

MIOCENE PLANKTONIC FORAMINIFERA FROM
NEWPORT BAY, CALIFORNIA

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I. ABSTRACT

Twenty species of planktonic foraminifera are reported from the Miocene Monterey Shale at Newport Bay, California. Rocks of the Luisian Stage contain numerous individuals and species; those of the overlying Mohnian Stage contain fewer species and individuals. Two local zones, recognized in the Luisian, are tentatively correlated with the lower *Globorotalia fohsi* Assemblage Zone in Trinidad (Burdigalian). Higher parts of the Mohnian may correlate with the Helvetian.

The classification adopted in this paper is based on the surface texture of the test. Forms with hispid tests (spinose when living) are separated from smooth and pitted

forms (non-spinose when living). This criterion has been utilized for distinguishing taxa at all systematic levels. *Protentella* gen. nov. (type species, *P. prolixa* sp. nov.) is described from the upper Luisian. Six new species are described: *Turborotalia lata*, *Globigerina tecta*, *Protentella prolixa*, and *Globorotaloides trema* from the Luisian; and *Globigerina bramlettei* and *Eoglobigerina operta* from the Mohnian.

II. INTRODUCTION

Planktonic foraminifera have proved useful in age determination and correlation of Miocene rocks in many parts of the world. Although a sequence of planktonic foraminiferal zones has been recognized throughout

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the world, recognition of these zones or the establishment of new ones has not been attempted seriously in California. To date, California micropaleontologists have utilized the stages and zones of Kleinpell (1938) established on the basis of benthonic foraminifera. Because the distribution of benthonic foraminifera is subject to control by sea bottom conditions which vary sharply from place to place, some discrepancies in correlation of these stages and zones have arisen. As planktonic foraminifera are apparently independent of bottom conditions, their distribution may allow more accurate correlation.

Study of the Miocene planktonic foraminifera from various parts of California (now in progress) has revealed the presence of many species, of value in correlation and age dating. A particularly rich planktonic biota is contained in rocks exposed along the east shore of Newport Bay, California (Figure 1). The foraminifera recorded from this biota (Table 1), provide a basis for further investigations of the California Miocene planktonic species and their use in stratigraphic and ecologic interpretations.

This study was undertaken during 1963 while the writer was a summer student employee at California Research Corporation, La Habra. The Corporation financed much of the field and laboratory work, as well as illustrations and drafting. Alfred R. Loeblich and Helen Tappan Loeblich assisted in the field and in critical review of the manuscript. Frances L. Parker permitted access to the collections of planktonic foraminifera at Scripps Institution of Oceanography, and type specimens also were loaned for study by the U. S. National Museum.

III. STRATIGRAPHY

The rocks in the area of Newport Bay have been arched into an anticline along whose limbs Miocene to Pleistocene sediments crop out (Vedder, Yerkes, and Schoellhamer, 1957). These rocks, best exposed on the northern limb of the anticline, include the Miocene Monterey Shale, Mio-Pliocene Capistrano Formation, and unnamed Plio-Pleistocene sediments. Samples for this study were taken in the Monterey Shale, beginning with the oldest rocks exposed in

LUISIAN										MOHNIAN										STAGE
-	N	W	A	U	D	J	W	O	-	-	N	W	A	U	D	J	W	O	-	SAMPLE NUMBER
																				Globigerina quadrilatera
																				Eoglobigerina minutissima
																				Turborotalia scitula
																				Turborotalia lata
																				Globigerina tecta
																				Globoquadrina venezuelana
																				Globigerina cf. G. digitata
																				Globigerinita uvula
																				Globigerina ? sp.
																				Globigerinoides ? sp.
																				Globoquadrina larmeui
																				Globigerina dubia
																				Globigerinoides trilobus
																				Candorbulina universa
																				Protentella proluxa
																				Globorotaloides trema
																				Globigerina bulloides
																				Globigerina bramlettei
																				Eoglobigerina operta
																				Turborotalia mayeri

Table 1—Stratigraphic distribution of planktonic foraminifera in part of the Miocene Luisian and Mohnian stages exposed at Newport Bay, California.

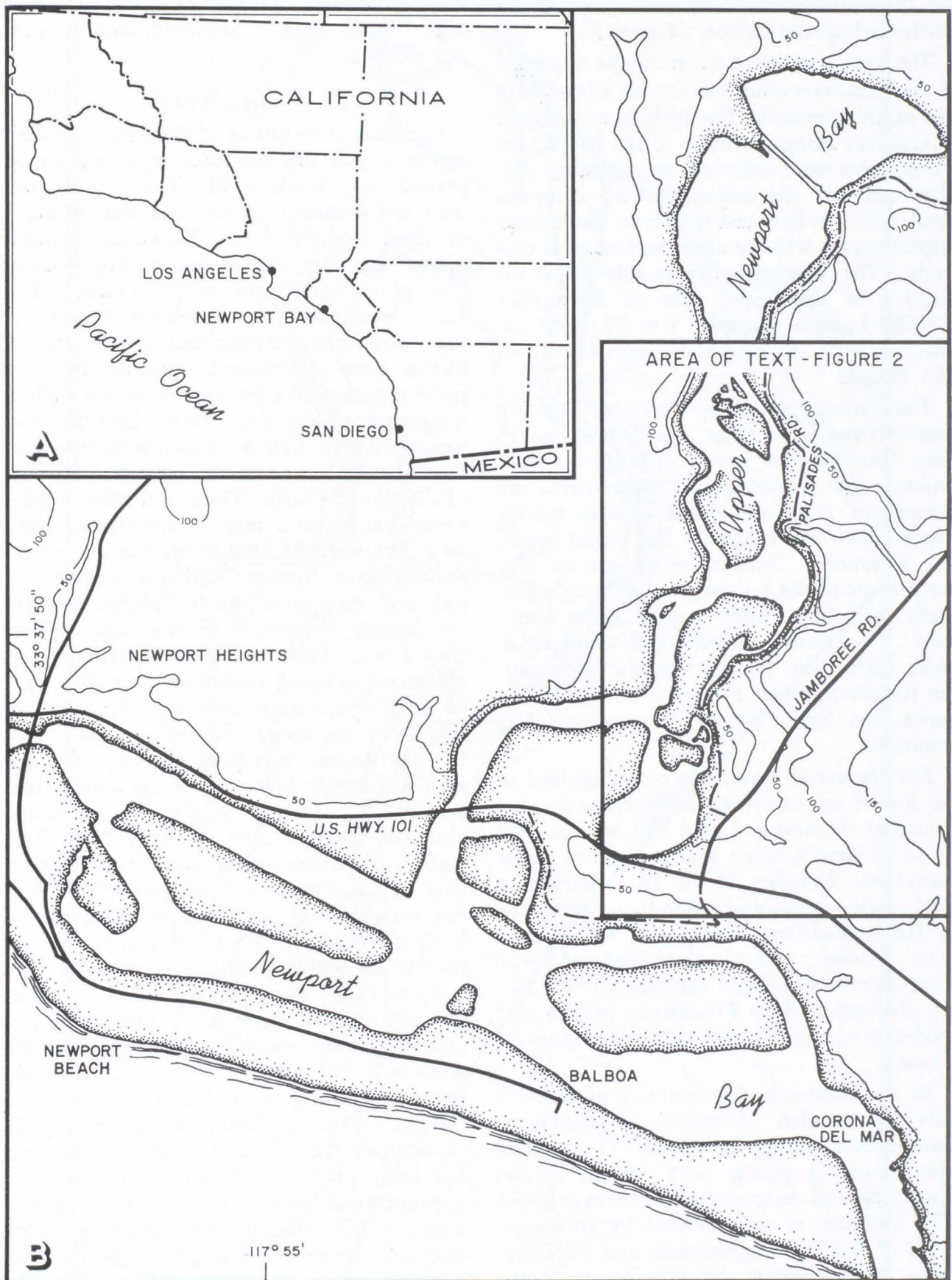


FIGURE 1

- A. Map of Southern California showing the location of Newport Bay.
- B. Newport Bay region showing the area of Figure 2.

the crest of the anticline and progressing northward up the section (Figure 2).

The strata consist of a continuous sequence of diatomaceous mudstones, with a few chert and sandy interbeds. The beds have slumped several feet along the shore of the bay where the samples were collected, but observed displacements in the sequence were compensated, and it is believed that even undetected displacements will not alter the results of this study. The benthonic foraminifera are indicative of the upper part of Kleinpell's (1938) Luisian (samples 1 to 22) and the lower part of his Mohnian (samples 22 to 36) Stages.

The Luisian rocks at Newport Bay are characterized by a large and diverse planktonic foraminiferal fauna. *Globigerina quadrilatera* and *Eoglobigerina minutissima* are present in great abundance. These species persist into the Mohnian but occur much less commonly. Fifteen other species also are present in the Luisian, and although generally rare they locally may be quite abundant. *Turborotalia scitula* and *Globorotaloides trema* also persist into the Mohnian; the former in about the same relative abundance, the latter becoming somewhat less common.

No distinctive zones can be recognized in the lowest ten samples. *Globigerina tecta* is abundant in sample 2, but this species may prove to have a much greater vertical range elsewhere. Samples 11 to 16 constitute a local zone containing abundant specimens of *Globoquadrina venezuelana*, *Globigerinoides trilobus*, and *Candorbulina universona*. The uppermost Luisian samples (17 to 22) are characterized by *Protentella proluxa* and moderate numbers of typical *Globorotaloides trema*.

In the Mohnian, the quantity of individuals and number of species of planktonic foraminifera greatly decreased. The vertical distribution is patchy with certain species appearing and disappearing at various levels. The Mohnian is characterized by an assemblage of *Globigerina bulloides* and *Eoglobigerina minutissima*. *Eoglobigerina operta*, which may prove useful in correlation, and *Turborotalia mayeri* first appear in the uppermost part of the section examined. Ingle (1963) reported *Globigerina pachyderma* from the Mohnian in the area of Newport Bay. This species was not found in the

lower Mohnian during this study, however higher parts of the Mohnian section were not studied.

IV. CORRELATION

Correlation by means of planktonic foraminifera commonly has been assumed to be precise and world-wide. This assumption does not consider the ecologic requirements of these foraminifera. Planktonic foraminifera are not distributed homogeneously throughout the world simply because they float. Bradshaw (1959) observed that living planktonic foraminifera in the Pacific Ocean were distributed latitudinally in a pattern generally correlated with sea surface temperatures, but also affected by other factors. Belyaeva (1963) found a similar pattern of distribution in the bottom sediments of the Indian Ocean. These and other studies show that tropical regions are characterized by a diverse fauna, that temperate and cooler regions have different and less diverse faunas, and that after death the foraminifera are largely deposited in the areas where they lived. This latitudinal distribution is commonly altered, especially near the edges of these temperature belts, by other oceanographic phenomena. In the geologic past the distribution was probably controlled by similar factors. Since mid-Oligocene a latitudinal temperature gradient has existed along the Pacific Coast (Durham, 1950) as well as elsewhere in the world, and correlation of the warmer-water, low-latitude faunas with those of the cooler, higher latitudes is less certain in the fossil record than is correlation within a single temperature belt.

Planktonic species may differ in morphology, depending on where they live. Some existing species show morphologic variation with latitude (Parker, 1962) which would require splitting into distinct taxa if the criteria utilized by many stratigraphic paleontologists were applied. Much emphasis has been placed on "datums," or the first appearance, of certain species. Such appearances, particularly in the higher latitudes, may only correspond to a change in some oceanographic condition and not to the phylogenetic first appearance. For these reasons, correlation of the Newport Bay planktonic faunas with those of the standard reference sections in tropical America is only tentative. Further studies, now in progress on the fossil planktonic faunas of California

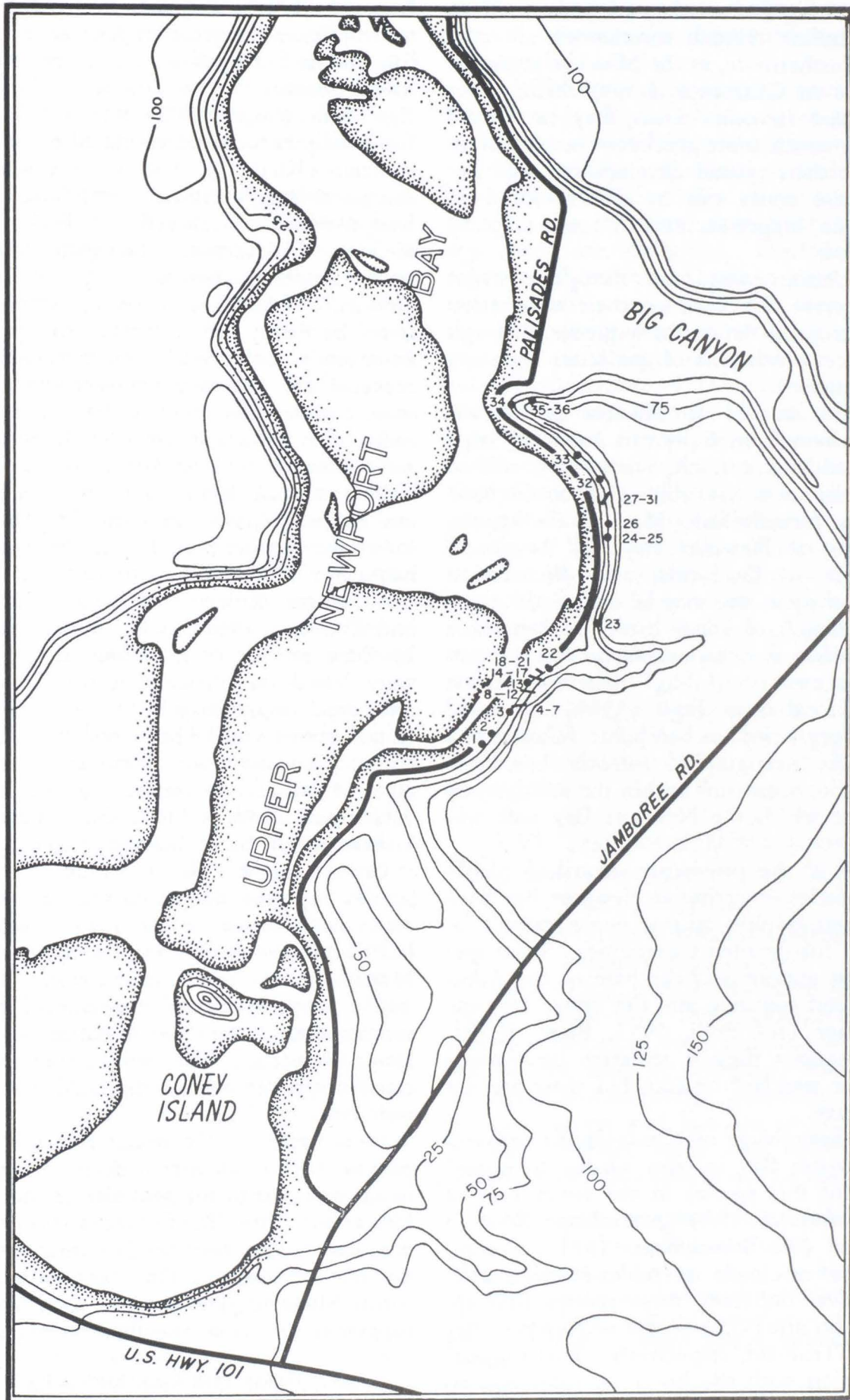


Figure 2—Map of a portion of upper Newport Bay showing the sample localities along the east shore of the Bay.

and other higher latitude areas, must be completed before reliable correlations are possible. Furthermore, as the Miocene sequence of rocks in California is very thick, zones established in other areas may be spread through much more thickness here than in areas of their typical development, and before these zones can be discriminated in California, longer sections of rocks must be examined.

Correlations with the European stages made herein are based on their recognition in the tropical American sequence although the exact correlations of the latter also may be questioned.

Critical studies of Miocene planktonic foraminifera from California have not been published. As a result, correlations within California are not feasible as yet on the basis of these foraminifera. Most of the species occurring at Newport Bay will be found elsewhere in California, and the vertical ranges of some also may be extended.

Correlation of zones based on benthonic foraminifera is questionable because of ecologic factors controlling their distribution even in local areas. Ingle (1963) has stated that stages based on benthonic foraminifera transgress stratigraphic surfaces based on planktonic organisms within the sedimentary basin of which the Newport Bay area was a part.

Most of the previously described planktonic species occurring at Newport Bay have long stratigraphic ranges, hence cannot be utilized for detailed correlations. Some species first appear near the base of the Aquitanian and continue into the upper Miocene or higher (see Bolli, 1957; Blow, 1959). Other species suggest tentative correlations with the standard sections but these are not conclusive.

The assemblage of *Candorbolina universa* at Newport Bay is most similar to assemblages of this species in the lower part of the *Globorotalia fohsi* Assemblage Zone in Trinidad (see Brönnimann, 1951). *Protentella proluxa* closely resembles *Hastigerinella bermudezi* Bolli and these species first appear soon after *C. universa* at Newport Bay and in Trinidad, respectively. This suggests correlation with the lower *G. fohsi* Assemblage Zone of Trinidad, and this zone has been considered Burdigalian in age (Bandy, 1964b).

In a synthesis of planktonic occurrences,

Bandy (1964b) recognized an *Orbulina* "datum" (first phylogenetic appearance) at the base of the Burdigalian. There are two published records of pre-Luisian *Orbulina* in California. Bagg (1905) reported *Orbulina* from sediments later determined to be upper Relizian (Kleinpell, 1938, p. 22). Kleinpell examined Bagg's original sample and did not find *Orbulina*. Kleinpell (in Packard and Kellogg, 1934) reported this genus from the upper Saucesian Astoria Formation in Oregon (not from California, as erroneously stated by Bandy and Kolpack, 1963, p. 152). Later study of the Astoria Formation has not revealed the presence of *Orbulina* (Cushman, Stewart and Stewart, 1948). Furthermore, the Astoria Formation is now considered to be at least late Relizian in age (Weaver, *et al.*, 1944). Nevertheless, Bandy and Kolpack (1963, text-fig. 32) placed the lower Burdigalian boundary in the Saucesian based on Kleinpell's statement (1938, p. 346) of its occurrence in Oregon. Loeblich and Tappan (1961) have shown that pre-Miocene records of *Orbulina* in California were based on misidentifications, and the two pre-Luisian records of *Orbulina* mentioned above are doubtful and probably incorrect. The first well documented appearance of orbulinids thus is in the Luisian (Kleinpell, 1938, p. 346). On this basis the Luisian would be of Burdigalian age.

On a world-wide basis, Bandy (1964b, p. 9, 10) reported the appearance of *Globigerina pachyderma* in the lower Helvetian. If Bandy's observation and the occurrence in Mohnian rocks near Newport Bay (Ingle, 1963) represent initial appearances of this species, then part of the Mohnian would be lower Helvetian. This would further indicate Burdigalian age for the Luisian at Newport Bay.

In summary, at Newport Bay the upper part of the Luisian is considered Burdigalian in age and part of the Mohnian is considered Helvetian. The Burdigalian-Helvetian boundary could not be determined within the section studied. Thus, the entire California Miocene may be older than has been suggested by most previous stratigraphers.

V. BASIS FOR CLASSIFICATION

The classification of planktonic foraminifera has recently undergone numerous changes. Various classifications have been proposed based on different criteria. New

information on the biology, history, and morphology of these foraminifera is fast accumulating and as with any subject, this results in rapid change. The classification adopted in this paper has resulted from current studies of the systematics of planktonic foraminifera.

The planktonic environment is ecologically specialized and the same convergent, adaptive morphology can be observed in most planktonic organisms (Hesse, Allee, and Schmidt, 1937, p. 223; Bolli, Loeblich and Tappan, 1957, p. 9). As test form, apertural position and certain apertural modifications are believed to be highly adaptive features which have reappeared several times throughout the geologic record, they are not considered here to be of major taxonomic importance. The structure of the test wall reflects basic physiological and biochemical processes of test formation and thus probably indicates close relationships. The test structure is considered of primary importance in the determination of natural groups of foraminifera (Loeblich and Tappan, 1964, p. C153).

Parker (1962) recognized the importance of this criterion and found that grouping planktonic foraminifera on the basis of the presence or absence on the test wall of long, thin spines resulted in a more meaningful, natural classification. These spines, each a single crystal of calcite (Wood, 1949, p. 240), probably also reflect basic physiologic differences between the foraminifera which have them and those which do not. Planktonic foraminifera are seldom preserved with their spines intact, but the presence or absence of spines in the living organism can be inferred from the texture of the test wall. Those Recent forms with long, thin spines when living have truly hispid tests (Parker, 1962, p. 221). Ujiie (1963) stated that the roughness of the surface was due to the increase in the diameter of the "hollows" on the test. This is true to some degree but the spacing of the hollows and their diameter is dependent on the presence or absence of spines. In this respect, this spacing is a partial measure of spinosity. The character of these hollows may be significant at the specific level, but does not seem to be so at the generic or suprageneric level. Morozova (1958, p. 36) recognized the importance of details of the test wall in taxonomy but did not distinguish taxa based on it. The texture

of the test wall is herein utilized as an important criterion for distinguishing taxa at all levels.

Identifications of planktonic species based on a few or single specimens are generally unreliable, due to the great variation within a single species. Previous determinations made on a limited number of specimens may prove to be incorrect when large suites of specimens are examined. Obviously such misidentifications will affect past correlations. Studies of planktonic foraminifera should be made, when possible, on the basis of large assemblages of specimens, a more reliable indication of the variation in the once living populations. Identifications and descriptions in this paper are based on several hundred specimens, except where noted. Complete synonymies are not attempted; generally only the original reference is given, because of the unreliability of identifications based solely on published records or a type specimen unless large suites of paratypes or topotypes are also available. Figured type material of the present paper is deposited in the Invertebrate Type Collections, Department of Geology, University of California, Los Angeles (UCLA), and paratypes of new species are deposited in the U. S. National Museum and at Tulane University.

VI. SYSTEMATIC DESCRIPTIONS

Superfamily GLOBIGERINACEA Carpenter,
Parker, and Jones, 1862

Family GLOBIGERINIDAE Carpenter,
Parker, and Jones, 1862

Parker (1962, p. 220) restricted this family to include only those globigerinid-like species with hispid walls (spinose when living) in the adult or ontogeny. Subfamilies are distinguished herein primarily on the basis of the test wall but also on gross morphology. Further study may indicate that certain subfamilies should not be recognized.

Subfamily GLOBIGERININAE Carpenter,
Parker, and Jones, 1862

Test trochospiral in adult or ontogeny. Primary aperture umbilical to spiroumbilical, secondary sutural apertures may be present. Wall of adult hispid, spinose when living.

Genus GLOBIGERINA d'Orbigny, 1826

Many species that have very different types of test walls have been included in this genus. Loeblich and Tappan (1964, p.

C669) include forms whose walls are smooth, pitted, cancellate, hispid, or spinose. As the type species, *G. bulloides* d'Orbigny, is spinose when living and hispid without the spines, this genus has been restricted by Parker (1962, p. 221) to such forms.

GLOBIGERINA BRAMLETTEI Lipps, sp. nov.

Pl. I, figs. 4a-c

Test free, small, trochospiral, globose, of 2½ to 3 whorls, outline quadrate, lobate, periphery broadly rounded, spiral side convex, spire low to high, sharp, in center of test. Chambers inflated, quadrate in spiral view, oval to quadrate in umbilical view, circular to slightly rectangular in edge view, increasing rapidly in size, 4 in last whorl. Sutures radial, depressed. Wall relatively thin, finely hispid. Aperture umbilical, a low oval, about twice as wide as high to nearly circular, bordered by a small raised commonly upturned lip.

Greatest diameter of holotype .204 mm; greatest thickness .153 mm.

Remarks: *Globigerina bramlettei* is similar to the warm-water variety of *Globigerina pachyderma* of Parker (1962, p. 224). It differs primarily in its more lobate outline, larger size, and thinner test walls. The aperture in *G. bramlettei* is consistently umbilical in position whereas the apertures of typical and warm-water *G. pachyderma* may tend to be extraumbilical. The surface texture of *G. bramlettei* is finely hispid; that of most specimens of *G. pachyderma* is peculiarly pitted and the wall is much thicker.

Globigerina bramlettei occurs only in the Mohnian.

This new species is named in honor of M. N. Bramlette, Scripps Institution of Oceanography, in recognition of his studies of the Miocene stratigraphy and micropaleontology in California.

Types: Holotype UCLA no. 34713; 100 unfigured paratypes UCLA no. 34714; and 10 unfigured paratypes USNM no. 641565. All types from sample 34, Mohnian.

GLOBIGERINA BULLOIDES d'Orbigny

Pl. II, figs. 1a-c

Globigerina bulloides d'ORBIGNY, 1826, Ann. Sci. Nat. Paris, ser. 1, v. 7, p. 277.

Test free, trochospiral, biconvex, outline lobate, apex in center of test. Chambers globular, increasing slowly in size during ontogeny, 4 to 5 in last whorl. Sutures depressed, radial. Wall calcareous, hispid, coarsely perforate. Aperture umbilical, height generally less than half that of last chamber.

Remarks: The specimens from Newport Bay are identical with topotypes from Rimini, Italy. For comparisons, see remarks under *Globigerina quadrilatera* below.

As restricted in this study, *G. bulloides* first appears in the Lower Mohnian. It is not abundant.

Types: Figured hypotype UCLA no. 34700; and 100 unfigured hypotypes UCLA no. 34701, sample 34, Mohnian.

GLOBIGERINA cf. G. DIGITATA Brady

Pl. II, figs. 2a-c

? *Globigerina digitata* BRADY, 1879, Quart. Jour. Micr. Sci., new ser., v. 19, p. 286.

Test free, small, trochospiral, consisting of three whorls, spiral side flattened. Chambers spherical in early stages, elongate in last formed, each increasing about twice the size of the preceding, four in last whorl. Sutures radial, depressed, distinct. Wall finely hispid with small pores. Aperture umbilical, circular, bordered by narrow poreless rim.

Remarks: This identification is based on one specimen and is therefore questionable. Although much additional sample was examined, more specimens could not be found. The specimen could be an aberrant *Globigerina quadrilatera*, which occurs abundantly but intermediate specimens are absent. The present specimen is identical to small specimens of *G. digitata* from the central Pacific Ocean. It differs from typical examples of the species only in its smaller size and fewer elongate chambers.

Globigerina digitata is the type species for the genus *Beella* Banner and Blow, but is here retained in *Globigerina* following Parker (1962, p. 222).

Type: Figured hypotype UCLA no. 34704, sample 6, Luisian.

GLOBIGERINA DUBIA Egger, 1857

Pl. I, figs. 5a-c

Globigerina dubia EGGER, 1857, Neues Jahr. Mineral. Geogn., Petrefak.-Kunde, 1857, p. 281, taf. 9, figs. 7-9.

Test free, small to medium in size, trochospiral, spiral side flattened or slightly convex, outline lobate, circular, periphery rounded. Chambers spherical, increasing evenly and slightly in size with growth, commonly five but may be four in last whorl. Sutures radial, distinct, depressed, sharp to "U"-shaped. Wall hispid, perforate, pores randomly spaced, small. Aperture umbilical, a low arch, bordered by a smooth to ragged lip which may be a tooth-like projection.

Remarks: The specimens from Newport Bay are identical with topotypes of this species from the Maierhof Meersand, Bavaria. For comparison see remarks under *Globigerina quadrilatera* below.

This species occurs in its typical form only in sample 11 (Luisian) where it is the dominant *Globigerina* present. A few specimens of *Globigerina quadrilatera* also occur there, but the two species do not intergrade.

Types: Figured hypotype UCLA no. 34702, sample 11, Luisian; 200 unfigured hypotypes UCLA no. 34703, sample 11, Luisian.

GLOBIGERINA QUADRILATERA Galloway
and Wissler

Pl. I, figs. 1a-3c

Globigerina quadrilatera GALLOWAY and
WISSELER, 1927, Jour. Paleontology, v. 1,
no. 1, p. 44, pl. 7, fig. 11a-c.

Test free, a low to high trochospire of 2½ whorls, biconvex, outline lobate, periphery rounded, apex of spire in center of test. Chambers globular, rapidly enlarging as added, all visible on spiral side, smaller terminal chamber present on some specimens. Sutures radial, deeply depressed, incised or U-shaped. Wall calcareous, perforate, hispid, perforations of varying size randomly distributed on surface. Aperture large, open, umbilical to spiroumbilical, bordered by narrow non-spinose rim.

Remarks: This species shows much variation in size and morphology, from large specimens with big spiroumbilical apertures (Plate I, figures 2a-c) to smaller forms with small, restricted apertures (Plate I, figures 1a-c). Further study of these variations elsewhere may reveal that more than one species has been included herein, although all of these variations intergrade in single samples and between samples. The assemblage as a whole is unlike assemblages of other species of *Globigerina*, hence all variations are considered to belong to single populations of *G. quadrilatera*. The species also closely resembles *G. dubia* and *G. bulloides*, both of which may occur with it. However, comparison of large series of topotypes of the three species shows that *G. quadrilatera* differs from *G. bulloides* by its much more rapidly increasing chamber size with growth and, in general by its larger and higher aperture. *Globigerina dubia* is commonly lower-spined and smaller with the chambers increasing more regularly in size. Its aperture is smaller, nearly always umbilical in position but tending in some specimens to

be umbilical-extraumbilical, and bordered by a narrow rim which is commonly jagged.

These three species were found to vary in proportional abundance. In samples where *Globigerina dubia* or *G. bulloides* occurred, the abundance of *G. quadrilatera* was greatly decreased. Possibly the three forms are phenotypic variants of a single species, their morphology differing, perhaps, because of varying environmental factors. In the Luisian, *G. quadrilatera* is extremely abundant, commonly comprising 60-90 per cent of the foraminifera in a sample. This species varies greatly in Luisian samples that contain planktonic species indicating tropical or near tropical conditions.

Apparently with the influx of cooler water in the Mohnian, the previously abundant *G. quadrilatera* almost disappeared and *Globigerina bulloides* became the common planktonic species. In certain Mohnian samples, *G. quadrilatera* is quite abundant. Further study of these and other closely related species must be undertaken before definite conclusions about their relationships can be reached.

Globigerina quadrilatera occurs in all Luisian and most Mohnian samples at Newport Bay. It has also been observed in younger deposits in California.

Types: Figured hypotypes UCLA no. 34705 from sample 16; no. 34706, from sample 13, no. 34707, from sample 9; all are Luisian. Two hundred unfigured hypotypes UCLA no. 34708, sample 1, Luisian; 200 unfigured hypotypes UCLA no. 34709, sample 13, Luisian; 50 unfigured hypotypes UCLA no. 34710, sample 34, Mohnian.

GLOBIGERINA TECTA Lipps, sp. nov.

Pl. I, figs. 6a-c

Test free, small, trochospiral, 2½ to 3 whorls, flattened to slightly convex on both sides, umbilicus small, deep when uncovered, outline lobate, periphery rounded. Chambers inflated, increasing slightly in size with growth, circular to slightly rectangular in side view, ovate in umbilical and edge views, final chamber with elongation covering umbilicus in most specimens. Sutures distinct, radial, in narrow depression. Wall coarsely hispid. Aperture an umbilical arch of differing height, at end of extension of terminal chamber.

Greatest diameter of holotype .208 mm; greatest thickness .102 mm.

Remarks: This new species is similar to *Globigerina quinqueloba* described from Recent sediments off Southern California (Nat-

land, 1938). In the spiral view, the chambers of *G. tecta* are generally ovate, whereas those of *G. quinqueloba* are rectangular. In general, *G. tecta* has more chambers (5 to 7) than *G. quinqueloba* (4 to 5), and the final chamber does not cover the umbilical area as completely. The spire of *G. tecta* is most commonly flat whereas that of *G. quinqueloba* varies from flat to mainly convex. These two species appear to be very closely related. Forms intermediate in age have not been described nor figured, hence inferences as to the relationship of the Miocene species to the Recent one as yet cannot be made.

Although the final chamber and apertural characters are similar to typical *Globigerinita*, this new species is placed in *Globigerina* because of the distinctly hispid test. It is closely similar to *Globigerina quinqueloba*, which Parker (1962, p. 225) also considered to be a true *Globigerina*, on the basis of surface wall character.

Globigerina tecta is common in sample 2 (Luisian).

The specific name is from the Latin *tectus* meaning "cover," in reference to the modified last chamber which covers the umbilical area.

Types: Holotype (Plate I, figures 6a-c) UCLA no. 34711; 100 unfigured paratypes UCLA no. 34712. All types from sample 2 (Luisian).

GLOBIGERINA? sp.

Pl. I, figs. 7a-c

Test free, highly trochospiral, of $3\frac{1}{2}$ whorls, highly convex on spiral side, outline lobate, periphery broadly rounded. Chambers globular, inflated, increasing rapidly with growth, 4 in last whorl. Sutures radial, deeply depressed in later whorls, slightly so in early whorls. Wall calcareous, thin, finely hispid. Aperture umbilical, a small oval slit at base of final chamber, with small lip on upper edge.

Remarks: This species appears to be distinct from all other species at Newport Bay, but its rarity prevents specific identification. The high spire and low umbilical aperture are similar to those of *Globigerinita uvula* (Ehrenberg), but the present form differs in its larger size and more hispid test. The degree of hispidity suggests that this species is a *Globigerina* although *Globigerinita* may also be finely hispid (Parker, 1962, p. 253).

Types: Figured specimen UCLA no. 34715, 5 additional specimens UCLA no. 34716, sample no. 18, Luisian.

PLATE I

(All figures: a. spiral view, b. umbilical view, c. edge view, unless otherwise noted)

Figures	Page
1. <i>Globigerina quadrilatera</i> Galloway and Wissler Small individual (UCLA 34705) with restricted aperture. x 135. Luisian	117
2. <i>Globigerina quadrilatera</i> Galloway and Wissler Large individual (UCLA 34706) with a big spiroumbilical aperture. x 65. Luisian	117
3. <i>Globigerina quadrilatera</i> Galloway and Wissler Typical individual (UCLA 34707). x 35. Luisian	117
4. <i>Globigerina bramlettei</i> Lipps sp. nov. Holotype (UCLA 34713). x 190. Mohnian	116
5. <i>Globigerina dubia</i> Egger Hypotype (UCLA 34702). x 85. Luisian	116
6. <i>Globigerina tecta</i> Lipps sp. nov. Holotype (UCLA 34711). x 190. Luisian	117
7. <i>Globigerina?</i> sp. Figured specimen (UCLA 34715). x 95. Luisian	118

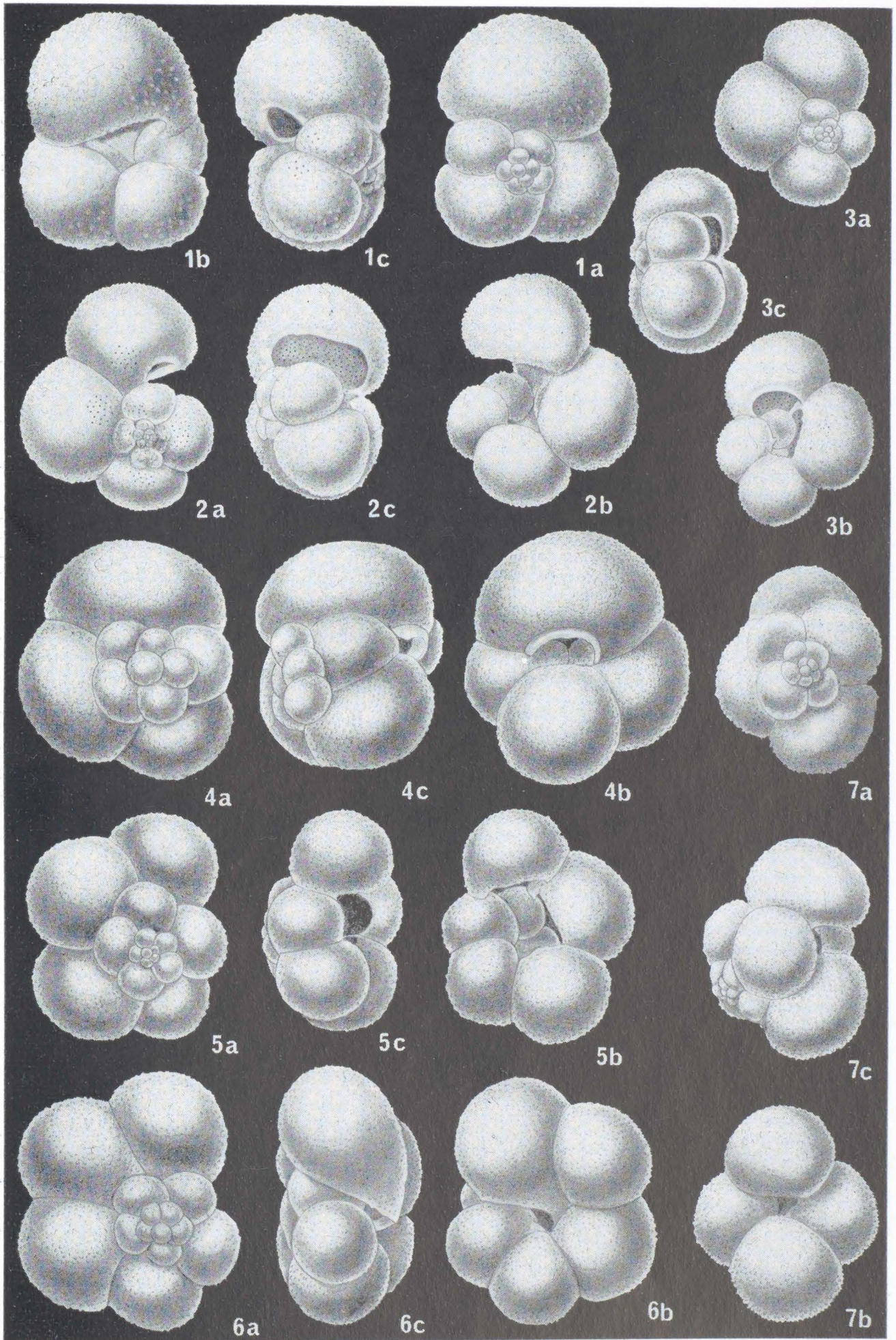


PLATE I

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES TRILOBUS (Reuss)

Pl. II, figs. 3a-c

Globigerina triloba REUSS, 1850, Denkschr. Akad. Wiss. Wien. Math.-Nat. Classe, v. 1, p. 374.

Test free, large, trochospiral, of about $2\frac{1}{2}$ whorls, outline trilobate to quadrilobate, periphery broadly rounded. Chambers spherical, increasing rapidly in size, generally 4 in last whorl. Sutures radial, deeply depressed in later stages. Wall coarsely perforate, forming pits on exterior surface, spines of earlier chambers commonly preserved in the interior, when enveloped by later chambers. Primary aperture umbilical, a low flattened arch extending over the umbilical margins of the previous three chambers, supplementary apertures semicircular to slit-like arches at intersection of radial and spiral sutures on spiral side.

Remarks: Typical specimens occur in samples 13 to 16 (Luisian) and are most numerous in 14 and 15.

Banner and Blow (1960) designated a specimen of *Globigerinoides trilobus* as the lectotype of *Globigerina quadrilobata*, but Bandy (1964a) noted the invalidity of this selection. Bandy's opinion is followed here.

Types: Figured hypotype UCLA no. 34717, sample 16; 50 unfigured hypotypes UCLA no. 34718, sample 16; 50 unfigured hypotypes UCLA no. 34719, sample 13. All Luisian.

GLOBIGERINOIDES? sp.

Pl. II, figs. 4a, b

Test free, of small to medium size, trochospiral, outline lobate, periphery rounded, spiral side convex, umbilical side flattened. Chambers spherical, increasing slightly in size with growth, four in last whorl. Sutures radial, depressed, distinct. Wall hispid, finely perforate. Primary aperture umbilical, ovate to a low arch; small, oval to triangular, secondary aperture on spiral side at junction of spiral and radial suture of last-formed chamber.

Remarks: Only a few specimens of this form were found in the Luisian strata. The general proportions of the test and chambers are similar to those of *Globigerina quadrilobata* and they may be aberrant specimens of this *Globigerina*.

Types: Figured specimen UCLA no. 34720; 5 unfigured specimens UCLA no. 34721; sample 18, Luisian.

Subfamily ORBULININAE Schultze, 1854

Test trochospiral, later stage enveloping previous chambers. Wall hispid, spinose when living, perforate. Primary aperture not visible in adult, secondary apertures multiple, sutural or areal in position.

This subfamily cannot be differentiated on the basis of spinosity, but is recognized by the distinctive enveloping final stage. Genera here included are very closely related to the Globigerininae and possibly should be included therein.

Genus CANDORBULINA Jedlitschka, 1934

Candorbulina JEDLITSCHKA, 1934, Naturf. Ver. Brünn, Verh., Brünn, Tschechoslowakei, Bd. 65 (1933), p. 20.

Praeorbulina OLSSON, 1964, Jour. Paleontology, v. 38, no. 4, p. 770.

Type species: *Candorbulina universa* Jedlitschka, 1934, fixed by monotypy.

Test free, trochospiral in early part, circular or lobate in outline. Chambers globular, last chamber partially enveloping previous chambers, final two or three chambers enlarged in some specimens. Sutures radial, distinct. Wall of calcite, radial, bilamellid, perforate, perforations of differing sizes, hispid. Apertures multiple, umbilical in early trochospiral stages, sutural in adult, some areal near sutures.

Remarks: *Candorbulina* is here considered to be a distinct genus, including those orbulinids with multiple apertures along the sutures between the last spherical chamber and the earlier trochospiral whorls. It is distinguished from *Orbulina* d'Orbigny by the multiple sutural apertures which are lacking in true *Orbulina*. Confusion exists as to the generic status of *Candorbulina*, because the generic name has been frequently used for true *Orbulina* in which the trochospiral stages protrude through the last chamber but which do not possess sutural apertures (Figure 3). The forms without sutural apertures can be found in any normal Miocene to Recent population of *Orbulina* but should not be confused with *Candorbulina*. *Candorbulina* is differentiated by the possession of sutural apertures and not by the protruding early trochospire. *Praeorbulina* is here regarded as a synonym of *Candorbulina* and their type species are regarded as synonymous.

The present genus is apparently restricted to the middle Miocene, whereas true *Orbulina* ranges from Miocene to Recent.

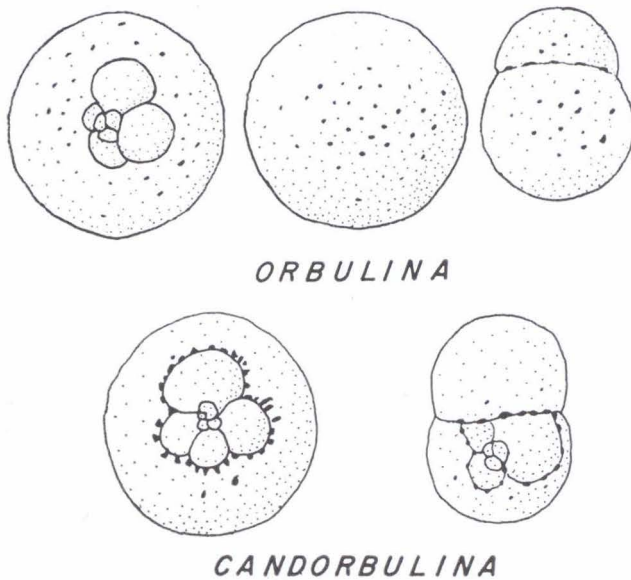


Figure 3—Variation in *Orbulina* and *Candorbulina* showing the distinguishing generic characters. The specimens of *Candorbulina* have sutural apertures; those of *Orbulina* lack sutural apertures. (Top row: After Bolli, Loeblich, and Tappan, 1957, pl. 7, figs 2-4; Lower right: UCLA hypotype 34722; Lower left: After Blow, 1956, text-fig. 2, No. 16)

CANDORBULINA UNIVERSA Jedlitschka

Pl. II, figs. 5a-7

Candorbulina universa JEDLITSCHKA, 1934, Naturf. Ver. Brünn, Verh., Brünn, Tschechoslowakei, Bd. 65 (1933), p. 21, text-figs. 1-7.

Candeina triloba JEDLITSCHKA, 1934, Naturf. Ver. Brünn, Verh., Brünn, Tschechoslowakei, Bd. 65 (1933), p. 22, text-figs. 13-18, 20.

Orbulina suturalis BRÖNNIMANN, 1951 (partim), Contr. Cushman Found. Foram. Res., v. 2, p. 135, text-fig. 2, figs. 1-2, 5-8, 10; text-fig. 3, figs. 3-7, 11, 13-14, 18; text fig. 4, figs. 2-3, 15.

Globigerinoides glomerosa glomerosa BLOW, 1956, Micropaleontology, v. 2, no. 1, p. 65, text-fig. 1, nos. 15-19; text-fig. 2, nos. 1-2. OLSSON, 1964, Jour. Paleontology, vol. 38, no. 4, p. 770.

Globigerinoides glomerosa circularis BLOW, 1956, Micropaleontology, v. 2, no. 1, p. 65, text-fig. 2, nos. 3-4.

Biorbulina bilobata (d'Orbigny). BLOW, 1956 (partim), Micropaleontology, v. 2, No. 1, p. 69, text-fig. 2, no. 16.

Test free, spherical to lobate, initially trochospiral. Chambers globular, last chamber partially to nearly completely enveloping previous globigerine chambers, 3 to 4 chambers in last globigerine whorl. Sutures distinct, depressed, radial. Wall calcareous, coarsely perforate, hispid. Aperture circular, umbilical in early globigerine stage, multiple sutural pore-like apertures or rarely multiple areal pores near sutures in final spherical chamber.

Remarks: Most specimens of this species at Newport Bay are typical (Pl. II, fig. 6) although rarely the final chamber does not completely envelop the preceding chambers, resulting in a trilobate or bilobate outline (Pl. II, fig. 5).

This species has been confused with *Orbulina universa*, which may also have protruding trochospiral whorls, because this trivial name is used in both *Candorbulina* and *Orbulina*.

Specimens showing the characters of *Globigerinoides glomerosa glomerosa* Blow, 1956, *G. glomerosa circularis* Blow and part of Blow's *Biorbulina bilobata* have been observed in single samples from both Newport Bay and Trinidad. All three forms are here placed in synonymy with *C. universa*. Blow (1956) figured specimens of each from the same samples and reported the same stratigraphic range for all. Therefore, these nominal species and subspecies are considered to be part of the single species, *Candorbulina universa*, and such varied specimens can be found in any normal population. Blow (1956) also included bilobed specimens of both *Candorbulina* and *Orbulina* in *B. bilobata* (d'Orbigny) as he recognized it. In populations of both *C. universa* and *O. universa* bilobed varieties may be present. They may be differentiated generically by the presence or absence of sutural apertures (Fig. 3) just as their normal forms are separated. *Globigerina bilobata* d'Orbigny, the type species of *Biorbulina* Blow, is a variant of *O. universa* d'Orbigny, hence *Biorbulina* is a synonym of *Orbulina*.

Candorbulina universa as defined herein apparently is restricted to the Middle Miocene. Specimens assignable to true *C. universa* were described from rocks of this age in Czechoslovakia (Jedlitschka, 1934) and have been reported elsewhere in Europe (Cushman and Dorsey, 1940), the pre-Carpathians of Russia (Subbotina, Pishvanova, and Ivanova, 1960), Ecuador (Stainforth, 1948), Trinidad (Bolli, 1957), Australia (Jenkins, 1960) and Sumatra (Le Roy, 1948). Many additional references to this species may be found in the literature, but need rechecking to determine whether *Candorbulina* or *Orbulina* is present. Brönnimann (1951) reported *C. universa* (as *O. suturalis*) from the *Globorotalia fohsi* Assemblage Zone (now believed to be Burdigalian in age) in Trinidad and was able

to recognize distinct assemblages of this form for different parts of that zone. The Newport Bay specimens resemble most closely Brönnimann's figures of specimens from the lower part of the *G. fohsi* zone (*G. fohsi barisanesis* and *G. fohsi fohsi* subzones). At Newport Bay the species occurs in sample 13 and suggest a correlation with some part of the lower *G. fohsi* zone of Trinidad.

Types: Figured hypotypes UCLA nos. 34722, 34723, 34724; 100 unfigured hypotypes UCLA no. 34725. All types from sample 13, Luisian.

Subfamily HASTIGERININAE Bolli, Loeblich and Tappan, 1957

Test trochospiral to planispiral. Chambers ovate, spherical, radially elongate, or clavate. Wall hispid (spinose) in early stages, smooth or with large spines in adult. Aperture peripheral, without supplementary apertures.

Remarks: When living, the juvenile specimens (early stages) of species of the type genus, *Hastigerina* Thomson, 1876, have

long, thin spines such as are typical of the globigerinids (Parker, 1962, p. 228). For this reason the subfamily is placed in the family Globigerinidae. It may be differentiated from the Globigerininae by the lack of long, thin globigerinid spines in the adult.

Genus PROTENTELLA Lipps, gen. nov.

Type species: *Protentella proluxa* Lipps, sp. nov.

Test free, trochospiral in first whorl, planispiral in later stages. Chambers spherical in juvenile stage, later chambers radially elongate. Wall calcareous, smooth, finely perforate, of radially crystalline structure, septa bilamellid. Aperture basal, a low equatorial arch.

Remarks: *Protentella* may be differentiated from other hastigerinids and globigerinids by its planispiral test with radially elongate chambers in the later stages, and by the smooth wall texture. A few specimens have slight knobs on the chambers which may represent the bases of large spines, although because of their rare occur-

PLATE II

(All figures: a. spiral view, b. umbilical view, c. edge view, unless otherwise noted)

Figures	Page
1. <i>Globigerina bulloides</i> d'Orbigny..... Hypotype (UCLA 34700). x 95. Mohnian	116
2. <i>Globigerina</i> cf. <i>G. digitata</i> Brady..... Hypotype (UCLA 34704). x 95. Luisian	116
3. <i>Globigerinoides trilobus</i> (Reuss)..... Hypotype (UCLA 34717). x 65. Luisian	120
4. <i>Globigerinoides?</i> sp..... Figured specimen (UCLA 34720). x 95. Luisian	120
5. <i>Candorbulina universa</i> Jedlitschka..... Trilobate specimen (UCLA 34722); a. Spiral view, b. Side view; x 95. Luisian	121
6. <i>Candorbulina universa</i> Jedlitschka..... Typical specimen (UCLA 34723). x 65. Luisian	121
7. <i>Candorbulina universa</i> Jedlitschka..... Dissected specimen (UCLA 34724) showing umbilical view of inner globigerine whorls. x 95. Luisian	121
8. <i>Protentella proluxa</i> Lipps sp. et gen. nov..... Holotype (UCLA 34726). x 95. Luisian	124
9. <i>Protentella proluxa</i> Lipps sp. et gen. nov..... Paratype (UCLA 34727). x 135. Luisian	124

Figures 1, 2, 4, 5 by Jill Penkhus; others by Margaret Rogers.

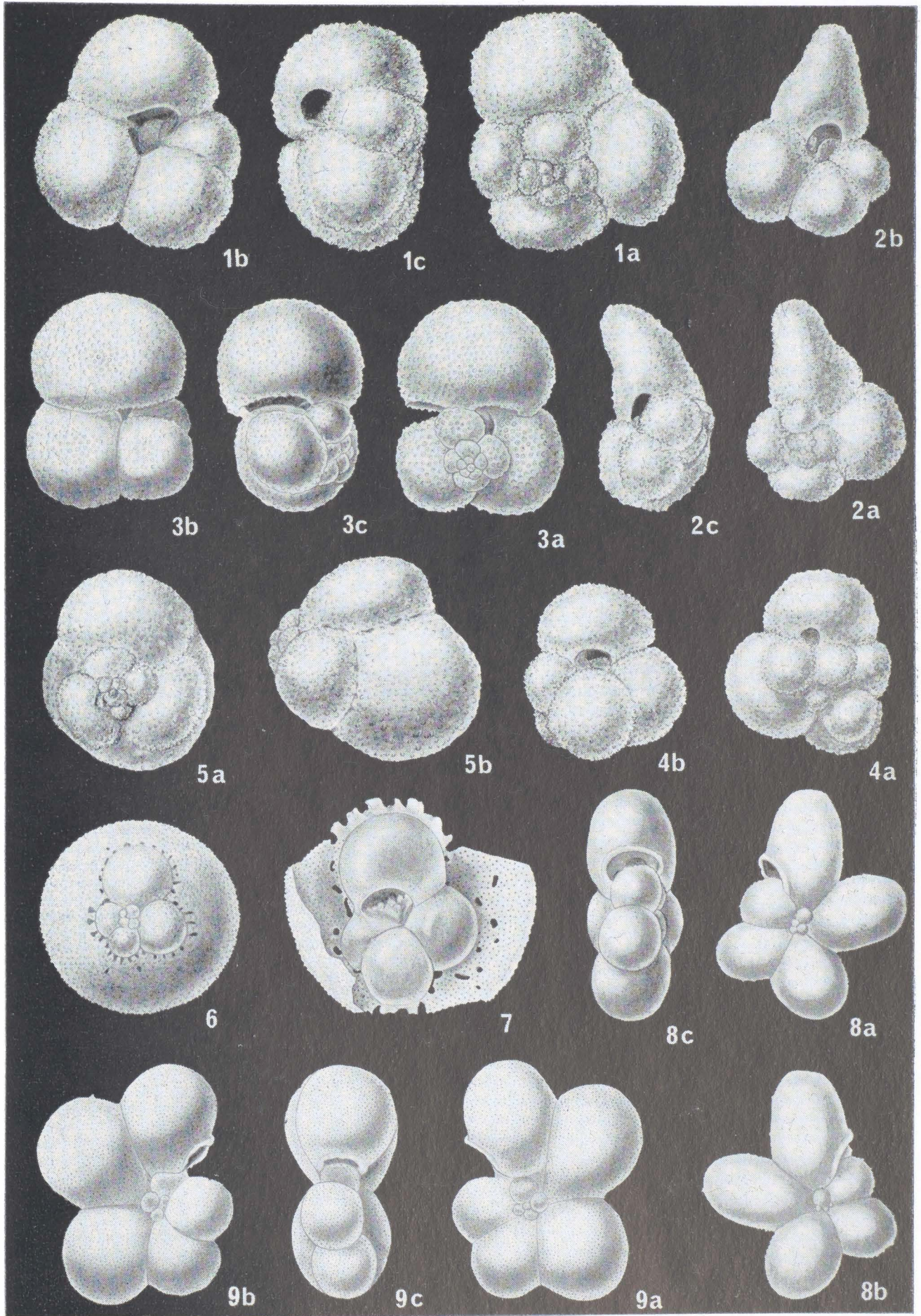


PLATE II

rence their significance could not be determined.

The generic name is from the Latin *protensus*, *protentus* meaning "stretched out," in reference to the typically elongate chambers of this genus + *ella*, diminutive. Gender: feminine.

PROTENTELLA PROLIXA Lipps, sp. nov.

Pl. II, figs. 8a-9c

Test free, small, planispiral, involute, bimilicicte, outline deeply lobate, periphery rounded. Chambers spherical in early whorls, becoming radially elongate in last whorl, ovate to cylindrical, five or less commonly six chambers in last whorl, nearly completely embracing previous whorl. Sutures distinct, deeply depressed, radial. Wall calcareous, smooth, finely perforate. Aperture basal, equatorial, a low to high arch embracing previous whorl, up to one-third height of final chamber, with upper margin bordered by a slightly protruding lip.

Greatest diameter of holotype .357 mm; greatest thickness .128 mm.

Remarks: This new species resembles *Hastigerinella bermudezi* Bolli, but differs in the more planispiral rather than trochospiral adult test, and the somewhat smaller size. *Protentella prolixa* is restricted to the upper part of the Luisian (samples 17 to 22).

The specific name is from the Latin *prolixus*, meaning "long, stretched out," in reference to the elongate chambers of this species.

Types: Holotype UCLA no. 34726, sample 18, figured paratype UCLA no. 34727, sample 22, 100 unfigured paratypes UCLA no. 34728 and 10 unfigured paratypes USNM no. 641566. All Luisian.

Family GLOBOROTALIIDAE Cushman, 1927

Parker (1962, p. 234) restricted this family to include only those species which are non-spinose when living. The species included by her were divided into three groups: 1.) those with imperforate keels; 2.) those without imperforate keels and with smooth walls; 3.) those without imperforate keels and with pitted walls. Parker noted that the carinate species may have developed from various noncarinate lineages, but this relation is yet to be demonstrated in most cases. The third group, however, seems less closely related to the other two. It is herein recognized as the subfamily Catapsydracinae, although some evidence in-

dicates that it perhaps should be elevated to family status.

Subfamily GLOBOROTALIINAE Cushman, 1927

Test free, trochospiral, periphery keeled or unkeeled, chambers angular to ovate. Wall calcareous, smooth, perforate, may have secondary short, stubby spines. Aperture extraumbilical to umbilical in position.

Genus TURBOROTALIA Cushman and Bermudez, 1949

This genus, originally described as a subgenus of *Globorotalia*, is now recognized as a separate genus because it lacks a keeled periphery (see Loeblich and Tappan, 1964, p. C668).

TURBOROTALIA LATA Lipps, sp. nov.

Pl. III, figs. 2a-3c

Test free, trochospiral, about 3 whorls, planoconvex to slightly biconvex, with spiral side generally planar, umbilicus may be closed or open widely, outline slightly lobate, periphery rounded. Chambers trigonal and much inflated on umbilical side, lunate on spiral side, oval in edge view with axis of oval tilted about 45° to equatorial plane of test, last chamber may be reduced to half or less of normal chamber size. Sutures distinct, slightly depressed, curved backward, may be radial on umbilical side. Wall smooth, fine to coarsely perforate. Aperture umbilical-extraumbilical, a high rounded arch, bordered by a small lip.

Greatest diameter of holotype .234 mm; greatest thickness .162 mm.

Remarks: This species is distinguished from *Turborotalia scitula* by its more inflated chambers and biconvex test. It is most similar to *Globorotalia hirsuta* (d'Orbigny) which possesses a keeled periphery, although some specimens in certain populations may be unkeeled (Parker, 1962, p. 237). No carinate specimens were found with *T. lata*. *Turborotalia lata* occurs in most Luisian samples and is especially abundant in sample 2.

Types: Holotype UCLA no. 34729; figured paratype UCLA no. 34730; 100 unfigured paratypes UCLA no. 34731; 10 unfigured paratypes USNM no. 641567. All types from sample 2, Luisian.

TURBOROTALIA MAYERI (Cushman and Ellisor)

Pl. III, figs. 4a-5c

Globorotalia mayeri CUSHMAN and ELLISOR, 1939, Contr., Cushman Lab. For. Res., v. 15, pt. 1, p. 11, pl. 2, figs. 4a-c.

Test free, trochospiral, biconvex to flat-

tened on spiral side, 2½ whorls, periphery rounded, outline slightly lobate. Chambers inflated, trigonal in umbilical view, ovate to rectangular in spiral view, broadly rounded in edge view. Sutures distinct, depressed slightly, curved back on spiral side, recurved on umbilical side. Wall calcareous, smooth, coarsely perforate. Aperture a wide extraumbilical arch, bordered by small protruding lip.

Remarks: The specimens from Newport Bay are smaller than the holotype of *T. mayeri* (Pl. III, figs. 4a-c) with which they were compared, but do not differ significantly in other respects. Some specimens are aberrant and the last few chambers may show irregular coiling, being somewhat deflected to the umbilical side. Both right and left coiling specimens are present but the specimens are too rare to determine a significant coiling ratio. The species occurs only in the Mohnian at Newport Bay, although elsewhere in the world it has a long stratigraphic range, from the Aquitanian to the Tortonian (see Bandy, 1964b, text-fig. 6). Therefore, it should have occurred throughout the Newport Bay section had the ecologic conditions been suitable.

Types: Figured hypotype UCLA no. 34732; 5 unfigured hypotypes UCLA no. 34733, sample 34, Mohnian.

TURBOROTALIA SCITULA (Brady)

Pl. III, figs. 1a-c

Pulvinulina scitula BRADY, 1882, Roy. Soc. Edinburgh, Proc., v. 11 (1880-1882), no. 111, p. 716.

Test free, trochospiral, nearly 3 whorls, flattened to convex on spiral side, convex on umbilical side except for slight depression at umbilicus, umbilicus open, small, deep, outline slightly lobate, periphery subacute. Chambers lunate in spiral view, triangular in umbilical view, rhomboid in edge view, commonly increasing rapidly in height in the final whorl, inflated on umbilical side near base, tapering toward periphery, slightly recurved inward above aperture in edge view, flattened on spiral side, overlapping about one-third to one-half of previous chamber; commonly 5 chambers in last whorl. Sutures distinct, curved back on spiral side, radial or slightly curved back on umbilical side. Wall smooth, finely perforate. Aperture umbilical-extraumbilical, basal, a low arch with slight lip.

Remarks: Specimens from Newport Bay are nearly identical with the lectotype selected by Banner and Blow (1960). Because of variation occurring in chamber height and test thickness, some specimens could be allocated to one of the subspecies described

by Blow (1959), but since they all occur together, they probably represent individual variants of the same population.

This species was found in most of the samples studied, but never in abundance. From all the samples, a total of several hundred specimens were studied.

Type: Figured hypotype UCLA no. 34734, sample 21, Luisian.

Subfamily CATAPSYDRACINAE Bolli, Loeblich and Tappan, 1957

Test trochospiral, chambers spherical to ovate or angular, with or without apertural bullae. Primary aperture umbilical to extraumbilical in position, may have secondary apertures or infralaminar accessory apertures. Wall calcareous, surface coarsely pitted, may have short, stubby spines, non-spinose when living.

Remarks: Bolli, Loeblich and Tappan (1957, p. 36) erected this subfamily to include forms with apertural bullae. However, bullae have developed independently in many different lineages and are considered taxonomically unimportant at the suprageneric level. The type genus, *Catapsydrax* Bolli, Loeblich and Tappan, 1957, has a coarsely pitted wall identical with that of *Globoquadrina*, which is non-spinose when living (Parker, 1962, p. 240). *Catapsydrax* probably was also non-spinose when living. The non-spinose, coarsely pitted wall texture distinguishes this subfamily from all other groups of the Globigerinidae and Globorotaliidae.

Genus GLOBOQUADRINA Finlay, 1947

This genus is placed in the Catapsydracinae because of the coarsely pitted wall and non-spinose condition in life. It is very closely related to *Catapsydrax*, differing primarily in lacking an apertural bulla.

GLOBOQUADRINA LARMEUI Akers

Pl. III, figs. 6a-7c

Globoquadrina larmei AKERS, 1955, Jour. Paleontology, v. 29, no. 4, p. 661, pl. 65, figs. 4a-c.

Test free, small to medium in size, trochospiral, spiral side slightly convex, umbilical side convex, periphery broadly rounded, outline lobate. Chambers 4 or 5 in last whorl, lunate in spiral view, rounded in other views, increasing gradually in size with growth, occasionally with small terminal chamber. Sutures distinct, radial, depressed. Wall smooth with large, deep pits. Aperture a low arch, extraumbilical to umbilical in small specimens, umbilical in large ones, with ragged margin or projecting tooth.

Remarks: Specimens similar to the original figures of this species occur in sample 11. These specimens intergrade with forms with large umbilical apertures and more numerous chambers in the final whorl.

Types: Figured hypotypes UCLA nos. 34737 and 34738; 100 unfigured hypotypes UCLA no. 34739; sample 11, Luisian.

GLOBOQUADRINA VENEZUELANA
(Hedberg)

Pl. IV, figs. 1a-c

Globigerina venezuelana HEDBERG, 1937, Jour. Paleontology, v. 11, no. 8, p. 681, pl. 92, figs. 7a-b.

Test free, low trochospire of 2½ whorls, outline lobate and quadrate, periphery rounded to slightly truncate. Four or less commonly three chambers in last whorl, inflated, flattened slightly on periphery, all visible on spiral side, those of last whorl nearly overlapping previous whorls. Sutures distinct, deeply depressed, radial on both sides. Wall calcareous, exterior rough and pitted with pores in bottom of each pit, interior smooth with small perforations. Apertures square or angular, umbilical in position, with umbilical teeth and coarse, short, needle-like spines in apertural area.

Remarks: Typical specimens of this species occur in samples 4 to 16, but are most abundant in samples 13 to 16, of Luisian age. The species has a long range through

the later Tertiary in other parts of the world, and it is probable that it is more widely distributed in California.

Types: Figured hypotype UCLA no. 34735, sample 16, and 200 unfigured hypotypes UCLA no. 34736, sample 13, Luisian.

Genus GLOBOROTALOIDES Bolli, 1957

Bolli (1957, p. 117) erected this genus primarily on the basis of the bulla-like last chamber of some specimens. This character was not considered to be of generic importance by Loeblich and Tappan (1964, p. C671), who retained the genus on the basis of the globular chamber form. Parker (1962, p. 240) suggested that it was a synonym of *Globoquadrina*. The holotype of the type species, *Globorotaloides variabilis* Bolli, has a small bulla-like final chamber, which gives it a superficial resemblance to *Globoquadrina*. Some specimens of species that correctly should be assigned to *Globorotaloides* have a slight projecting apertural lip, which is believed by Parker to represent the apertural tooth of *Globoquadrina*. However, the globular chambers, low trochospiral test, generally extraumbilical aperture, the characters of the apertural lip, and the pitted surface distinguish *Globorotaloides* from all previously described genera.

PLATE III

(All figures: a. spiral view, b. umbilical view, c. edge view, unless otherwise noted)

Figures	Page
1. <i>Turborotalia scitula</i> (Brady).....	125
Hypotype (UCLA 34734). x 135. Luisian	
2. <i>Turborotalia lata</i> Lipps sp. nov.....	124
Paratype (UCLA 34730) with very small final chamber. x 140. Luisian	
3. <i>Turborotalia lata</i> Lipps sp. nov.....	124
Holotype (UCLA 34729). x 190. Luisian	
4. <i>Turborotalia mayeri</i> (Cushman and Ellisor).....	124
Holotype (USNM Cushman Coll. no. 25236), refigured for comparison with California specimen. x 90. Miocene, Louisiana	
5. <i>Turborotalia mayeri</i> (Cushman and Ellisor).....	124
Hypotype (UCLA 34732). x 180. Mohnian	
6. <i>Globoquadrina larmeni</i> Akers.....	125
Hypotype (UCLA 34737) with wide, open aperture. x 95. Luisian	
7. <i>Globoquadrina larmeni</i> Akers.....	125
Hypotype (UCLA 34738). x 95. Luisian	

Figures 1, 2, 3, 6 by Margaret Rogers; 4, 5 by Helen Loeblich; 7 by Jill Penkus.

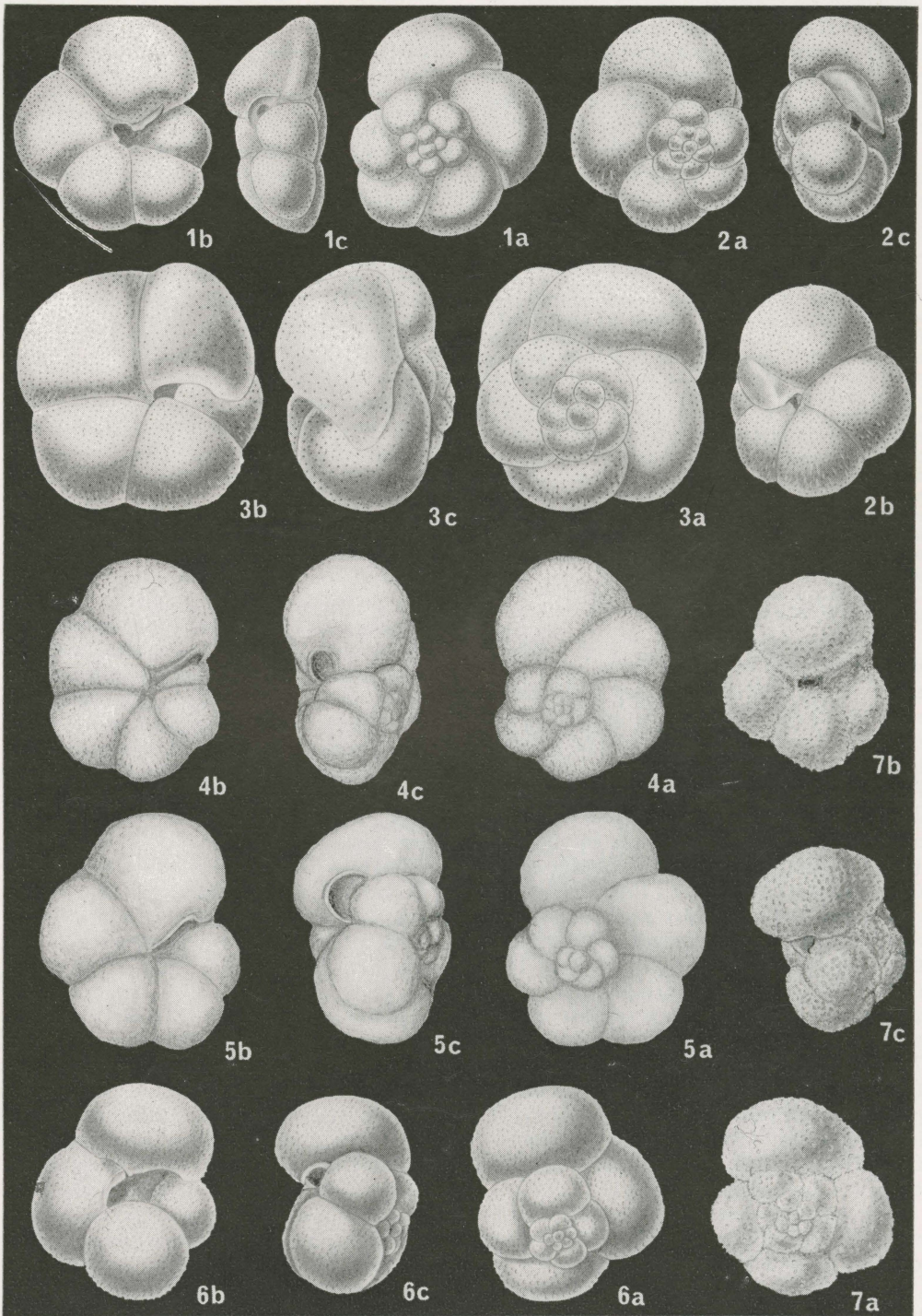


PLATE III

Globoquadrina has a higher trochospire, larger ovate or quadrate chambers, an umbilical aperture and well-formed apertural teeth. The present genus is differentiated from *Catapsydrax* by the lack of umbilical bullae.

This genus is placed in the Catapsydracinae on the basis of its coarsely pitted surface texture.

GLOBALOTALOIDES TREMA Lipps, sp. nov.

Pl. IV, figs. 3a-c

Test free, small, trochospiral about 2½ whorls, flat to slightly convex on spiral side, flattened to concave on umbilical side, umbilicus wide, deep, outline deeply lobate, periphery rounded. Chambers spherical to slightly lunate, increasing evenly in size with growth, 6 to 7 in last whorl, last chambers of large specimens tend to shift onto the umbilical side of test. Sutures radial, depressed, distinct. Wall calcareous, surface with numerous small pits. Aperture extraumbilical, a low, semicircular arch, basal in position, visible only in edge view, with small apertural lip bordering upper edge.

Greatest diameter of holotype .179 mm; greatest thickness .080 mm.

Remarks: Specimens of this new species were compared to the holotype and paratypes of *Globorotaloides suteri* Bolli and *G. variabilis* Bolli. The holotype and four paratypes of *G. suteri* were found to be identical to specimens of *G. hexagona* (Natland) from Recent sediments off southern California. *Globorotaloides hexagona* was originally referred to *Globigerina* by Natland (1938) and subsequently transferred to *Globoquadrina* by Parker (1962). It is here placed in *Globorotaloides* because it has all the distinguishing characters of that genus. *Globorotaloides trema* is differentiated from *G. hexagona* and *G. variabilis* by its much smaller size (generally less than 50%), more numerous chambers in the last whorl (6 to 7 rather than 5 to 6), less inflated chambers, flatter test, smaller diameter of the surface pits, and an apparent lack of terminal bullae-like chambers. In addition it is separated from *G. variabilis* by its nearly spherical chambers and straight sutures.

The specific name is from the Greek *trema*, *trematos*, meaning "hole," in reference to the deep umbilicus of the new species.

Types: Holotype UCLA no. 34740; 10 unfigured paratypes UCLA no. 34741; 10 unfigured paratypes USNM no. 641568; all from sample 18, Luisian.

Subfamily GLOBIGERINITINAE Bermudez, 1961

Test trochospiral. Chambers ovate to spherical, last chamber may be modified to cover umbilical area, or test may have apertural bullae. Primary aperture umbilical, secondary apertures sutural or infralaminar. Wall calcareous, perforate, smooth or finely hispid, non-spinose when living.

Remarks: This subfamily is here recognized to contain those planktonic foraminifera with smooth and finely hispid wall textures, globular or ovate chambers, and with modified last chambers or bullae. Parker (1962, p. 244) did not attempt to classify these forms on the basis of surface texture because they show affinities to both the Globigerinidae and the Globorotaliidae. These foraminifera are non-spinose when living, hence appear to be more closely related to the Globorotaliinae, as previously noted by Parker. They are here regarded as a separate subfamily of the Globorotaliidae.

Bermudez (1961, p. 1.261) erected this subfamily as a substitute name for the Catapsydracinae whose type genus, *Catapsydrax*, he believed to be synonymous with *Globigerinita*. However, on the basis of surface texture, as well as other morphologic features, the two genera are not considered to be closely related. The subfamilies based on them are therefore not regarded as synonymous, and the name Globigerinitinae is available for the subfamily group which includes *Globigerinita*.

Genus GLOBIGERINITA Brönnimann, 1951

Parker (1962, p. 246) redefined this genus to include those species with smooth or finely hispid walls which are non-spinose when living and which have a modified final chamber or bulla over the apertures. Loeblich and Tappan (1957) erected *Tinophodella* to contain those species with a separate, distinct plate covering the aperture, hence unlike the holotype of the type species of *Globigerinita*. Parker (1962, p. 248-249) also noted discrepancies in the distributional pattern of the forms with modified terminal chambers and those with a plate-like bulla. It appears advisable to retain *Tinophodella* for those foraminifera with plate-like bullae closely covering the aperture until the distributions and biology of the two types are more completely known. *Tinophodella*, although placed in the Globigerinitinae, is excluded from true *Globig-*

erinita. Species of so-called *Globigerinita* with low trochospiral whorls and modified last chambers probably should be placed in *Eoglobigerina*.

GLOBALIGERINITA UVULA (Ehrenberg)

Pl. IV, figs. 2a-c

Pyloidesia uvula EHRENBURG, 1861, K. Preuss. Akad. Wiss. Berlin, Monatsber., p. 276, 277, 308.

Test free, highly trochospiral, trigonal in side view, quadrate in umbilical view, lobate, periphery rounded. Chambers spherical, 4 in last whorl. Sutures radial, distinct, depressed. Wall thin, finely hispid, perforate. Aperture umbilical, a low arch, may have a small bulla-like inflated chamber and small slit-like accessory apertures.

Remarks: The synonymy and discussion of this species by Parker (1962, p. 252) is followed herein. She noted the possible synonymy of *Globigerina juvenilis* Bolli. Forms resembling this species were found in Luisian strata although it is not possible to distinguish the small specimens from tiny *Eoglobigerina minutissima*. In the Mohnian there are rare specimens resembling *Globigerinoides minuta* Natland, a junior synonym of *Globigerinita uvula* according to Parker.

Type: Figured hypotype UCLA no. 34742, sample 34, Mohnian.

Genus EOGLOBIGERINA Morozova, 1959

Globigerina (Eoglobigerina) MOROZOVA, 1959, Akad. Nauk SSSR, Doklady, v. 124, no. 5, p. 1115.

Type species: *Globigerina (Eoglobigerina) eobulloides* Morozova, 1959. Fixed by original designation.

Test free, small, trochospiral, periphery rounded. Chambers spherical to quadrate, final chamber may be modified with umbilical projection covering aperture and umbilicus. Wall smooth to very finely hispid. Aperture umbilical to extraumbilical, may be covered or uncovered.

Remarks: *Eoglobigerina* was described by Morozova (1959) to contain smooth-walled, globigerinid-like species from Paleocene sediments in Russia. Loeblich and Tappan (1964, p. C671) regarded it as a synonym of *Globorotaloides*. However these genera can be clearly distinguished on the basis of wall texture, chamber shape and test proportions.

Eoglobigerina is recognized herein by its smooth surface texture, nearly globular chambers and the umbilical extension of the final chamber in some adult specimens.

EOGLOBIGERINA MINUTISSIMA (Bolli)

Pl. IV, fig. 4a-6c

Globorotalia minutissima BOLLI, 1927, U. S. Natl. Mus. Bull., 215, p. 119, pl. 29, figs. 1a-c.

Test free, small, trochospiral, spire flat to high, 2½ to 3½ whorls, umbilical side concave in center, umbilicus most commonly covered, outline slightly to deeply lobate, periphery broadly rounded. Chambers spherical to ovate, inflated, increasing evenly in size, 5 to 6 in last whorl, last chamber may be reduced or bulla-like and cover aperture and umbilicus. Sutures radial, distinct, depressed. Wall smooth to finely hispid. Aperture umbilical to extraumbilical, a low arch, bordered by lip or projection of last chamber which may also cover umbilicus.

Remarks: Much variation occurs in this species throughout the section at Newport Bay (see Pl. IV, figs. 4-6). Many specimens are identical to topotypes from Trinidad and these grade into larger high-spined varieties.

This species is placed in *Eoglobigerina* rather than *Globorotalia* because of its spherical to oval chambers and modified terminal chambers.

Types: Figured hypotypes UCLA nos. 34743, 34744, 34745, from samples 1, 2, and 18 respectively; 200 unfigured hypotypes each, UCLA nos. 34746, 34747, 34748, from samples 1, 16, and 34, respectively.

EOGLOBIGERINA OPERTA Lipps, sp. nov.

Pl. IV, figs. 7a-c

Test free, trochospiral, about 2½ whorls, convex on spiral side, slightly concave to convex on umbilical side, umbilicus small, deep when open, or may be covered, outline lobulate, circular in small specimens, quadrate in large ones, edges broadly rounded on umbilical side, more sharply rounded on spiral side. Chambers inflated, spherical in early stages, becoming elongate tangentially, chambers larger where adjacent to earlier chambers, then tapering and becoming smaller toward aperture, 4 to 5 in last whorl, latest chambers tend to coil onto umbilical side of test, final chamber commonly reduced and covering umbilicus. Sutures radial, depressed, more deeply incised on umbilical side. Wall smooth, very finely perforate. Aperture extraumbilical, semi-circular, with small protruding lip, commonly covered by small modified terminal chamber with an umbilical-extraumbilical opening.

Greatest diameter of holotype .204 mm; greatest thickness .136 mm.

Remarks: This new species is differentiated from other species by its tangentially

elongate, tapering chambers. *Globorotalia acostaensis* Blow, 1959, and *G. birnageae* Blow, 1959, are similar to *E. aperta* but the chambers are not as wide in the former. The generic assignment of Blow's species could not be determined from the original descriptions and illustrations, and they may not be related to *Eoglobigerina*.

Eoglobigerina aperta occurs near the top of the section studied, in Mohnian sample 34.

The specific name is from the Latin *operatus*, meaning "cover, hide," in reference to the covered or hidden aperture and umbilicus.

Types: Holotype UCLA no. 34749; 100 unfigured paratypes UCLA no. 34750; 10 unfigured paratypes USNM no. 641569; all from sample 34, Mohnian.

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(All figures: a. spiral view, b. umbilical view, c. edge view, unless otherwise noted)

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Figure 2 by Jill Penkhus; others by Margaret Rogers.

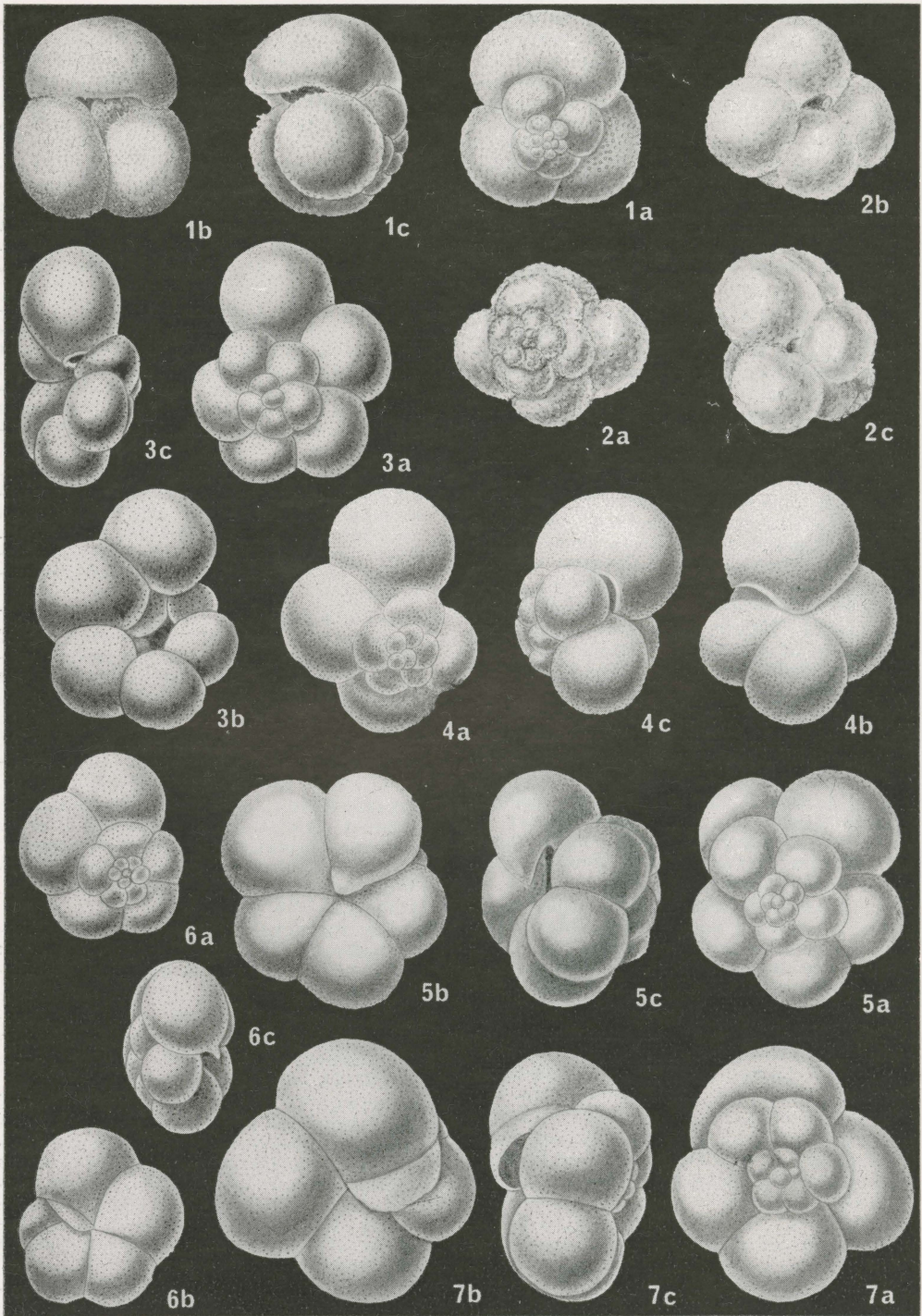


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