

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 135, NUMBER 2

Charles D. and Mary Vaux Walcott
Research Fund

MORPHOLOGY AND TAXONOMY OF
THE FORAMINIFERAL GENUS
PARAROTALIA LE CALVEZ, 1949

(WITH FIVE PLATES)

By

ALFRED R. LOEBLICH, JR.

California Research Corporation
La Habra, Calif.

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U. S. Geological Survey



(PUBLICATION 4303)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
DECEMBER 3, 1957

THE LORD BALTIMORE PRESS, INC.
BALTIMORE, MD., U. S. A.

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MORPHOLOGY AND TAXONOMY OF THE
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INTRODUCTION

Material collected by the writers from the Paleocene and lower Eocene of the Atlantic and Gulf Coastal Plains was found to contain foraminiferal species with distinctive apertural characters. A comparison of this material with some collected by the authors in England and France in 1953-1954 showed the presence of related species in somewhat younger Eocene and Oligocene strata, and proved that these species belong to the genus *Pararotalia* Le Calvez.

The earlier and more primitive species show better the ontogenetic apertural development of this genus; they made possible the later recognition of these same apertural characters in the type species. The generic definition is therefore here emended and the type species, *Pararotalia inermis* (Terquem), is redescribed.

Other new species are here described from the Paleocene and Eocene of the Atlantic and Gulf Coastal Plains and the Oligocene of England and France.

Certain species previously described as *Rotalia* or *Globorotalia* are also shown to belong to *Pararotalia*. These include *Rotalia armata* d'Orbigny from the Miocene, *R. byramensis* Cushman (and *R. incisura* Todd, here shown to be a synonym of *byramensis*) from the

¹ Publication authorized by the Director, U. S. Geological Survey.

² Mrs. Helen N. Loeblich.

Oligocene, *R. parva* Cushman from the Oligocene, *R. canui* Cushman (part, from the Oligocene of France; not including *Rotalia stellata* Reuss, 1856, from the German Oligocene, for which *canui* was proposed as a new name), and *Globorotalia spinigera* Le Calvez from the middle Eocene, Lutetian, of France.

In addition to the type species, *Pararotalia inermis* (Terquem), only *P. subinermis* Bhatia from the Oligocene has been previously placed in this genus. This latter species is also here described and figured.

One additional specimen, from the Miocene of France, is figured as *Pararotalia* species. The lack of sufficient material makes specific identification impossible, but it is here recorded for its stratigraphic interest.

GEOLOGIC OCCURRENCE

Previously reported from the middle Eocene and Oligocene, the genus is now known to range from the Paleocene (Landenian) to Miocene (Burdigalian) (see fig. 1). The oldest species known, *P. macneili*, new species, is from the Matthews Landing marl member of the Porters Creek clay (Midway group) of Alabama, equivalent to a part of the Landenian stage of the European section. The other Paleocene species, *P. ishamae*, new species, also occurs in the lower Eocene. The lower Eocene (Ypresian) of Europe contains *P. calvezae*, new species, and the middle Eocene (Lutetian) contains *P. inermis* (Terquem) and *P. spinigera* (Le Calvez). Reaching its climax in the Oligocene, *Pararotalia* is represented by *P. subinermis* Bhatia, *P. curryi*, new species, *P. parva* (Cushman), and *P. byramensis* (Cushman). From the Miocene, only *P. armata* (d'Orbigny) has been described, although a single specimen of an undetermined species is also here figured.

Although no species are yet reported from the upper Eocene or lower Miocene, further search will undoubtedly show their presence.

In addition to the above-mentioned species, which are here illustrated and described, the specimen figured by Kaasschieter (1955, pl. 9, fig. 2) as *Rotalia rimosa* Reuss from the lower Aquitanian-upper Burdigalian of the Aquitaine Basin of France, also appears to be a *Pararotalia*. The species was originally described from the Oligocene of southern France (Gaas), and although the original figure does not show the true apertural character, it seems to represent the same species as that of Kaasschieter. As no material of this species was at present available to the writers, this species cannot here be definitely allocated.

		macnelli	ishamae	calvezae	inermis	spinigera	subinermis	curryi	byramensis	parva	armata	species
MIOCENE	Helvetian											
	Burdigalian										■	■
	Aquitainian											
OLIGOCENE	Stampian							■	■	■		
	Lattorfian						■	■				
EOCENE	Priabonian											
	Lutetian				■	■						
	Ypresian		■	■								
PALEOCENE	Landenian	■	■									
	Danian											

FIG. 1.—Geologic occurrence of known species of *Pararotalia*.

MORPHOLOGY

The character of the aperture of *Pararotalia* is discussed in detail in the generic diagnosis which follows. Only general comments on its relationship to the taxonomy are here included.

Pararotalia was originally separated from *Rotalia* Lamarck because of the areal aperture, which was first observed in *P. inermis* (Terquem). Le Calvez (1949, p. 33) noted that other species which she considered as *Rotalia* were otherwise similar (e.g., *Rotalia armata*, *R. audouini*) but that they had an "ouverture typique de *Rotalia*."

Kaasschieter (1955, p. 86) considered *Pararotalia* to be only a subgenus of *Rotalia*, regardless of the apertural character. He added that specimens of *R. audouini* "were observed which are in this respect identical with *R. inermis*, but other individuals show typical *Rotalia*-apertures or a position in between the two extremes. Unfortunately most of our specimens are too badly damaged for a clear analysis of this important characteristic." He also added that "*R. byramensis* Cushman is entirely within the range of variation of our specimens of *R. audouini*."

Examination of *R. audouini* shows that this species always has a completely basal aperture, dissections showing no earlier chambers that have developed the umbilical apertural plate characteristic of *Pararotalia* which leaves an areal opening in the face of the chamber. *Rotalia byramensis* is, however, a true *Pararotalia*, the areal aperture being well developed. Dissection of specimens of *Pararotalia* always shows this areal aperture in earlier chambers, as here shown in *P. inermis*, even in specimens in which it is absent from the final chamber. Such dissections show that the margin of the next chamber is added so as to curve around the areal opening, and the later umbilical plate is only secondarily attached at its lower margin, expanding anteriorly to cover the umbilical portion of the previously extraumbilical-umbilical interiomarginal opening. Thus, in a large suite of specimens of any species, one may observe both those specimens with basal aperture exposed and those with areal aperture and umbilical plate. In those species with relatively open umbilicus, such as the *P. ishamae-spinigera* group, this plate may also be secondarily broken out. This character has undoubtedly led to some taxonomic confusion, and specimens of the same species may have been variously placed in one or the other genus, or the genera regarded as transitional (Kaasschieter, 1955, p. 86).

A comparison of the various species here illustrated suggests that

two lineages developed within the genus. The simplest and geologically oldest species, *Pararotalia macneili*, new species, and *P. ishamae*, new species, are simple discorbidlike forms with rounded and inflated chambers, without peripheral spines, and without a strongly angled umbilical shoulder. The umbilicus is relatively open and the umbilical apertural plate can be easily observed. Later species show a progressive development of angularity of chambers, the development of nodes at the more acute umbilical shoulders, and the appearance of peripheral spines and keels. Young specimens of the lower Eocene *P. calvezae* show the ancestral type, with nonspinose rounded chambers, whereas the adult test becomes more angled with peripheral spines. This lineage becomes more ornate with the development of the umbonal thickening and pustules on the spiral sides, nodes at the umbilical shoulder on the opposite side, the peripheral keel, and the more prominent spines of *P. spinigera* (Le Calvez). This group continues into the Oligocene, as represented by *P. curryi*, new species, and *P. parva* (Cushman), and in the Miocene by *P. armata* (d'Orbigny).

A second and more specialized group branched off in the middle Eocene and Oligocene with the development of a more lenticular test, limbate sutures and peripheral keel, and characterized in particular by a very sharply angled umbilical shoulder, which together with the prominent umbilical plug serve to close the umbilicus and obscure the umbilical apertural plate, although the areal aperture is distinct and prominent. This group is represented by *P. inermis* (Terquem) in the middle Eocene, *P. byramensis* (Cushman) and *P. subinermis* Bhatia in the Oligocene.

RELATIONSHIPS OF THE GENUS

Although many of these species have been regarded by earlier workers as *Rotalia*, and the genus *Pararotalia* has even been considered as a subgenus of *Rotalia*, there is actually no close relationship between these genera. As recently revised by Smout (1954, 1955) the present genus would not even belong to the same family (Rotaliidae) or superfamily (Rotaliidea) as the genus *Rotalia*.

Smout restricted the superfamily Rotaliidea to include forms having the test built of radial, laminated calcite and (1955, p. 202) "canaliculate with no aperture, or pores on the apertural face, or pores elsewhere, sometimes with interiomarginal intercameral foramina, or showing derivation from such a form." All genera of the Rotaliidae "have radial canals or fissures or umbilical cavities and intraseptal

and subsutural canals are common if not universal." *Rotalia* s. s. is typical of this group.

The superfamily Discorbidea, according to Smout (1955, p. 202), includes genera that are "noncanaliculate with an interiomarginal aperture, areal aperture, or showing derivation from such a form." Furthermore (Smout, 1954, p. 10), "perforation of the intercameral foramen as an aperture seems universal in the Discorbidea." Smout (1954, p. 10) included in the superfamily the families "Discorbidae, Amphisteginidae, Cymbaloporidae, Planorbulinidae, and perhaps, the Globorotaliidae."

Pararotalia does not have radial canals or fissures, nor does it have intraseptal and subsutural canals and thus does not belong to the Rotaliidae. It does have an interiomarginal aperture (originally) and areal aperture (derived from the basal aperture, by the addition of the umbilical apertural plate) and thus belongs to the superfamily Discorbidea and most probably to the family Discorbidae.

Furthermore, as many of the species of "*Rotalia*" which have been confused with species of *Pararotalia* also have a basal aperture, although lacking the later umbilical apertural plate and consequent secondarily areal aperture, they do not belong to true *Rotalia*, but possibly also should be referred to the Discorbidea. Additional study of these forms is necessary for generic placement.

ACKNOWLEDGMENTS

The writers wish to acknowledge the field assistance of M. Henri Tintant, Université de Dijon, France, who accompanied us in the collecting at Grignon, France; of Mr. Dennis Curry, Pinner, Middlesex, England, and Mr. A. G. Davis, London, England, in the collecting of the Oligocene Middle Headon beds of southern England; and of Mr. Richard Page, Smithsonian Institution, in the collecting of the Aquia formation of Virginia. Illustrations of the various species are camera lucida drawings prepared by Patricia Isham, scientific illustrator, U. S. National Museum.

SYSTEMATIC DESCRIPTIONS

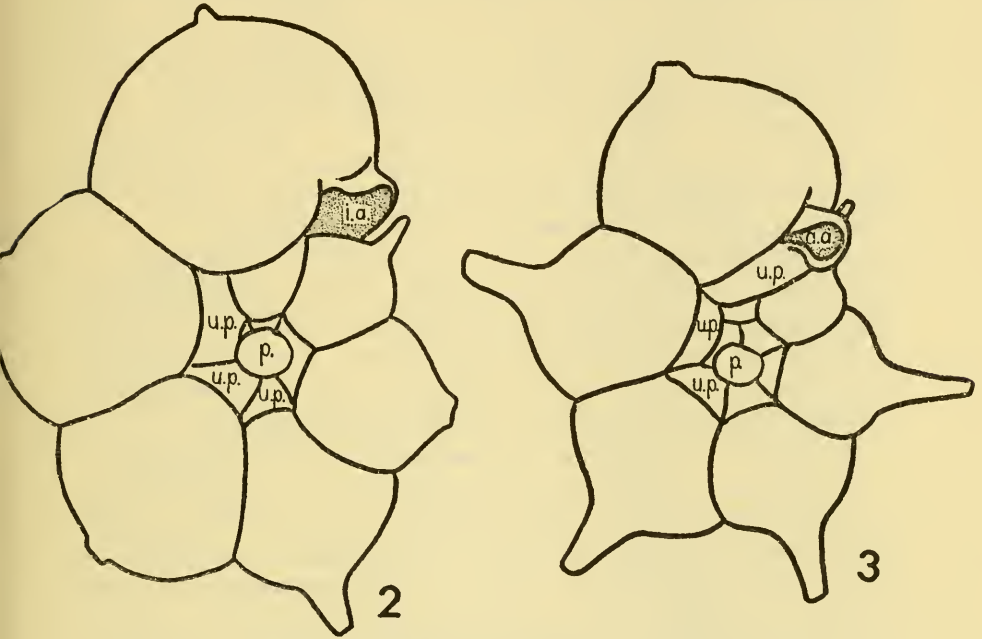
Family DISCORBIDAE Cushman, 1927

Genus PARAROTALIA Le Calvez, 1949, emended

Pararotalia LE CALVEZ, Mém. Expl. Carte Géol. Dét. France, Rev. Foram. Lutétiens. II Rotaliidae, p. 32, 1949.

Type species.—*Rotalina inermis* Terquem, 1882. Fixed by original designation and monotypy.

Test free, trochospiral, planoconvex to biconvex, umbilicus filled with a plug which may be broken out in preservation, chambers rounded to ovate in plan, may have smoothly rounded periphery or may develop a short, blunt peripheral spine on each chamber, umbilical



FIGS. 2, 3.—*Pararotalia parva* (Cushman).

2. Outline drawing of specimen, showing protruding lip above an open interiomarginal aperture (i.a.) with umbilical apertural plates (u.p.) present on earlier chambers around the umbilical plug (p.), but not on final chamber.

3. Outline drawing of specimen with umbilical apertural plate (u.p.) covering umbilical margin of final chamber, and partially closing the primary aperture, leaving open only the areal aperture (a.a.) typical of the genus *Pararotalia*. Early chambers also show umbilical apertural plates (u.p.) around the umbilical plug (p.).

region of each chamber partially covered by secondary umbilical plates; sutures flush to moderately depressed, straight to gently curved; wall calcareous, perforate, radial in structure, smooth or variously ornamented with large, solid spines or fine scattered spines or nodes; aperture on the umbilical side, originally interiomarginal and extraumbilical-umbilical (see text figs. 2, 4), with a lip above; a thin and delicate secondary umbilical plate is then formed before the development of the next chamber (text figs. 3, 5), covering the

umbilical portion of the aperture and leaving visible only a narrow, elongate, comma-shaped or slitlike areal portion of the aperture roughly paralleling the base of the apertural face, an internal septum being formed at the junction of the umbilical plate and the chamber wall, and the septum may be reflected at the surface by a more or less distinct suture; this thin umbilical plate may be very narrow and almost unnoticeable or relatively large and commonly broken away after development, showing only the interiomarginal aperture.

Remarks.—*Pararotalia* Le Calvez differs from *Globorotalia* Cushman in having an areal aperture, formed by a secondary umbilical plate which partially covers the umbilical portion of the aperture, and leaving open only a slitlike portion of the aperture.

Eponidella Cushman and Hedberg superficially resembles the present genus in having chamberlets on the umbilical side (similar in appearance to the umbilical plates of *Pararotalia*) and an areal aperture, but the aperture of *Eponidella* is restricted to the face of the final chamber and does not have the morphologic relationship to the secondary umbilical plates that is found in the present genus.

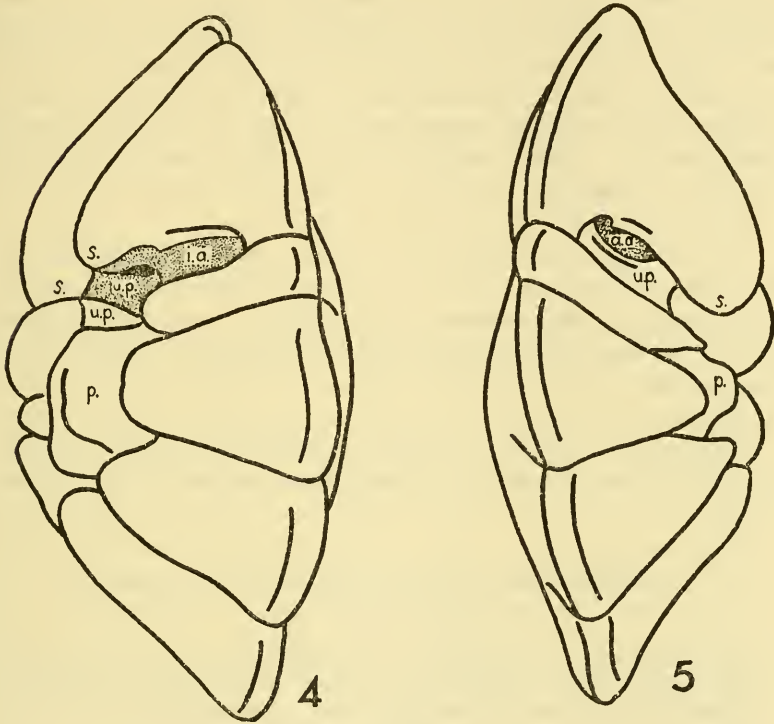
This genus was originally described as having a simple areal aperture, which is strongly suggested in the type species. The observation of the secondary plate in other species and strong similarity in final appearance of the areal apertures led the writers to examine carefully at high magnifications a large suite of specimens of the type species from Grignon, France. Although the external suture is almost invisible (text figs. 4, 5), dissected specimens proved the presence of this secondary umbilical plate in the type species also (see pl. 1, figs. 3a, b), hence the generic diagnosis is herewith emended.

The species thus far studied show an evolutionary trend from a biconvex test with lobulate periphery and rounded chambers to a nearly lenticular or planoconvex test with angular chambers and a keeled, spinose, or stellate periphery.

The secondary umbilical plates are more prominent in the early species, with a well-marked suture at the junction of this plate and the chamber wall, and the fragile nature of the plates coupled with their later development allows for a greater frequency of specimens in which it has not yet been developed in the final chamber or has been secondarily destroyed. Younger species show a much narrower series of plates restricted to the area below the umbilical shoulder and commonly obscured by a combination of elevated umbilical shoulder and protruding umbilical plug. They also seem to be formed almost simultaneously with the original chambers, as very few of the speci-

mens show the early marginal aperture either before its development or by later breakage.

Range.—Paleocene (Landenian) to Miocene (Burdigalian).



FIGS. 4, 5.—*Pararotalia inermis* (Terquem).

4. Outline drawing of specimen, showing narrow lip above the open interior-marginal aperture (i.a.) in the final chamber through which can be seen the areal aperture of the penultimate chamber and its umbilical apertural plate (u.p.). Plate of earlier chambers nearly hidden beneath the overhanging umbilical shoulder (s.) of the chambers, and further protected by the extremely large umbilical plug (p.).

5. Outline drawing of specimen with umbilical apertural plate (u.p.) covering umbilical margin of final chamber, partially closing the primary aperture, leaving open only the areal aperture (a.a.), typical of the genus. Umbilical plates are more difficult to see and are better protected in these angular and sharply keeled species.

PARAROTALIA ARMATA (d'Orbigny), emended

Plate 5, figures 2a-c

Rotalia (Rotalie) armata D'ORBIGNY, Ann. Sci. Nat., sér. I, vol. 7, p. 273, 1826.

Test free, trochospiral, biconvex, periphery acute, peripheral outline stellate, spiral side evenly convex, umbilical side with chambers

strongly inflated near the umbilical shoulder, tending to form a circle of umbilical nodes, umbilicus filled by a large rounded and greatly elevated plug; chambers in 2 whorls, 6 to 7 in the final whorl, each with a short, blunt spine at the peripheral chamber angle; sutures limbate, nearly flush and gently curved on the spiral side, depressed and radial on the umbilical side; wall calcareous, smooth except for the umbilical plug, the umbilical node on each chamber and the peripheral spines, the peripheral border nonperforate and keel-like; aperture interiomarginal, on the umbilical side, the lower portion secondarily closed by an umbilical plate, leaving only a small areal opening.

Figured hypotype 0.33 mm. in diameter.

Remarks.—*Pararotalia armata* is characterized by the stellate outline, depressed sutures on the umbilical side, elevated plug, and the nodes formed on each chamber at the umbilical shoulder. It is similar to *P. byramensis* (Cushman) in general appearance, differing in the stellate outline, more compressed test, and the more regularly convex spiral side.

Types and occurrence.—Figured hypotype (U.S.N.M. P5807) from the Miocene (probably Burdigalian) at Dax, Dept. Landes, France.

PARAROTALIA BYRAMENSIS (Cushman), emended

Plate 1, figures 1a-c

Rotalia byramensis CUSHMAN, U. S. Geol. Surv. Prof. Pap. 129-E, p. 99, pl. 23, fig. 1, 1922; Prof. Pap. 129-F, p. 138, 1922.—CUSHMAN and TODD, Contr. Cushman Lab. Foram. Res., vol. 22, p. 100, pl. 16, fig. 23, 1946.

Rotalia dentata Parker and Jones? CUSHMAN, U. S. Geol. Surv. Prof. Pap. 129-E, p. 100, pl. 23, fig. 2, 1922.

Rotalia incisura TODD, U. S. Geol. Surv. Prof. Pap. 241, p. 39, pl. 5, fig. 25a-c, 1952.

Test free, relatively large, trochospiral, planoconvex to biconvex, periphery angular to keeled, peripheral outline angularly lobulate; all of the $1\frac{1}{2}$ to $2\frac{1}{2}$ whorls visible on the flat to gently convex spiral side, only the 7 (rarely 6 to 9) chambers of the final whorl visible on the elevated umbilical side, chambers radially elevated on the umbilical side, forming a nodelike projection at the umbilical shoulder, then dropping sharply into the deep umbilicus, which is completely filled with an umbilical plug in small specimens, but in large specimens a deep and narrow umbilical depression remains around the umbilical plug, each chamber with a single short peripheral spine at the dorsal angle, the rate of increase in chamber size and resultant overlap of the preceding chamber resulting in a slight variation in apparent posi-

tion of these spines in earlier chambers from near the midpoint of the chamber to near the following suture, this variation occurring from chamber to chamber in the same specimen; sutures gently curved, distinct, limbate, and may be elevated on the spiral side, deeply incised and radial on the umbilical side; wall calcareous, finely perforate, surface smooth or more rarely somewhat wrinkled in large or gerontic specimens, ornamented by the raised sutures and peripheral keel and spines; aperture interiomarginal, extraumbilical-umbilical, secondarily filled at the umbilical margin with an umbilical plate which leaves only a small rounded or ovate areal aperture completely surrounded by a narrow lip.

Greatest diameter of figured hypotype 0.40 mm.

Remarks.—*Pararotalia byramensis* resembles most closely *P. inermis* (Terquem) from the Eocene (Lutetian) of France, but the chambers increase more rapidly in height, the peripheral outline is more angularly lobulate and the chambers more strongly spinose, and the sutures are more limbate and elevated on the spiral side.

The holotype of *P. byramensis* is a somewhat atypical specimen, as it is a gerontic form which is unusually large, with more than the usual number of chambers per whorl. It has 9 in the final whorl, but earlier whorls show the more common number of 7 per whorl, similar to the average specimen at that size. Noting the differences of the type *byramensis*, the smaller specimens were later placed in a separate species, *Rotalia incisura* Todd (1952), which was said to differ from *R. byramensis* in having "shorter spines, which originate from the sutural angle rather than the central part of the chamber, and project tangentially forward rather than radially, and in the lesser protrusion of the chambers, such that except for the spines the periphery would be only very slightly lobulated. This species also differs in its strongly limbate dorsal sutures and the presence of a blunt keel on the periphery, and in its lack of surface ornamentation." These differences, however, vary considerably from specimen to specimen, and from chamber to chamber of even the "holotypes" of the two species. The type of *R. byramensis* has more limbate sutures than that of *R. incisura*, in contrast to their descriptions, and both are distinctly keeled. Examination of a large suite of specimens from the type locality of the Byram formation collected by the writers, shows all gradations between these two "species," hence they are here considered synonymous.

Types and occurrence.—Holotype (Cushman Coll. 25563) from the Byram formation, Pearl River at bridge, Byram, Miss.

Figured hypotype (U.S.N.M. P5697) from the Byram formation,

west bank of Pearl River, just north of suspension bridge east of Byram, Hinds County, Miss. Collected by A. R. Loeblich, Jr., October 11, 1941.

PARAROTALIA CALVEZAE Loeblich and Tappan, new species

Plate 2, figures 3a-7c

Test free, trochospiral, biconvex, umbilicus filled with a protruding plug, periphery subacute to rounded, peripheral outline gently lobulate to stellate, chambers in 2 whorls, 5 to 6 in the final whorl, more commonly 5, one or more may have a single peripheral spine, chambers gently convex on the spiral side, with a subangular umbilical shoulder on the opposite side, umbilical portion partially covered by an elongate secondary umbilical plate; sutures distinct, depressed, radial on the umbilical side, gently curved on the spiral side; wall calcareous, distinctly perforate, ornamented with the peripheral spines; aperture on the umbilical side, interiomarginal and extra-umbilical-umbilical, with a narrow lip on the forward margin paralleling the outer periphery of the test, the very narrow secondary umbilical plate covering the umbilical portion of the aperture, but largely within the angle formed by the umbilical shoulder so that only those of the latest chambers can be well seen.

Greatest diameter of holotype 0.35 mm. Paratypes range from 0.23 to 0.35 mm. in diameter.

Remarks.—This species differs from *P. spinigera* (Le Calvez) in being more biconvex, in possessing a more rounded rather than keeled periphery, more depressed sutures on the spiral side, in being smaller and with more commonly 5 rather than 6 chambers in the final whorl. It is probably ancestral to *P. spinigera*, which is larger, more highly ornamented, and has a more angular periphery, chambers, and umbilical shoulders.

This species is named in honor of Mme. Yolande Le Calvez, Bureau des Recherches Géologiques et Géophysiques, Paris, France, in recognition of her excellent work on the Foraminifera of the Lutetian of the Paris Basin.

Types and occurrence.—Holotype (U.S.N.M. P5686) and figured paratypes (U.S.N.M. P5687a-d) from the lower Eocene, Ypresian, about 8 feet above the base of the exposure in the brick pit at Gan, about 8 kilometers south of Pau, Dept. Basses Pyrénées, France. Collected by H. T. and A. R. Loeblich, Jr., April 1954.

PARAROTALIA CURRYI Loeblich and Tappan, new species

Plate 3, figures 5a-7c

Rotalia canui CUSHMAN (part; not *Rotalia stellata* Reuss, 1856), Bull. Soc. Sci. Seine-et-Oise, sér. 2, vol. 9, No. 4, p. 55, pl. 3, figs. 2a-c, 1928.—BHATIA, Journ. Paleontol., vol. 29, No. 4, p. 684, pl. 66, figs. 32a-c, 1955.

Test free, small, biconvex, periphery subacute, peripheral outline lobulate to stellate, spiral side strongly convex, umbilical side with a large umbilical plug; chambers slightly inflated on both sides with 2 whorls, commonly 6 chambers in the final whorl, but young specimens may have only 4 or 5 chambers per whorl, adult chambers commonly each with a single short, blunt peripheral spine; sutures depressed and gently curved; wall calcareous, finely perforate, surface of early whorl somewhat nodose on the spiral side, a peripheral spine is commonly developed on some of the chambers of adult tests, but may not be present in young tests or on the final chambers of adult tests; aperture interiomarginal, with a distinct lip at the upper forward margin, the lower portion of the aperture secondarily closed by an umbilical plate which leaves only a small areal opening.

Holotype 0.23 mm. in diameter. Paratypes range from 0.15 to 0.38 mm. in diameter.

Remarks.—This species is very similar in appearance to *P. parva* (Cushman) but is somewhat thicker and more robust, with a more closed umbilicus.

Cushman (1928, p. 55) proposed *Rotalia canui* as a new name for *Rotalia stellata* Reuss, 1856, not *R. stellata* Ehrenberg, 1840. Inasmuch as Cushman proposed a new name for the homonym of Reuss, the type specimen must be that of Reuss and cannot be "Jeurs (holotype)" as Cushman erroneously stated (1928, p. 55). The species of Reuss is from the Oligocene, Casseler Schichten, of Luithorst, Germany, and is a larger planoconvex species with more angular chambers, similar to *Pararotalia armata* (d'Orbigny), although an areal aperture was not noted and Reuss's species may not belong to the present genus. However, Cushman figured as *R. canui* from the French Oligocene a specimen with more gently lobulate peripheral outline, less acutely angled periphery, and a typical *Pararotalia* aperture. One of the French specimens of Cushman is here figured (pl. 3, fig. 7). Bhatia (1955, p. 684) also recorded the present species as *Rotalia canui* from the Middle Headon, Brockenhurst beds of England. His figured specimen lacks the umbilical apertural plate on the final chamber and thus shows only an interiomarginal aperture. The French and English species is thus quite distinct from that of Reuss, and this species is here named for Mr. Dennis Curry of Pinner, Middlesex, England, in

recognition of his work on the English Tertiary stratigraphy and paleontology. Mr. Curry accompanied the writers in 1953 while collecting from the Tertiary of southern England and the Isle of Wight.

Types and occurrence.—Holotype (U.S.N.M. P5808) and figured paratype (U.S.N.M. P5809) from the Oligocene (Lattorfian), Middle Headon, Brockenhurst beds, at White Cliff Bay, east coast Isle of Wight, England. Collected by H. T. and A. R. Loeblich, Jr., with Dennis Curry and A. G. Davis.

Figured paratype (U.S.N.M. P5810) from the Oligocene, Stampian, at Jeurs, Dept. Seine-et-Oise, France.

PARAROTALIA INERMIS (Terquem), emended

Plate I, figures 2a-3b

Rotalina inermis TERQUEM, Mém. Soc. Géol. France, sér. 3, vol. 2, p. 68, pl. 6, fig. 1a-c, 1882.

Pararotalia inermis (Terquem) LE CALVEZ, Mém. Expl. Carte Géol. Dét. France. Rév. Foram. Lutétiens. II Rotaliidae, p. 32, pl. 3, figs. 54-56, 1949.

Test free, trochospiral, lenticular, biconvex, periphery sharply acute and strongly keeled, all whorls visible on the convex spiral side, only the 7 to 8 chambers of the last whorl visible on the deeply umbilicate opposite side around the prominent umbilical plug; chambers much inflated near the umbilicus, forming nodelike elevations at the umbilical shoulders; sutures curved, limbate, but flush on the spiral side, radial and deeply depressed and slitlike on the umbilical side; wall calcareous, finely perforate, surface smooth, except for the nodose umbilical elevations of the chambers, the umbilical plug, peripheral keel, and rare short peripheral spines of solid nonporous calcite; aperture an areal ovate opening surrounded by a slight lip, and may have as a minor toothlike projection from the upper margin the remnant of an earlier upper lip of the marginal aperture, the final areal opening due to secondary constriction by very narrow umbilical plates developed below the umbilical shoulder and closely joined to the lower chamber margin, the presence as a distinct structure being evident internally in dissected specimens.

Hypotypes range from 0.28 to 0.50 mm. in diameter.

Types and occurrence.—Hypotypes (U.S.N.M. P5693a-b) from the middle Eocene, Lutetian, Calcaire grossier (Zone IV of Abrard), in the sand pit at Grignon, now in the Parc d'École Nationale d'Agriculture, Grignon, Dept. Seine-et-Oise, France. Collected by H. T. and A. R. Loeblich, Jr., with Henri Tintant, April 1954.

PARAROTALIA ISHAMAE Loeblich and Tappan, new species

Plate 3, figures 1a-4

Test free, tiny, trochospiral, periphery rounded, peripheral outline gently lobulate, about 2 whorls visible on the spiral side, final whorl composed of 5 chambers, umbilical side deeply umbilicate, with a protruding umbilical plug; sutures gently arcuate, somewhat thickened and those of final whorl very slightly depressed on the spiral side, less thickened and more depressed on the umbilical side; wall calcareous, finely perforate, surface smooth and unornamented; aperture interiomarginal, extraumbilical-umbilical, a relatively high open arch, with a narrow lip above, but with the umbilical portion commonly secondarily covered by an umbilical plate which leaves open only the narrow ovate or slitlike areal remnant of the aperture nearest the peripheral margin of the test, the portion of the plate adjacent to the aperture somewhat thickened to resemble a lower lip.

Greatest diameter of holotype 0.20 mm. Paratypes range from 0.13 to 0.28 mm. in diameter.

Remarks.—This more primitive-appearing species is smaller and does not develop the peripheral spines of *P. calvezae*, new species, and *P. spinigera* (Le Calvez), lacks the nodose ornamentation of the early spire, and is more nearly biconvex, without a keel or angular periphery. A few small specimens of *P. calvezae* approach the characteristics of this species, suggesting that these later and more ornate species may have developed from such an ancestral type.

Types and occurrence.—Holotype (U.S.N.M. P5689) and figured paratype (U.S.N.M. P5690) from the Aquia formation, 3-foot shell bed between two 1-foot indurated layers 10 to 13 feet above the base of the exposure, west bank of the Potomac River near mouth of Aquia Creek, S. 10° E. of Brent Point, Va. Collected by A. R. Loeblich, Jr., and Richard Page, 1956.

Paratype (U.S.N.M. P5691) from the Nanafalia formation, at the type locality of the formation, Nanafalia Landing, Tombigbee River, Marengo County, Ala. Collected by A. R. Loeblich, Jr., July 1956.

Paratype (U.S.N.M. P5692) from the Matthews Landing marl member of the Porters Creek clay, Naheola Landing, Tombigbee River, SE¼ sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Ala. Collected by A. R. Loeblich, Jr., July 1956.

PARAROTALIA MACNEILI Loeblich and Tappan, new species

Plate 2, figures 1a-2b

Test free, small, trochospiral, biconvex, periphery subacute, peripheral outline lobulate; chambers arranged in about 2 whorls, all visible on the spiral side, only the 6 or 7 of the final whorl visible around the large, protruding umbilical plug on the opposite side; inflated chambers of nearly equal breadth and height; sutures gently curved, slightly depressed on the spiral side, those of earlier whorl somewhat obscured by the nodose surface ornamentation, sutures nearly radial and depressed on the umbilical side; wall calcareous, finely perforate, surface hirsute with numerous short, blunt spines; aperture originally interior-marginal, extraumbilical-umbilical but secondarily closed by a narrow umbilical plate which leaves only the small ovate areal opening typical of the genus.

Greatest diameter of holotype 0.20 mm. Paratypes range from 0.13 to 0.25 mm. in diameter.

Remarks.—*Pararotalia macneili*, new species, differs from *P. ishamae*, new species, in having a strongly hirsute wall, and more globular-appearing chambers. *Pararotalia spinigera* (Le Calvez) differs in having angular chambers and a peripheral keel, a nodose umbilical shoulder around the umbilical plug, and in having a more coarsely perforate wall, a single peripheral spine per chamber instead of the completely hirsute wall.

The species is named in honor of F. Stearns MacNeil, U. S. Geological Survey, in recognition of his contributions to the stratigraphy of the Paleocene of Alabama.

Types and occurrence.—Holotype (U.S.N.M. P5694) and figured paratype (U.S.N.M. P5695) from the Matthews Landing marl member of the Porters Creek clay, Naheola Landing, Tombigbee River, SE $\frac{1}{4}$ sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Ala. Collected by A. R. Loeblich, Jr., July 1956.

PARAROTALIA PARVA (Cushman), emended

Plate 4, figures 4-5c

Rotalia dentata Parker and Jones var. *parva* CUSHMAN, U. S. Geol. Surv. Prof. Pap. 129-F, p. 139, pl. 35, figs. 1, 2, 1922; U. S. Geol. Surv. Prof. Pap. 133, p. 47, 1923.

Rotalia parva Cushman, CUSHMAN and TODD, Contr. Cushman Lab. Foram. Res., vol. 22, p. 100, pl. 16, figs. 24, 25, 1946; TODD, U. S. Geol. Surv. Prof. Pap. 241, p. 40, pl. 5, fig. 26, 1952.

Test free, trochospiral, periphery rounded, peripheral outline lobulate to stellate, umbilicus filled with broad umbilical plug; chambers

of nearly equal breadth and height, commonly 6 in the final whorl, more rarely 5 to $5\frac{1}{2}$, early whorls nodose on the spiral side; sutures radial, slightly depressed in the final whorl, those of earlier whorls obscured on the spiral side by the nodose ornamentation; wall calcareous, finely perforate, smooth except for the umbonal nodes, and a single solid imperforate spine at the peripheral margin of each chamber; the spines may, however, be lacking in some of the later chambers or in rare specimens may be absent from all chambers; aperture interiomarginal, extraumbilical-umbilical, later filled with a secondary umbilical plate which leaves open only a small areal opening at the end nearest the test periphery, this areal opening surrounded by a lip, formed partially by the secondary plate and partially by the upper lip of the original opening.

Hypotypes range from 0.18 to 0.38 mm. in diameter.

Remarks.—Originally described as *Rotalia*, this species has little in common with that genus, completely lacking the internal canal system of true *Rotalia*. The very distinctive areal aperture, visible even on the holotype, has never been accurately described. Early descriptions mentioned only the number of chambers and size of peripheral spines, and did not discuss the aperture (Cushman, 1922, 1923; Cushman and Todd, 1946). Todd (1952, p. 40) described the aperture as "a rather large arched opening under the ventral edge of the last formed chamber." Specimens do occur that show the open arched marginal aperture (one of the two specimens figured by Cushman and Todd [1946] shows this, although they figured only the spiral side). The other specimen figured by Cushman and Todd (1946), the holotype selected by Cushman (1922), and many other specimens in the Cushman collection show the typical areal aperture of *Pararotalia*. In other specimens, however, extraneous matter obscures the aperture and umbilical region because of inadequate preparation of material.

Pararotalia parva is very similar to *P. spinigera* (Le Calvez) in appearance, but has less angular and more globular chambers, and a more gently rounded umbilical shoulder and relatively larger umbilical plug, which leaves open very little of the umbilical depression. *Pararotalia parva* differs from *P. ishamae* in possessing peripheral spines and in being about twice as large.

Types and occurrence.—Holotype (Cushman Coll. 59665) from the type locality of the Mint Spring marl member of the Marianna limestone, shell and sand bed at foot of high waterfall, Mint Spring Bayou, Vicksburg, Miss. Collected by C. W. Cooke and E. N. Lowe.

Paratype (Cushman Coll. 59664) from same horizon, foot of high waterfall in Glass Bayou, near Vicksburg, Miss.

Figured hypotypes (U.S.N.M. P5696a, b) from the Byram formation, west bank of Pearl River, just north of suspension bridge east of Byram, Hinds County, Miss. Collected October 11, 1941, by A. R. Loeblich, Jr.

PARAROTALIA SPINIGERA (Le Calvez), emended

Plate 4, figures 1a-3

Globorotalia spinigera (Terquem) LE CALVEZ (not *Rosalina spinigera* Terquem, 1882), Mém. Expl. Carte Géol. Dét. France. Rév. For. Lutétiens. II Rotaliidae, p. 39, pl. 6, figs. 97-99, 1949.

Globorotalia spinigera LE CALVEZ, *ibid.*, IV Valvulinidae, Peneroplidae, Ophthalmitidae, Lagenidae, p. 48, 1952.

"*Rotalia*" *spinigera* Terquem, GULLENTOPS, Mém. Inst. Géol. Univ. de Louvain, vol. 20, p. 17, pl. 1, figs. 15a-c, 1956.

Test free, trochospiral, planoconvex, spiral side gently to strongly convex, umbilical side flattened and umbilicate with an umbilical plug, periphery angled, peripheral margin lobulate to stellate; chambers in about 2 whorls, 5 to 6 in the final whorl with a single short, blunt spine arising from the periphery of each chamber or the spines may be reduced or absent in the later 1 or 2 chambers; early chambers appear nodose on spiral side, later portion gently convex and of nearly equal breadth and height, chambers with a rather abrupt umbilical shoulder on the umbilical side which may become sufficiently pronounced as to suggest a node at the umbilical shoulder, umbilical portion of chambers covered by a secondary plate which reaches from the umbilicus over the umbilical portion of the aperture, flaring outward to form a lower lip to the thus constricted areal remnant of the aperture; sutures radial, distinct, and deeply depressed on the umbilical side, gently curved and somewhat depressed in the later whorl on the spiral side, those of earlier whorls being obscured by the nodose surface of the early whorl; wall calcareous, relatively coarsely perforate, the umbonal knobs, peripheral spines, umbilical plug, and the nodes at the umbilical shoulder appearing solid and imperforate, secondary umbilical plates relatively thin and delicate and appear less coarsely perforate; aperture on the umbilical side, interior marginal and extraumbilical-umbilical with a short spatulate lip covering the forward one-third of its upper margin, the secondary umbilical plate later covering the umbilical portion of the aperture to the lower margin of the spatulate upper lip, leaving visible only a narrow comma-shaped areal opening and flaring to form a protruding lower lip to the aperture, which is roughly parallel to the lower margin of the chamber.

Hypotypes range from 0.30 to 0.55 mm. in diameter.

Remarks.—This species was described by Le Calvez (1949, p. 39)

as *Globorotalia spinigera* (Terquem). She stated that the original type of Terquem had disappeared, but on the basis of the original figures, she identified as Terquem's species this form which was stated to be frequent at Grignon and Septeuil. In the addenda to this publication Le Calvez (1952, p. 48) later stated that types of additional species had been found, including a slide of *Rosalina spinigera* Terquem. The two individuals contained therein were not the same as the present species, but Le Calvez identified one as a badly preserved *Rotalia septifera* (Terquem) and the other as a good specimen of *Rotalia armata* d'Orbigny. She therefore placed *Rosalina spinigera* in the synonymy of *Rotalia armata* and the present species was considered as a distinct species, *Globorotalia spinigera* Le Calvez.

The specimen figured by Le Calvez and the description given represent forms in which the delicate secondary umbilical plate of this species has been broken away, giving the erroneous appearance of a simple interiomarginal aperture.

Gullentops (1956) recently suggested that *Rotalia spinigera* might belong to *Pararotalia* or to *Neorotalia* Bermudez, 1952, stating (p. 19) that among some hundreds of specimens of *R. spinigera* there were some with an areal aperture. He believed that only the aperture of the final chamber was marginal, and that all earlier ones were wholly areal. The present writers have also observed and figured (pl. 4, fig. 1) a complete specimen with an areal aperture on the final chamber. Gullentops referred the species *spinigera* to the genus "*Rotalia*," in the sense of Cushman, although he stated (p. 19) that it had not the least resemblance to the group of *R. trochidiformis*. He also commented that the genus *Pararotalia* had not yet been completely defined. Gullentops (1956, p. 18) placed both *Rotalia dentata* var. *parva* Cushman and *R. canui* Cushman in the synonymy of *R. spinigera*, thus implying that they also have areal apertures, and could belong to *Pararotalia*. We agree to their congeneric status, but believe the younger species can be separated from *P. spinigera*, as discussed under their respective descriptions above.

Types and occurrence.—Hypotypes (U.S.N.M. P5688a-c) from the middle Eocene, Lutetian, Calcaire grossier (Zone IV of Abrard), in the sand pit at Grignon, now in the Parc d'Ecole Nationale d'Agriculture, Grignon, Dept. Seine-et-Oise, France. Collected by H. T. and A. R. Loeblich, Jr., with Henri Tintant, April 1954.

In the description given by Le Calvez (1949, p. 39), this species was recorded as frequent at Grignon and Septeuil, but no locality was given for the specimen figured, nor was a holotype mentioned in either

publication of Le Calvez. The specimens here figured are from the Grignon locality and may thus be topotypes.

PARAROTALIA SUBINERMIS Bhatia, emended

Plate 5, figures 1a-c

Pararotalia subinermis BHATIA, Journ. Paleontol., vol. 29, No. 4, p. 683, pl. 67, figs. 3a-c, 1955.

Test free, relatively large, periphery keeled and sharply angled, peripheral outline subangular; about 2 whorls visible on the flat spiral side, only the 7 chambers of the final whorl visible on the strongly elevated umbilical side, chambers about twice as high as broad, wedge-shaped in outline, much elevated around the umbilicus and with acutely angled umbilical shoulders, umbilicus with a large and strongly protruding plug; sutures flush, straight but oblique on the spiral side, deeply incised and radial on the umbilical side; wall calcareous, finely perforate, surface minutely granular in appearance; aperture appearing to be a narrow areal slit as the umbilical apertural plate is obscured at the surface by the strongly protruding chambers with acutely angled umbilical shoulders.

Diameter of figured topotype 0.50 mm.

Remarks.—This species differs from *Pararotalia inermis* (Terquem) in the more angled peripheral outline, the flatter spiral side with straight and oblique rather than curved sutures, and the more elevated umbilical side with large umbilical plug which nearly completely fills the umbilicus.

Types and occurrence.—Figured topotype (U.S.N.M. P5811) from the Oligocene (Lattorfian), Middle Headon, Brockenhurst beds, at White Cliff Bay, east coast of Isle of Wight, England. Collected by H. T. and A. R. Loeblich, Jr., with Dennis Curry and A. G. Davis, September 24, 1953.

PARAROTALIA species

Plate 5, figures 3a-c

A single specimen of a *Pararotalia* was obtained from the Miocene (Burdigalian) near Dax. It somewhat resembles *P. curryi*, new species, but is more strongly keeled, more compressed, and has relatively higher chambers. The umbilical side lacks a plug, but as only a single specimen is available, it is not certain whether or not this is an accidental feature. The elevated chambers around the umbilicus somewhat resemble *P. spinigera* (Le Calvez) but the spiral side is less convex and the peripheral spines less prominent.

Diameter of figured specimen 0.35 mm.

Types and occurrence.—Figured specimen (U.S.N.M. P5812) from the Miocene, Burdigalian, at Mont de Marson, near St. Avit, region of Dax, Dept. Landes, France.

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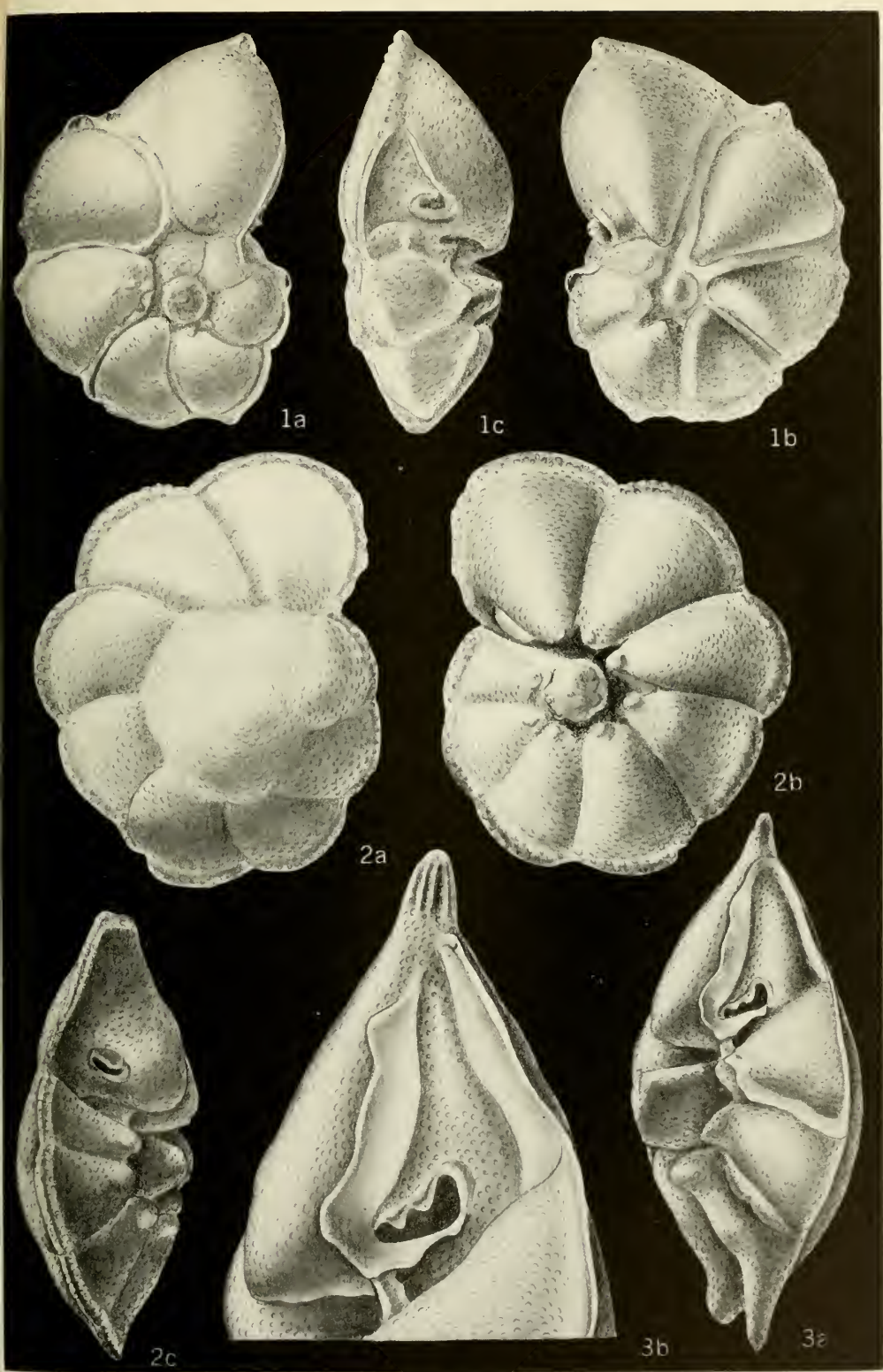
of hypotype (U.S.N.M. P5696b), showing thickened sutures, lobulate and spinose periphery. 5b, Umbilical view of specimen with interiomarginal opening in final chamber, and prominent lip at forward margin of aperture. 5c, Edge view, showing biconvex, nearly symmetrical test, contrasting with the planoconvex test of *P. spinigera*. Both from the Byram formation (Oligocene) of Mississippi.

PLATE 5. *Pararotalia subinermis*, *P. armata*, *P. species*

All figures $\times 146$

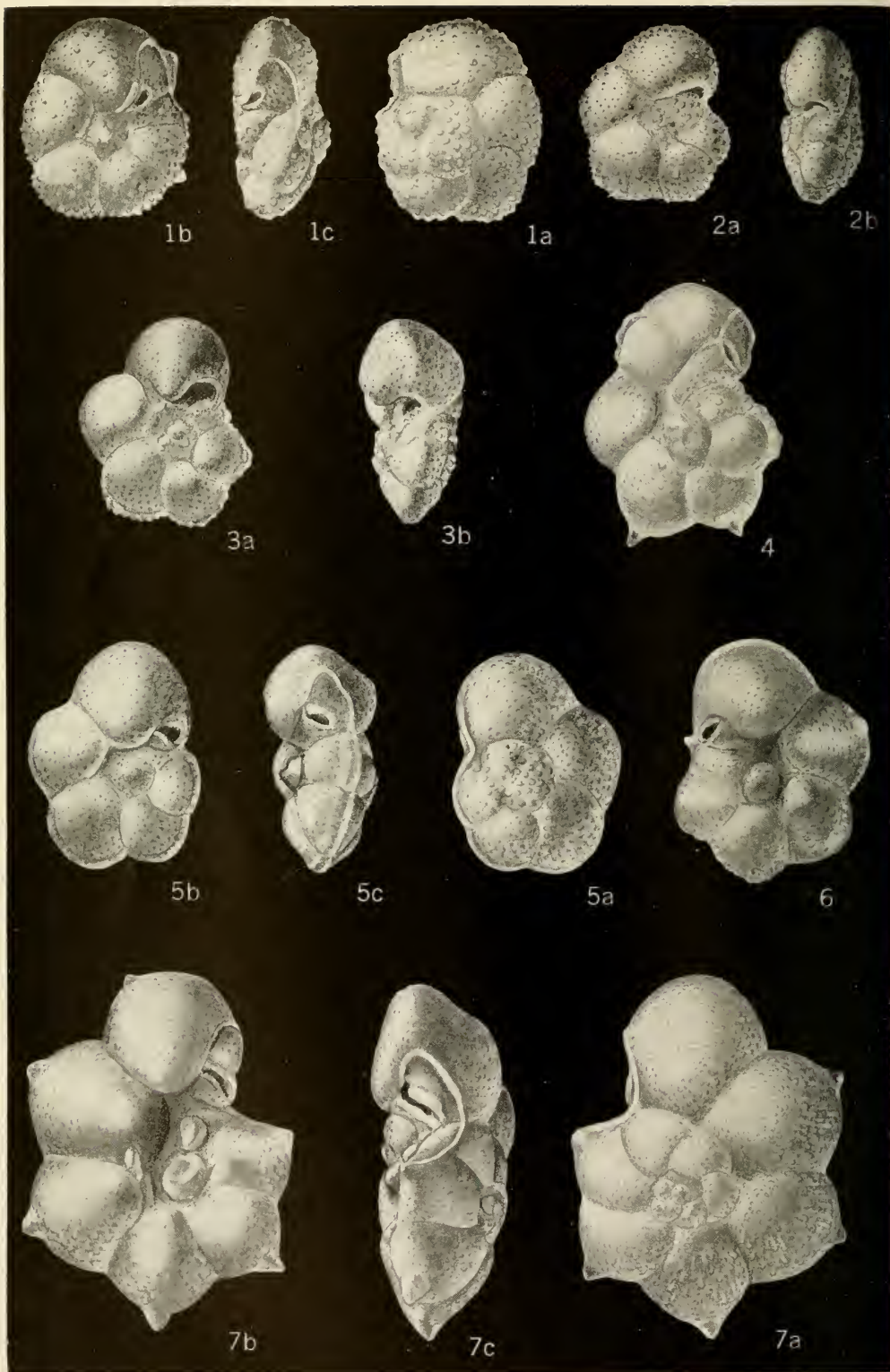
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PLATES



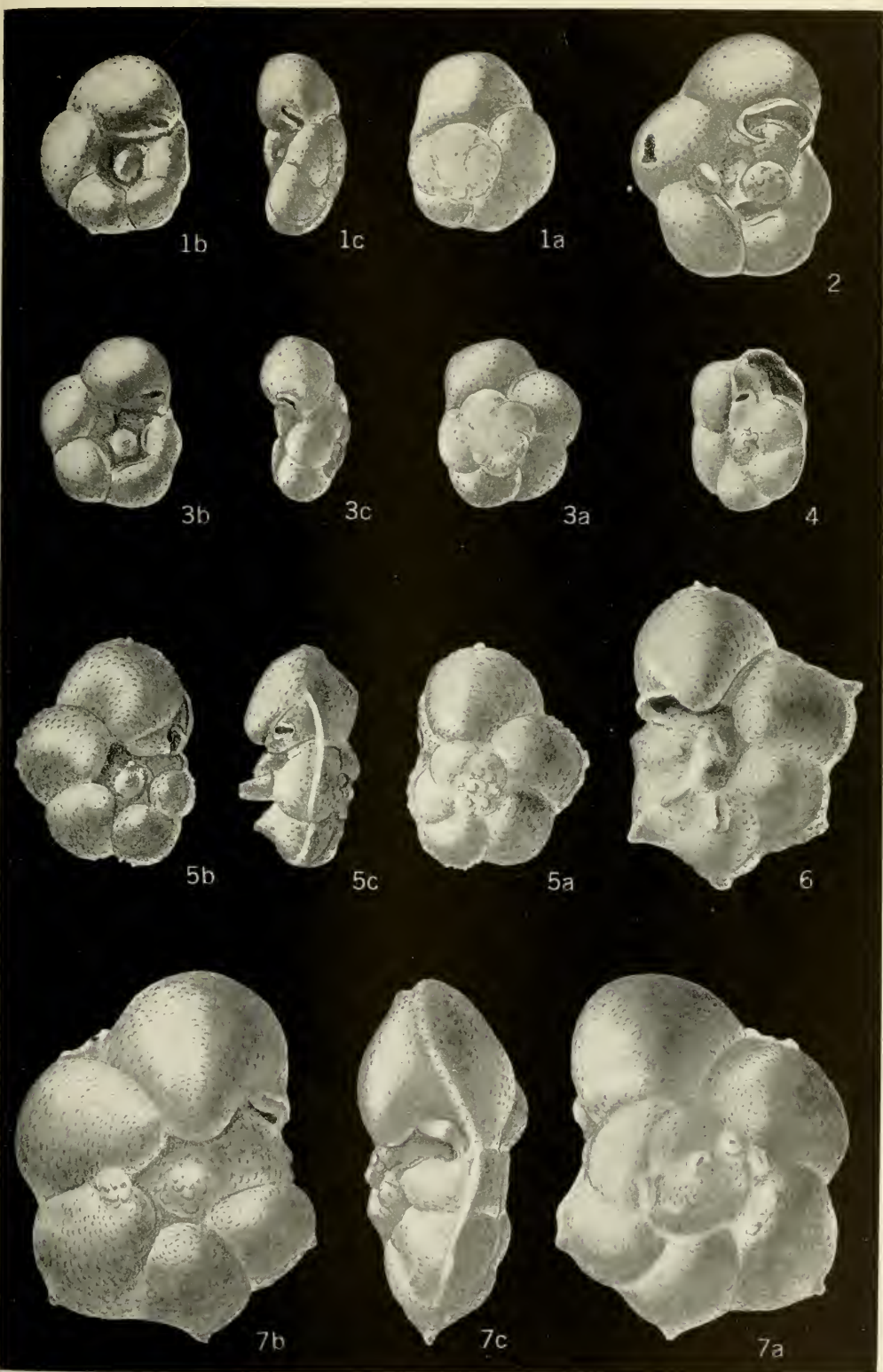
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(See explanation at end of text.)



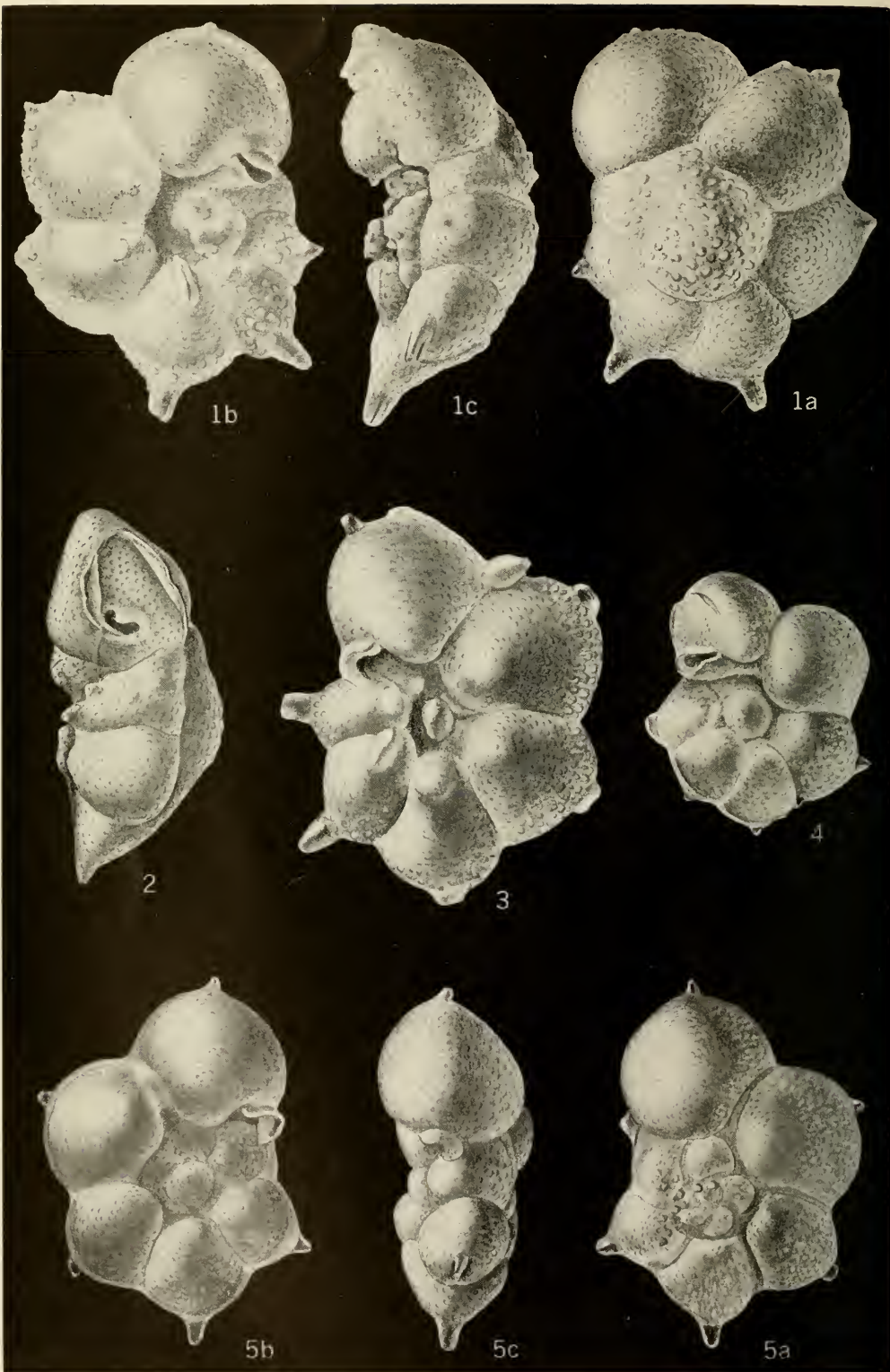
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(See explanation at end of text.)



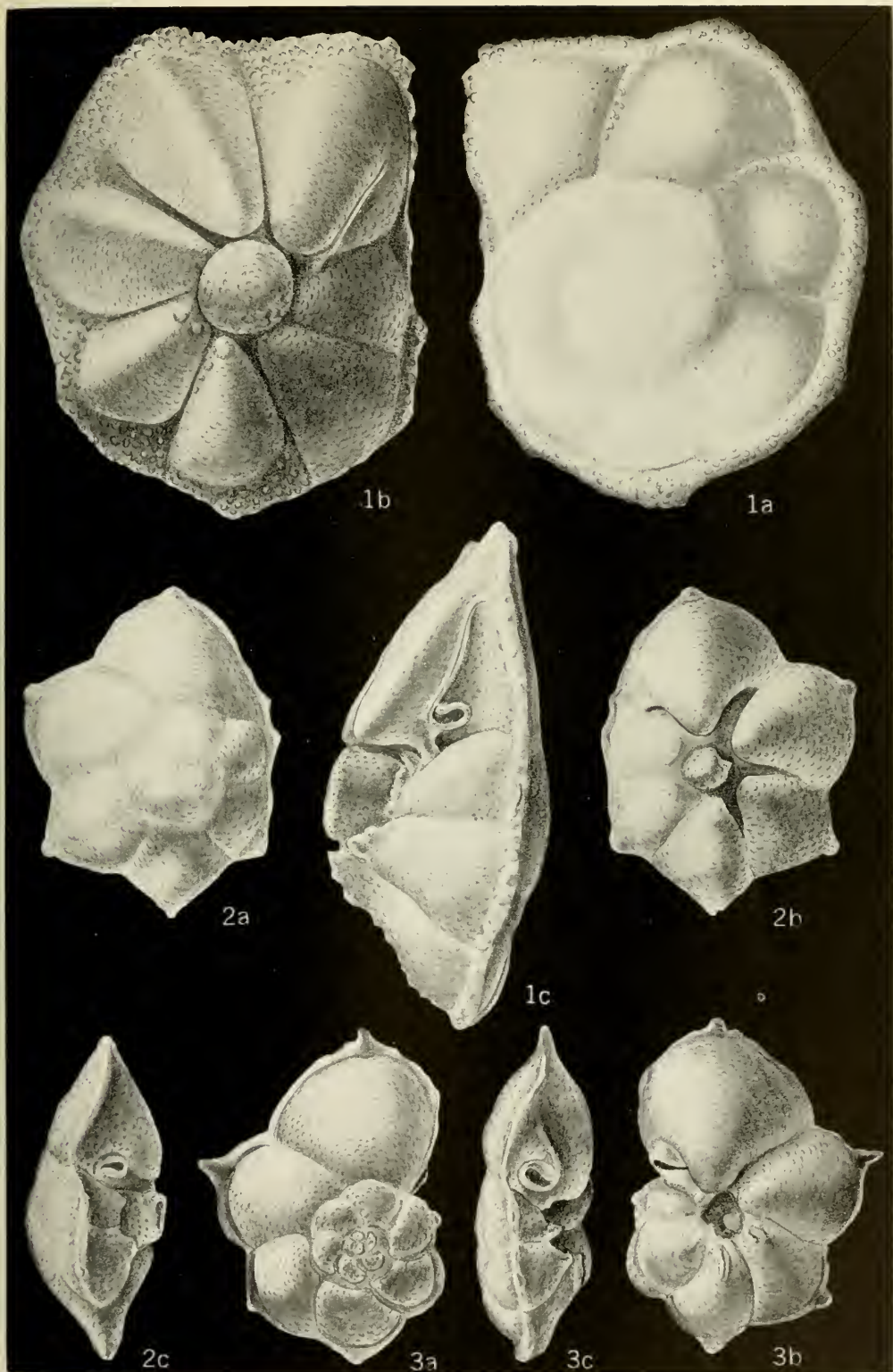
PARAROTALIA ISHAMAE, P. CURRYI

(See explanation at end of text.)



PARAROTALIA SPINIGERA, *P. PARVA*

(See explanation at end of text.)



PARAROTALIA SUBINERMIS, P. ARMATA, P. SPECIES

(See explanation at end of text.)