oligocene and Miocene Series. It also appears to be ancestral to several other stratigraphically significant species of *Siphogenerina* in the Miocene of both the Atlantic Seaboard and the Pacific Coast Ranges farther north.

Originally recorded as in the Culebra Formation of the Canal Zone (Cushman 1918a, p. 41), the strata at the type locality of *S. transversa* have subsequently been assigned to the La Boca Formation. In turn the La Boca, once considered a marine member of the Panamá Formation (Woodring 1957, p. 41; Cole 1964, p. 140) has subsequently been given formation rank (Woodring 1964, p. 244). The locality in reference, U.S.G.S. no. 6010 (locality 130 of Woodring 1957, pl. 2, locality 9 of Cole *loc. cit.*) "in dark clay," is about one-half mile northwest of Pedro Miguel in the Panama Canal<sup>3</sup> (see text fig. 1). It was in the canal excavation. There are no natural exposures nearby, and nothing is known about the stratigraphic position of this locality 6010 within the La Boca Formation. At a locality about six miles northwest of Pedro Miguel, made available in 1965 as a result of widening of the Panama Canal in Gaillard Cut, *Siphogenerina transversa* was again found in abundance. Here, on the west side of Las Cascadas Reach, fresh exposures of the La Boca Formation yielded a sequence of foraminiferal assemblages from the base of the formation through a thickness of 250 feet (see text fig. 1 for the locality of this measured foraminiferal sequence). An additional thickness of 195 feet was sampled in cores from a nearby core hole. From a stratigraphic horizon about one hundred feet above the top of the Emperador Limestone Member of the La Boca

(see text fig. 2), and upward through some twenty feet of section, the La Boca is especially rich in *Siphogenerina transversa* and other species of smaller foraminifers. Benthonic foraminifers occur also below the Emperador Limestone Member, about fifteen feet above the contact between the La Boca and the underlying Las Cascadas Agglomerate, and also higher, about two hundred fifty feet above the base of the La Boca in outcrop. They are also well developed through almost another two hundred feet of beds stratigraphically still higher in the La Boca, in the samples from the core hole mentioned, drilled about a thousand feet west of the outcrops (see text fig. 2).

In 1965, a suite of nineteen foraminiferal samples from this La Boca sequence, collected by W. P. Woodring from the outcrops and provided from the cored subsurface sequence through the cooperation of R. H. Stewart of the Panama Canal Company, was sent to Gustavo Blacut in California for comparison with stratigraphic sequences bearing *Siphogenerina transversa* in the West Coast Ranges. At that time Blacut was working toward an M.A. degree at the University of California in Berkeley. By the summer of 1966 he was well along in his work on the La Boca foraminifers and had launched his field work in California when suddenly leukemia brought to a tragic close this young man's promising career.

Blacut's type specimens, faunal slides, and notes have been assembled by the junior author under whose guidance his academic program had been conducted. The type specimens have been illustrated by Mary Taylor and the illustrations (Plates 1-6) prepared for publication by Gordon Hornaday of the Museum of Paleontology at Berkeley. Although Blacut's work in the Coast Ranges had only begun, in view of the several published records of the Coast Range fossil faunas with which *Siphogenerina transversa* is associated there it has been possible to place his study of the Panama material within the context of these published Coast Range records and thus in part at least to put on record the substance of the study he was not granted time to complete.

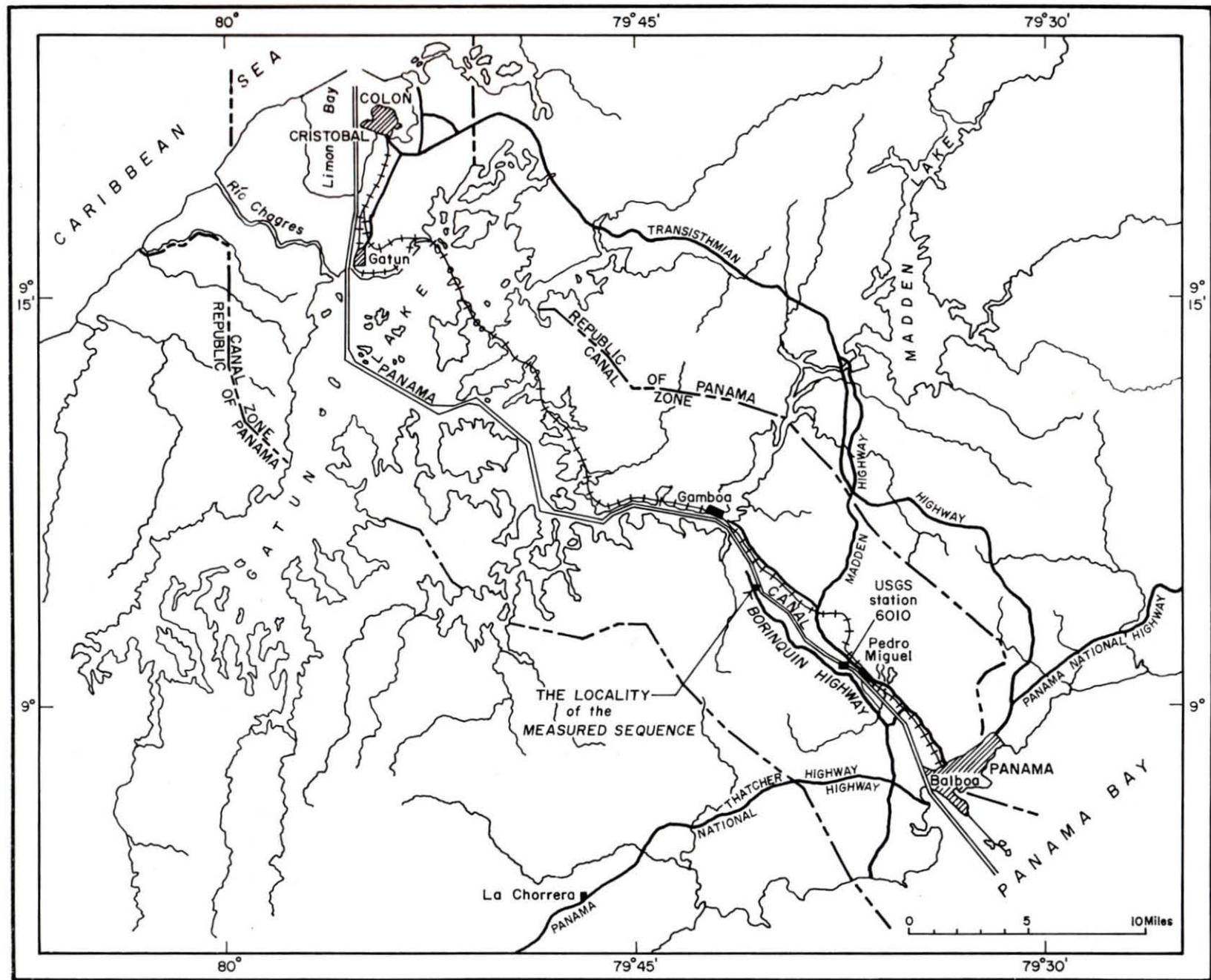
ACKNOWLEDGMENTS

Several people have in one way or another helped bring Blacut's work through to posthumous

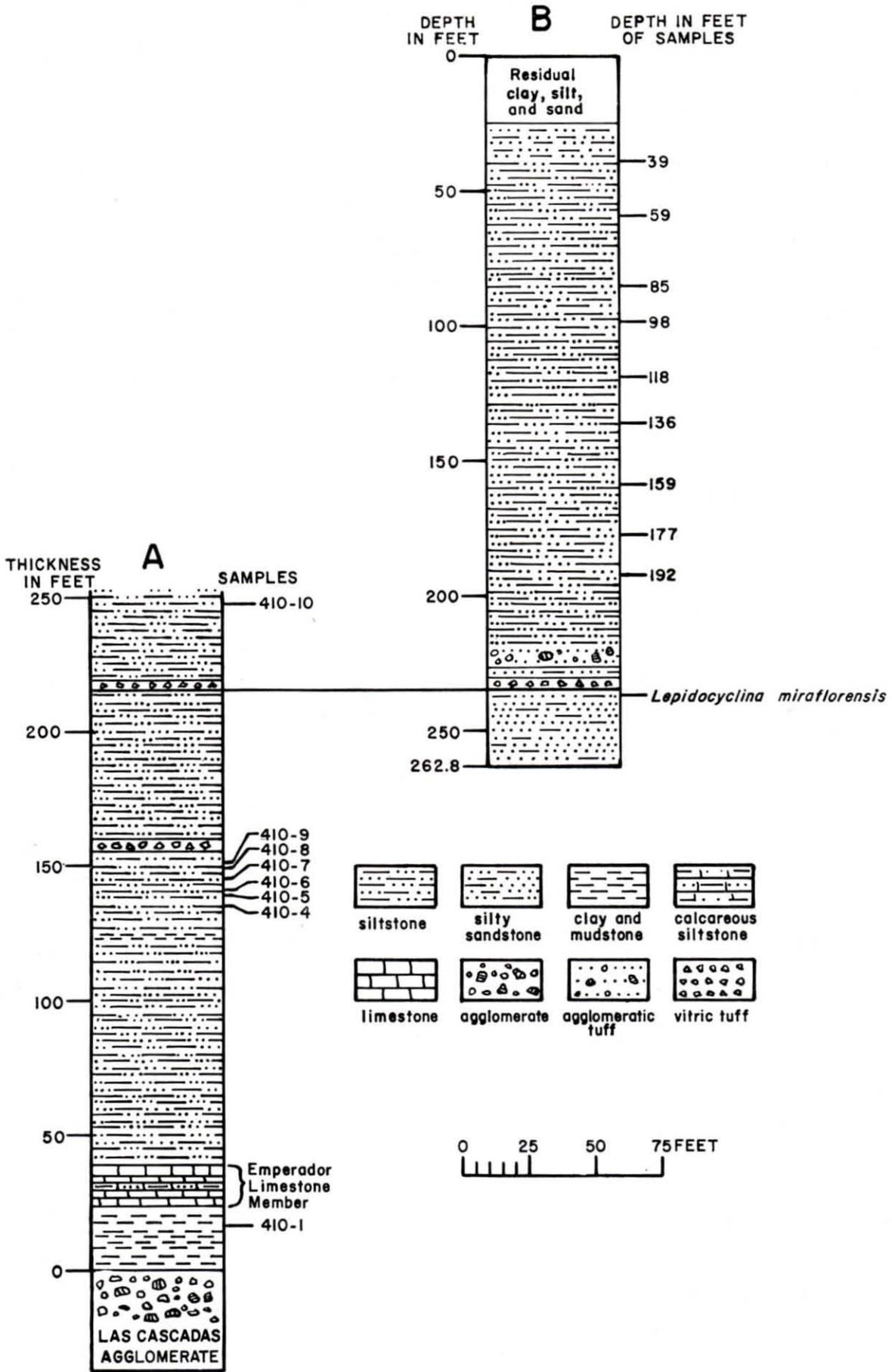
\* A contribution from the Museum of Paleontology, University of California, Berkeley.

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TEXT FIGURE 1. LOCALITY MAP



Sections of La Boca Formation on west side of Las Cascadas Reach, Panama Canal.  
 A. Outcrop section opposite Canal station 1622. Measured by W. P. Woodring.  
 B. Core hole LBW 149, 1,000 feet west of outcrop section. Logged by R.H. Stewart.

TEXT FIGURE 2. COLUMNAR SECTION

presentation. Thanks are especially due W. P. Woodring of the U. S. National Museum who collected the outcrop samples, contributed the field data from Panama, and provided the map and columnar sections; R. H. Stewart, through whose cooperation the core samples were made available; Miss Ruth Todd and K. Norman Sachs, Jr., of the U. S. Geological Survey, for pertinent commentary on more or less associated planktonic and larger foraminifera from the La Boca, respectively; Zach M. Arnold, editor for the Cushman Foundation; D. E. Savage, Gordon Hornaday and Mary Taylor, of the Museum of Paleontology, University of California, Berkeley; and the Museum of Paleontology for financial assistance.

### THE FORAMINIFERA

The smaller foraminifers and their distribution in the surface and subsurface sections of the La Boca Formation on the west side of Las Cascadas Reach, Panama Canal, are shown in text fig. 3. More than sixty species or varieties of benthonic foraminifers are present. In the core samples higher in the local section the assemblages become more meagre and specifically less diverse. Planktonic foraminifers are present in all the samples from above the Emperador Limestone but notably, throughout the section, these allochthonous planktonic populations are poorly preserved.

### PALEOECOLOGY

Some diversity in the habitat of the foraminifers at the time of deposition is reflected in the sequence of assemblages through the local La Boca section. The faunule in sample 410-1, from below the Emperador Limestone (see text fig. 2), is clearly indicative of life and deposition in shallow marine waters. Composed entirely of elphidiids, its constituent elements lived at littoral or sublittoral depths, and the absence of globigerinids—common throughout the balance of the column—emphasizes its current-protected, near-shore, shallow-water origins. By the time of the deposition of the beds bearing the assemblages in samples 410-4 through 410-10 apparently the local area had already foundered to depths beyond those characteristic of the continental shelf, though probably not much beyond those depths. As indicated morphotypically by most of the species common or abundant in all the samples from this stratigraphic interval, the ocean bottom then was probably at inner rather than outer bathyal depths. With cassidulinids numerous and in some samples even common, cool temperatures for these latitudes are indicated, though merely in keeping with such depths of one hundred fathoms or more. Apparently such depths, or nearly such depths, persisted through deposition of the beds bearing the faunule of core-sample 159, although a few elphidiids had returned to the area

—about here in the column—in small numbers. The balance of the higher La Boca beds bear foraminifers of small size for their respective species and faunules that are notable for their content of sharp-peripheried nonionids, finely costate uvigerinids, small robulids, cassidulinids and anomalinids, and some globigerinids. These higher La Boca faunules appear to be of more nearly shallow shelf-sea depositional origin, but lived in waters still connected at the surface with the open ocean.

Thus, except for its lowermost hundred feet or so of beds which were deposited in shallow water protected from open-ocean currents, the La Boca Formation on the west side of Las Cascadas Reach would appear to have been deposited under normal marine conditions at medium depths: for a time somewhat beyond the edge of the continental shelf but subsequently above those depths, on the shelf itself though still in waters connected with the open ocean.

### AGE AND CORRELATION

*Age of the La Boca Formation.* The La Boca Formation, like the Culebra, has in the past been considered to be of early Miocene age. Although the larger fossils from the La Boca and Culebra are said to represent two somewhat different biofacies of this time-stratigraphic interval, it is thought that they have essentially the same age significance. In 1957 Woodring wrote: "both have Oligocene and Miocene affinities. The La Boca member—and presumably the entire Panamá formation—is not much younger than the Culebra formation. Like the Culebra, it is considered early Miocene. The entire succession above the Las Cascadas agglomerate (Culebra, Cucaracha, and . . . [La Boca] formations) is thought to represent the early half of early Miocene time; that is, the disputed Oligocene or Miocene" (Woodring 1957, p. 42). Seven years later Woodring again wrote: "Though the strata, including the Emperador limestone-member, transferred to the La Boca Formation, are younger than formerly supposed, the difference in age is not great. It has already been pointed out (p. 42) that the La Boca is not much younger than the Culebra. Both are assigned to the early half of early Miocene time" (Woodring 1964, p. 244).

The larger foraminifers seem to tell much the same story as the mollusks. Based on the distribution of the American species of larger foraminifers, Cole (1964, p. 141) has subdivided the tropical American Mid-Tertiary into two major zones: (1) a lower or *Eulepidina* zone with two subzones, (a) a lowermost or *Lepidocyclina sensu strictu* subzone and (b) an upper *Miogypsina* subzone; and (2) an upper or *Lepidocyclina sensu stricto* - *Miogypsina* zone (see Fig. 4). On the basis of the occurrence

of *Miogypsina antillea* Cushman at the type locality of *Siphogenerina transversa*, the strata there have been assigned by Cole to his upper, or *Lepidocyclina s.s. - Miogypsina*, zone, highest of the American Mid-Tertiary larger foraminifer zones (Cole 1964, pp. 140-141, 146, pl. 13, Figs. 7, 10). Cole adds that this uppermost large-foraminifer zone "spans the interval included in the *Catapsydrax dissimilis*, *Catapsydrax stainforthi*, and *Globigerinatella insueta* planktonic zones. Similar zonal correlations were suggested by Woodring (1960, p. 27) and are in conformity with the data obtained in this study" (Cole 1964, p. 141).

The type locality of a lepidocycline orbitoid, *Lepidocyclina miraflorensis*, also occurs "(locality 132a)" in the La Boca marine member according to Woodring (1957, p. 41). It appears to be present in the La Boca core samples (see text fig. 2). Across the canal from the measured La Boca section and in a stratigraphic position corresponding to the upper part of the measured outcropping sequence, R. H. Stewart has collected numerous well-preserved specimens of orbitoids identified by K. Norman Sachs as *L. miraflorensis* (USGS 23658). From the *Lepidocyclina s.s. - Miogypsina* zone though elsewhere in tropical America Cole (*op. cit.*, pp. 145-148) records still another large foraminifer, *Miogypsina panamensis* (Cushman), the type locality of which is in the late Oligocene Caimito Formation; and he also records this species as from lower horizons as well (*viz.*, those of the *Miogypsina* subzone, highest of the two subzones of his *Eulepidina* zone, which is next below his *Lepidocyclina s.s. - Miogypsina* zone). However, neither of these two large-foraminifer species is included, at least as such, in his list of those long-range species which are also present in the *Lepidocyclina s.s. - Miogypsina* zone: "The only species of larger Foraminifera which seemingly is restricted to this zone is *Miogypsina antillea*. Species with longer stratigraphic ranges which occur in the *Lepidocyclina-Miogypsina* zone are: *Camerina panamensis* (Trinidad), *Lepidocyclina (Lepidocyclina) mantelli* (Trinidad), *L. (L.) canellei* (Trinidad, Jamaica, and Panama) and *L. (Eulepidina) yurnagunensis* (Panama)" (*op. cit.*, p. 146). Thus the *Lepidocyclina sensu stricto - Miogypsina* zone may also be referred to as the Teilzone (if not the Biozone) of *Miogypsina antillea*.

More direct evidence as to which part of the Teilzone of *Miogypsina antillea* (*i.e.*, the *Lepidocyclina s.s. - Miogypsina* zone) is represented at the type locality of *Siphogenerina transversa* in the La Boca Formation comes from some of the planktonic foraminifers occurring there. Among these are *Globigerinoides trilobus* (Reuss), *G. trilobus sacculifer* (Brady), *Globigerina dissimilis* Cushman and Bermudez, and *Globigerina (Globorotal-*

*oides) suteri* (Bolli). The two *Globigerinoides* are not known from horizons lower than the *Catapsydrax dissimilis* zone, and the two *Globigerina* are not known to range higher than this zone. On the basis of the joint occurrences therein of these species, the assemblage at this locality has been considered as falling within the *Catapsydrax dissimilis* zone, at the base of the Miocene (Ruth Todd, personal communication). Thus this La Boca locality (U.S.G.S. locality 6010) is apparently in the lowest of the three planktonic zones spanned by the Teilzone of *Miogypsina antillea* (see text fig. 4).

Further light is thrown on the age of the La Boca Formation, in terms of Caribbean planktonic foraminifer zones, by four other La Boca samples<sup>4</sup> examined by Miss Todd. The stratigraphic position of these samples in the La Boca is uncontrolled. They are rich in *Siphogenerina transversa*, with very abundant planktonic foraminifers. At least one of these samples apparently would fall in the upper part of the zone next lowest in the Caribbean column, the *Globorotalia kugleri* zone (uppermost zone of the Oligocene), though it is thought to be perhaps not quite so old as that of Bolli (refer to Woodring 1958, especially pp. 22-23) from the Caimito Formation on Barro Colorado Island, also assigned to that zone. It should be noted, furthermore, that Bolli has listed *Siphogenerina transversa* in the *kugleri* zone of the Caimito Formation of Barro Colorado Island. In any event the *kugleri* planktonic zone is apparently a little older than the lowest beds of the *Miogypsina antillea* Teilzone (see text fig. 4) and a little older than the beds at the type locality of *Siphogenerina transversa*.

*Age of the La Boca Benthonic Smaller Foraminifer Sequence.* Within the Caribbean area (*viz.*, the Tertiary Caribbean Province of Woodring 1966, p. 425, text fig. 1) the stratigraphic ranges of the benthonic foraminifer species represented in the La Boca of Las Cascadas Reach have not been known to either of the writers of the present paper. With a few exceptions, however, these La Boca foraminifer species are well known from the middle Tertiary of the West Coast Ranges farther north. If this La Boca sequence had been collected in California, Oregon, Washington or Alaska these strata would be assigned to the Saucian Stage, and those assemblages which are rich in *Siphogenerina transversa* (see Fig. 3) most probably to its lower Substage: *i.e.*, the *Siphogenerina transversa* Zone, with possibly, at the horizons of samples 410-9 to 177 at least, to the *Plectofrondicularia miocenica* Zone (see Fig. 4). In the rich siphogenerine population of sample 410-9 a few individuals appear to be at least as close to *Siphogenerina kleinPELLI* as to the parent *S. transversa* stock which is so abundantly represented here and also lower in the La Boca column. A comparable if more clearly defined evo-

LEGEND ■ Abundant ● Common ○ Few X Rare	U.C. Museum of Paleontology Locality Numbers		Samples										Depth in Feet, Core Hole LBW-149									
			410-1	- 4	- 5	- 6	- 7	- 8	- 9	- 10	192	177	159	136	118	98	85	84	59	39		
Stratigraphic feet above base of LaBoca Formation			15	135	139	141	145	149	153	245	254	269	287	295	310	328	348	361	362	387	407	
TEXTULARIA SAGITTULA DeFrance										X												
SIGMOILINA TENUIS (Czjzek)																					X	
ROBULUS cf. CLERICII (Fornasini)																						
ROBULUS PROTUBERANS (Cushman)				X																		
ROBULUS REEDI Kleinpell											X		X									
ROBULUS SIMPLEX (d'Orbigny)			X	X						X												
ROBULUS WARMANI Barbat and von Estorff					○				●	■		○	○	○				X	X	X	X	
MARGINULINA SUBBULLATA Hartken																						
VAGINULINOPSIS MEXICANA var. LABOCAENSIS n. var.									●													
VAGINULINOPSIS SAUNDERSI var. PANAMAENSIS n. var.					○																	
DENTALINA ADOLPHINA d'Orbigny				X	X						X									X		
DENTALINA aff. CUCARENSIS Cole					○																	
DENTALINA PAUPERATA d'Orbigny						?																
DENTALINA cf. RAPHINISTRUM (Linné)																						
NODOSARIA cf. ANOMALA Reuss																						
NODOSARIA cf. HOLSERICA Schwager																						
FRONDICULARIA aff. BULBOSA Coryell and Rivero																						
LAGENA spp.																					X	
GUTTULINA PROBLEMA d'Orbigny																						
GLANDULINA (?) SP.																						
NONION COSTIFERUM (Cushman)				X	X																○	
NONION INCISUM var. KERNENSIS Kleinpell							X															
NONION MEDIO-COSTATUM (Cushman)												○	●	●	○	X		X	X	X		
ELPHIDIUM CRATICULATUM (Fichtel and Moll)				○																		
ELPHIDIUM SAGRUM (d'Orbigny)				●							X											
ELPHIDIUM aff. E. SAGRUM (d'Orbigny)																						
ELPHIDIUM STRIATO-PUNCTATUM (Fichtel and Moll)				X	X																	
ELPHIDIUM SP. cf. E. TROPICALE Petri				○	X											X	X					
PECTOFRONDICULARIA MIOCENICA var. LAIMINGI Kleinpell																						
NODOGENERINA aff. COOPERENSIS Cushman																						
BULIMINELLA CURTA Cushman																						
BULIMINELLA SUBFUSIFORMIS Cushman																						
BULIMINA ALLIGATA Cushman and Laiming				○	○																	
VIRGULINA PONTONI Cushman																						
BOLIVINA ADVENA Cushman																						
BOLIVINA ADVENA var. STRIATELLA Cushman																						
BOLIVINA MARGINATA Cushman				○	○																	
BOLIVINA ROBUSTA H.B. Brady				○	X																	
UVIGERINELLA OBESA Cushman																						
UVIGERINELLA OBESA var. IMPOLITA Cushman and Laiming																						
UVIGERINA BECCARII Fornasini																						
UVIGERINA aff. CANARIENSIS d'Orbigny																						
UVIGERINA cf. TENUISTRATA Reuss																						
SIPHOGENERINA KLEINPELLI Cushman																						
SIPHOGENERINA MAYI Cushman and Parker																						
SIPHOGENERINA TRANSVERSA (Cushman)				○	○	●	●	●	■													
CASSIDULINA LAEVIGATA var. CARINATA Cushman				○	○																	
CASSIDULINA SUBGLOBOSA H.B. Brady				○	●																	
VALVULINERIA CASITASENSIS Cushman and Laiming																						
VALVULINERIA DEPRESSA Cushman																						
GYROIDINA SOLDANII d'Orbigny				X																		
EPONIDES aff. AFFINIS (Czjzek)																						
EPONIDES UMBONATUS (Reuss)																						
SIPHONINA cf. RETICULATA (Czjzek)				X	●	X	?															
EPISTOMINELLA (?) SPP.																						
AMPHISTEGINA LESSONII d'Orbigny																						
GLOBIGERINA BULLOIDES d'Orbigny				■	■	■	■	○														
GLOBIGERINA BULLOIDES d'Orbigny var.				■	■	■	■	○														
GLOBIGERINA CONGLOMERATA Schwager				●	●	●	●	○														
GLOBIGERINA cf. VENEZUELANA Hedberg				●	●	●	●	○														
ANOMALINA CALIFORNIENSIS Cushman and Hobson				X	X	X																
CIBICIDES AMERICANUS (Cushman)				●	●	●	●	○														
CIBICIDES AMERICANUS var. CRASSISEPTUS Cushman and Laiming				X	●																	
CIBICIDES CULEBRENSIS (Cushman)																						
CIBICIDES PSEUDOUNGERIANUS var. EVOLUTUS Cushman and Hobson				■	■	■	■	○														
CIBICIDES WUELLERSDORFI (Schwager)				X																		

TEXT FIGURE 3. CHECKLIST OF FORAMINIFERA



lution takes place, in the more northerly Coast Ranges, in the *P. miocenica* Zone and is in fact characteristic of that Zone. Also *Siphogenerina mayi*, present in the La Boca as high as sample 177, is in the Coast Ranges known from no higher than the *P. miocenica* Zone, upper Zone of the Lower Saucesian Substage. Assemblages from horizons stratigraphically above sample 177 in the La Boca would be zonally undiagnostic, although, with *Uvigerinella obesa impolita*, no younger than the *Uvigerinella obesa* Zone, Upper Saucesian of the West Coast Ranges at the youngest.

Thus an early Miocene age assignment of the La Boca benthonic smaller foraminifers is in keeping with the previous age assignments based upon other lines of evidence. The relative ages of West Coast Range mid-Tertiary Stages and Zones based on congregations of benthonic smaller foraminifers, and tropical American zones based on planktonic foraminifers have recently been summarized by Lipps (1967).<sup>5</sup> Such correlations (Lipps 1965; Lipps 1967, text figs. 2, 3, 4) are of interest in the bearing they may have on the age of the foraminiferal La Boca of Las Cascadas Reach as indicated by different kinds of paleontological evidence both in Panama and in California.

In terms of tropical American planktonic foraminiferal zones Lipps (1967, p. 994, text fig. 2) considers the Saucesian Stage in California to be equivalent in age to the sequence: upper *Globigerina ciperensis* zone—*Turborotalia kugleri* zone—lower *Catapsydrax dissimilis* zone (upper 3-4-lower 5 of Banner and Blow 1965).<sup>6</sup> However, some question as to the Stage boundaries in reference is raised by the ranges given (*loc. cit.*) for the two benthonic species Lipps has listed, *Uvigerinella sparsicostata* Cushman and Laiming and *Siphogenerina transversa* Cushman. The former, with its type locality within the type section of the Zone of that name in the upper Zemorrian Stage, is shown by Lipps as ranging upward into the Lower Saucesian in California. Now, a number of species originally thought to range no higher in California than upper Zemorrian were in 1963 noted (Kleinpell and Weaver 1963: I, pp. 39-40) as ranging instead upward into Lower Saucesian strata,<sup>7</sup> but *Uvigerinella sparsicostata* was not one of these species. Again, *Siphogenerina transversa* is shown by Lipps as ranging upward through the lower Relizian Stage in California, whereas it has been considered a diagnostic element in the congregations (see Berry 1964, p. 70; 1966) of the Zemorrian and Saucesian Stages. In the Coast Ranges, *S. transversa* makes its last stand in the Upper Saucesian (*Uvigerinella obesa* Zone) wherein it occurs with more than one upward-ranging descendant species (*S. kleinPELLi* Cushman, *S. branneri* [Bagg]) already jointly present in that Zone; and by the

time that *Siphogenerina hughesi* has evolved from *S. branneri*, at the horizon marking the base of the Relizian Stage, *S. transversa* has—to the best of the writers' knowledge—become extinct.

Presumably the basis for these extensions in range of *U. sparsicostata* and *S. transversa* in California will be forthcoming; for the present it is not clear whether they stem from phyletic and faunal evolutionary evidence under superpositional discipline or from so-called "stratotypical" evidence.<sup>8</sup> However this may turn out to be, chiefly concerned here would be age discrepancies perhaps of a nominalistic nature, and even these of minor magnitude. Affected, nevertheless, would be the position of the bottom and top horizons of the California Saucesian Stage in terms of the tropical planktonic zones as shown by Lipps. Thus, employing congregations originally diagnostic of the Saucesian Stage as distinguished from the subjacent Zemorrian and Superjacent Relizian Stages, *i.e.*, excluding *U. sparsicostata* from the Saucesian Stage and excluding *S. transversa* from the Relizian Stage in California, but otherwise still following Lipps in his correlations of planktonic zones with the "tops" (highest known occurrences) of these benthonic species in California, then: (1) top of *Siphogenerina transversa* Teilzone = top of Saucesian Stage = top of *Globorotaloides stainforthi* zone, yielding a discrepancy of "one and a half planktonic zones" (see Fig. 4); and (2) top of *Uvigerinella sparsicostata* Teilzone = base of Saucesian Stage = base of *Turborotalia kugleri* zone, yielding a discrepancy of at least "a half of a planktonic zone" (see text fig. 4). Moreover, if the *kugleri* zone is upper Oligocene, it would then still be separated by three intervening planktonic zones from the Oligocene *Globigerina oligocaenica* zone (= *G. selli* zone) of Eames *et al* (1962), which has been correlated by Lipps with the Upper Zemorrian *Uvigerinella sparsicostata* Zone at the type locality of this Zone in the upper part of the Lower Member of the type Rincon shale of Los Sauces Creek, Ventura County, California (see Lipps, 1965). Here the discrepancies become formidable, and especially so in view of the correlation by Eames *et al* (1962, p. 35, and charts), of the Relizian Stage of California with the *Globigerina ciperensis ciperensis* Zone (compare Fig. 4).<sup>9</sup> Since however, from the evidence of the benthonic foraminifers neither top nor bottom of the Saucesian Stage is discernible in the La Boca foraminiferal sequence under study, the effect of all these discrepancies upon the correlations indicated would remain at least intangible if not actually negligible, however interesting and significant may be their eventual resolution in general.<sup>10</sup> Unless certain California species with tropical and Caribbean affinities persisted in the Caribbean Province long after they had disappeared from the

West Coast Ranges, the interrelationships in time of the benthonic and planktonic Zones in the Coast Ranges are at least not greatly at variance with the interrelationships in time of these two kinds of Zones as represented in the La Boca foraminiferal sequence of Las Cascadas Reach in the Panama Canal Zone. Employing the West Coast Range benthonic Zones and Stages and their diagnostic congregations as a common standard of reference, the alternative foraminiferal correlations discussed above are graphically summarized in text fig. 4.

*Faunal Affinities and Miocene Zoogeography.* In these comparisons of zonation based upon benthonic and planktonic foraminifers (and larger fossils as well) it seems of especial interest and significance to note that over and above the discrepancies that may prove merely semantical, the timelines based on evolution in different phyletic stocks, faunal dominants, and faunas do not always correspond, (see Lipps *op. cit.*, text fig. 2), even in the same areas—not to mention in zoogeographically distinct faunal provinces. Since geological changes in environment do not affect all organismal lineages equally, and since, in terms of natural selection, organic evolution and adaptive radiation take place laterally through space as well as vertically through time, discrepancies in geologic time-unit boundaries such as here summarized would appear to be quite in keeping with the principles of chorology as currently understood. Thus, to cite another kind of example, during the Saucian Age in the West Coast Ranges, inshore faunas of the Astoria molluscan Subprovince—with scallops of the "*Pecten*" *protatulus* gens and extending as far to the southeast as the Vallecitos in California—differ from the faunas of the more southwesterly Temblor Subprovince with their turritellids, cones, lyropectens, etc., much more notably than do the offshore benthonic foraminifer faunas in these same two areas. During the Saucian Age, and apparently during the Relizian Age also (though not during subsequent Luisian time), these two West Coast Range areas seem to fall in essentially the same offshore benthonic faunal Subprovince while their inshore marine molluscan faunas differ at least subprovincially.

Of further interest in connection with such problems of zoogeographic facies (Kleinpell and Weaver, 1963; Weaver and Kleinpell, 1963) is the high degree of similarity in the benthonic smaller foraminifer faunas of the La Boca Formation of Panama and those of the Rincon Shale, Temblor, Nye Shale, Astoria, Clallam, and upper Poule Creek Formations of California, Oregon, Washington, and Alaska (Cushman and Laiming, 1931; Packard and Kellogg, 1934; Kleinpell, 1938; Cushman, Stewart and Stewart, 1947; Rau, 1951, 1958, 1963, 1966, 1967). Latitudinal ecologic facies may be enough to account for the absence—or at least the scarcity

as suggested by the records to date—of tropical La Boca elements such as *Amphistegina*, *Siphonina*, *Vaginulinopsis*, and the orbitoids from the West Coast Ranges. Most of the La Boca species, however, are also present in the Coast Ranges to the north at this time. If the correlations are as indicated (text fig. 4) these two distant areas would appear to have been within the same offshore benthonic foraminiferal Province (see Woodring 1966, p. 425, especially the question mark in Fig. 1).

The Caribbean affinities of West Coast Range Eocene, Oligo-Miocene, and Miocene marine invertebrate faunas generally have long been known (Smith 1919). *Turritella inezana* and *T. oayana*, to mention only two conspicuous examples, represent in the Coast Ranges invading stocks in two separate faunas involved in an earlier (Oligo-Miocene) and a later (early Miocene) invasion there from the Caribbean. Again, if the benthonic foraminiferal correlations between Panama and California are as indicated, then this time—Saucian—of close faunal connection between Panama and the West Coast Ranges was that which immediately preceded the notable provincialization of California's mid-Miocene benthonic foraminifer faunas. This provincialization, and the associated endemic evolution so conspicuous there especially among the siphogenerinids and valvulinids of the Relizian and Luisian Stages, began during latest Saucian time; and in turn this early and mid-Miocene provincialization in California seems to follow in the wake of that extensive volcanism, block-faulting and breccia-deposition that is associated in time (mid-*Uvigerinella obesa* Zone, Upper Saucian) with what Dibblee (1950) has termed the Lompocan Orogeny and which was eventually followed, in the West Coast Ranges, by the extensive marine transgressions of Relizian time.

#### NOTES

1-2. Footnotes, p. 1.

3. "Near Canal station 1910, northwest of Pedro Miguel Locks [About 600 meters northwest of north end of Pedro Miguel Locks]. Mudstone. D. F. MacDonald and T. W. Vaughn 1911 (MacDonald, 1919, p. 534, pl. 154)" (see Woodring 1957, p. 124; Cole *loc. cit.*).

4. BBR 37-1. Balboa Bridge core hole BBR 371, near Pacific entrance of Canal, Canal Zone, depth 57-59 feet, drilled 1958, sampled Nov. 1959. BBR 133. Balboa Bridge core hole BBR 133, near Pacific entrance of Canal, Canal Zone, depth 60-61 feet. Drilled 1958, sampled Nov. 1959.

NGB 1. Gorgas Hospital core hole NGB 1, Gorgas Hospital, Ancon, Canal Zone, depth 64.7-66.3 feet. Drilled 1958, sampled Nov. 1959.

ERW 29. Empire Reach core hole ERW 29, Panama Canal, Gaillard Cut, west bank of Empire

Reach, former site of Town of Culebra, depth 121-122 feet. Drilled Sept. 1959, sampled Dec. 1959.

5. Lipps (*op. cit.*) has also related these Stages and Zones, through planktonic foraminifer content, to the type sections of the Stages of the European Mid-Tertiary based originally on fossil larger invertebrates.

6. These are apparently the *Globigerina ciperoensis ciperoensis*, *Globorotalia kugleri*, and *Catapsydrax dissimilis* zones, respectively, of Bolli 1957.

7. Much as, among mollusks, *Turritella inezana* does in relation to the range of *Turritella ocoyana* which, in terms of foraminiferal zonation, appears in the Coast Ranges at the base of the Saucian Stage. See the "Vaqueros - Temblor Transition Zone" of Loel and Corey (1932) in which these two species of *Turritella* occur together.

8. In this connection it is also of significance to note—though less directly so here—that the stratigraphically interrelated benthonic and planktonic foraminifers referred to the Refugian Stage by Lipps (1967, p. 996: "near the top of the Refugian" and "uppermost Refugian") are actually older than as shown. UC localities B-6914 and B-6916 are "upper Gaviota Formation" in stratigraphic occurrence but B-6914 is clearly "lower Refugian" in age, i.e., *Uvigerina cocoaensis* Zone; and B-6916, with a very meagre though otherwise similar assemblage, is zonally less diagnostic. Though ambiguously shown otherwise in those accompanying graphics (*op. cit.*, Figs. 5, 8) in which the informal time terminology is based at least in part on mollusks, the *Uvigerina cocoaensis* Zone age of these foraminiferal assemblages is indicated and discussed (Kleinpell and Weaver 1963:I on pages 31-33), including the tentative nature of the Refugian zonation and the conclusion that in the type Refugian area the age equivalents of the *Uvigerina vicksburgensis* zone, upper Refugian, were the mollusk-bearing shallow-water deposits of the lower 200 feet of the Alegria Formation (*op. cit.*, p. 33, see also Fig. 2). Correlation of the upper Refugian mollusk zone or subzone with the upper Refugian foraminifera of the *Uvigerina vicksburgensis* Zone (though not necessarily the coincidence of their respective limits) hinged on the joint occurrence of the age-diagnostic mollusks and foraminifers in the "Leda" Zone, upper Member of the Tumey Formation of the San Joaquin Valley as recorded by Cushman and Simonson (1944), which was therefore tentatively taken to typify an upper Refugian *Uvigerina vicksburgensis* Zone (Kleinpell and Weaver 1963:I, pp. 32-33; see also Schenck and Kleinpell 1936). To the best of the writers' knowledge no upper Refugian foraminifers have as yet been found in the outcrops at the type locality of the Refugian Stage, although foraminifer assem-

blages characteristic of the *Uvigerina vicksburgensis* Zone have been found elsewhere in the Santa Barbara Embayment (D. E. Weaver, personal communication). Thus, these benthonic foraminifer data from the Upper Gaviota Formation, of lower Refugian and late Eocene age (*op. cit.*, Fig. 2), are, as evidence, seemingly in keeping with the evidence from the planktonic foraminifers (Lipps 1967, p. 996) also found there.

9. More recently Bramlette and Wilcoxon (1967, table 2) have, on the basis of calcareous nannoplankton, correlated the benthonic foraminiferal Saucian-Relizian sequence of California with the planktonic foraminiferal upper *Catapsydrax dissimilis* zone—*Catapsydrax stainforthi* zone—*Globigerinatella insueta* zone sequence of the Caribbean.

10. In interrelating benthonic and planktonic zones in the middle Tertiary of the West Coast Ranges, a tendency currently notable is to find, in usage, "Relizian" planktonic assemblages "spilling over" somewhat into both underlying Saucian and overlying Luisian intervals as these are determined on the basis of benthonic foraminifers. Whether this is due to unrecognized homotaxial and ecologic factors, to evolutionary realities, or simply to needed extensions of species ranges still unrecognized, is as yet far from clear. Any of all three of these factors could seemingly be involved. Since the Relizian was a time of one of the most extensive marine transgressions in the middle Tertiary of the West Coast Ranges, a comparable situation encountered in the Coast Range late Paleocene - early Eocene, as summarized by Sullivan (1965, pp. 27-29), and involving nannoplankton, is of interest and might be more than simply analogous. The sudden and extensive spreading of a previously established planktonic community, locally at any one of three or four zonal intervals distinct though closely spaced in geologic time, is also characteristic of the early Miocene "Beboeloe Transgression" in the East Indies, including the Philippines.

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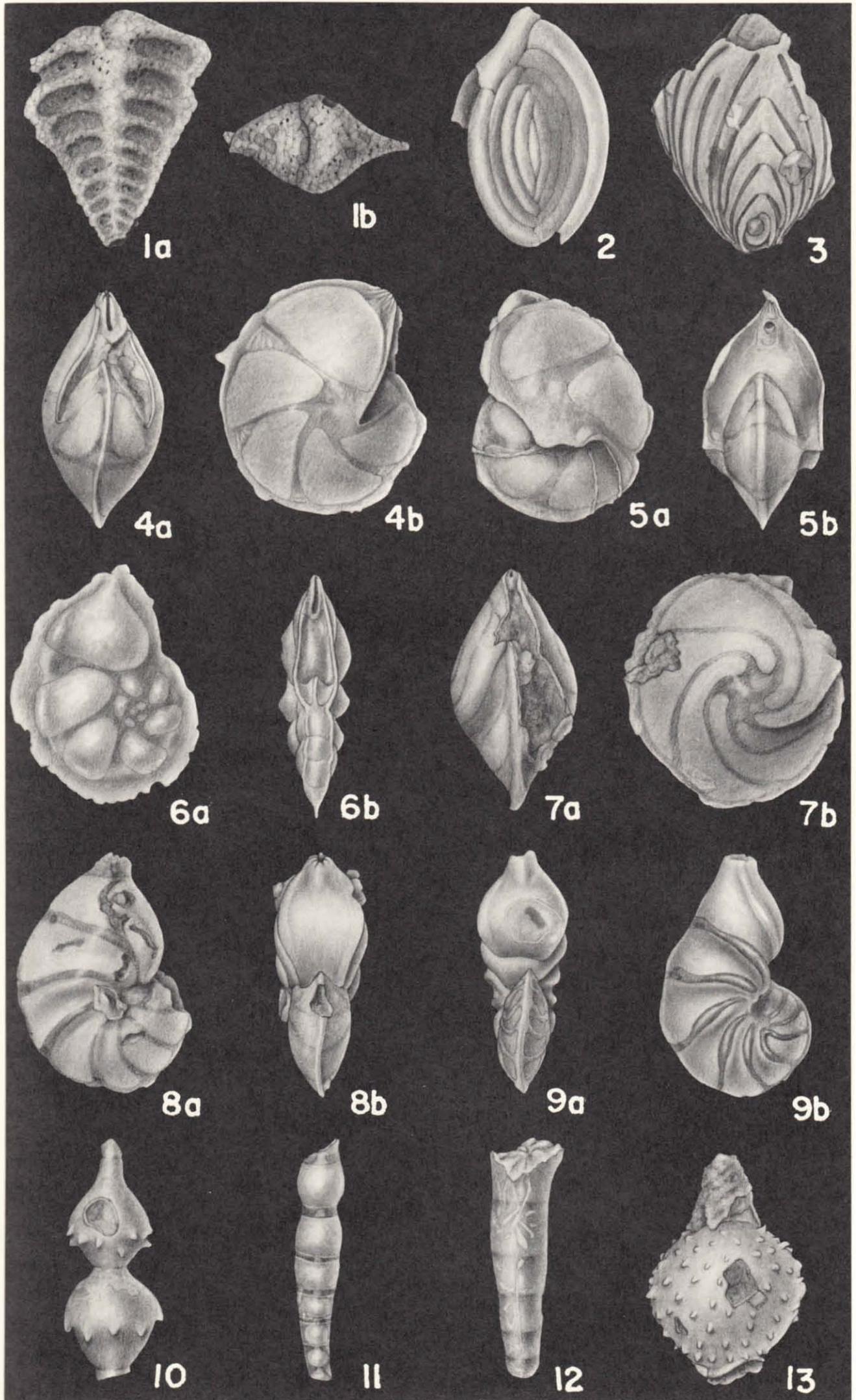
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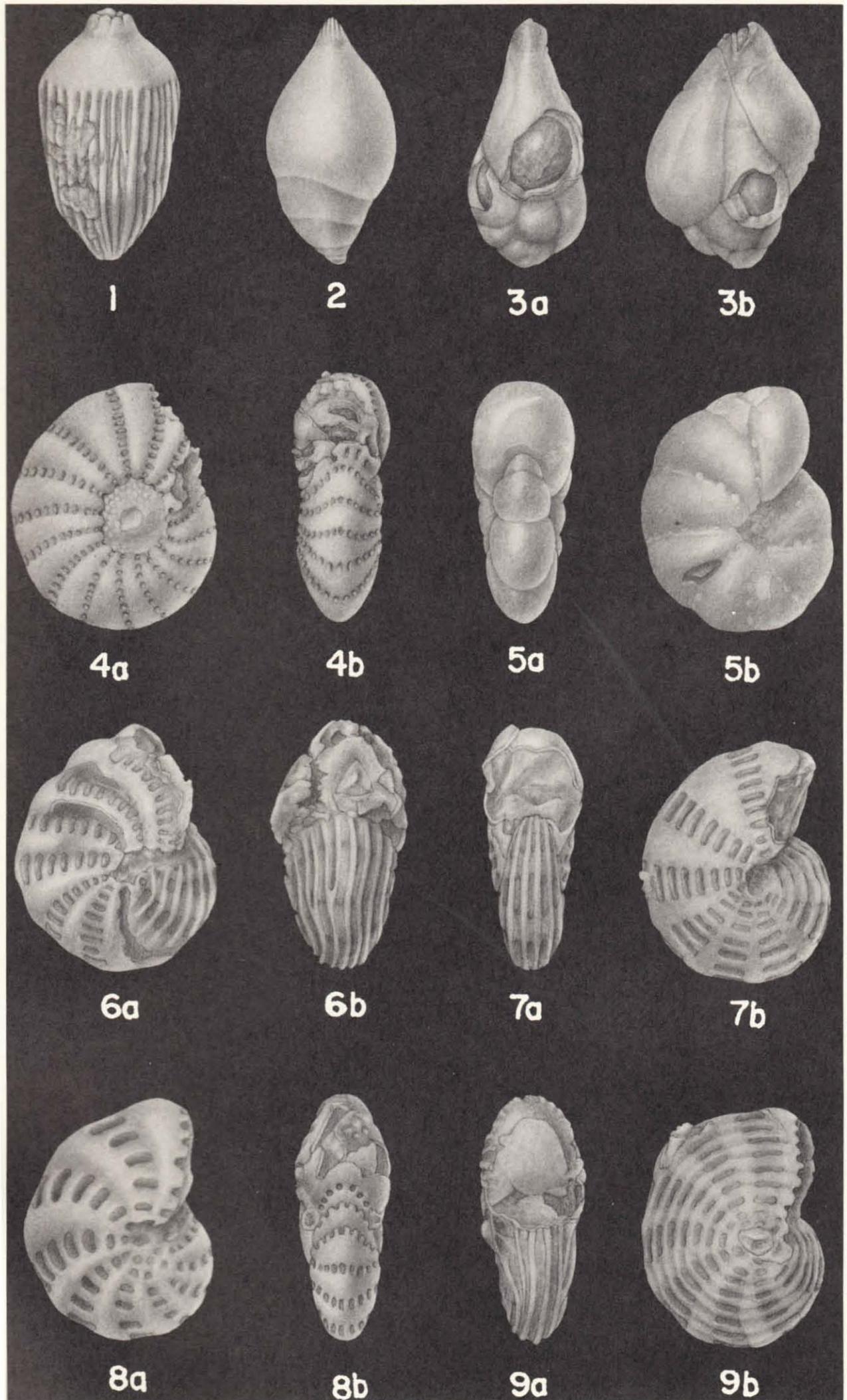
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## EXPLANATION OF PLATE 1

FIGS.	SPECIES	TYPE No.	MAG.	LOC. No.	PAGE
1a, b.	<i>Textularia sagittula</i> DeFrance	46401	50×	D-1605	13
2.	<i>Sigmoilina tenuis</i> (Czjzek)	46402	75×	D-1605	13
3.	<i>Frondicularia</i> aff. <i>bulbosa</i> Coryell and Rivero	46415	50×	D-1608	15
4a, b.	<i>Robulus warmani</i> Barbat and von Estorff	46408	50×	D-1604	14
5a, b.	<i>Robulus warmani</i> Barbat and von Estorff	46407	59×	D-1604	14
6a, b.	<i>Robulus protuberans</i> (Cushman)	46404	63×	D-1604	14
7a, b.	<i>Robulus</i> cf. <i>clericii</i> (Fornasini)	46403	63×	D-1604	14
8a, b.	<i>Vaginulinopsis mexicana</i> var. <i>labocaensis</i> Blacut and Kleinpell	46410	39×	D-1604	14
9a, b.	<i>Vaginulinopsis saundersi</i> var. <i>panamaensis</i> Blacut and Kleinpell	46411	36×	D-1604	14
10.	<i>Dentalina adolphina</i> d'Orbigny	46412	83×	D-1606	14
11.	<i>Dentalina</i> aff. <i>cucarensis</i> Cole	46413	28×	D-1604	14
12.	<i>Dentalina pauperata</i> d'Orbigny	46414	29×	D-1604	15
13.	<i>Nodosaria</i> cf. <i>holserica</i> Schwager	46472	77×	D-1604	15



Blacut and Kleinpell: Panama Canal Zone Foraminifera



Blacut and Kleinpell: Panama Canal Zone Foraminifera

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## SYSTEMATICS

In the following systematics the scheme of phyletic classification followed has been essentially that of Cushman (1948), modified. No approach to a complete synonymy has been attempted, although much additional synonymy and related data will be found upon pursuit of the references cited. Clearly many of the species in the sequence from the west side of Las Cascadas Reach are those already recorded from the type locality of *Siphogenerina transversa* and other localities in the Canal Zone by Cushman (1918). But the emphasis here has been upon a comparison of the benthonic foraminifers from the La Boca sequence with published California Coast Range benthonic materials, beyond which the studies here reported upon did not attain.

The type specimens, listed by number, have been deposited in the paleontological collections of the University of California Museum of Paleontology, Berkeley, California. All type and U.C. locality numbers refer to the above collections.

## Family TEXTULARIIDAE

Genus *Textularia* DeFrance, 1824*Textularia sagittula* DeFrance

Plate 1, figures 1a, b

*Textularia sagittula* DeFrance, CUSHMAN, 1918, p. 51, pl. 19, figs. 2a, b.

Hypotype 46401, locality D-1605.

Early stages in the rare specimens of this form are too poorly preserved to determine whether or not it should be referred to the genus *Spiroplectamina*. It appears to be the same species Cushman assigned to *Textularia*.

## Family MILIOLIDAE

Genus *Sigmoilina* Schlumberger, 1887*Sigmoilina tenuis* (Czjzek)

Plate 1, figure 2

*Sigmoilina tenuis* (Czjzek), CUSHMAN, 1918, p. 81, pl. 31, figs. 4a-c.

Hypotype 46402, locality D-1605.

## EXPLANATION OF PLATE 2

FIGS.	SPECIES	TYPE NO.	MAG.	LOC. NO.	PAGE
1.	<i>Glandulina</i> (?) sp.	46417	63×	D-1604	15
2.	<i>Marginulina subbullata</i> Hantken	46409	53×	D-1605	14
3a, b.	<i>Guttulina problema</i> d'Orbigny	46416	50×	D-1604	15
4a, b.	<i>Elphidium craticulatum</i> (Fichtel and Moll)	46422	67×	D-1598	16
5a, b.	<i>Elphidium striato-punctatum</i> (Fichtel and Moll)	46426	143×	D-1598	16
6a, b.	<i>Elphidium sagrum</i> d'Orbigny	46423	71×	D-1598	16
7a, b.	<i>Elphidium</i> aff. <i>E. sagrum</i> (d'Orbigny)	46424	91×	D-1598	16
8a, b.	<i>Elphidium</i> cf. <i>E. tropicale</i> Petri	46444	111×	D-1611	16
9a, b.	<i>Elphidium</i> aff. <i>E. sagrum</i> (d'Orbigny)	46425	84×	D-1598	16

## Family LAGENIDAE

Genus *Robulus* Montfort, 1808*Robulus* cf. *clericii* (Fornasini)

Plate 1, figures 7a, b

*Robulus* cf. *clericii* (Fornasini), KLEINPELL, 1938, p. 197.

Hypotype 46403, locality D-1604.

Cushman and Hobson (1935, p. 56, pl. 8, figs. 7a, b) have compared a specifically unidentified form from the upper type San Lorenzo Formation (Lower Zemorrian) of California to Fornasini's species. The same species, recorded from the "Vaqueros" (Temblor) formation of the Sunset Valley district, southern San Joaquin Valley, California, is from beds of Lower Saucesian age (Kleinpell 1938, p. 197 and Table XII; see also Kleinpell and Weaver, 1963, pp. 39-40).

*Robulus protuberans* (Cushman)

Plate 1, figures 6a, b

*Cristellaria protuberans* CUSHMAN, 1918, p. 61, pl. 22, fig. 2.

Hypotype 46404, locality D-1604.

Genus *Marginulina* d'Orbigny, 1826*Robulus reedi* Kleinpell*Robulus reedi* KLEINPELL, 1938, p. 201, pl. 7, figs. 23a, b; pl. 8, fig. 5.

Hypotype 46405, locality D-1608.

Rare specimens from the La Boca are very close to this species from the West Coast Range upper Saucesian and Relizian Stages.

*Robulus simplex* (d'Orbigny)*Robulus simplex* (d'Orbigny), CUSHMAN and LAI-MING, 1931, p. 98, pl. 10, figs. 5a, b; 6. KLEINPELL, 1938, p. 202, pl. 8, fig. 1.

Hypotype 46406, locality D-1600.

In the West Coast Ranges this large species ranges from the upper Zemorrian into the Relizian Stage.

*Robulus warmani* Barbat and von Estorff

Plate 1, figures 4a, b; 5a, b

*Robulus nikobarensis* (Schwager) var. *warmani* BARBAT and VON ESTORFF, 1933, p. 168, pl. 23, figs. 12a, b.*Robulus warmani* Barbat and von Estorff, CUSHMAN and HOBSON, 1935, vol. 11, no. 3, p. 56, pl. 8, figs. 8a, b. ?KLEINPELL, 1938, p. 204, pl. 8, fig. 2.

Hypotypes 46407, 46408, locality D-1604.

These somewhat variable robulids from Panama appear to be conspecific with a comparably variable group from the Zemorrian and Saucesian Stages of the Coast Ranges.

Genus *Marginulina* d'Orbigny, 1826*Marginulina subbullata* Hantken

Plate 2, figure 2

*Marginulina subbullata* Hantken, CUSHMAN and LAI-MING, 1931, p. 99, pl. 10, fig. 8. MALLORY, 1959, p. 151, pl. 9, figs. 13a, b, 14a, b, 15a, b. Hypotype 46409, locality D-1605.

In its West Coast Range occurrences this species ranges from the Ynezian (Paleocene) to the Saucesian Stage.

Genus *Vaginulinopsis* Silvestri, 1904*Vaginulinopsis mexicana* (Cushman) var.*labocaensis* Blacut and Kleinpell n. var.

Plate 1, figures 8a, b

Variety differing from the typical in the reduction of the costae to barely raised areas adjacent to the limbate sutures, and a markedly more compressed test. The mature specimens also are in general somewhat smaller than the Eocene varieties of the species.

Holotype 46410, locality D-1604.

This variety seems closest to the varieties *vacavillensis* (Hanna) and *nudicostata* (Cushman and Hanna) from the California Eocene (see Mallory 1959, p. 157), though with a smaller and more compressed test and the ribbing greatly reduced.

*Vaginulinopsis saundersi* (Hanna and Hanna)var. *panamaensis* Blacut and Kleinpell n. var.

Plate 1, figure 9a, b

Variety differing from the typical in its narrower later stages, which become more loosely coiled and the chambers of which tend to flare more.

Holotype 46411, locality D-1605.

Although the mature specimens from Panama are somewhat smaller than those from the Washington and California Eocene the early stages of both are indistinguishable (see Hanna and Hanna 1924, p. 61, pl. 13, figs. 5, 6, 15; Beck 1943, p. 598, pl. 105, figs. 1, 2, 4, 5, 10; Mallory 1959, pp. 157-158, pl. 11, fig. 10a, b).

Genus *Dentalina* d'Orbigny, 1826*Dentalina adolphina* d'Orbigny

Plate 1, figure 10

*Dentalina adolphina* d'Orbigny, KLEINPELL, 1938, p. 209, pl. 4, fig. 1.

Hypotype 46412, locality D-1606.

The La Boca forms, though all of them incomplete, appear to be conspecific with those recorded from Zemorrian and Lower Saucesian horizons in the West Coast Ranges (see also Kleinpell and Weaver 1963, pp. 39-40).

*Dentalina* aff. *cucarensis* Cole

Plate 1, figure 11

*?Dentalina cucarensis* COLE, 1927, p. 14, pl. 3, fig. 14.

Hypotype 46413, locality D-1604.

The sutures of the Panamanian species are more clearly limbate than are those shown in the figure of Cole's otherwise very similar Mexican species.

*Dentalina pauperata* d'Orbigny

Plate 1, figure 12

*Dentalina pauperata* d'Orbigny, CUSHMAN and LAI-MING, 1931, p. 99, figs. 11, 12.

Hypotype 46414, locality D-1604.

This species is common in the late Oligocene and Miocene of the West Coast Ranges.

*Dentalina* cf. *raphanistrum* (Linné)

?*Dentalina raphanistrum* (Linnaeus), CUSHMAN, 1918, pp. 59-60, pl. 21, fig. 10.

Hypotype 46481, locality D-1605.

Fragments of a striate *Dentalina* probably represent broken specimens of the species Cushman previously recorded from the Canal Zone.

Genus *Nodosaria* Lamarck, 1812

*Nodosaria* cf. *anomala* Reuss

*Nodosaria* cf. *anomala* Reuss, CUSHMAN and LAI-MING, 1931, p. 100, pl. 10, fig. 10.

?*Nodosaria anomala* Reuss, KLEINPELL, 1938, p. 216.

Hypotype 46482, locality D-1605.

Incomplete specimens appear to be the same as those found in the Vaqueros, Rincon, and Temblor formations of the West Coast Ranges.

*Nodosaria* cf. *holserica* Schwager

Plate 1, figure 13

Fragments of a faintly hispid *Nodosaria* appear to be the same as West Coast Range Oligo-Miocene forms referred to Schwager's species or simply recorded as "*Nodosaria*(?) sp." (Kleinpell 1938, pp. 218, 220, pl. 4, figs. 8, 9).

Hypotype 46472, locality D-1604.

Genus *Frondicularia* DeFrance, 1826

*Frondicularia* aff. *bulbosa* Coryell and Rivero

Plate 1, figure 3

Hypotype 46415, locality D-1604.

Rare specimens seem closest to *F. bulbosa* from the Miocene of Haiti (Coryell and Rivero 1940), though the proloculus is not so excessively raised above the surface of the test.

Genus *Lagena* Walker and Jacob, 1798

*Lagena* spp.

Hypotypes 46483, 46484, localities D-1605, D-1614.

More than one species of *Lagena* are very sparingly represented in the La Boca material. *Lagena striata* (d'Orbigny) var. *strumosa* Reuss has been

recorded from elsewhere in the La Boca by Cushman (1918, p. 58, pl. 21, fig. 7).

Family POLYMORPHINIDAE

Genus *Guttulina* d'Orbigny, 1839

*Guttulina problema* d'Orbigny

Plate 2, figures 3a, b

*Guttulina byramensis* (Cushman), CUSHMAN and SCHENCK, 1928, pl. 309, pl. 43, figs. 6-8.

*Guttulina problema* d'Orbigny, CUSHMAN and SCHENCK, 1928, p. 310, pl. 43, figs. 9-11. H. P. SMITH, 1956, p. 92, pl. 11, fig. 10a, b.

*Guttulina irregularis* (d'Orbigny) CUSHMAN and SIMONSON, 1944, p. 196, pl. 31, figs. 10-12. WILSON, 1954, p. 137, pl. 15, fig. 4a, b.

*Guttulina* sp. WILSON, 1954, p. 137, pl. 15, fig. 5a, b.

Hypotype 46416, locality D-1604.

This variable species is common in the upper Eocene and Oligocene of the West Coast Ranges.

Genus *Glandulina* d'Orbigny, 1826

*Glandulina* (?) sp.

Plate 2, figure 1

Hypotype 46417, locality D-1604.

A few specimens of a striate lagenid, apparently a *Glandulina*, are present in a single sample. The best preserved specimen is figured.

Family NONIONIDAE

Genus *Nonion* Montfort, 1808

*Nonion costiferum* (Cushman)

Plate 3, figures 2a, b; 3a, b

*Nonionina costifera* CUSHMAN, 1925c, p. 90, pl. 13, figs. 2a-c; 1926, p. 65.

*Nonion costifera* (Cushman), CUSHMAN and LAI-MING, 1931, p. 104, pl. 11, figs. 9a, b.

*Nonion costiferum* (Cushman), KLEINPELL, 1938, pp. 229-231, pl. 15, figs. 13a, b.

Hypotypes 46419, 46420, locality D-1604.

In the Coast Ranges this species ranges from the base of the Saucian to the top of the Luisian Stage.

*Nonion incisum* (Cushman) var.

*kernensis* Kleinpell

Plate 3, figures 1a, b

*Nonion incisum* (Cushman), CUSHMAN and LAI-MING, 1931, p. 104, pl. 11, fig. 9; p. 83; p. 85.

*Nonion incisum* (Cushman), CUSHMAN and PARKER, 1931, p. 7, pl. 1, figs. 26a, b.

*Nonion incisum* (Cushman) var. *kernensis* KLEINPELL, 1938, pp. 232-233.

Hypotype 46418, locality D-1604.

The La Boca specimens are poorly preserved but seem to be the same as those from the Vaqueros, Rincon, and Temblor formations of California.

**Nonion medio-costatum** (Cushman)

Plate 3, figure 4a, b

*Nonionina medio-costata* CUSHMAN, 1925c, pp. 89-90, pl. 13, figs. 1a-c; 1926, p. 65.*Nonion medio-costatum* (Cushman), KLEINPELL, 1938, pp. 233-234, pl. 9, fig. 11.

Hypotype 46421, locality D-1609.

In the West Coast Ranges this species ranges from the base of the Saucesian into the lowermost Mohnian Stage. Saucesian occurrences were at first questionably referred to *Nonion incisum* (Kleinpell 1938, p. 146).

Genus *Elphidium* Montfort, 1808**Elphidium craticulatum** (Fichtel and Moll)

Plate 2, figures 4a, b

*Polystomella craticulata* (Fichtel and Moll), CUSHMAN, 1918, p. 77, pl. 27, figs. 3a, b.

Hypotype 46422, locality D-1598.

**Elphidium sagrum** (d'Orbigny)

Plate 2, figures 6a, b

*Polystomella sagra* d'Orbigny, CUSHMAN, 1918, p. 75, pl. 26, figs. 5a, b.

Hypotype 46423, locality D-1598.

**Elphidium** aff. *E. sagrum* (d'Orbigny)

Plate 2, figures 7a, b, 9a, b

Hypotypes 46424, 46425, locality D-1598.

Cushman (1918, p. 77) records under "*Polystromella*, species?", a "species of *Polystromella* which is very much like *P. sagra* and yet is not so definitely characterized. . .", but he does not figure it. At least two distinct variants (figured), also close to *E. sagrum*, occur in the La Boca assemblage from below the Emperador limestone member.

**Elphidium striato-punctatum** (Fichtel and Moll)

Plate 2, figures 5a, b

*Polystomella striato-punctata* (Fichtel and Moll), CUSHMAN, 1918, pp. 74-75, pl. 26, figs. 3a, b; 4a, b.

Hypotype 46426, locality D-1598.

**Elphidium** sp. cf. *E. tropicale* Petri

Plate 2, figures 8a, b

Hypotype 46444, locality D-1611.

A distinct form of *Elphidium* without keel and with concentric ribbing well developed only on the final four or five chambers, resembles the species of Petri (1954, p. 81, pl. 5, figs. 17-18) from the Miocene of Brazil, but has fewer chambers per coil.

## Family HETEROHELICIDAE

Genus *Plectofrondicularia* Liebus, 1903**Plectofrondicularia miocenica** Cushmanvar. *laiming* Kleinpell

Plate 3, figure 5

*Plectofrondicularia miocenica* Cushman, CUSHMAN and PARKER, 1931, pl. 1, fig. 28.*Plectofrondicularia miocenica* Cushman var. *laimingi*, KLEINPELL, 1938, p. 241.

Hypotype 46427, locality D-1605.

In California this variety is restricted to the lower Saucesian Stage.

Genus *Nodogenerina* Cushman, 1927**Nodogenerina** aff. *cooperensis* Cushman

Plate 3, figure 6

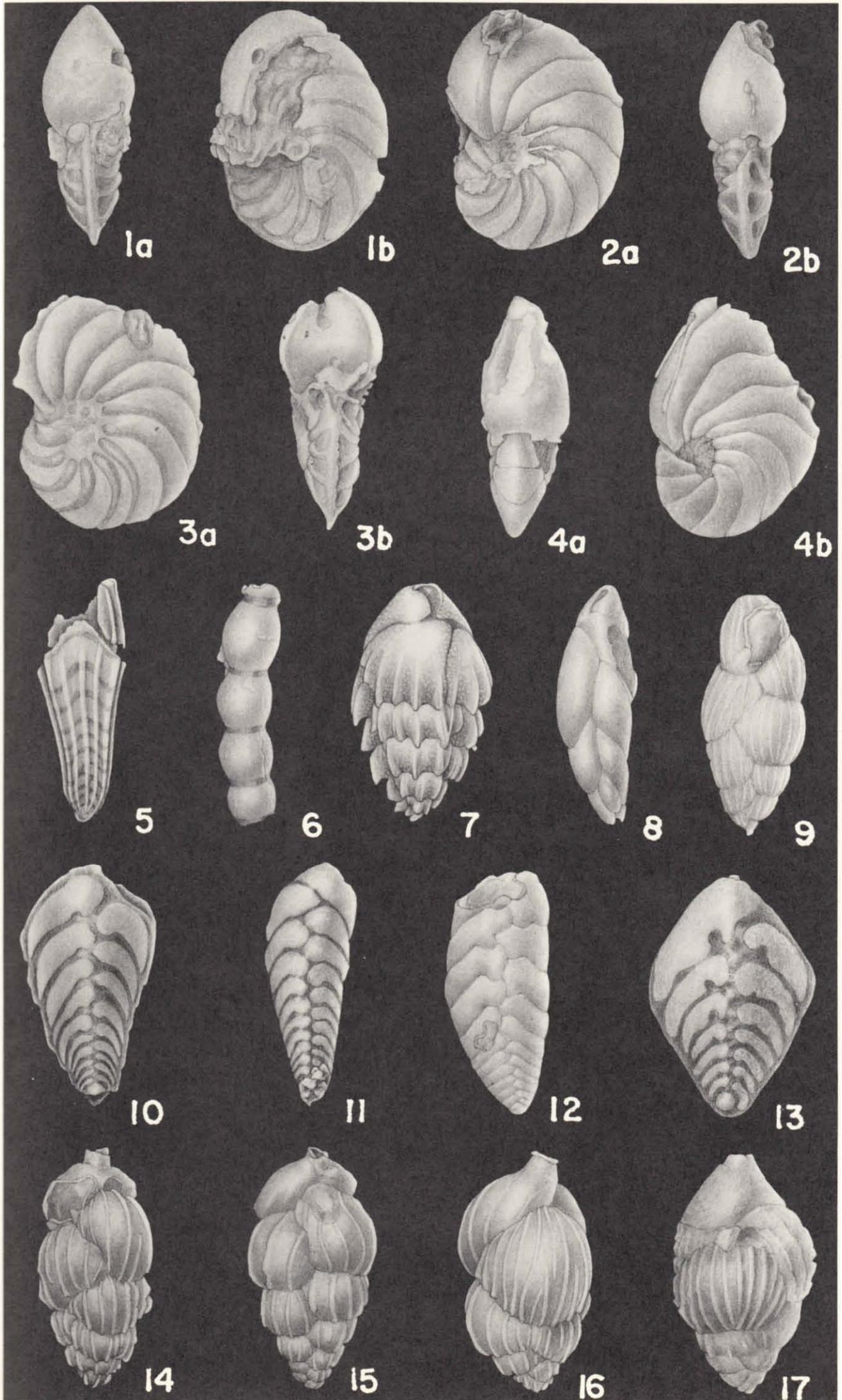
*?Nodogenerina cooperensis* CUSHMAN, 1933, p. 11, pl. 1, fig. 27.

Hypotype 46428, locality D-1604.

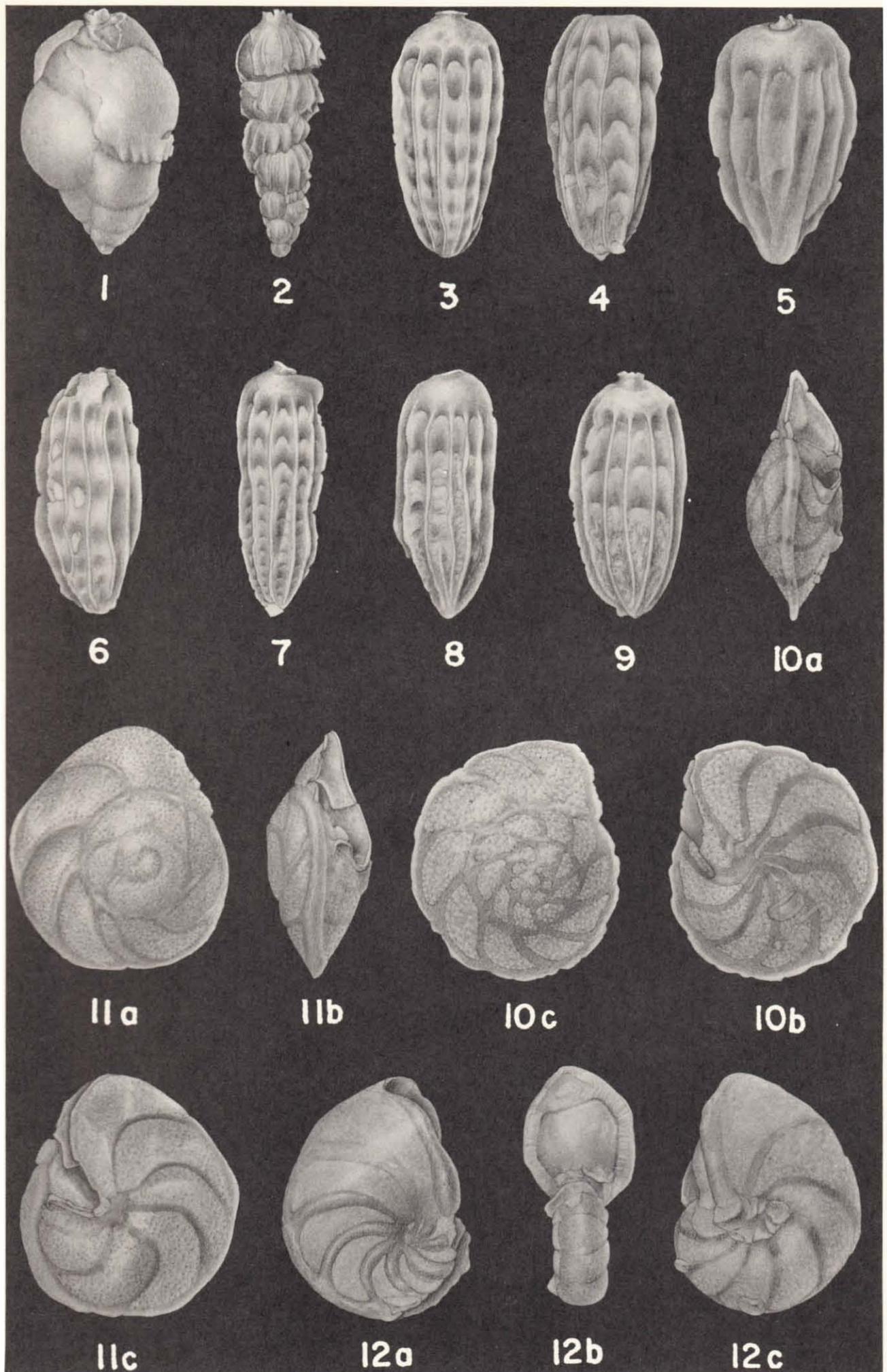
The few fragmentary La Boca specimens that

## EXPLANATION OF PLATE 3

FIGS.	SPECIES	TYPE NO.	MAG.	LOC. NO.	PAGE
1a, b.	<i>Nonion incisum</i> var. <i>kernensis</i> Kleinpell	46418	55×	D-1604	15
2a, b.	<i>Nonion costiferum</i> (Cushman)	46419	55×	D-1604	15
3a, b.	<i>Nonion costiferum</i> (Cushman)	46420	59×	D-1604	15
4a, b.	<i>Nonion medio-costatum</i> (Cushman)	46421	83×	D-1609	16
5.	<i>Plectofrondicularia miocenica</i> var. <i>laimingi</i> Kleinpell	46427	63×	D-1605	16
6.	<i>Nodogenerina</i> aff. <i>cooperensis</i> Cushman	46428	29×	D-1604	16
7.	<i>Bulimina alligata</i> Cushman and Laiming	46429	71×	D-1605	17
8.	<i>Virgulina pontoni</i> Cushman	46430	77×	D-1609	17
9.	<i>Uvigerina</i> cf. <i>tenuistriata</i> Reuss	46441	77×	D-1600	18
10.	<i>Bolivina marginata</i> Cushman	46432	50×	D-1604	17
11.	<i>Bolivina marginata</i> Cushman	46433	100×	D-1604	17
12.	<i>Bolivina advena</i> Cushman	46431	143×	D-1599	17
13.	<i>Bolivina robusta</i> H. B. Brady	46434	111×	D-1604	18
14.	<i>Uvigerinella obesa</i> var. <i>impolita</i> Cushman and Laiming	46437	71×	D-1606	18
15.	<i>Uvigerinella obesa</i> var. <i>impolita</i> Cushman and Laiming	46438	91×	D-1610	18
16.	<i>Uvigerinella obesa</i> Cushman	46436	100×	D-1599	18
17.	<i>Uvigerinella obesa</i> Cushman	46435	71×	D-1600	18



Blacut and Kleinpell: Panama Canal Zone Foraminifera



Blacut and Kleinpell: Panama Canal Zone Foraminifera

seem closely related to this species are slightly arcuate, but the apertural characters are nodogenerine and clearly not radiate. One specimen shows traces of a few very faint costae at one of the sutures.

Family BULIMINIDAE

Genus *Buliminella* Cushman, 1911

*Buliminella curta* Cushman

*Buliminella curta* CUSHMAN, 1925b, p. 33, pl. 5, fig. 13; 1926, p. 55. CUSHMAN and LAI-MING, 1931, pp. 106-107, pl. 11, fig. 16. KLEINPELL, 1938, pp. 248-249, pls. 7, fig. 3; pl. 15, fig. 4; pl. 16, fig. 8.

Hypotype 46485, locality D-1609.

This species, sparingly represented in the La Boca material, is common and widespread in California where it ranges from the lowermost Zemorrian Stage upward throughout the Miocene.

*Buliminella subfusiformis* Cushman

*Buliminella subfusiformis* CUSHMAN, 1925b, p. 33, pl. 5, fig. 12; 1926, p. 55. CUSHMAN and LAI-MING, 1931, p. 106, pl. 11, figs. 14a, b. KLEINPELL, 1938, pp. 251-252, pl. 9, fig. 8. RAU, 1951, p. 439, pl. 65, fig. 5; 1963, p. 140, pl. 12, fig. 4.

Hypotype 46486, locality D-1608.

In California this species has the same stratigraphic range as *Buliminella curta*, of which it may be a variety rather than a distinct species.

Genus *Bulimina* d'Orbigny, 1826

*Bulimina alligata* Cushman and Laiming

Plate 3, figure 7

*Bulimina inflata* Seguenza var. *alligata* CUSHMAN and LAI-MING, 1931, p. 107, pl. 11, figs. 17a, b. KLEINPELL, 1938, p. 254, pl. 7, fig. 1.

*Bulimina alligata* Cushman and Laiming, RAU, 1951, p. 440, pl. 65, fig. 6.

Hypotype 46429, locality D-1605.

In the Coast Ranges this species is restricted to the Saucesian Stage.

Genus *Virgulina* d'Orbigny, 1826

*Virgulina pontoni* Cushman

Plate 3, figure 8

?*Virgulina squamosa* d'Orbigny, CUSHMAN, 1918, p. 58, pl. 21, fig. 6.

*Virgulina floridana* Cushman, CUSHMAN and LAI-MING, 1931, p. 109, pl. 12, figs. 3a, b.

*Virgulina pontoni* Cushman, KLEINPELL, 1938, p. 263.

Hypotype 46430, locality D-1609.

This species occurs sporadically through Oligo-Miocene and Miocene strata in the West Coast Ranges.

Genus *Bolivina* d'Orbigny, 1839

*Bolivina advena* Cushman

Plate 3, figure 12

*Bolivina advena* CUSHMAN, 1925b, p. 29, pl. 5, figs. 1a, b; 1926, p. 54. KLEINPELL, 1938, pp. 264-265, pl. 7, fig. 6; pl. 9, fig. 7. RAU, 1951, p. 442, pl. 65, fig. 9.

Hypotype 46431, locality D-1599.

In the West Coast Ranges, this species appears at the base of the Saucesian Stage and ranges upward through the Mohnian Stage, upper Miocene.

*Bolivina advena* Cushman var. *striatella* Cushman

*Bolivina advena* Cushman var. *striatella* CUSHMAN, 1925, p. 30, pl. 5, figs. 3a, b; 1926, p. 54. CUSHMAN and LAI-MING, 1931, p. 110, pl. 12, fig. 5. KLEINPELL, 1938, p. 266, pl. 15, fig. 1.

Hypotype 46487, locality D-1599.

Like the species *sensu stricto* this variety has not been recorded from below Saucesian horizons in California.

*Bolivina marginata* Cushman

Plate 3, figures 10, 11

*Bolivina marginata* Cushman, CUSHMAN and LAI-MING, 1931, p. 110, pl. 12, figs. 6, 8. KLEINPELL, 1938, pp. 275-276, pl. 9, fig. 2.

Hypotypes 46432, 46433, locality D-1604.

EXPLANATION OF PLATE 4

FIGS.	SPECIES	TYPE NO.	MAG.	LOC. NO.	PAGE
1.	<i>Uvigerina beccarii</i> Fornasini	46440	63×	D-1604	18
2.	<i>Siphogenerina mayi</i> Cushman and Parker	46445	63×	D-1614	19
3.	<i>Siphogenerina transversa</i> Cushman	46450	39×	D-1605	19
4.	<i>Siphogenerina transversa</i> Cushman	46449	45×	D-1600	19
5.	<i>Siphogenerina transversa</i> Cushman	46447	63×	D-1604	19
6.	<i>Siphogenerina transversa</i> Cushman (worn specimen)	46448	31×	D-1604	19
7.	<i>Siphogenerina transversa</i> Cushman (worn specimen)	46446	33×	D-1604	19
8.	<i>Siphogenerina kleinPELLI</i> Cushman	46443	31×	D-1604	18
9.	<i>Siphogenerina kleinPELLI</i> Cushman	46442	37×	D-1604	18
10a, b, c.	<i>Eponides</i> aff. <i>affinis</i> (Czjzek)	46454	67×	D-1604	20
11a, b, c.	<i>Eponides</i> aff. <i>affinis</i> (Czjzek)	46455	45×	D-1605	20
12a, b, c.	<i>Valvulineria casitasensis</i> Cushman and Laiming	46453	55×	D-1604	19

This species is widespread in the middle Tertiary of the West Coast Ranges.

*Bolivina robusta* H. B. Brady

Plate 3, figure 13

*Bolivina robusta* H. B. Brady, CUSHMAN, 1918, p. 55, pl. 21, fig. 4.

Hypotype 46434, locality D-1604.

La Boca specimens show the limbate sutures "often slightly lobulated or occasionally showing traces of reticulation on the surface" mentioned previously by Cushman though not apparent in his figure; and, as in his specimens, there is no apical spine.

Genus *Uvigerinella* Cushman, 1926

*Uvigerinella obesa* Cushman

Plate 3, figures 16, 17

*Uvigerinella obesa* Cushman, CUSHMAN and LAI-MING, 1931, p. 111, pl. 12, figs. 10a, b. KLEINPELL, 1938, p. 290, pl. 9, fig. 15.

Hypotypes 46435, locality D-1600; 46436, locality D-1599.

La Boca specimens compare well with suites of the typical form which in California ranges throughout the Saucesian and Relizian Stages.

*Uvigerinella obesa* Cushman var. *impolita* Cushman and Laiming

Plate 3, figures 14, 15

*Uvigerinella obesa* Cushman var. *impolita* CUSHMAN and LAI-MING, 1931, p. 111, pl. 12, figs. 10a, b. KLEINPELL, 1938, pp. 291-292, pl. 7, fig. 8.

*Uvigerinella obesa impolita* Cushman and Laiming, RAU, 1951, pp. 443-444, pl. 65, fig. 18.

Hypotypes 46437, locality D-1606; 46438, locality D-1610.

The typically "shaggy" form of this variety, so characteristic of the Saucesian Stage in California (see Laiming in Kleinpell, 1938, pp. 291-292) is well represented in the La Boca sequence. It may have been included earlier under *Uvigerina pygmaea* d'Orbigny by Cushman (1918, pp. 49, 63), but his figure of the latter form from Panama (pl. 22, fig. 4) is not close.

Genus *Uvigerina* d'Orbigny, 1826

*Uvigerina beccarii* Fornasini

Plate 4, figure 1

*Uvigerina beccarii* Fornasini, KLEINPELL, 1938, p. 293, pl. 5, figs. 3, 4.

Hypotypes 46439, 46440, locality D-1604.

This species, somewhat variable in ornamentation, occurs in the lower Saucesian Stage of California (see Kleinpell and Weaver 1963, pp. 39-40). Some of the La Boca specimens are more striate than others, although only faintly so at most. In some specimens traces of costae are apparent at the base of the final chamber or final whorl of chambers.

*Uvigerina* aff. *canariensis* d'Orbigny

Hypotype 46488, locality D-1599.

Both varieties of the smooth-surfaced *Uvigerina* referred by Cushman (1918, pp. 62, 63, pl. 22, figs. 5, 6) to *U. canariensis* are sparingly represented in the La Boca sequence.

*Uvigerina* cf. *tenuistriata* Reuss

Plate 3, figure 9

*Uvigerina tenuistriata* Reuss, CUSHMAN, 1918, pp. 63-64, pl. 22, fig. 7.

Hypotype 46441, locality D-1600.

This distinctive small striate uvigerinid, with its *Hopkinsina*-like final chamber, is very rare in the La Boca material.

Genus *Siphogenerina* Schlumberger, 1883

*Siphogenerina kleinpelli* Cushman

Plate 4, figures 8, 9

*Siphogenerina kleinpelli* CUSHMAN, 1925a, p. 3, pl. 4, fig. 5; 1926, p. 59. KLEINPELL, 1938, p. 301-302, pl. 7, fig. 24; pl. 11, fig. 4. RAU, 1963, p. 141, pl. 12, fig. 12.

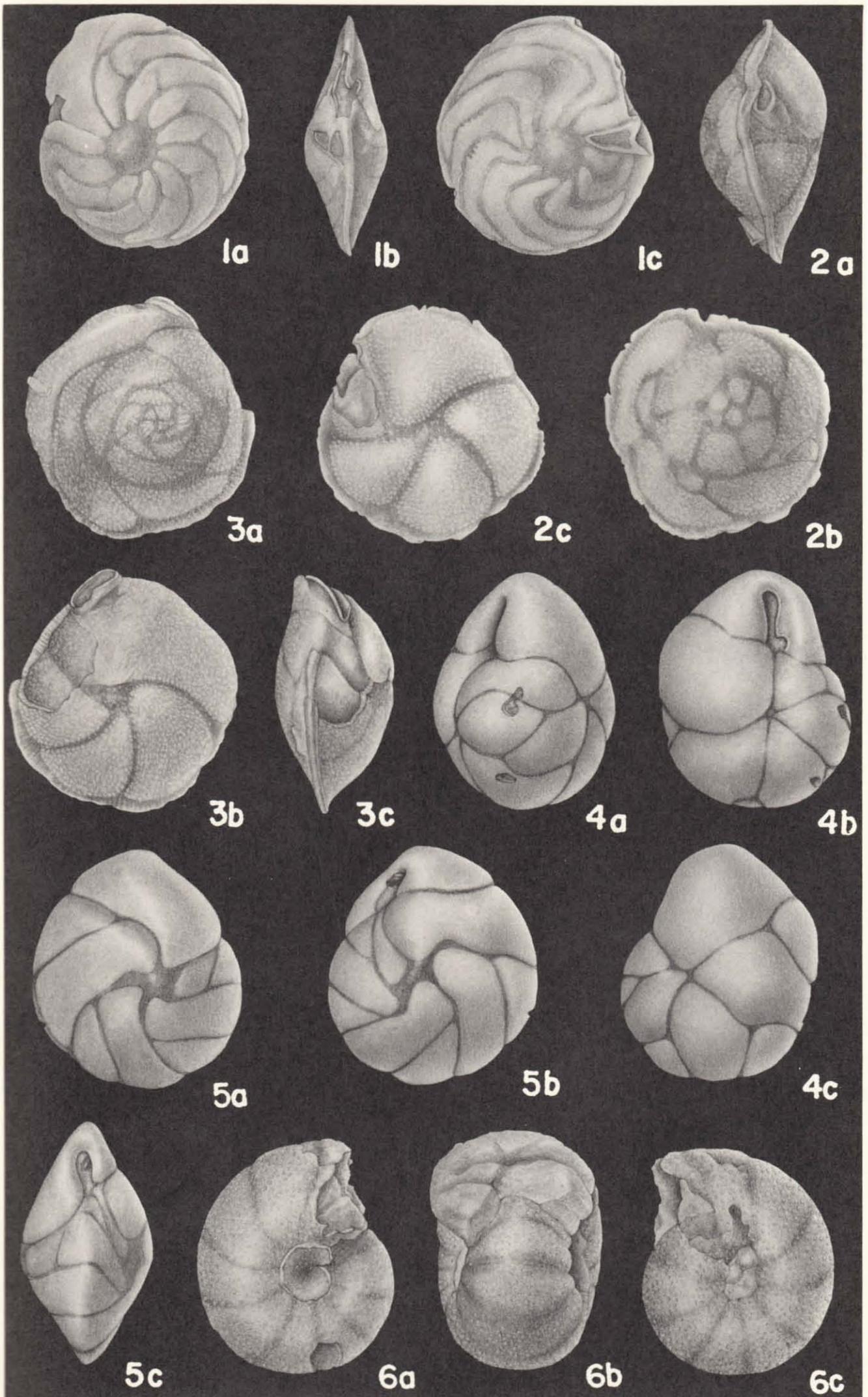
Hypotypes 46442, 46443, locality D-1604.

In the West Coast Ranges this species makes its appearance in the *Plectofrondicularia miocenica* Zone, upper of the two Zones comprising the Lower Saucesian Substage. Derived from *S. transversa* with which its earliest forms tend to intergrade, it ranges upward through the Luisian Stage.

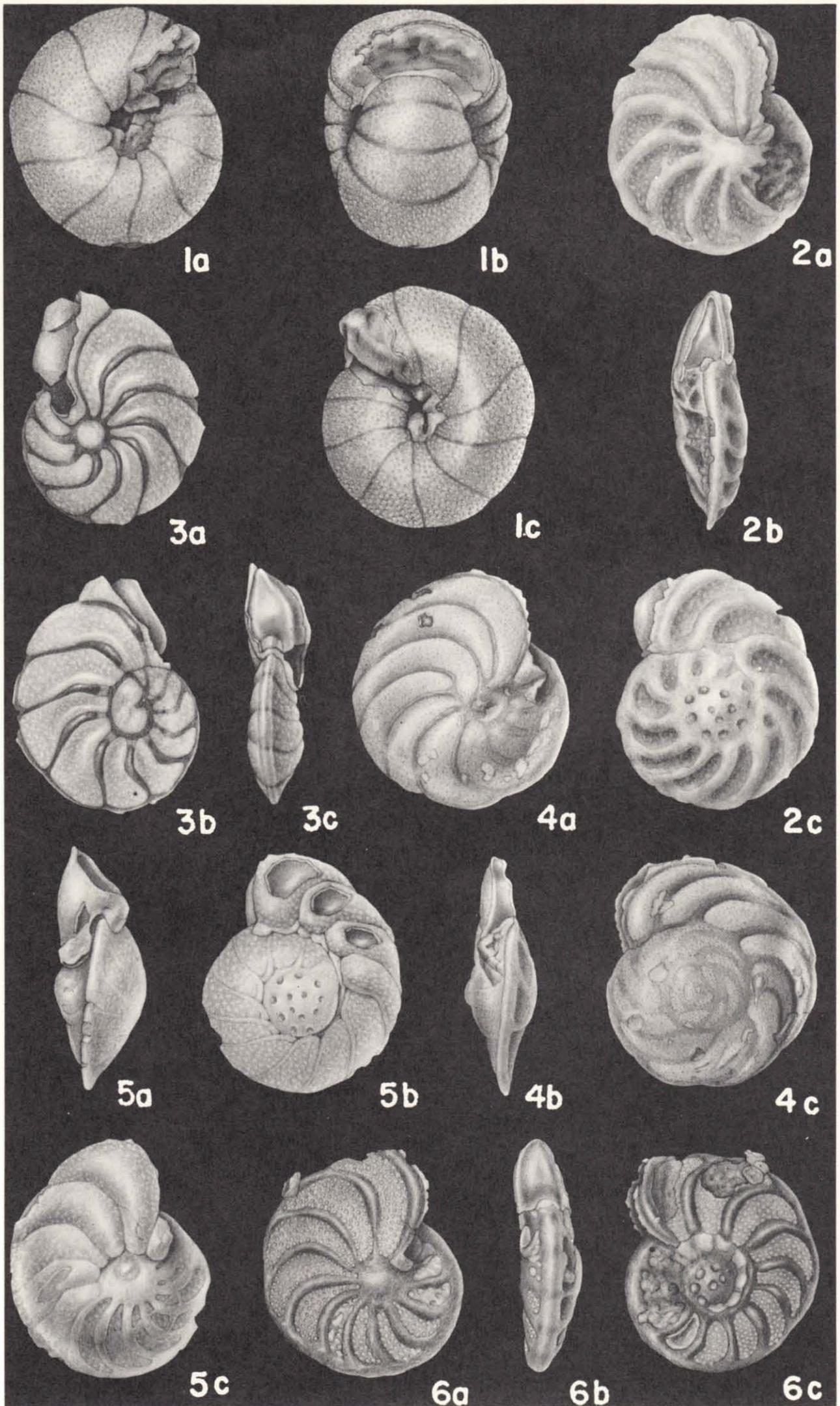
Cushman, Stewart, and Stewart (1947a, p. 20) record the species also from the Astoria Miocene of Oregon, along with *S. branneri*, the figured specimen of which (pl. 2, fig. 18) approaches this spe-

EXPLANATION OF PLATE 5

FIGS.	SPECIES	TYPE No.	MAG.	LOC. No.	PAGE
1a, b, c.	<i>Amphistegina lessonii</i> d'Orbigny	46458	83×	D-1605	..... 21
2a, b, c.	<i>Siphonina</i> cf. <i>reticulata</i> (Czjzek)	46456	71×	D-1604	..... 20
3a, b, c.	<i>Siphonina</i> cf. <i>reticulata</i> (Czjzek)	46457	50×	D-1604	..... 20
4a, b, c.	<i>Cassidulina subglobosa</i> H. B. Brady	46452	125×	D-1605	..... 19
5a, b, c.	<i>Cassidulina laevigata</i> var. <i>carinata</i> Cushman	46451	71×	D-1608	..... 19
6a, b, c.	<i>Anomalina californiensis</i> Cushman and Hobson	46459	71×	D-1604	..... 21



Blacut and Kleinpell: Panama Canal Zone Foraminifera



Blacut and Kleinpell: Panama Canal Zone Foraminifera

cies very closely. Rau's material from the upper Poule Creek Formation of Alaska apparently includes specimens very close to *S. transversa* (pl. 12, fig. 14), and the two figured specimens from the Miocene of the Willapa River, Washington, previously referred to *S. transversa* but subsequently synonymized with *S. kleinPELLi*, would appear from the pictures to be *S. transversa* as previously identified (Rau, 1951, pl. 65, figs. 25, 26). In his discussion of the Alaska material (Rau 1963, pp. 137, 139, 141) he notes that some of the specimens also approach *S. branneri*. In the California Coast Ranges, the three species occur together only in the *Uvigerinella obesa* Zone, Upper Saucesian, the age favored by Rau for the upper Poule Creek foraminiferal horizon in Alaska.

*Siphogenerina mayi* Cushman and Parker

Plate 4, figure 2

*Siphogenerina mayi* CUSHMAN and PARKER, 1931, pp. 10-11, pl. 2, figs. 7a, b. KLEINPELL, 1938, p. 302.

Hypotype 46445, locality D-1614.

This species was described from the Lower Temblor Formation, lower Saucesian of eastern Kern County, California. Though also reported from higher horizons, the writers have as yet been unable to corroborate such younger occurrences (see Kleinpell, 1938, p. 302).

*Siphogenerina transversa* Cushman

Plate 4, figures 3, 4, 5, 6, 7

*Siphogenerina raphanus* (Parker and Jones) var. *transversus*, CUSHMAN, 1918, p. 64, pl. 22, fig. 8.

*Siphogenerina transversa* Cushman, CUSHMAN and LAI-MING, 1931, p. 112, pl. 12, fig. 13. CUSHMAN and PARKER, 1931, p. 10 (in part), pl. 2, figs. 5, 6. CUSHMAN and BARBAT, 1932, p. 36. KLEINPELL in TALIAFERRO and SCHENCK, 1933, p. 77. KLEINPELL in PACKARD and KELLOGG, 1934, p. 17. KLEINPELL, 1938, p. 305. RAU, 1951, p. 445, pl. 65, figs. 25, 26.

Hypotypes 46446, 46447, 46448, locality D-1604; 46449, locality D-1600; 46450, locality D-1605.

As noted in the accompanying text, the writers have as yet been unable to corroborate reported post-Saucesian occurrences in California (see Kleinpell, 1938, pp. 305-306). This is a common species in the California Coast Ranges where it occurs stratigraphically between the base of the Zemorrian and top of the Saucesian Stages. Farther north, in Washington, the species appears for the first time higher in the column, along with the earliest *Nonion costiferum*, at the base of the Saucesian Stage there. Individual specimens in the La Boca material vary between the five forms figured here on plate 4; figures 6 and 7 are of worn specimens.

Family CASSIDULINIDAE

Genus *Cassidulina* d'Orbigny, 1826

*Cassidulina laevigata* d'Orbigny

var. *carinata* Cushman

Plate 5, figures 5a-c

*Cassidulina laevigata* d'Orbigny var. *carinata* Cushman, CUSHMAN and PARKER, 1931, pp. 14, 15, pl. 2, figs. 14a, b. KLEINPELL, 1938, p. 333, pl. 8, figs. 11a, b.

*Cassidulina* cf. *laevigata carinata* Cushman, RAU, 1963, p. 142, pl. 13, figs. 1a, b, 2a, b.

Hypotype 46451, locality D-1608.

Traces of a keel are found only in well preserved specimens. Apparently this variety is closely related to *C. crassipunctata* Cushman and Hobson and *C. galvinensis* Cushman and Frizzell, none of them known from horizons older than Refugian in the West Coast Ranges.

*Cassidulina subglobosa* H. B. Brady

Plate 5, figures 4a-c

*Cassidulina subglobosa* H. B. Brady, CUSHMAN, 1929, p. 100, pl. 14, figs. 11a, b. KLEINPELL, 1938, p. 337.

Hypotype 46452, locality D-1605.

Family ROTALIIDAE

Genus *Valvulineria* Cushman, 1926

*Valvulineria casitasensis* Cushman and Laiming

Plate 4, figures 12a-c

*Valvulineria casitasensis* CUSHMAN and LAI-MING,

EXPLANATION OF PLATE 6

FIGS.	SPECIES	TYPE NO.	MAG.	LOC. NO.	PAGE
1a, b, c.	<i>Anomalina californiensis</i> Cushman and Hobson	46460	63×	D-1605	..... 21
2a, b, c.	<i>Cibicides americanus</i> var. <i>crassiseptus</i> Cushman and Laiming	46462	71×	D-1601	..... 21
3a, b, c.	<i>Cibicides americanus</i> (Cushman)	46461	111×	D-1599	..... 21
4a, b, c.	<i>Cibicides wuellerstorfi</i> (Schwager)	46465	26×	D-1600	..... 22
5a, b, c.	<i>Cibicides pseudoungerianus</i> var. <i>evolutus</i> Cushman and Hobson	46464	50×	D-1600	..... 22
6a, b, c.	<i>Cibicides culebrensis</i> (Cushman)	46463	55×	D-1604	..... 22

1931, p. 113, pl. 13, fig. 1a-c. CUSHMAN and LEROY, 1938, p. 125, pl. 22, figs. 21a-c. KLEINPELL, 1938, p. 311.

Hypotype 46453, locality D-1604.

Hedberg (1937, p. 678) pointed out the close relationship between this species and the more inflated *V. venezuelana* of South America.

The "*Nonionina panamaensis*" figured by Cushman (1918, p. 74, pl. 26, figs. 1a, b) from Panama may be conspecific. Many specimens of *Valvulineria casitasensis* approach bilateral symmetry and are nearly involute on both sides.

This species is apparently ancestral to most of the Miocene valvulineries of California, through *V. depressa* to *V. californica obesa*, *V. californica appressa*, and *V. californica californica*, and through *V. ornata* to *V. miocenica*. In the Coast Ranges it appears in the lower Zemorrian Stage and makes its last stand in the *Plectofrondicularia miocenica* Zone, upper of the two Zones in the Lower Substage of the Saucesian Stage. It may be of anomalous origin, through *Cibicides hodgei* Cushman and Schenck, rather than of rotalid (*Discorbis*) origins; if so this lineage, which includes the genotype, would be parallel rather than cladal in relation to several other species assigned to *Valvulineria*. In this connection it is of interest to note that the "*Valvulineria californica* zone," a Teilzone widely used in the Coast Ranges, was originally termed the "*Anomalina* zone" in local usage before Cushman in 1926 described the form in reference as the genotype of *Valvulineria*. Conceivably the living "*Anomalina grosserugosa*" may be in the same lineage (and see Kleinpell 1938, p. 14).

#### *Valvulineria depressa* Cushman

*Valvulineria miocenica* Cushman var. *depressa* CUSHMAN, 1926, p. 61, pl. 9, figs. 7a-c. CUSHMAN and PARKER, 1931, p. 11, pl. 2, figs. 8a-c. *Valvulineria depressa* Cushman, KLEINPELL, 1938, pp. 311-312, pl. 9, figs. 22a-c; pl. 13, figs. 5a-c. Hypotype 46476, locality D-1606.

Specimens from the upper part of the La Boca sequence are conspecific with the widespread early and middle Miocene West Coast Range species (see the discussion under *V. casitasensis* above; see also Kleinpell 1938, p. 312).

#### Genus *Gyroidina* d'Orbigny, 1826

##### *Gyroidina soldanii* d'Orbigny

*Gyroidina soldanii* d'Orbigny, CUSHMAN and LAIMING, 1931, p. 114, pl. 13, fig. 2a-c. CUSHMAN and PARKER, 1931, p. 11, pl. 2, figs. 9a, b. CUSHMAN and BARBAT, 1932, pp. 36-40. BARBAT and VON ESTORFF, 1933, p. 173, pl. 26, figs. 6a, b. KLEINPELL, 1938, pp. 316-317.

Hypotype 46477, locality D-1599.

Rare in the La Boca material, this species is widespread in the Zemorrian and Saucesian Stages of the West Coast Ranges and in the deeper-water facies of the higher Relizian and Luisian and Mohnian, with a close relative also at upper Eocene horizons (see Mallory 1959, p. 236).

#### Genus *Eponides* Montfort, 1808

##### *Eponides* aff. *affinis* (Czjzek)

Plate 4, figures 10a-c, 11a-c

?*Eponides affinis* (Czjzek), CUSHMAN and LAIMING, 1931, p. 114, pl. 13, figs. 8a-c.

Hypotypes 46454, locality D-1604; 46455, locality D-1605.

A few specimens appear to be identical to Cushman and Laiming's species from the Lower Member of the type Rincon Shale (Upper Zemorrian of California); but most of what appears to be a single population show the sutures more limbate and ventrally more strongly arched to meet the periphery obliquely. Figure 11 is the typical form, figure 10 a smaller, apparently immature individual with more chambers per whorl, as in the earlier stages of some of the broken larger specimens.

##### *Eponides umbonatus* (Reuss)

*Eponides umbonatus* (Reuss), CUSHMAN, 1929, p. 98, pl. 14, figs. 8a-c. KLEINPELL, 1938, p. 322, pl. 6, figs. 9, 12.

Hypotype 46478, locality D-1605.

Widespread in the Paleogene of the West Coast Ranges (see Mallory 1959, p. 239) and elsewhere, this species is rare in the La Boca material.

#### Genus *Siphonina* Reuss, 1850

##### *Siphonina* cf. *reticulata* (Czjzek)

Plate 5, figures 2a-c, 3a-c

?*Siphonina reticulata* (Czjzek), CUSHMAN, 1918, p. 72, pl. 24, fig. 5.

Hypotypes 46456, 46457, locality D-1604.

The La Boca specimens of *Siphonina* agree fairly well with Cushman's description of the species in Panama, although his figure of it is very indistinct. Two La Boca specimens are figured here.

#### Genus *Epistominella* Husezima and Maruhasi, 1944

##### *Epistominella* (?) spp.

Very poorly preserved and very small specimens, occurring sparingly in the upper part of the La Boca sequence, apparently represent this genus. Included are forms close to those figured as "*Pulvinulinella*" *parva* and "*P.*" *subperuviana* var. *minuta* by Cushman and Laiming (1931, pp. 115-116, pl. 13, figs. 5a-c, 6a-c) from the Rincon Shale of Los Saucos Creek, Ventura County, California.

Hypotypes 46479, 46480, locality D-1608.

Family AMPHISTEGINIDAE  
Genus *Amphistegina* d'Orbigny, 1826  
*Amphistegina lessonii* d'Orbigny

Plate 5, figure 1a-c

*Amphistegina lessonii* d'Orbigny, H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 740, pl. 111, figs. 1-7.

Hypotype 46458, locality D-1605.

Cushman (1918, pp. 77-78) recorded this common Tertiary species from the "Culebra formation," Emperador limestone and Gatun formation, but did not figure it.

Family GLOBIGERINIDAE  
Genus *Globigerina* d'Orbigny, 1826

From the Culebra (La Boca) and Gatun Formations of Panama, Cushman (1918, pp. 64-67) recorded—though he did not figure—the following species of *Globigerina*: *G. bulloides* d'Orbigny, *G. dubia* Egger, and *G. inflata* d'Orbigny; and, from the Gatun, *G. aequilateralis* H. B. Brady and *G. sacculifera* H. B. Brady. From elsewhere in the La Boca than the measured sequence of Las Cascadas Reach, *G. dissimilis* Cushman and Bermudez, *G. (Globorotaloides) suter* (Bolli), *Globigerinoides trilobus* (Reuss) and *G. t. sacculifer* (Brady) have been recorded in the accompanying text. The globigerinids in the measured La Boca sequence, though abundantly represented, are consistently in a poor state of preservation, and, as such, add little of significance to the previous records. At least four distinct species or varieties are recognisable, ranging throughout the measured section from above the Emperador Limestone Member.

*Globigerina bulloides* d'Orbigny

Hypotype 46466, locality D-1613.

The species *sensu stricto*, with its highly inflated and very loosely coiled chambers, is abundant in most of the samples from above the Emperador Limestone.

*Globigerina bulloides* d'Orbigny var.

*Globigerina bulloides* d'Orbigny, CUSHMAN and LAIMING, 1931, p. 117, pl. 14, figs. 4a-c.

Hypotypes 46467, locality D-1604; 46468, locality D-1613.

A more tightly coiled, more compact variety of the species appears to be the same as the one figured from the Rincon Shale of California by Cushman and Laiming.

*Globigerina conglomerata* Schwager

*Globigerina conglomerata* Schwager, CUSHMAN and LAIMING, 1931, p. 117, pl. 14, figs. 5a-c.

Hypotypes 46469, locality D-1604; 46470, locality D-1613.

This form is less abundantly represented in the La Boca material.

*Globigerina* cf. *venezuelana* Hedberg

Hypotype 46471, locality D-1604.

A compactly coiled and generally somewhat larger form is common in the lower samples of the measured section but becomes more scarce at the higher horizons. Most of them seem very close to Hedberg's species from Venezuela (Hedberg 1937, p. 681, pl. 92, fig. 7a, b.).

Family ANOMALINIDAE

Genus *Anomalina* d'Orbigny, 1826

*Anomalina californiensis* Cushman and Hobson

Plate 5, figures 6a-c; Plate 6, figures 1a-c

?*Nonionina anomalina* CUSHMAN, 1918, p. 74, pl. 26, figs. 2 a, b.

*Anomalina californiensis* CUSHMAN and HOBSON, 1935, p. 64, pl. 9, figs. 8a-c. KLEINPELL, 1938, p. 346.

Hypotypes 46459, locality D-1604; 46460, locality D-1605.

This species is common in the Zemorrian and lower Saucesian Stages of the West Coast Ranges.

The cassiduline growth-plan tendency of the last two chambers, mentioned by Cushman, does not appear in the La Boca specimens, though broken ultimate chambers (Plate 5, figure 6) can create such an effect.

Genus *Cibicides* Montfort, 1808

*Cibicides americanus* (Cushman)

Plate 6, figures 3a-c

*Truncatulina americana* CUSHMAN, 1918, p. 68, pl. 23, figs. 2a-c.

*Cibicides americanus* (Cushman), CUSHMAN and LAIMING, 1931, p. 119, pl. 14, figs. 6a-c. CUSHMAN and PARKER, 1931, p. 15, pl. 3, figs. 1a-c. KLEINPELL, 1938, p. 352, pl. 8, figs. 13a-c.

Hypotype 46461, locality D-1599.

In the West Coast Ranges this species is characteristic of faunas found in the Zemorrian, Saucesian, and Relizian Stages.

*Cibicides americanus* (Cushman)

var. *crassiseptus* Cushman and Laiming

Plate 6, figures 2a-c

*Cibicides americanus* (Cushman) var. *crassiseptus* CUSHMAN and LAIMING, 1931, p. 119, pl. 14, figs. 7a-c. KLEINPELL, 1938, pp. 352-353.

Hypotype 46462, locality D-1601.

In California this variety is recorded from the Zemorrian and Lower Saucesian Stages only.

*Cibicides culebrensis* (Cushman)

Plate 6, figures 6a-c

*Truncatulina culebrensis* CUSHMAN, 1918, p. 70, pl. 24, figs. 4a, b.

Hypotype 46463, locality D-1604.

In their limbate, strongly raised sutures, which fuse with a heavily "keeled" peripheral margin, and in their tendency to develop umbilical bosses, larger specimens of this species come to resemble superficially small specimens of the bilaterally symmetrical and bilaterally evolute operculinid often referred to *Operculina ammonoides* Gronovius.

*Cibicides pseudoungerianus* (Cushman)var. *evolutus* Cushman and Hobson

Plate 6, figure 5a-c

*Cibicides pseudoungerianus* (Cushman) var. *evolutus* CUSHMAN and HOBSON, 1935, p. 64, pl. 9, figs. 11a-c.

Hypotype 46464, locality D-1600.

This variety is widespread in the Zemorrian and lower Saucesian Stages of the West Coast Ranges (see Kleinpell 1938, p. 355, and Kleinpell and Weaver 1963, pp. 39-40). Rau's *Cibicides* cf. *C. ungerianus evolutus* Cushman and Hobson from Alaska (Rau 1963, p. 143, pl. 13, fig. 7a-c) appears to be the same variety.

*Cibicides wuellerstorfi* (Schwager)

Plate 6, figures 4a-c

*Truncatulina wuellerstorfi* (Schwager), CUSHMAN, 1918, pp. 69-70, pl. 24, fig. 3.

Hypotype 46465, locality D-1600.

Though closely related to at least one species from the Oligo-Miocene of California (sometimes informally referred to as "*C. cf. perlucida*"), this large species is otherwise unrecorded from the West Coast Ranges.

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361. ON SOME TYPE SPECIMENS OF CRETACEOUS  
PLANKTONIC FORAMINIFERA

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ABSTRACT

Based on a reëxamination of the original type specimens, some planktonic foraminiferal species of the Cretaceous are redescribed and refigured. Most of these were introduced by Gandolfi in 1942.

INTRODUCTION

The objective of the present paper is to discuss and illustrate some of the type specimens of the species of planktonic foraminifera introduced by Gandolfi in 1942.

Gandolfi was among the first authors to follow the evolution of planktonic foraminifera from the Aptian through the Turonian. His thesis is a fundamental paper for all students of open-marine deposits of this time interval. The species of planktonic foraminifera introduced in 1942 by Gandolfi have been found subsequently to be of worldwide stratigraphical value. The present revision of some of these species is not intended to be critical of Gandolfi's work. The authors of the present paper wish to express their greatest respect for the pioneer work represented by Gandolfi's thesis.

One of the authors (H.P.L.) of the present paper is currently engaged in a revision of the Breggia River section (Southern Switzerland) upon which Gandolfi based his investigation published in 1942. Concurrently, a restudy has been initiated of Gandolfi's original collection deposited at the Museum of Natural History, Basel (Switzerland). As it will probably be a considerable time until this project is completed and the final results published, it seems desirable to make available the present reillustration and discussion of Gandolfi's type specimens at this time.

With the kind help of Prof. Dr. J. Klaus, it was possible to reillustrate some of Gandolfi's type specimens. The figures were drawn by G. Papaux (Institut de Géologie, Fribourg) under supervision of one of the authors (M.C.). Profs. Dr. M. Reichel, Dr. H. M. Bolli and Dr. J. Sigal critically read the manuscript and made many useful suggestions. The authors are indebted to all of them for their kind cooperation. This project was supported in part by the Swiss National Science Foundation.

The arrangement of the species described follows the stratigraphic succession of their first occurrence in the Breggia River section (see also Premoli Silva & Luterbacher, 1965, and text fig. 1).

SYSTEMATIC DESCRIPTIONS

*Hedbergella trocoidea* (Gandolfi)

Plate 7, figures 1, 2

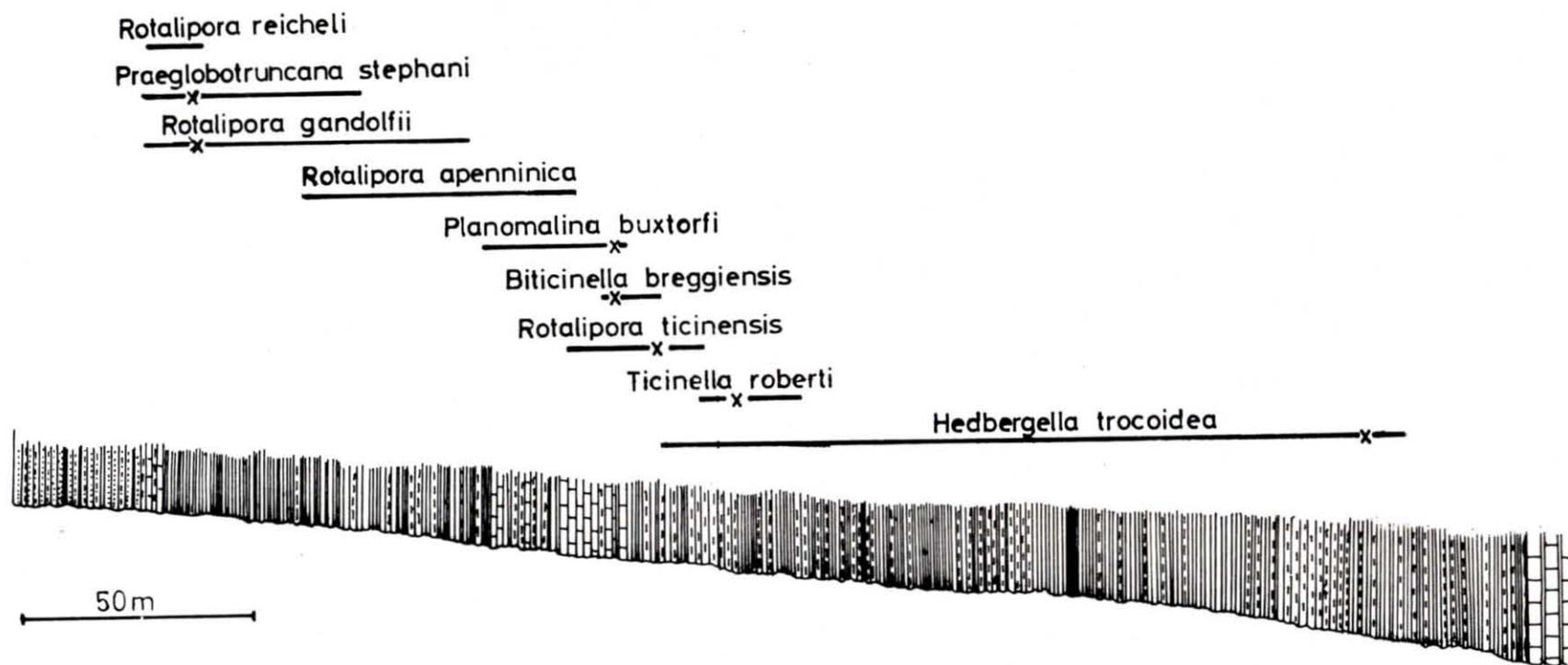
1942. *Anomalina lorneiana* var. *trocoidea* GANDOLFI, p. 99, pl. 2, fig. 2; pl. 4, figs. 2, 3; pl. 13, figs. 2, 5.
1958. *Hedbergella trocoidea* (Gandolfi), BRÖNNIMANN and BROWN, p. 16, fig. 1.
1959. *Hedbergella trocoidea* (Gandolfi), KLAUS, p. 792, pl. 1, fig. 1.

The specimen figured by Gandolfi on plate 2, figure 1 has been lost. The specimen figured by the same author on plate 4, figure 2 is herewith designated as lectotype of the species (Naturhistorisches Museum Basel, C 25550).

Test medium-high to low trochospiral, composed of 16 to 22 oval to globular chambers arranged in 2½ whorls. Last-formed whorl with 7 to 9 chambers which increase only slowly in size as added. Last chamber slightly protruding into the generally fairly wide umbilicus. Aperture extraumbilical-umbilical; a low arch extending from the umbilicus towards the periphery. No supplementary apertures visible. A faint and narrow lip rarely observable.

The variability of the species is expressed by the height of the spire, the number of the chambers in the last-formed whorl and the intensity of the ornamentation. In some of the topotypes, the inner whorls are covered on the spiral side by thick spines and pustules.

*Hedbergella trocoidea* was first described by Gandolfi as "*Anomalina lorneiana* var. *trocoidea*" from level 14 of the Breggia-section. In 1958, Brönnimann and Brown chose this species as type-species of the new genus *Hedbergella*. The authors of the present paper agree with Klaus (1959) in including forms described by Gandolfi as "*Anomalina lorneiana*" in *Hedbergella trocoidea*. *Praeglobotruncana rohri* Bolli is a very similar species, but its last-formed chamber is not protruding into the umbilicus. In the type assemblage of *Hedbergella trocoidea*, these two species are linked by intermediate forms. The wall structure of *Hedbergella trocoidea* has been described by Premoli Silva (1966, p. 225, pl. 2, fig. 1).



LITHOL. UNITS	"Flysch"	"Scaglia rossa"	"Scaglia bianca"	"Scaglia variegata"	"Maiolica"
AGE	?	CENOMANIAN	ALBIAN	APTIAN	BARREMIAN

TEXT FIGURE 1

Distribution of some planktonic foraminifers in the Breggia River section (Southern Switzerland). Partly following Gandolfi, 1942.

*Ticinella roberti* (Gandolfi)

Plate 7, figure 3

1942. *Anomalina roberti* GANDOLFI, p. 100-101, fig. 22; pl. 2, fig. 2; pl. 4, figs. 5-7; pl. 13, figs. 3, 6.
1950. *Globotruncana (Ticinella) roberti* (Gandolfi), REICHEL, p. 600-603, text figs. 1, 2.
1959. *Rotalipora (Ticinella) roberti* (Gandolfi), KLAUS, p. 803, pl. 1, fig. 3.
1966. *Ticinella roberti* (Gandolfi), SIGAL, p. 203-207, pl. 4, figs. 10-12; pl. 5, figs. 1-4.

Holotype: Gandolfi (1942), pl. 2, fig. 2, designated by the author. (The same specimen also was figured by Gandolfi on pl. 4, fig. 5). (Naturhistorisches Museum Basel, C 25551).

Recently, this species has been described and discussed extensively by Sigal (1966).

The supplementary apertures, which are very distinct on well preserved topotypes and have been used in the generic diagnosis, are hidden in the holotype by the sediment which fills the umbilicus. In order to avoid any risk of damaging the test, no attempt was made to clean the type specimen. The wall structure of topotypes of *Ticinella roberti* has been described recently by Premoli Silva (1966, p. 225, pl. 2, fig. 5).

*Biticinella breggiensis* (Gandolfi)

Plate 7, figure 4

1942. *Anomalina breggiensis* GANDOLFI, p. 102-103, text figs. 34 (1-4); pl. 3, fig. 6; pl. 5, fig. 3; pl. 9, fig. 1; pl. 13, figs. 7, 8.
1956. *Biticinella breggiensis* (Gandolfi), SIGAL, p. 35-36, text fig. 1.
1962. *Biticinella breggiensis* (Gandolfi), LUTERBACHER and PREMOLI SILVA, p. 272-274, pl. 22, figs. 2-4.
1966. *Ticinella spectrum-breggiense* (Gandolfi, 1942) et Sigal, SIGAL, p. 192-195, pl. 1, figs. 1-10; pl. 2, fig. 2.

Holotype: Gandolfi, 1942, pl. 3, fig. 6, designated by the author. (Naturhistorisches Museum Basel, C 25552).

This species has been discussed by Sigal (1966) and Luterbacher and Premoli Silva (1962). Arguments for the validity of the genus (or subgenus) *Biticinella* are given in these two papers.

The specimen representing the holotype has a smoothed and polished surface. The supplementary apertures and the coarse pores which are characteristic of the species cannot be observed. In lateral view, the holotype appears slightly asymmetrical because of the hidden trochospiral arrangement of the chambers. Intermediate specimens demonstrating the transition between *Ticinella* and *Biticinella* are present in the type sample.

*Planomalina buxtorfi* (Gandolfi)

Plate 8, figure 5

1942. *Planulina buxtorfi* GANDOLFI, p. 103-104, text fig. 35 (1-11); pl. 3, fig. 7; pl. 5, figs. 4, 5; pl. 6, figs. 1-4; pl. 8, fig. 8; pl. 9, fig. 2; pl. 13, fig. 13.
1946. *Planomalina apsidostroba* LOEBLICH and TAPPAN, p. 285, pl. 37, figs. 22, 23.
1959. *Planomalina buxtorfi* (Gandolfi), KLAUS, p. 829-30, pl. 8, fig. 5.
1966. *Labroglobigerinella spectrum-buxtorfi* (Gandolfi, 1942) et Sigal, SIGAL, p. 26, pl. 4, figs. 1-5.

Holotype: Gandolfi, 1942, pl. 3, fig. 7, designated by the author. (Naturhistorisches Museum Basel, C 25553).

Test planispiral, flattened. Last whorl composed of 8 to 12 chambers which increase slowly in size as added. Tendency towards uncoiling in last-formed chamber. Sutures and marginal double keel raised and partly beaded or nodose. Aperture a low median arch. In well preserved topotypes, the lateral portions of the aperture visible as supplementary apertures.

The umbilici of the somewhat smoothed and polished holotype are filled by sediment and therefore no supplementary apertures are visible.

*Rotalipora ticinensis* (Gandolfi)

Plate 8, figure 6

1942. *Globotruncana ticinensis* GANDOLFI, p. 113-115, pl. 2, fig. 3; pl. 4, figs. 10, 11, 23; pl. 5, figs. 2, 4; pl. 8, figs. 4-7; pl. 12, fig. 1; pl. 13, figs. 11, 12, 14; text fig. 39.
1950. *Globotruncana (Thalmaninella) ticinensis* Gandolfi), REICHEL, p. 603-604, pl. 16, fig. 3; pl. 17, fig. 3.
1959. *Rotalipora (Thalmaninella) ticinensis ticinensis* (Gandolfi), KLAUS, p. 804, pl. 2, fig. 1.

Holotype: Gandolfi, 1942, pl. 2, fig. 3, designated by the author. (Naturhistorisches Museum, C 25554).

Test low trochospiral, composed of 14 to 16 chambers arranged in 2½ whorls. Last whorl with 7 to 9 chambers which increase only very slowly in size as added. Sutures on spiral side raised and beaded in older portion of the test, depressed between the 3 to 4 last-formed chambers. Main aperture a low umbilical-extraumbilical arch, occasionally with a faint lip. Supplementary apertures, as typical for the genus, at the umbilical end of the sutures.

The holotype is poorly preserved; no supplementary apertures are visible. The last two chambers show only a faint indication of a keel.

The lectotype of *Rotalipora subticinensis* (Gandolfi) has been lost.

*Praeglobotruncana stephani* (Gandolfi)

Plate 8, figure 7

1942. *Globotruncana stephani* GANDOLFI, p. 130-133, pl. 3, figs. 3, 4; pl. 4, figs. 36, 37, 41-44; pl. 6, figs. 4, 6; pl. 9, figs. 5, 8; pl. 14, fig. 2.
1950. *Globotruncana* (*Globotruncana*) *stephani* Gandolfi, REICHEL, p. 608-609, pl. 16, fig. 6; pl. 17, fig. 6.
1953. *Rotundina stephani* (Gandolfi), SUBBOTINA, p. 165-166, pl. 2, figs. 5-7; pl. 3, fig. 1.
1957. *Globotruncana* (*Globotruncana*?) *stephani* Gandolfi, GANDOLFI, p. 62, pl. 9, fig. 3.
1959. *Praeglobotruncana stephani stephani* (Gandolfi), KLAUS, p. 794-795; pl. 6, fig. 1.
1961. *Praeglobotruncana stephani* (Gandolfi), LOEBLICH and TAPPAN, p. 284-290, pl. 6, fig. 1.

Holotype: Gandolfi, 1942, pl. 3, fig. 4, designated by the author. (Naturhistorisches Museum Basel, C 25555).

Test trochospiral, composed of 12 to 14 chambers arranged in 2½ whorls. Last whorl formed by 5 to 7 chambers which increase gradually in size as added. Umbilicus deep and narrow. Aperture a low extraumbilical-umbilical arch, with a distinct lip. In well preserved specimens, remains of the lips of the apertures of earlier chambers possibly visible in the umbilicus. Periphery lobate. Sutures between older chambers raised and beaded, between youngest 2 to 3 chambers smooth or depressed. Keel well developed in earlier chambers of the last whorl, in youngest chambers faintly indicated or missing.

In the holotype, the aperture is hidden by sediment.

The type-specimen of *Praeglobotruncana stephani turbinata* (Reichel) has been lost.

*Rotalipora apenninica* (Renz)

Plate 8, figure 8

1936. *Globotruncana apenninica* RENZ, p. 14, fig. 2.
1942. *Globotruncana apenninica* var. *alpha* GANDOLFI, p. 117, fig. 40.
1950. *Globotruncana* (*Rotalipora*) *apenninica* var. *alpha* Gandolfi, REICHEL, p. 604-607, figs. 3, 4.

1957. *Globotruncana* (*Rotalipora*) *apenninica balernaensis* GANDOLFI, p. 60, pl. 8, fig. 9.

1959. *Rotalipora* (*Thalmaninella*) *apenninica balernaensis* (Gandolfi), KLAUS, p. 808, pl. 3, fig. 2.

1961. *Rotalipora balernaensis* (Gandolfi), LOEBLICH and TAPPAN, p. 297, pl. 8, fig. 11.

1962. *Rotalipora apenninica apenninica* (Renz), LUTERBACHER and PREMOLI SILVA, p. 266-268, pl. 19, figs. 1, 2; pl. 20, figs. 1-4; pl. 21, figs. 1-4.

Lectotype: O. Renz, 1936, p. 14, fig. 2 (specimen on left side), designated by P. Marie, 1948. (Collection O. Renz, Naturhistorisches Museum Basel).

*Rotalipora apenninica* was erected by O. Renz in 1936 on the basis of thin sections only. Isolated topotypes of this species were described and figured by Luterbacher and Premoli Silva (1962). These authors demonstrated that the topotypes of *Rotalipora apenninica* correspond to the form which was named *Globotruncana apenninica* var. *alpha* [= *Globotruncana* (*Rotalipora*) *apenninica balernaensis*] which was given specific rank by subsequent authors (e.g., Loeblich and Tappan, 1957). The form described by Gandolfi in 1942 as *Globotruncana apenninica* var. *typica* [= *Globotruncana* (*Rotalipora apenninica apenninica* in Gandolfi, 1957)] differs in its morphology and stratigraphic distribution from the topotypes of *Rotalipora apenninica* (see also Klaus, 1959, p. 809). Therefore, a new name was given to this form: *Rotalipora apenninica gandolfii* Luterbacher and Premoli, 1962. This taxon now is considered to be of specific rank.

*Rotalipora apenninica* (Renz) differs from *Rotalipora gandolfii* mainly in being less tightly coiled, in being more flattened, and in the gentle sloping of the umbilical shoulders of the elongate youngest two chambers into the shallow umbilicus.

The holotype of *Rotalipora balernaensis* (= *Rotalipora apenninica*) is well preserved.

The correct spelling of the trivial name is "apenninica" (Latin: *apenninicus*) and not "appenninica" (Italian: *appenninico*) (see ICZN, art. 32).

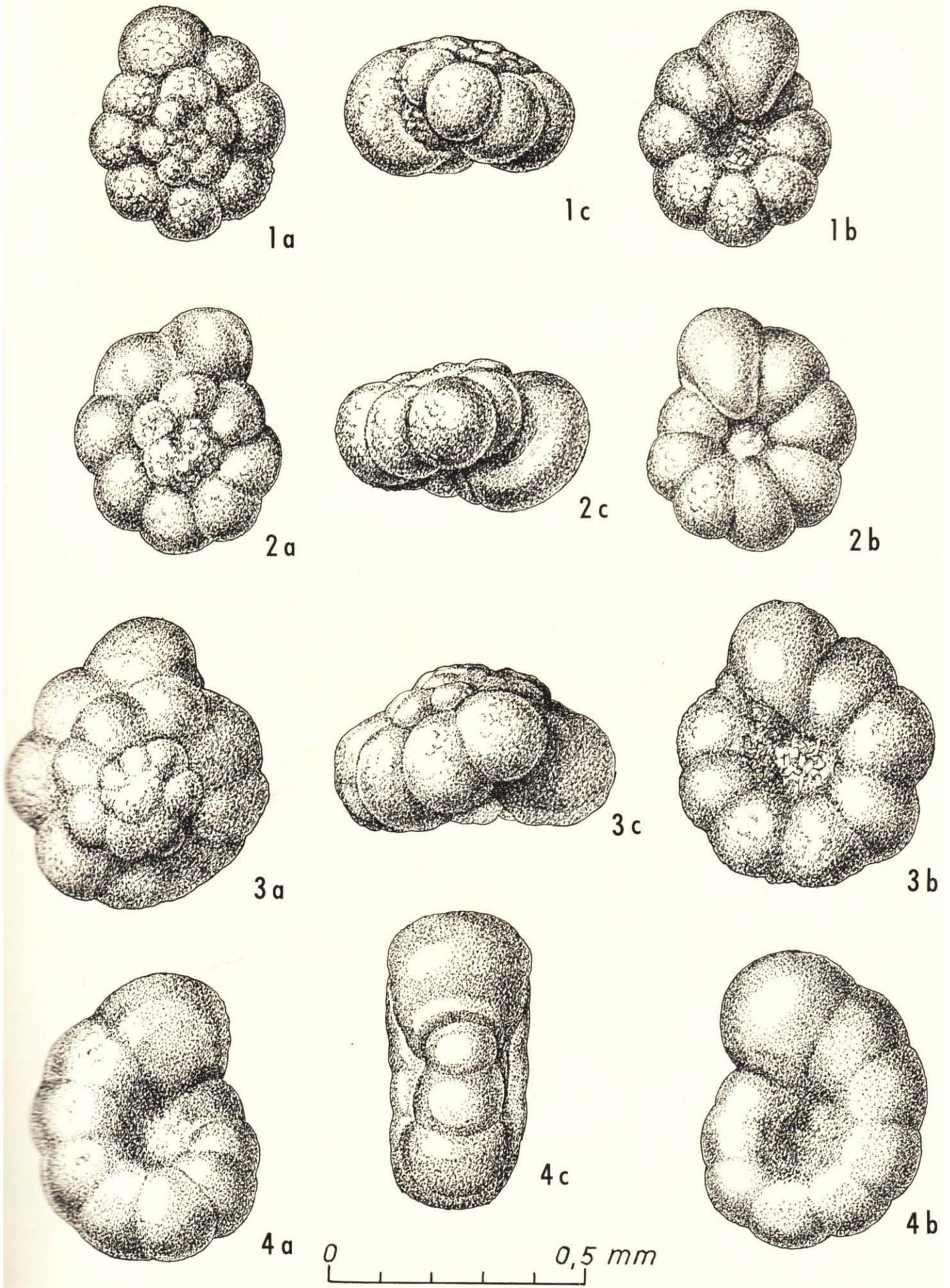
*Rotalipora gandolfii* Luterbacher and Premoli Silva

Plate 9, figure 9

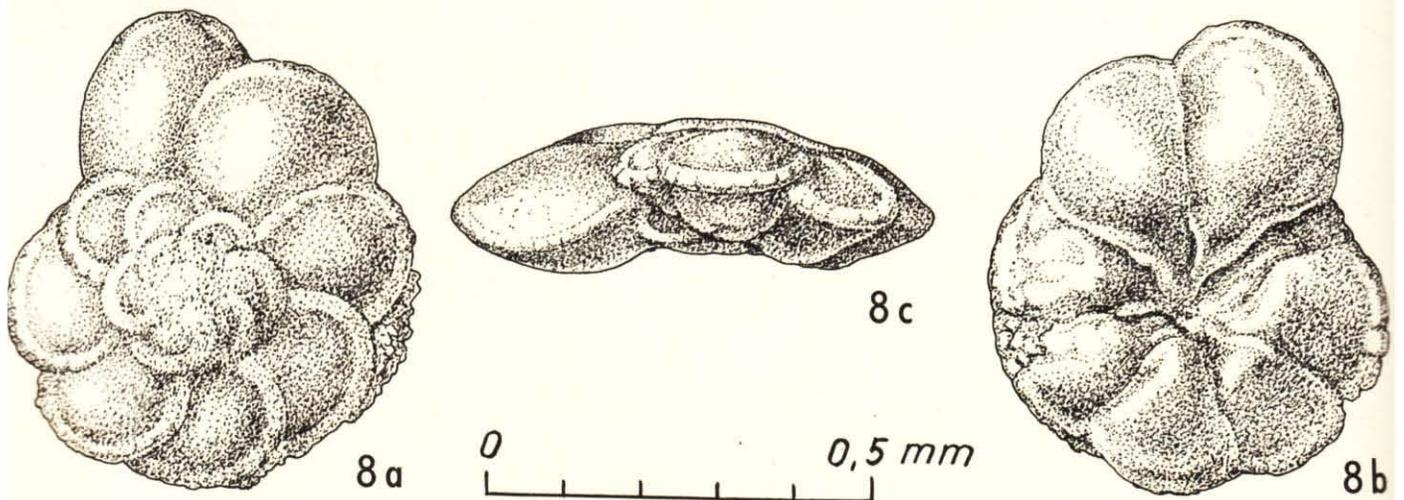
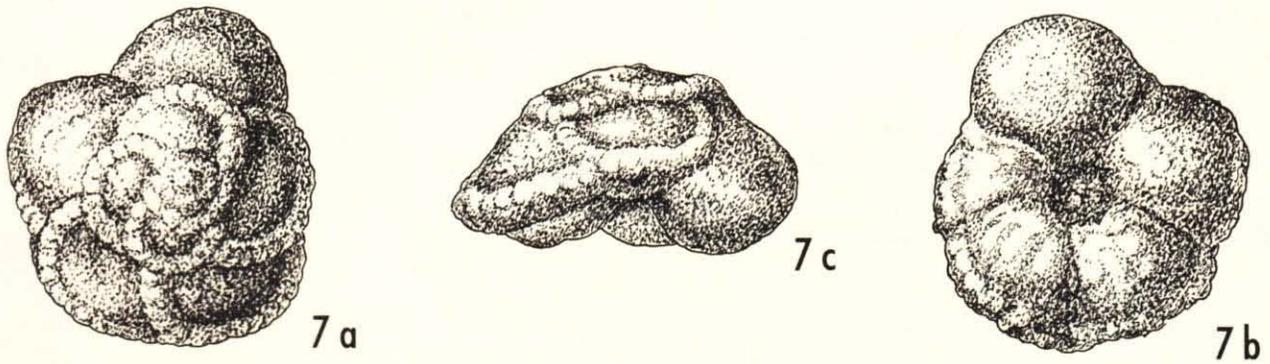
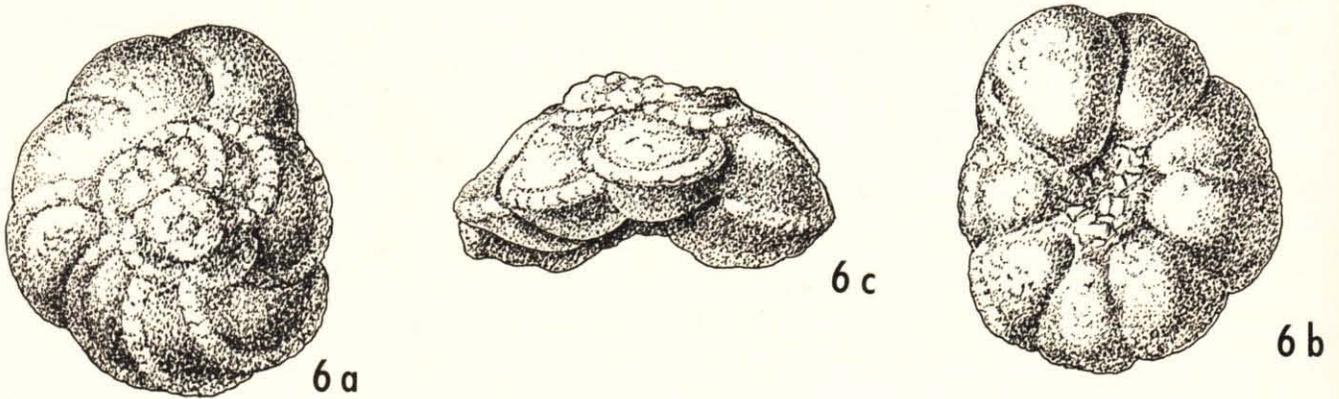
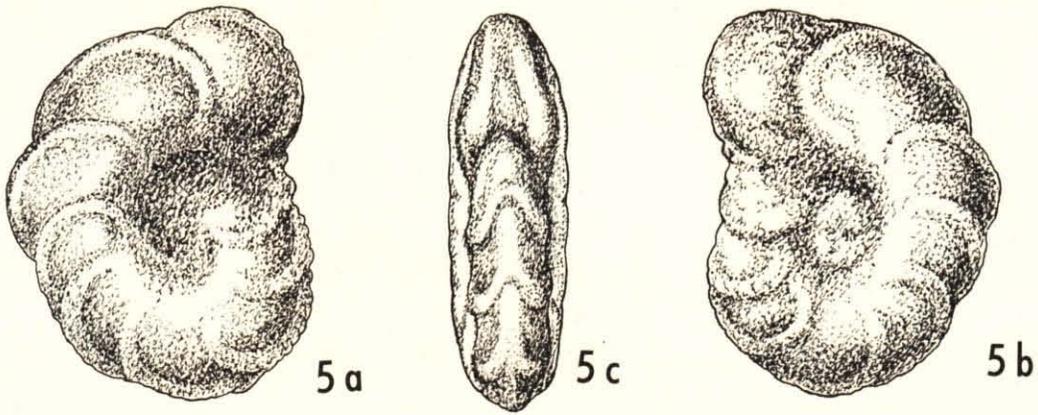
1942. *Globotruncana apenninica* var. *typica* GANDOLFI, p. 116-123, fig. 43 (2, 3); pl. 2, fig.

## EXPLANATION OF PLATE 7

FIGS.	PAGE
1a-c. <i>Hedbergella trocoidea</i> (Gandolfi). Same specimen as figured by Gandolfi, 1942, pl. 4, fig. 3 (NHMB C 25549). .....	23
2a-c. <i>Hedbergella trocoidea</i> (Gandolfi). Same specimen as figured by Gandolfi, 1942, pl. 4, fig. 2, lectotype. (NHMB C 25550). .....	23
3a-c. <i>Ticinella roberti</i> (Gandolfi). Same specimen as figured by Gandolfi, 1942, pl. 2, fig. 2 and pl. 4, fig. 5, holotype. (NHMB C 25551). .....	25
4a-c. <i>Biticinella breggiensis</i> (Gandolfi). Same specimen as figured by Gandolfi, 1942, pl. 3, fig. 6, holotype. (NHMB C 25552). .....	25



Caron and Luterbacher: Cretaceous Type Specimens



Caron and Luterbacher: Cretaceous Type Specimens

- 6; pl. 4, figs. 13, 14; pl. 9, fig. 6; pl. 12, figs. 4-6; pl. 14, figs. 3, 4.
1950. *Globotruncana (Rotalipora) apenninica* RENZ, REICHEL, p. 604-607; pl. 16, fig. 4; pl. 17, fig. 4.
1957. *Globotruncana (Rotalipora) apenninica apenninica* RENZ, GANDOLFI, p. 60, pl. 9, fig. 1.
1961. *Rotalipora apenninica* (Renz), LOEBLICH and TAPPAN, p. 296-297, pl. 7, figs. 11, 12.
1962. *Rotalipora apenninica gandolfii* LUTERBACHER and PREMOLI SILVA, p. 267-268, pl. 19, fig. 3.

Holotype: Gandolfi, 1942, pl. 2, fig. 5, designated by Luterbacher and Premoli Silva, 1962, p. 267. (Naturhistorisches Museum Basel, C 25557).

For remarks see *Rotalipora apenninica*.

#### *Rotalipora reicheli* (Mornod)

Plate 9, figure 10

1942. *Globotruncana apenninica* var. *gamma*, GANDOLFI, p. 116-123, fig. 41 (1); fig. 42 (1); fig. 44 (3, 4); pl. 6, fig. 6.
1950. *Globotruncana (Rotalipora) reicheli* MORNOD, p. 583, fig. 5 (4); fig. 6 (1-6); pl. 25, figs. 3, 4.
1953. *Rotalipora reicheli* MORNOD, SUBBOTINA, p. 162-164, pl. 2, figs. 3, 4.
1959. *Rotalipora (Thalmaninella) reicheli* (Mornod), KLAUS, p. 806-808, fig. 7 (3); pl. 4, fig. 2.
1961. *Rotalipora marchigiana* BORSETTI, p. 36-37; figs. 34-37, 48, 49; pl. 4, fig. 2.

Holotype: Mornod, 1950, fig. 5 (4), designated by the author.

This species was first described by Mornod from the Upper Cenomanian of the Préalpes Romandes (Western Switzerland). This author included in this species the forms described in 1942 by Gandolfi as *Globotruncana apenninica* var. *gamma*.

The distinguishing characteristics of *Rotalipora reicheli* were extensively discussed by Klaus (1959, p. 807). The main features of the species are the truncated chambers and the well ornamented umbilical shoulders which tend to be turned outward.

A new name, *Rotalipora marchigiana*, was introduced by Borsetti (1961) to distinguish the forms described by Gandolfi as *Globotruncana apenninica*

var. *gamma* from *Rotalipora reicheli*. An examination of topotypes of *Rotalipora reicheli* and *Globotruncana apenninica* var. *gamma*, however, allows the inclusion of *Rotalipora marchigiana* in the range of variability of *Rotalipora reicheli*.

The well preserved redrawn specimen was figured by Gandolfi (1942) in text figs. 41 and 42.

#### *Globotruncana renzi* Gandolfi

Plate 9, figure 12

1942. *Globotruncana renzi* GANDOLFI, p. 124-125, pl. 3, fig. 1; pl. 4, fig. 16; non p. 124, fig. 45.
1957. *Globotruncana coldrieriensis* GANDOLFI, p. 64; pl. 9, fig. 7 (= Gandolfi, 1942, pl. 3, fig. 1).
1963. *Globotruncana (Globotruncana) renzi renzi* Gandolfi, VAN HINTE, p. 66, pl. 2, figs. 1, 2.

In the original publication, Gandolfi figured two different species as *Globotruncana renzi* (p. 124, fig. 45 and pl. 3, fig. 1). [The section figured (pl. 10, fig. 2) belongs probably to the group *Praeglobotruncana stephani*]. In the text, no holotype was designated. In Gandolfi's collection, however, the specimen figured on pl. 3, fig. 1 (Naturhistorisches Museum Basel, C 25560) was labelled as the holotype, but, following strictly the rules of zoological nomenclature, the specimen figured in first place should be considered as the holotype.

The authors have discussed extensively this nomenclatorial problem with M. Reichel and J. Sigal who agree that the specimen figured by Gandolfi on p. 124, fig. 45 is too badly preserved to serve as a holotype. The drawing by Gandolfi is somewhat idealized. A reexamination of this specimen (pl. 3, fig. 11, Naturhistorisches Museum Basel, C 25559) indicates that:

1. the preservation of the specimen is poor. The last-formed chamber is crushed and covered by an agglomeration of calcite crystals which also invades the umbilicus.
2. the specimen represents an intermediate form, either *Globotruncana praeconcovata* or a juvenile specimen of *Globotruncana concavata* which has not yet acquired the adult number of chambers. Several characters contribute to this: delicate double keel with parallel branches, flattened spiral side, strongly convex umbilical side with

#### EXPLANATION OF PLATE 8

FIGS.	PAGE
5a-c. <i>Planomalina buxtorfi</i> (Gandolfi). Same specimen as figured by Gandolfi, 1942, pl. 3, fig. 7, holotype. (NHMB C 25553). .....	25
6a-c. <i>Rotalipora ticinensis</i> (Gandolfi). Same specimen as figured by Gandolfi, 1942, pl. 2, fig. 3, holotype. (NHMB C 25554). .....	25
7a-c. <i>Praeglobotruncana stephani</i> (Gandolfi). Same specimen as figured by Gandolfi, 1942, pl. 3, fig. 4, holotype. (NHMB C 25555). .....	26
8a-c. <i>Rotalipora apenninica</i> (Renz). Same specimen as figured by Gandolfi, 1942, p. 117, fig. 40a-c. (NHMB C 25556). .....	26

inflated chambers. On the figure given by Gandolfi, the umbilical side is represented too schematically: it shows a sigmoidal, raised, reflected ventral keel reaching the periphery of the umbilicus in the sutures between the chambers; in fact, only a few pustules can be observed at the periphery of the umbilicus of the third chamber of the youngest whorl.

The authors of the present paper reject this ambiguous and controversial specimen as the holotype for a widely used species having great stratigraphic importance.

On the other hand, a reëxamination of the second specimen figured by Gandolfi (1942, pl. 3, fig. 1) as *Globotruncana renzi* indicates that:

1. although the drawing by Gandolfi is slightly schematic, the main features which characterize *Globotruncana renzi* as a well defined and independent species are well represented. The youngest chamber is crushed and no true keel can be observed. The previous chambers possess, however, the narrow double keel with its bifurcation at the base of the next-formed chamber.
2. the majority of the authors describing *Globotruncana renzi* have referred to this specimen. Moreover, in 1957, Gandolfi designated this specimen as the holotype of *Globotruncana coldrieriensis*, an invalid new name for *Globotruncana renzi* Gandolfi, 1942 (see editorial note in "Catalogue of Foraminifera," supplement 1958, no. 2).

Consequently, the authors of the present paper consider the specimen figured by Gandolfi, 1942, pl. 3, fig. 1 (Naturhistorisches Museum Basel, C 25560) as the lectotype of *Globotruncana renzi*.

Description (in part following Gandolfi, 1942, p. 124):

Older whorls double keeled or with rows of pustules suggesting a double keel, last formed whorl single keeled. Imperforate carenal band pustulate, slightly oblique or undulated. On umbilical side, chambers convex and somewhat elongate as in *Globotruncana linnei*. Umbilicus wide and deep. Each

chamber contoured by the lower branch of the keel, which passes, after a sigmoidal reflection, into the thickened periphery of the umbilicus. The carenal band of the internal whorls forming a more or less narrow double keel, often observable only in thin section, but possibly persisting on the oldest chambers of the last-formed whorl. In well preserved specimens, apertures covered by small and delicate lips which may extend into the umbilicus. In peripheral view, test biconvex and more or less unsymmetrical. Spiral side slightly to strongly convex owing to the more or less inflated spiral surfaces of the chambers.

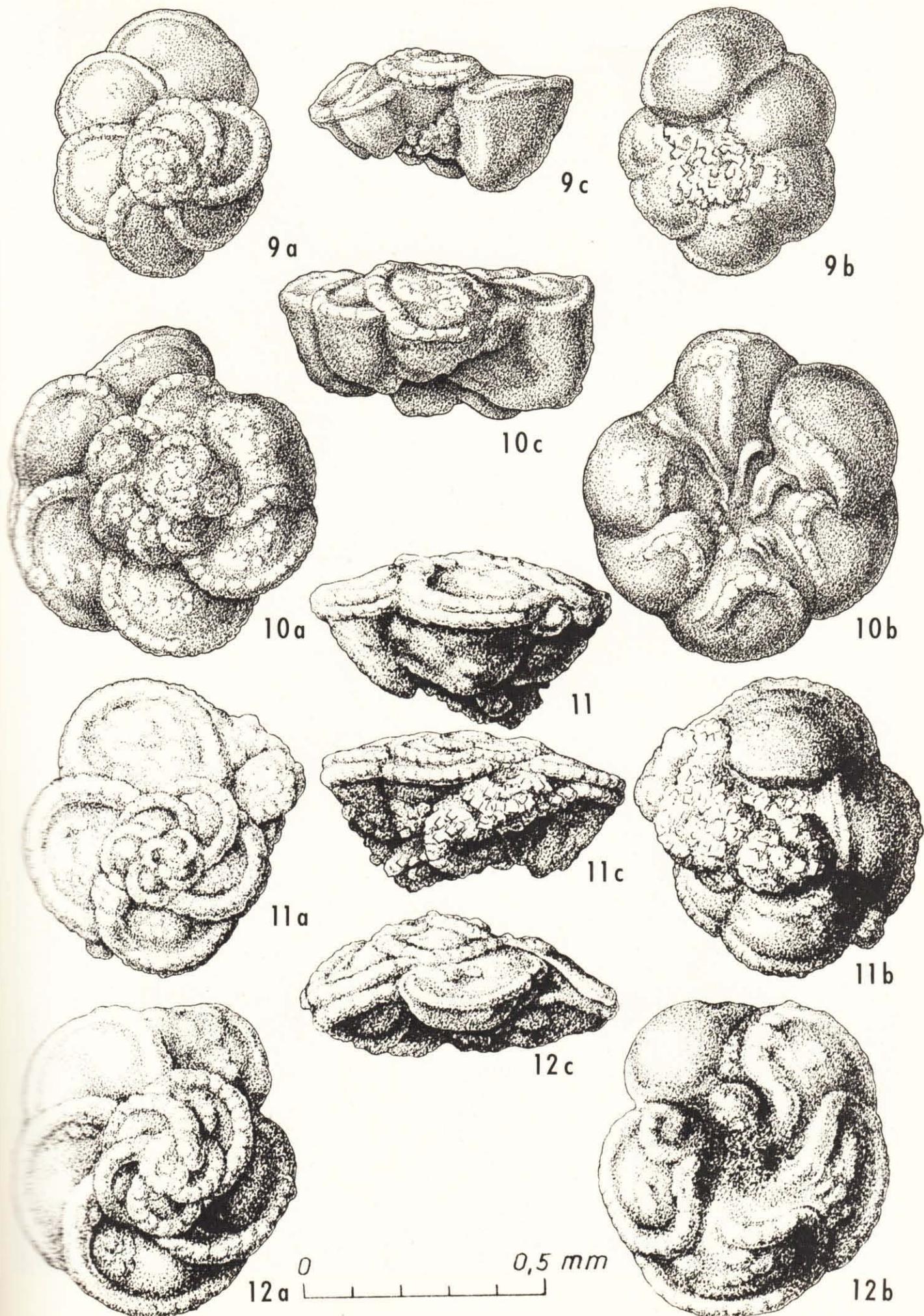
*Remarks.*—The umbilicus of the holotype is filled with sediment. *Globotruncana araratica* Martirosjan (1958, p. 15-16, fig. 2) might be a junior synonym of *Globotruncana renzi*. The specimen figured by the same author on pl. 4, fig. 1 is probably a *Globotruncana praeconcovata* or a juvenile specimen of *Globotruncana concavata* closely resembling the specimen figured by Gandolfi (1942, fig. 45) as *Globotruncana renzi*.

The holotype of *Globotruncana angusticarinata* Gandolfi, 1942, has been lost. The specimens labelled as "*Globotruncana angusticarinata*" in Gandolfi's collection generally have fewer chambers (6) than those figured by the author. Specimens intermediate to *Globotruncana renzi* are frequent. In typical representatives of *Globotruncana angusticarinata*, the spiral side is more convex than the umbilical side owing to the inflation of the spiral surface of the chambers. The two keels are distinct, but very close at the proximal septum of each chamber. They are bifurcating and distinctly separated at the base of the next younger chamber.

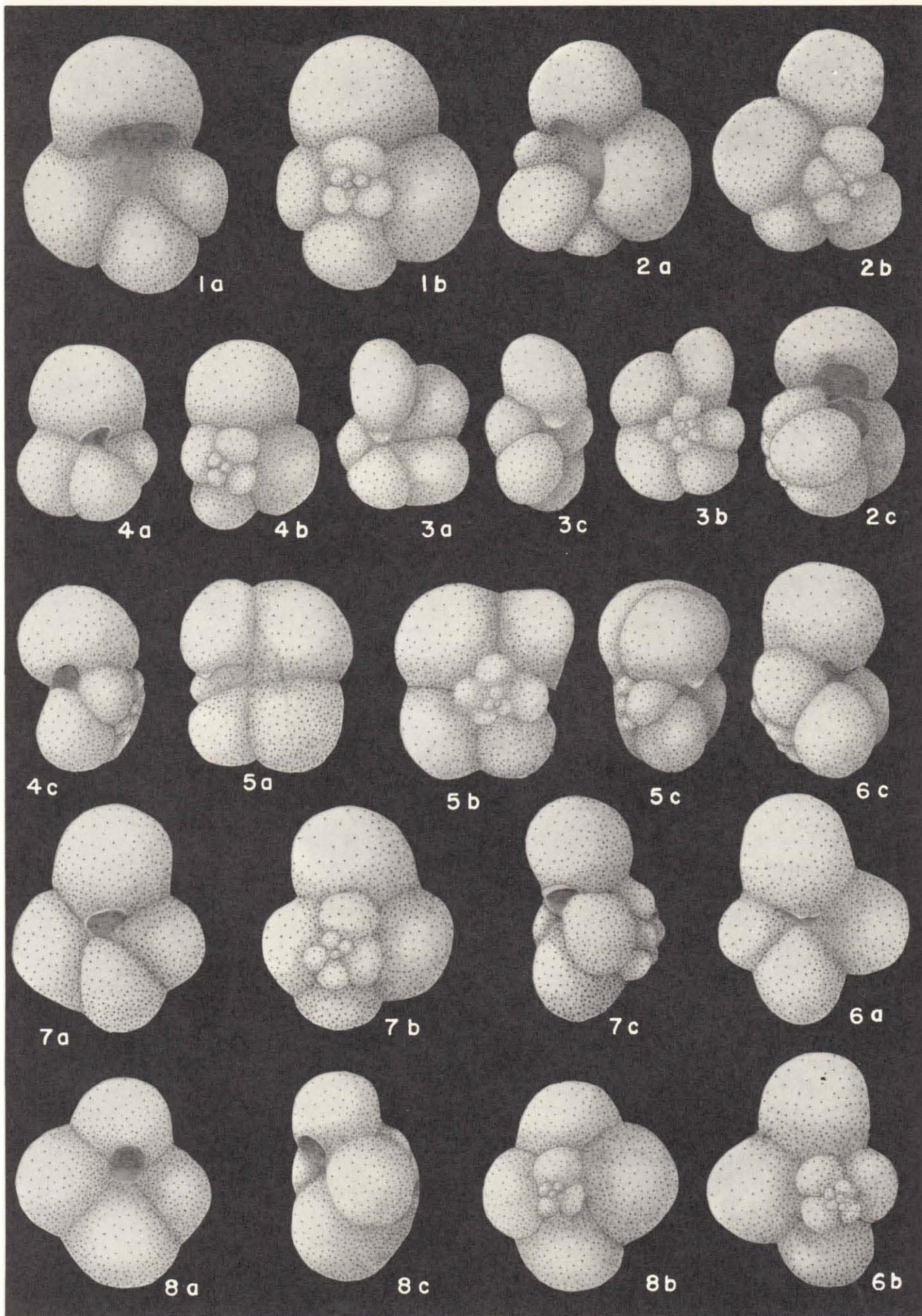
The type level of *Globotruncana renzi* and *Globotruncana angusticarinata* is given as "Flysch, Cava di Scabriana near Coldrerio (Ct. Ticino, Southern Switzerland)". The age of the Flysch deposits of the Mendrisiotto is given as Turonian by Gandolfi. The type locality, "Cava di Scabriana," has been destroyed by the construction of the Chiasso-Lugano highway. A preliminary reëxamination of the faunas collected by Vonderschmitt and Gandolfi from this locality indicates a Late Turonian to Early Senonian age. A more detailed study of these microfaunas and of supplementary

#### EXPLANATION OF PLATE 9

FIGS.	PAGE
9a-c. <i>Rotalipora gandolfii</i> Luterbacher and Premoli Silva. Same specimen as figured by Gandolfi, 1942, pl. 2, fig. 5, holotype. (NHMB C 25557). .....	26
10a-c. <i>Rotalipora reicheli</i> (Mornod). Same specimen as figured by Gandolfi, 1942, p. 118, fig. 41 (1) and p. 119, fig. 42 (1). (NHMB C 25558). .....	27
11a-d. <i>Globotruncana</i> sp. Same specimen as figured by Gandolfi, 1942, p. 124, fig. 45. (NHMB C 25559). .....	27
12a-c. <i>Globotruncana renzi</i> Gandolfi. Same specimen as figured by Gandolfi, 1942, pl. 3, fig. 1, lectotype. (NHMB C 25560). .....	27



Caron and Luterbacher: Cretaceous Type Specimens



Bhatt: Planktonic Foraminifera of India

samples originating from temporary outcrops uncovered in the Flysch deposits during the construction of the Chiasso-Lugano highway is planned.

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## EXPLANATION OF PLATE 10

FIGS.	PAGE
1a-b. <i>Globigerina bulloides</i> d'Orbigny. a, umbilical view; b, spiral view. $\times 86$ .	31
2a-c. <i>Globigerina calida</i> Parker. a, umbilical view; b, spiral view; c, edge view. $\times 77$ .	31
3a-c. <i>Globigerina quinqueloba</i> Natland. a, umbilical view; b, spiral view; c, edge view. $\times 124$ .	31
4a-c. <i>Globigerina</i> cf. <i>parabulloides</i> Blow. a, umbilical view; b, spiral view; c, edge view. $\times 82$ .	31
5a-c, 8a-c. <i>Globigerina pachyderma</i> (Ehrenberg). 5a and 8a, umbilical views; 5b and 8b, spiral views; 5c and 8c, edge views. 5a-c, $\times 82$ ; 8a-c, $\times 119$ .	31
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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION  
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362. PLANKTONIC FORAMINIFERA FROM SEDIMENTS OFF THE  
VISHAKHAPATNAM COAST, INDIA\*

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ABSTRACT

Fifteen species of modern planktonic foraminifera are recorded from a sample from the outer shelf region off the east coast of India. The occurrence in the assemblage of colder-water species, corresponding in general to those in temperate waters of the present oceans, has been inferred to show the result of glacial advance during the Pleistocene and in part, at least, the relict nature of the recovered fauna. However, the presence of warm water species as well indicates a mixing of planktonic faunas from different climatic zones. The postulation that the mixing might have been continuous from the Pleistocene to the present day seems most logical. The mixing of faunas during Pleistocene times has been attributed to the action of ocean currents.

INTRODUCTION

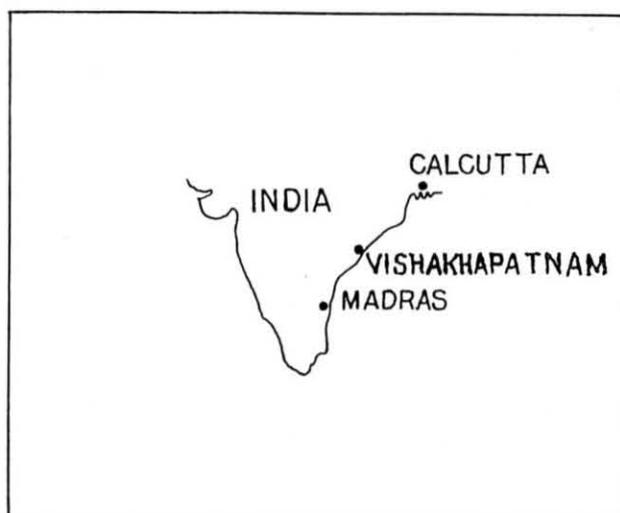
A perusal of published literature on foraminifera from India makes it apparent that the planktonic group of these organisms has drawn little attention of Indian workers. Very recently, however, certain students in the field have endeavoured to set right certain stratigraphic problems concerning Cretaceous and Paleogene sediments of South India, basing their observations mainly on planktonic foraminifera.

There is still, however, a complete lack of record of living planktonic foraminifera from the oceanic regions surrounding the Indian Peninsula. Regarding the shelf sediments foraminifera of this region, mention may be made of the paper by Ganapati and Satyavati (1958). But these authors, apart from listing a few planktonic species as well as benthonic species of foraminifera, have attempted no ecologic interpretation. This fact, coupled with an idea that such studies besides being of academic interest may have an important bearing on future more detailed works, has led the author to carry out the present initial study, an endeavour on the part of the author to record objective data.

The material studied (text fig. 1) was collected from the outer shelf region off the east coast of India, and constitutes bottom sediment from a depth of 71 fathoms. The exact spot of the sample collection is nearly 25 miles from the town of Vishakhapatnam ( $17^{\circ}44'N$ ,  $83^{\circ}16'E$ ), roughly in a southeasterly direction.

The material has yielded a rich assemblage of

planktonic foraminifera, which by no means includes all the forms inhabiting the modern oceans. Good preservation of individual specimens and the clarity of their structural details are some of the factors that led the author to document them.



TEXT FIGURE 1

Map showing the location of Vishakhapatnam

A large literature has accumulated in recent years concerning the distribution, ecology and morphologic variation of recent planktonic foraminifera. The waters of the Pacific and Atlantic oceans have been scanned most thoroughly.

One of the earliest contributions in this regard was made by Wiseman and Ovey (1950). Emiliani (1954) studied the living populations of planktonic foraminifera from the Gulf of Mexico, the equatorial Atlantic and the eastern equatorial Pacific and recorded significant observations regarding depth adjustments of such foraminiferal populations in respect to temperature and water density.

Bradshaw (1959), Parker (1960), Smith (1963) and others have made important contributions to our knowledge regarding the present-day distribution and ecology of planktonic foraminifera in the Pacific Ocean. Parker (1962) has studied extensively the bottom sediments of the South Pacific and has brought to record many new facts.

Similar studies have been carried out by Phleger, Parker and Peirson (1953), Bé (1959, 1966), and others for the Atlantic Ocean.

In addition, deep-sea bottom cores have been the subject of many important published reports. By

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comparing the planktonic foraminiferal species recovered from different horizons of these cores with the well-studied zonal distribution of planktonic foraminifera in present day oceans, interesting patterns in the earth's climatic fluctuations during the Pleistocene glacial epoch have been deduced. Among the more important publications that can be mentioned in this regard are those of Stubbings (1937), Phleger (1939, 1947), Arrhenius (1952), Schott (1952), Emiliani (1955, 1957), Ericson and Wollin (1956a, 1956b), Todd (1958), and Parker (1958).

#### SYSTEMATICS

The taxonomy of Parker (1962) has been followed. The synonymy list is not complete; only the type reference is given, as well as certain other references of immediate interest. Remarks concerning morphological variation have been included for those species for which a large number of individuals were recovered. In general, however, the scarcity of material has forced the author to refrain from touching such aspects in detail. All the specimens have been deposited in the Paleontology Laboratory of the Oil and Natural Gas Commission of India.

Family GLOBIGERINIDAE Carpenter,  
Parker and Jones  
Genus *Globigerina* d'Orbigny  
*Globigerina bulloides* d'Orbigny  
Plate 10, figures 1a-b

*Globigerina bulloides* D'ORBIGNY, 1826, Ann. Sci. Nat., Ser. 1, vol. 7, p. 277.

*Remarks.*—The species is abundant in the collection. The specimens show considerable variation in shape of the test as a whole. The coiling is random. The test size varies from 0.25 to 0.41 mm. in maximum diameter.

*Globigerina calida* Parker  
Plate 10, figures 2a-c

*Globigerina calida* PARKER, 1962, Micropal., vol. 8, no. 2, p. 221-222, pl. 1, figs. 9-15.

*Remarks.*—Forms akin to *G. bulloides* but showing the apertural tendency to become umbilical-extraumbilical in adult specimens and, also, a tendency of chambers of the last coil to become more separated than those of typical *G. bulloides*, have been included in *G. calida*. However, all morphologic intergrades between this species and *G. bulloides* occur. The test size varies from 0.30 mm. to 0.45 mm. in maximum diameter.

*Globigerina* sp. A  
Plate 10, figures 6a-c and 7a-c

*Remarks.*—The small trochospiral test consists of about 2½-3 whorls of subglobular, inflated and

very slightly embracing chambers. The last whorl invariably consists of 4 chambers with total number of chambers varying between 10 and 12. The equatorial profile is subquadrate and the equatorial periphery is lobulate. The shape of the chambers remains constant with progressively increasing size. Occasionally, however, the last chamber is equal in size or very slightly smaller than the penultimate chamber. The dorsal sutures are curved to subradial and the ventral sutures are radial. The umbilicus is moderately wide and shallow. The aperture is a low arch, sometimes covered considerably by an apertural lip, which to a lesser degree is present in all the specimens. The test size varies from 0.24 mm. to 0.47 mm. in maximum diameter.

*Globigerina pachyderma* (Ehrenberg)  
Plate 10, figures 5a-c, 8a-c

*Aristerospira pachyderma* EHRENBERG, 1861, Monats. K. Preuss Akad. Wiss Berlin, p. 303.  
*Globigerina pachyderma* (Ehrenberg), PARKER, 1958, Repts. Swedish Deep-Sea Exped., vol. 8, p. 278, pl. 5, fig. 9.

*Remarks.*—Specimens show considerable variation though maintain in all cases a typically square outline of the test. The final whorl may contain 4 or 5 chambers. Forms possessing a smaller final chamber than the penultimate one are more prevalent. Some of the specimens are identical to those figured by Parker (1962, pl. 2, fig. 6) from near the Near Islands. All the specimens, however, are typical in possessing a thinner test and lack the characteristic coarse crystalline wall structure typical of cold-water specimens of the species. All the specimens are dextrally coiled. The test size varies from 0.17 mm. to 0.35 mm. in maximum diameter. Certain other forms of indefinite affinity (Plate 10, figs. 8a-c) are presently included with *G. pachyderma*.

*Globigerina* cf. *G. paraboloides* Blow  
Plate 10, figures 4a-c

*Globigerina paraboloides* BLOW, 1959, Bull. Amer. Pal., vol. 39, no. 178, p. 179-180, pl. 10, figs. 46a-c.

*Remarks.*—Only a few specimens resembling *G. paraboloides* occur, distinguishable from typical *G. bulloides* by smaller aperture and presence of thickened apertural rim. In this species the equatorial outline of test in equatorial view is no longer subcircular but attains a triangular form. Most of the individuals present appear to be juveniles, consequently there is some doubt of their being *G. paraboloides*.

*Globigerina quinqueloba* Natland  
Plate 10, figures 3a-c  
*Globigerina quinqueloba* NATLAND, 1938, Bull.

Scripps Inst. Oceanography, Tech. Ser. vol. 4, no. 5, p. 149-150, pl. 6.

*Remarks.*—Only typical specimens (with a marked extension from last chamber that covers part of umbilicus) occur. More commonly, however, the last chamber as a whole is elongated radially.

Genus *Globigerinella* Cushman, 1927  
*Globigerinella siphonifera* (d'Orbigny)

Plate 11, figures 1a-2b; Plate 12, figures 1a-b

*Globigerina siphonifera* D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 83, pl. 4, figs. 15-18.

*Hastigerina (Hastigerina) siphonifera* (d'Orbigny), BANNER and BLOW, 1960, Micropal., vol. 6, no. 1, p. 22, text figs. 2, 3.

*Globigerinella siphonifera* (d'Orbigny), PARKER, 1962, Micropal., vol. 8, no. 2, p. 228, pl. 2, figs. 22-28.

*Remarks.*—The author's observation on the wall structure of this species is in conformity with that of Parker (*loc. cit.*). In accordance with the general concept the genus is here retained under Globigerinidae, with which view Saito (1963) also agrees. Both evolute and involute forms occur. All the specimens present belong to Group 1 of Parker (*loc. cit.*, pl. 2, figs. 22-26), which, according to her, is more prevalent in warmer latitudes in the South Pacific. Some specimens that may be put as transitional between *Globorotalia obesa* Bolli and *Globigerinella siphonifera* also occur (Plate 11, figs. 3a-c). The size ranges from 0.22 mm. to 0.67 mm. in maximum diameter.

Genus *Globigerinoides* Cushman, 1927  
*Globigerinoides ruber* (d'Orbigny)

Plate 12, figures 2a-c

*Globigerina rubra* D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 82, vol. 8, pl. 4, figs. 12-14.

*Remarks.*—Typical forms of the species occur in the collection. A few allied forms put under the subspecies *G. ruber cyclostomus* (Galloway and Wissler) by Takayanagi and Saito (1963) also occur (Plate 12, fig. 4). Present specimens, unlike those figured by Parker (1962, pl. 3, figs. 13-14; pl. 4, figs. 1-10) from the South Pacific sediments, are not markedly high spired.

*Globigerinoides tenellus* Parker

Plate 12, figures 3a-c

*Globigerinoides tenellus* PARKER, 1958, Swedish Deep-Sea Exped., 1947-1948, Repts., Fasc. 2, p. 280, pl. 6, figs. 7-11.

*Remarks.*—Specimens are identical to those figured by Parker (1962, pl. 4, figs. 12a-c) from the South Pacific sediments.

*Globigerinoides immaturus* LeRoy

Plate 12, figure 6

*Globigerinoides sacculiferous* (Brady) var. *immatura* LEROY, 1939, Natuurk. Tijdschr. Netherlandie, vol. 99, pt. 6, p. 263, figs. 19-21.

*Globigerinoides immaturus* LeROY, TAKAYANAGI and SAITO, 1962, Tohoku Univ., Sci. Repts., Sec. Ser. (Geol.), Spec. vol., no. 5, p. 95, pl. 27, figs. 2a-c.

*Remarks.*—Only typical specimens occur. Some of the forms present may be regarded as transitional between *Globigerinoides trilobus* (Reuss) and *G. immaturus* (Plate 12, figs. 5a-b). Such forms possess a slightly more inflated final chamber than typical *G. immaturus* and show a narrower aperture than the latter.

Family GLOBOROTALIDAE Cushman, 1927

Genus *Globorotalia* Cushman, 1927

*Globorotalia menardii* (d'Orbigny)

Plate 11, figures 5a-b

*Rotalia menardii* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 273, no. 26.

*Remarks.*—Specimens are fairly well represented in the collection. Few specimens possess an elongated, "tongue"-like last chamber, considered as typical of *Globorotalia tumida* (Brady), but lack the massive imperforate carina characteristic of the species. Such forms instead possess a smooth keel similar to that of *G. menardii* and may be regarded as intermediate between the above two species (Ericson and Wollin, 1956b; Ericson *et. al.*, 1961). Forms resembling *G. menardii flexuosa* (Koch) also occur in the assemblage.

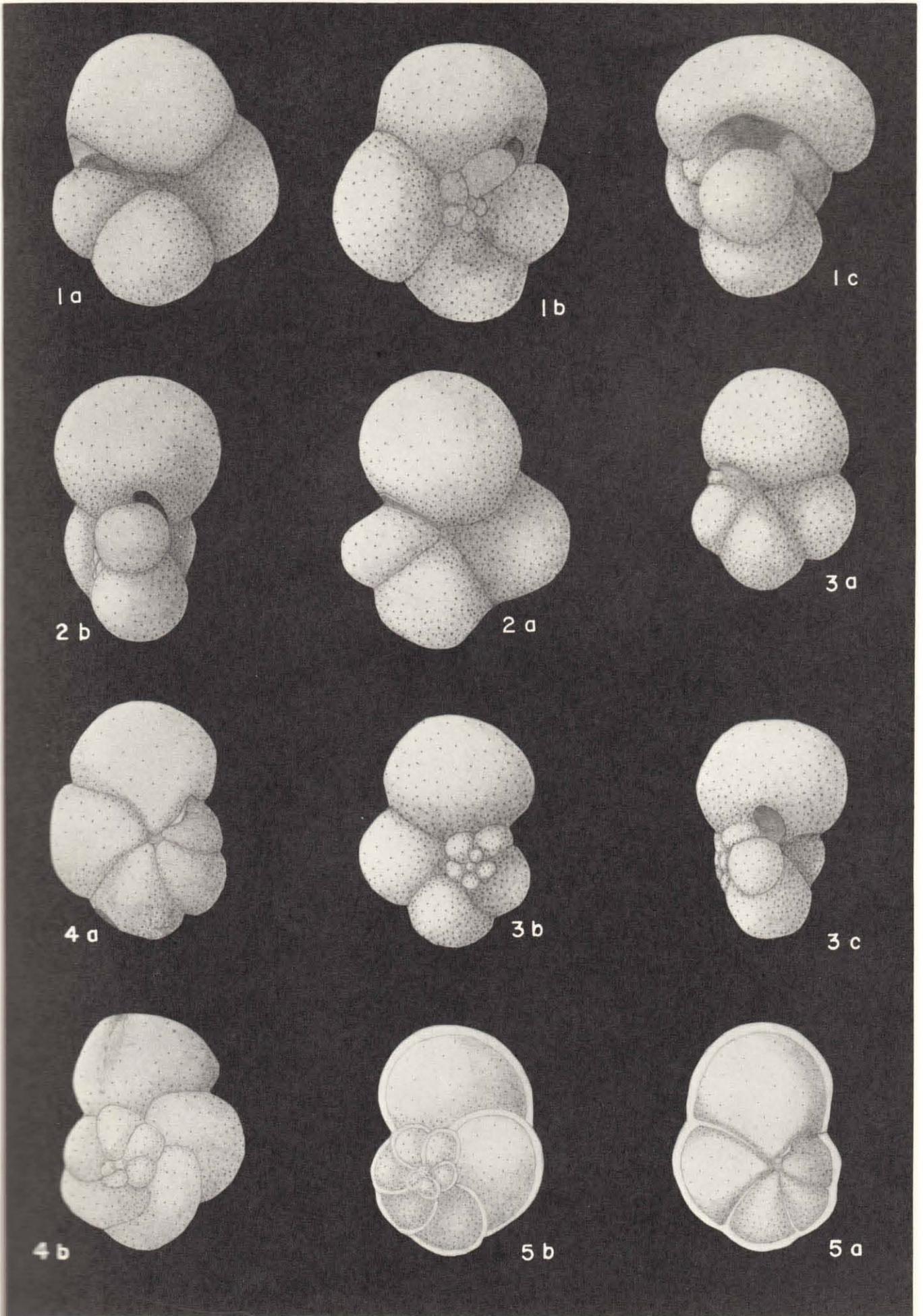
*Globorotalia scitula* (Brady)

Plate 11, figures 4a-b

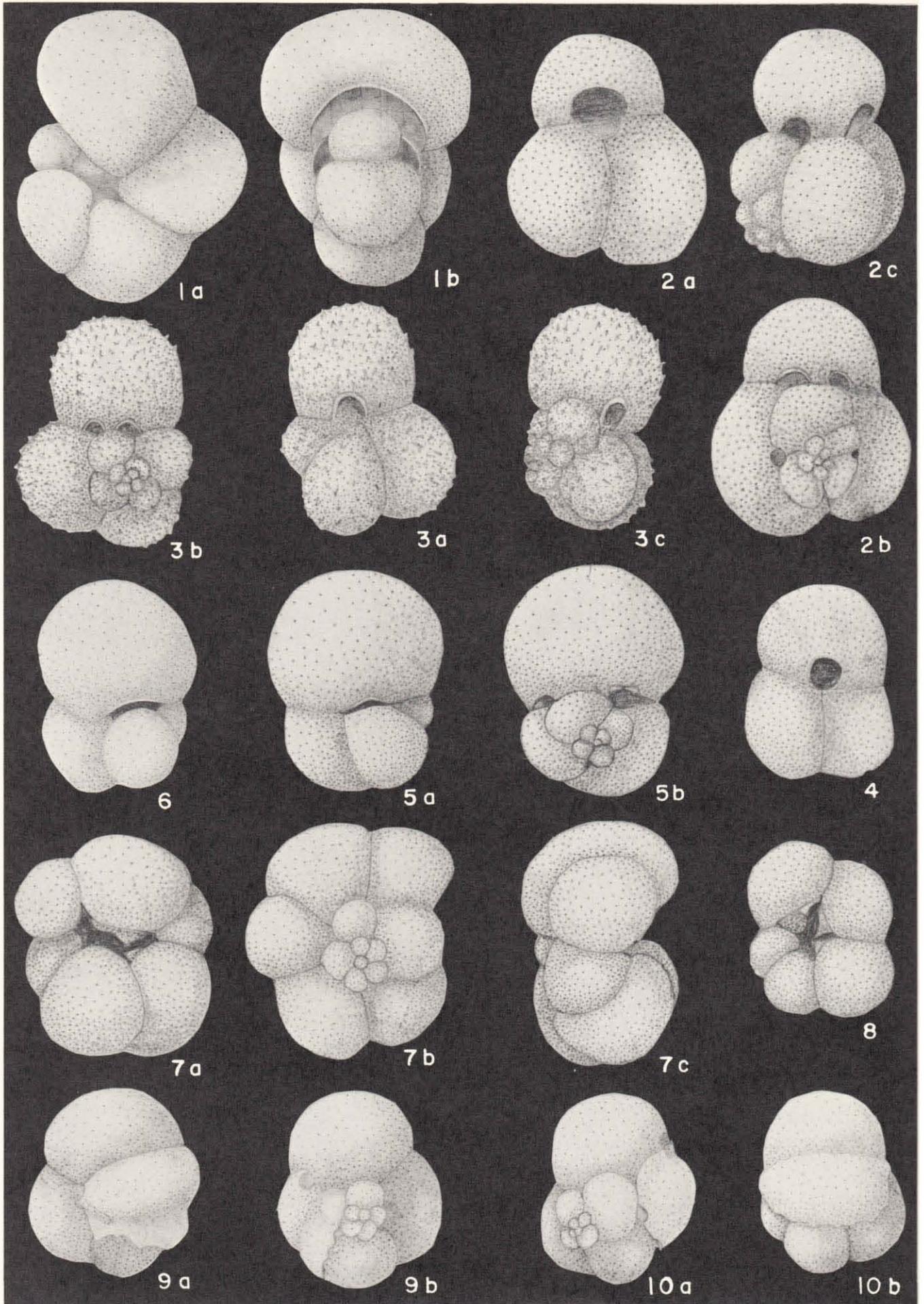
*Pulvinulina scitula* BRADY, 1882, Roy. Soc. Edin.,

#### EXPLANATION OF PLATE 11

FIGS.		PAGE
1a-c, 2a-b.	<i>Globigerinella siphonifera</i> (d'Orbigny). 1a, 1b and 2a, side views; 1c and 2b, edge views. 1a-c, $\times 80$ ; 2a-b, $\times 92$ .	32
3a-c.	Morphologic intergrade between <i>Globigerinella siphonifera</i> and <i>Globorotalia obesa</i> Bolli. a, umbilical view; b, spiral view; c, edge view. $\times 105$ .	32
4a-b.	<i>Globorotalia scitula</i> (Brady). a, umbilical view; b, spiral view. $\times 125$ .	32
5a-b.	<i>Globorotalia menardii</i> (d'Orbigny). a, umbilical view; b, spiral view. $\times 126$ .	32



Bhatt: Planktonic Foraminifera of India



Bhatt: Planktonic Foraminifera of India

Proc., vol. 11 (1880-1882), no. 111, p. 716-717.

*Remarks.*—Typical specimens occur. The final whorl invariably contains five chambers. All the specimens are sinistrally coiled.

Genus *Globoquadrina* Finlay, 1947  
*Globoquadrina deutertrei* (d'Orbigny)

Plate 12, figures 7a-c, 8

*Globigerina rotundata* D'ORBIGNY, 1826, Ann. Sci. Nat., Ser. 1, vol. 7, p. 277, no. 6 (nomen nudum). BANNER and BLOW, 1960, Cush. Found. Foram. Res., Contr., vol. 11, p. 19, pl. 2, fig. 2 (Lectotype).

*Globoquadrina deutertrei* (d'Orbigny), PARKER, 1962, Micropal., vol. 8, no. 2, p. 242, pl. 7, figs. 1-13, pl. 8, figs. 1-4.

*Remarks.*—The specimens exhibit low trochospiral test in contrast to the lectotype designated by Banner and Blow (*loc. cit.*), but are identical in this respect to those figured by Parker (*loc. cit.*, pl. 8, fig. 3). All the specimens are dextrally coiled and exhibit a wide range of morphologic variation. However, all the forms present may fall within the range of variation of the species. The size ranges from 0.59 mm. to 0.79 mm. in maximum diameter.

Genus *Globigerinita* Brönnimann, 1957

Parker (1962) is undecided regarding the affinity of this genus and opines that it can fall either in the family Globorotaliidae or in Globigerinidae, but in some respects it is more related to the former.

*Globigerinita glutinata* (Egger)

Plate 12, figures 10a-b

*Globigerina glutinata* EGGER, 1893, Abhandl. k. Akad. Wiss. München, CLII, vol. 18, p. 371, pl. 13, figs. 19-29.

*Remarks.*—Specimens with bulla are common. Absence of bulla is observed in one individual only. Specimens with bulla on dorsal side are absent.

Genus *Globorotaloides* Bolli, 1957

Bolli (1957) has put this genus in family Orbul-

inidae Schultze, 1854, and subfamily Catapsydracinae Bolli, Loeblich and Tappan, 1957.

?*Globorotaloides* sp.

Plate 12, figures 9a-b

*Remarks.*—Only a single specimen occurs. The chamber pattern of the test indicates a *Globorotalia*-like initial stage followed by a globigerine stage. The final chamber, which is much reduced in size as compared to the penultimate chamber, assumes an elongated bulla-like appearance, covering almost the whole of the umbilicus and extending on to the dorsal side of the test. The "bulla" possesses two apertural openings, one on the umbilical region and the other on the dorsal side. The margin of the "bulla" opposite to the last chamber appears to be irregularly extended, covering part of antipenultimate chamber. The test size is 0.20 mm. in maximum diameter.

#### REMARKS ON THE ASSEMBLAGE

Amongst the diagnostically significant planktonic foraminiferal species that occur in the assemblage, two types of faunal elements characterising different present-day climatic zones are discernible, one typical of mid-latitude waters, the other restricted to the low-latitude waters of modern oceans. The two faunal elements are described and discussed below and their significance interpreted.

#### Mid-Latitude Fauna

This faunal element is characterised by the abundance of two ecologically significant species—*Globigerina bulloides* and *G. pachyderma*. The former accounts for nearly 14% of the assemblage and the latter 12%. Although *G. pachyderma* is generally considered to be a characteristic high-latitude species, it is interesting to note that the studies of Ericson (1959), Bandy (1960), and others on the coiling characteristics of this species have made it possible to divide the Recent populations of *G. pachyderma* into two categories: one the sinistrally-coiled, cool-water type and the other dextrally-coiled, warm-water type, the former confined to

#### EXPLANATION OF PLATE 12

FIGS.	PAGE
1a-b. <i>Globigerinella siphonifera</i> (d'Orbigny). a, side view; b, edge view. ×84. ....	32
2a-c. <i>Globigerinoides ruber</i> (d'Orbigny). a, umbilical view; b, spiral view; c, edge view. ×82. ....	32
3a-c. <i>Globigerinoides tenellus</i> Parker. a, umbilical view; b, spiral view; c, edge view. ×127. ....	32
4. <i>Globigerinoides ruber cyclostomus</i> (Galloway and Wissler). umbilical view. ×84. ....	32
5a-b. Morphologic intergrade between <i>Globigerinoides immaturus</i> LeRoy and <i>Globigerinoides trilobus</i> (Reuss). a, umbilical view; b, spiral view. ×87. ....	32
6. <i>Globigerinoides immaturus</i> LeRoy. umbilical view. ×107. ....	32
7a-c, 8. <i>Globoquadrina deutertrei</i> (d'Orbigny). 7a and 8, umbilical views; 7b, spiral view; 7c, edge view. ×29. ....	33
9a-b. ? <i>Globorotaloides</i> sp. a, umbilical view; b, spiral view. ×29. ....	33
10a-b. <i>Globigerinita glutinata</i> (Egger). a, spiral view; b, umbilical view. ×130. ....	33

high latitudes, the latter abounding in temperate waters of mid-latitudes but sometimes extending to low latitudes. In the sample from off the Vishakhapatnam coast, all the specimens of *G. pachyderma* are dextrally coiled and in this respect fit the latter category. Additional evidence for their being warm-water types is furnished by their test wall—invariably thinner and lacking the characteristic calcareous thickening considered typical of cool-water forms. Thinner-test populations of *G. pachyderma*, reflecting the effect of warmer temperatures, have also often been noted by other workers (Parker, 1962; Saito, 1963).

Thus the occurrence of dextrally-coiled *G. pachyderma* in association with *G. bulloides* in significant numbers indicates the existence of mid-latitude faunal elements in the assemblage under review.

In the absence of any ocean current which could possibly account for the presence of mid-latitude planktonic faunal elements in the Bay of Bengal waters at the present day, it is suggested here that these mid-latitude planktonic species that occur in the assemblage may represent some relict element in the fauna. A part of the recovered assemblage may thus be relict in nature. This relict element in the fauna may, however, correspond to the lowering of the earth's surface temperatures during Pleistocene glaciation, when mid-latitude species could have extended down and thrived at such low latitudes as the area under investigation.

It is now widely recognised that a significant effect of widespread glaciation during the Pleistocene epoch was toward a general lowering of surface-water temperatures in the oceans and consequently a southerly shift in all the present-day climatic zones. Such periodic shifts in the earth's climatic belts during the Pleistocene are clearly discernible in the alternate occurrences of "warm-water" and "cold-water" planktonic faunas in the ocean-bottom cores from the Atlantic and the Pacific (Schott, 1952; Ericson and Wollin, 1956b; Arrhenius, 1952; Phleger, *et. al.*, 1953, and others), and also from the Arabian Sea (Stubbings, 1937), the Tyrrhenian Sea (Phleger, 1947), and the Gulf of Mexico (Ewing *et. al.*, 1958; Phleger, 1955).

The occurrence of a "cold-water" fauna in a sea-bottom core not normal to the latitude of the location of the core is interpreted as signifying the advance of glaciation during one of the glacial stages and/or substages of the Pleistocene. The faunal shift caused by glacial advance during the last glaciation has been estimated by McIntyre and Bé (1966) to be of the order of 10° latitude, based on the studies of Coccolithophoridae. A more general value may be 10°-15°, as evidenced by foraminiferal studies. Thus Phleger (1960) summarizes: "The colder-water faunas in cores from low lati-

tudes are like those now living in mid-latitudes; the colder-water faunas in cores from mid-latitudes are like those now living in high latitudes."

The presence of mid-latitude faunal elements in low-latitude oceanic sediments thus establishes the presence of Pleistocene glacial sediments on top of the outer shelf region, at least off the Vishakhapatnam coast of the east Indian continental shelf. As the present assemblage comes from the top layer on the shelf, it is logical to infer that the "cold-water" faunal element in the recovered assemblage corresponds to the latest stage and/or substage of the Pleistocene glaciation.

A similar conclusion has been reached by Rao (1964), basing his observations on sedimentological criteria. In his pioneering studies of Indian east coast shelf sediments, Rao (*loc. cit.*) has recorded certain calcareous oolitic sediments from the outer shelf region, these being particularly well developed off the Vishakhapatnam coast. These sediments, according to him, were probably deposited in the lowered Pleistocene sea. He further postulated that owing to a low influx of detritus in Recent times these sediments were covered only partially by later sediments, and that the relict Pleistocene sediments thus remained uncovered on top of the shelf roughly beyond the 45-50 isobath. Material of the present study comes from oolitic sands, forming a part of the relict calcareous sediments and confined roughly within the depth range of 50-80 fathoms (Rao, *loc. cit.*, fig. 17) on top of the shelf.

#### Low-Latitude Fauna

Among the species typical of present-day low latitude waters, only *Globorotalia menardii* occurs here. Ganapati and Satyavati (1958) have, however, earlier listed a few additional species that characterize the tropical zone of modern oceans from adjacent locations on the shelf. These are *Globigerinoides conglobatus* (Brady), *G. sacculifer* (Brady), *Pulleniatina obliquiloculata* (Parker and Jones), and *Sphaeroidinella dehiscens* (Parker and Jones).

The occurrence of two widely divergent faunal elements in the assemblage, one of colder-water and the other of warm water species, presents an obvious instance of faunal mixing. Further, the inferred mixing may either be "relict" in nature, too, as is, at least, the colder-water faunal element in the assemblage, or it may have taken place entirely subsequent to the Pleistocene epoch. A third possibility, however, that the mixing might have been continuous since Pleistocene through Recent to the present day appears to be most likely.

That the mixing is "relict" in nature, at least in part, is evinced by the presence of forms resembling *G. menardii flexuosa* (Koch). This subspecies of *G. menardii* is known to have become extinct be-

fore the Recent, a conclusion based upon the reported absence of this form from the Recent layers on top of sea-bottom cores from the North Atlantic, Caribbean, and Gulf of Mexico (Ericson and Wollin, 1956b).

Natural mixing of planktonic faunas is not uncommon in certain restricted areas of present-day oceans, and it is attributed in the main to the action of ocean currents. It is, however, logical to postulate in the present case also that the warm-water elements may have been introduced into the area by an ocean current flowing from the equatorial region up along the east coast of India during Pleistocene times, carrying with it in its northward flow elements of the southern warm-water fauna. It would not be out of place to mention here that a similar movement of warm water in this region during Pleistocene times has been deduced by Rao (1964), based on sedimentological interpretations.

In the absence of any published record of the living planktonic foraminifera inhabiting waters of the Bay of Bengal, it is not possible at present to estimate the magnitude of the present-day indigenous element in the assemblage, but, as seems logical, a part of the low-latitude planktonic fauna occurring in the assemblage may have been contributed during Recent times; in all probability, this process of mixing may still be continuing.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION  
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VOLUME XX, PART 1, JANUARY, 1969

**CORRECTIONS**

In paper no. 349 (Volume XIX, part 2, April, 1968), entitled "*Discocyclusina* from Pondicherry, South India," the author, B. K. Samanta, has requested that the following corrected magnifications be given for text figure 2: A-G,  $\times 63$  approx. H,  $\times 28$  approx.

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION  
FOR FORAMINIFERAL RESEARCH  
VOLUME XX, PART 1, JANUARY, 1969  
RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the Foraminifera that have come to hand.

- AIZENVERG, D. E., BRAZHNKOVA, N. E., and POTIEVSKAJA, P. D. Biostratigraficheskoe Raschlenenie Kamennougol'nykh Otlozhenij Juzhnogo Sklona Voronezhskogo Massiva (Starobel'sko-Millerovskaja Monoklinal'). — Akad. Nauk Ukrain. SSR, Instit. Geol. Nauk, Kiev, 1968, p. 1-151, pls. 1-60, text figs. 1, 2, (map, columnar section).—Endothyrids.
- AMORE, TINO. La sezione Plio-Pleistocenica di Senise (Potenza).—Riv. Ital. Paleont. Stratig., Mem. 13, 1967, p. 61-127, pls. 1, 2, text figs. 1-23 (map, photos, diagram, columnar section, graphs), tables 1-5.—Includes descriptions and illustrations of 21 species and varieties, none new.
- AOKI, NAOAKI. Benthonic foraminiferal zonation of the Kazusa group, Boso Peninsula.—Trans. Proc. Palaeont. Soc. Japan, n. ser., No. 70, June 30, 1968, p. 238-266, pl. 27, text figs. 1-5 (map, diagrams, range charts), tables 1-3.—Fourteen zones in the Pliocene and lower Pleistocene section. Four new species described, and several others illustrated.
- ASANO, KIYOSHI, INGLE, JAMES C., JR., and TAKAYANAGI, YOKICHI. Origin and development of *Globigerina quinqueloba* Natland in the North Pacific.—Sci. Repts. Tohoku Univ., 2nd Ser. (Geol.), v. 39, No. 3, 1968, p. 213-241, text figs. 1-16 (range charts, map, drawings, measurement tables, graphs).—In the middle Miocene to Recent lineage from *Globigerina angustiumbilitata* to *G. quinqueloba* the test diameter increases, shape of the final chamber changes from simple to aberrant with lip, and the wall changes from smooth to hispid. Morphologic variations are illustrated from Japan, California, Mohole cores, and the North Pacific.
- BARBULESCU, AURELIA. L'étude de la microfaune de l'horizon avec moules de Iara de Jos (Reg. Cluj) (French summary of Romanian text).—Anal. Univ. Bucuresti, ser. stiint. nat., Geol.-Geogr., Anul 16, No. 2, 1967, p. 73-103, pls. 1-7, text figs. 1, 2 (graphs), table 1.—A Lutetian fauna of 24 species of Foraminifera.
- BARTLETT, GRANT A. Planktonic Foraminifera—new dimensions with the Scanning Electron Microscope.—Canadian Jour. Earth Sci., v. 5, No. 2, April 1968, p. 231-233, pls. 1-6.—Examples of photographs.
- BÉ, ALLAN W. H. Shell porosity of Recent planktonic Foraminifera as a climatic index.—Science, v. 161, No. 3844, Aug. 30, 1968, p. 881-884, text figs. 1-3 (graphs, scanning electron micrographs), table 1.—Porosity is high in tropical species, low in polar species. Porosity is uniform in different species that occur together.
- BELYAEVA, N. V. Distribution of the shells of planktonic Foraminifera on the floor of the Bay of Bengal and some methodological aspects of the analysis of Foraminifera.—Oceanology (translated), v. 7, No. 4, 1967, p. 500-508, text figs. 1-7 (distrib. maps, graph), tables 1, 2.
- BERGGREN, W. A. Phylogenetic and taxonomic problems of some Tertiary planktonic foraminiferal lineages.—Tulane Studies in Geol., v. 6, No. 1, July 31, 1968, p. 1-22, text figs. 1-4 (phylogenetic diagrams).—Re-publication in English of 1966 Russian paper. Five lineages described and illustrated.
- BHALLA, S. N. A note of the validity of *Haplophragmoides hagni* Bhalla, 1965.—Jour. Paleontology, v. 42, No. 4, July 1968, p. 1091.
- BLOW, W. H., and SAITO, TSUNEMASA. The morphology and taxonomy of *Globigerina mexicana* Cushman, 1925.—Micropaleontology, v. 14, No. 3, July 1968, p. 357-360, text figs. 1-4 (drawings).—*Globigerina mexicana* belongs in *Globigerapsis*, and *Orbulinoides* n. gen. (type species *Porticulasphaera beckmanni* Saito 1962) includes "*Porticulasphaera mexicana*" of Bolli, Loeblich and Tappan, 1957. *Porticulasphaera* is a junior synonym of *Globigerapsis*. *Globigerapsis semiinvoluta* (Keijzer) is a junior synonym of *G. mexicana*.
- BOLTOVSKOY, ESTEBAN. Indicadores Biológicos en la Oceanografía.—C i e n c i a e Investigación, tomo 23, No. 2, Feb. 1967, p. 66-75.—Planktonic Foraminifera as biological indicators of water masses are more sensitive than temperature and salinity data.
- Campaña oceanografica "Corrientes Drake VI" (distribución de masas de aguas superficiales según el plancton).—Bol. Serv. Hidro. Naval, v. 4, No. 1, April 1967, p. 5-16, map.—Determination of surface water masses by planktonic Foraminifera.
- BOLTOVSKOY, E., and BOLTOVSKOY, A. Foraminiferos y Tecamebas de la parte inferior del Rio

- Quequen Grande, Provincia de Buenos Aires, Argentina (Sistemática, Distribución, Ecología).—Rev. Museo Argentino Ciencias Nat. "Bernardino Rivadavia," Instit. Nac. Invest. Ciencias Nat., Hidrobiología, v. 2, No. 4, March 1968, p. 127-164, pls. 1-3, map, tables 1, 2, charts 1-5.—Forty-nine species of Foraminifera, none new. In the lower reaches of the river are recognized 21 ecologic zones.
- BUTTERLIN, JACQUES. *Asterocyclina cruzi*, espèce nouvelle de l'Éocène moyen de Colombie.—Eclogae Geol. Helvetiae, v. 61, No. 1, July 31, 1968, p. 225-228, pls. 1-3.
- BUTTERLIN, JACQUES, and MOULLADE, MICHEL. Les Orbitolinidae de l'Éocène de la région des Caraïbes.—Archives des Sci., v. 21, fasc. 1, Jan.-April 1968 (June 1968), p. 5-20, pls. 1-3.—Includes description of *Heterodictyoconus* n. gen. (type species *Conulites americana* Cushman) and a key to the family.
- CARALP, M., KLINGEBIEL, A., LAMY, A., LATOUCHE, C., MOYES, J., and VIGNEAUX, M. Étude micropaléontologique, sédimentologique et géochimique de quelques carottes de sédiments récents du Golfe de Gascogne.—Bull. Institut. Geol. Bassin d'Aquitaine, 1968, No. 5, p. 1-73, pls. 1-17, map, text figs. 1-3 (graphs), tables 1-25.—Foraminifera assemblages illustrated and distribution of species in cores is recorded.
- CARALP, MICHELLE, MOYES, JEAN, and VIGNEAUX, MICHEL. La microfaune actuelle et subrécente d'une carotte atlantique (golfe de Gascogne): observations écologiques et climatiques.—Bull. Soc. Géol. France, ser. 7, v. 9, No. 3, 1967 (June 1968), p. 418-425, pls. 13, 14, text figs. 1, 2 (distrib. and abund. charts).—Quantitative analysis of benthonic and planktonic Foraminifera in a 1.6-meter core, indicating a glacial stage in the lower part.
- CHANG, LI-SHO. A biostratigraphic study of the Tertiary in the Coastal Range, eastern Taiwan, based on smaller Foraminifera (II: northern part).—Proc. Geol. Soc. China, No. 11, June 1968, p. 19-33, pls. 1-6, text figs. 1-4 (map, geol. sections, outcrop photos), tables 1-6.—Late Tertiary planktonic zones recognized and many species illustrated.
- CIFELLI, RICHARD. A note on the holotype of *Globorotalia fohsi* Cushman and Ellisor.—Micropaleontology, v. 14, No. 3, July 1968, p. 369-370.—Presence of faint keel around early chambers.
- CITA, MARIA BIANCA. Micropaleontologia.—La Goliardica, Milano, 1964, 458 p., 320 text figs.—Textbook includes Foraminifera section with family descriptions.
- CLOSS, DARCY. The presence and stratigraphical importance of the *Orbulina* surface in southern Brazil.—Notas e Estudos, Escola Geol., Univ. Federal do Rio Grande do Sul, v. 1, No. 2, Dec. 1966, p. 3-8.—Found in 8 wells.
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- COHEN, ARTHUR D., and GUBER, ALBERT L. Production of pollen-sized "microforaminifera" from "normal" foraminifera.—Micropaleontology, v. 14, No. 3, July 1968, p. 361-362, text figs. 1-3 (graph, photomicrographs).—Initial pseudochitinous chambers remain after treatment of *Ammonia limnetes* with 5% HCl.
- DI GERONIMO, ITALO. Contributo alla conoscenza del Pleistocene di Grammichele (Catania).—Riv. Ital. Paleont. Stratig., Mem. 13, 1967, p. 261-299, text figs 1-6 (map, geol. section, photo, graphs, photomicrographs of fossils), tables 1a-1f.—Age determined by Foraminifera. Occurrence and abundance shown for many species.
- DI GRANDE, ANGELO. Sezione-Tipo della Molassa di S. Mauro (Calabriano) nel Bacino Crotonese.—Riv. Ital. Paleont. Stratig., Mem. 13, 1967, p. 195-258, pls. 10-12, text figs. 1-6 (map, graphs, columnar sections), tables 1-3c.—Includes descriptions and illustrations of 34 species, none new. Three zones recognized.
- DIZER, A. Étude micropaléontologique du Nummulitique de Haymana (Turquie).—Revue de Micropaléontologie, v. 11, No. 1, June 1968, p. 13-21, pls. 1, 2, text fig. 1 (map).—One species of *Nummulites* and two new species of *Assilina* in the lower Lutetian. Several others illustrated.
- FORTI, IEDA R. S., and ROETTGER, ERICA. Further observations on the seasonal variations of mixohaline Foraminifera from the Patos Lagoon, southern Brazil.—Archivio Oceanografia e Limnologia, v. 15, fasc. 1, 1967, p. 55-61.—Second year observations show little change except for lack of live specimens of *Buliminella elegantissima*. Abnormal specimens common with greater frequency in winter. Maximum reproduction periods in fall and winter.
- GIBSON, THOMAS G. Stratigraphy and paleoenvironment of the phosphatic Miocene strata of North Carolina: Reply.—Geol. Soc. America Bull., v. 79, No. 10, Oct. 1968, p. 1437-1448.—Discussion of depth interpretation by Foraminifera.

- GIRI, M. B. S. *Hantkenina* within the frame-work of time and space.—*Jour. Univ. Geol. Soc. Nagpur*, v. 1, No. 12-15, 1964-68, p. 40-50, text figs. 1, 2.—Summary of previous work.
- GOBBETT, D. J. Palaeozoogeography of the Verbeekinae (Permian Foraminifera), in *Aspects of Tethyan biogeography*.—Systematics Assoc. Publ. No. 7, 1967, p. 77-91, text figs. 1-3 (maps, range chart, correl. chart).
- HERRICK, STEPHEN M., and RIMA, DONALD R. Foraminifera from the Clayton Formation (Paleocene) in southeastern Hardeman County, Tennessee.—*U.S. Geol. Survey Prof. Paper 600-C*, 1968, p. C69-C74, text figs. 1, 2 (maps), tables 1, 2.
- HILTERMANN, HEINRICH. Fortschritte der Mikropaläontologie in Deutschland mit einer Bibliographie für das Jahr 1967.—*Paläont. Zeitschr.*, Stuttgart, Band 42, Heft 3/4, Sept. 1968, p. 236-248.
- HOFKER, J. Tertiary Foraminifera of coastal Ecuador. Lower Oligocene and lower Miocene.—*Palaeontographica*, Band 130, Abt. A, 1968, p. 1-59, pls. 1-25, text figs. 1-8 (drawings, graphs), 3 maps.—Descriptions and illustrations of 39 species from the lower Oligocene and 29 from the lower Miocene.
- HOFMANN, GERHARD W. Untersuchungen an der Gattung *Bolivina* (Foraminifera) im Oligozän und Miozän der ostbayerischen Molasse.—*Geol. Bavarica* No. 57, 1967, p. 121-204, pls. 1-5, text figs. 1-20 (maps, columnar sections, graphs, phylogenetic diagram), tables 1, 2.—Includes descriptions and illustrations of 34 species and subspecies, 8 species and 5 subspecies new.
- HUANG, T. Y. A *Lepidocyclina* limestone from the Shangtao area, Miaoli, Taiwan.—*Contribs. to celebrate Prof. Ichiro Hayasaka's 76th Birthday*, Dec. 1967, p. 91-94, pl. 1.
- Some Paleocene planktonic foraminiferids from well PK-3 at Peikang, Yunling, Taiwan.—*Proc. Geol. Soc. China*, No. 11, June 1968, p. 34-43, pl. 1, text fig. 1 (columnar section).—Three species.
- IACCARINO, SILVIA. Ricerche sui Foraminiferi dell'alto Adriatico. Esame di 32 Campioni di fondo raccolti nella Crociera Adriatica Invernale 1966 della N/O Bannock.—*Archivio Oceanografia e Limnologia*, v. 15, fasc. 1, 1967, p. 11-54, text figs. 1-27 (distrib. maps), table 1.—Quantitative analyses based on 32 samples taken between 16 and 66 meters.
- JENDREJAKOVA, OTILIA. Die benthosen Foraminiferen des Alb der Westkarpaten.—*Geol. Zbornik, Geol. Carpathica*, Bratislava, v. 19, No. 1, June 1968, p. 255-278, pls. 1-4, text figs. 1-7 (drawings).—Descriptions and illustrations of 27 species, 1 new and 5 indeterminate.
- KENNETT, JAMES P. The fauna of the Ross Sea. Part 6, Ecology and distribution of Foraminifera.—*New Zealand Dept. Sci. and Industr. Research Bull.* 186, Feb. 1968, (New Zealand Oceanogr. Instit. Mem. No. 46), p. 1-48, text figs. 1-20 (maps, graphs, depth range chart), tables 1-8.—Study based on 36 samples, 18 shallower ones dominated by abundant and diverse calcareous species and 18 deeper ones dominated by sparse arenaceous species. Depth is the chief controlling factor and boundaries are recognized at 270 m, 450-550 m, 1300 m and 2200 m. Species are recorded quantitatively.
- Globorotalia truncatulinoides* as a paleo-oceanographic index.—*Science*, v. 159, No. 3822, March 29, 1968, p. 1461-1463, text figs. 1-3 (diagram, graphs).—Form of test, i.e., convexity of spiral side, varies with average surface water temperature—planoconvex species found in tropical waters; compressed biconvex ones in cold waters. Form ratios may be used to identify water masses.
- Latitudinal variation in *Globigerina pachyderma* (Ehrenberg) in surface sediments of the southwest Pacific Ocean.—*Micropaleontology*, v. 14, No. 3, July 1968, p. 305-318, pl. 1, text figs. 1-9 (maps, graphs), table 1.—In a continuous cline, *G. pachyderma* grades from larger sinistral 4-chambered forms with thickened tests in the south, below the Antarctic Convergence, through intermediate forms which are dominantly sinistral and 4½- to 5-chambered, to smaller dextral 4-chambered forms with thinner walls in the north.
- KOVATCHEVA, T. Barremian and Aptian Foraminifera near Malka-Gelezna and Bulgarsky-Izvor villages (District of Lovetch) (English summary of Bulgarian text).—*Bulgarian Acad. Sci., Bull. Geol. Instit.*, ser. Paleont., v. 17, April 1968, p. 5-35, pls. 1-3, text fig. 1 (map), tables 1, 2 (range charts).—Thirty-three species, none new.
- KURIHARA, KENJI. Notes on the benthonic Foraminifera of the Tonohama group, Shikoku, Japan.—*Trans. Proc. Palaeont. Soc. Japan*, n. ser., No. 70, June 30, 1968, p. 267-283, pl. 28, text figs. 1-5 (maps, columnar sections, chart, diagrams), table 1.—Fifteen species, 3 new, from the Nobori formation of late Miocene or Pliocene age.
- LANGER, WOLFHART. Studien an einigen Genera der Nonioninae (Foraminifera). — *Paläont. Zeitschr.*, Stuttgart, Band 42, Heft 3/4, Sept. 1968, p. 147-161, pls. 17, 18, text figs. 1-5

- (drawings, diagram).—A new subspecies of *Astrononion tumidus* is described.
- LEHMANN, ELROY P., ROZEBOOM, JAN J., WALLER, HARRY O., and CONLEY, CURTIS D., editors. *Microfacies of Libya*.—Petr. Explor. Soc. Libya, Amsterdam, 1967, p. 1-80, pls. 1-37, text fig. 1 (map).—Includes 72 photomicrographs, many showing Foraminifera.
- LEUTZE, WILLARD P. Stratigraphy and paleoenvironment of the phosphatic Miocene strata of North Carolina: Discussion.—*Geol. Soc. America Bull.*, v. 79, No. 10, Oct. 1968, p. 1433-1436.—Discussion of depth interpretation by Foraminifera.
- LINDSAY, J. M. Foraminifera and stratigraphy of the type section of Port Willunga beds, Aldinga Bay, South Australia.—*Trans. Roy. Soc. South Australia*, v. 91, 1967, p. 93-109, pl. 1, text figs. 1, 2 (map, range chart).—Seventeen planktonic species from 4 zones in a section of late Eocene and Oligocene age.
- LIPPS, JERE H. Miocene calcareous plankton, Reliz Canyon, California.—*Soc. Econ. Paleont. Mineral. Pacific Sec. Fieldtrip, Guidebook Gabilan Range and Adjacent San Andreas Fault*, Oct. 20-21, 1967, p. 54-60, pls. 1, 2, text fig. 1 (correl. chart), table 1 (range chart).—Illustrations of planktonic Foraminifera.
- MALUMIAN, NORBERTO. Foraminiferos del Cretácico Superior y Terciario del subsuelo de la provincia Santa Cruz, Argentina.—*Ameghiniana*, tomo 5, No. 6, Feb. 1968, p. 191-227, pls. 1-8, text fig. 1 (map).—In the Upper Cretaceous (upper Campanian-lower Maestrichtian) 15 species; in the Eocene 17 species; and in the Miocene 15 species. None are new; 4 in the Cretaceous are indeterminate.
- MAMET, B. L., and BELFORD, D. J. Carboniferous Foraminifera, Bonaparte Gulf Basin, northwestern Australia.—*Micropaleontology*, v. 14, No. 3, July 1968, p. 339-347, text figs. 1-5 (maps, columnar sections).—Tethyan endothyrids and other small species.
- MAXWELL, PHILLIP A. Two new records of larger Foraminifera from the New Zealand Eocene.—*New Zealand Jour. Geol. Geophys.*, v. 11, No. 1, March 1968, p. 236-238.—Two specimens, one each of *Heterostegina* and *Discocyclina*?
- MERIC, ENGIN. A propos d'un cas de schizogonie dans un individu d'*Orbitoides media* d'Archiac.—*Bull. Min. Res. Explor. Instit. Turkey*, No. 67, Oct. 1966, Foreign Ed., p. 93-96, pls. 1, 2, text fig. 1 (diagram).—Macrospheric embryos embedded around periphery.
- MONCHARMONT ZEI, MARIA. I foraminiferi di alcuni campioni di fondo prelevati lungo la costa di Beirut (Libano).—*Istit. Paleont. Univ. Napoli*, Pubbl. No. 24, 1968, p. 1-33, pls. 1-6, text figs. 1-7 (map, graphs), table 1.—A fauna of 183 species from 5 bottom samples between 11 and 246 meters is listed and some are illustrated.
- MORENO DE CASTRO, E. Sobre la presencia de *Neotrocholina valdensis* Reichel, en el Valanginiense de las provincias de Burgos y Santander.—*Bol. R. Soc. Española Hist. Nat., secc. Geol.*, v. 66, No. 1, 1968, p. 49-52, 2 pls.
- MOULINIER, MARIE. Repartition des Foraminifères benthiques dans les sédiments de la baie de Seine entre le Cotentin et le méridien de Ouistreham.—*Cahiers Oceanographiques*, v. 19, No. 6, June 1967, p. 477-494, text figs. 1-6 (maps, drawings), table.—Species listed and living distributions recorded.
- PAGHIDA-TRELEA, N., SIMIONESCU, T., and OLARU, L. L'étude micropaléontologique du Sarmatien des environs de Hirlau (Plateau Moldave) (French résumé of Rumanian text).—*Anal. Stiintifice Univ. "Al. I. Cuza" din Iasi (ser. n.)*, sect. 2, tom. 13, 1967, p. 83-99, pls. 1-8, tables 1-3.—Check list and illustrations of assemblages.
- PANIZZA, MARIO. Il Pleistocene di Crosia (Rosarno, Cosenza).—*Riv. Ital. Paleont. Stratig., Mem.* 13, 1967, p. 131-192, pls. 3-9, text figs. 1-8 (map, geol. section, graphs, photos), tables 1-2e.—Includes descriptions and illustrations of 25 species and subspecies, one subspecies given a new name, *Bulimina fusiformis* subsp. *sublimbata*. Three zones established.
- POPESCU, GH. *Mississippina neagui* n. sp. des dépôts Tortonien du couloir de Mures.—*Revue Roumaine Géol. Géophys. Géogr.*, ser. Géol., tome 12, No. 1, 1968, p. 109-112, 1 pl.
- RAMOS, REYNALDO FREITAS. Um Fusulinideo no Carbonífero do Para.—*Atas do Simpósio sobre a Biota Amazonica*, Belem, Brazil, June 6-11, 1966, v. 1: *Geociencias*, 1967, p. 403-406, 17 figs.—*Millerella*.
- RIUSCETTI, MARCELLO. La sezione Pliocenica di Monte Rabione (Caltanissetta).—*Riv. Ital. Paleont. Stratig., Mem.* 13, 1967, p. 301-345, text figs. 1-20 (map, graphs), tables 1a-1e.—Occurrence and abundance shown for many species.
- RUDEL, C. H. *Pullenia moorei-Rotalia becki* (Pseudosaucesian) biofacies of the Lower Mohnian.—*Soc. Econ. Paleont. Mineral., Pacific Sect., Guidebook, Geology and Oil Fields*, West side, southern San Joaquin Valley, 1968, p. 92.

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