

REVISION OF THE FORAMINIFERAL FAMILY
PSEUDOPARRELLIDAE VOLOSHINOVA

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I. ABSTRACT

The Pseudoparrellidae Voloshinova, 1952, is recognized as a distinct family of the Discorbacea (Foraminiferida) on the basis of trochospiral tests, hyaline calcite walls with radial crystalline structure, monolamellid septa and a vertical aperture parallel to the periphery of the test. As redefined, the family contains six genera: *Pseudoparrella* Cushman and ten Dam, *Epistominella* Husezima and Marubasi, *Megastomella* Faulkner, de Klasz and Rérat, *Stetsonia* F. L. Parker, *Concavella* Lipps, gen. nov. (type species *Pulvinulinella gyroidinaformis* Cushman and Goudkoff), and *Ambitropus* Lipps, gen. nov. (type species *Epistominella evax* Bandy). Species of the Pseudoparrellidae occur in Oligocene? to Recent deposits throughout the world.

Nineteen species and two varieties of foraminifera have been recorded from California as Pseudoparrellidae. Thirteen of these are considered valid and represent five of the six genera of Pseudoparrellidae. A new genus, *Eilobedra* (type species *Episto-*

minella levicula Resig), is erected in the Eponididae to contain species superficially similar to pseudoparrellids but differing in the bilamellid wall structure.

II. INTRODUCTION

The foraminiferal family Pseudoparrellidae Voloshinova, 1952, has been recognized as a distinct category only by Soviet paleontologists. Other workers have assigned the genera included herein to superficially similar families such as the Cassidulinidae (Cushman, 1948), the Discorbidae (Glaessner, 1945; Loeblich and Tappan, 1964), or less frequently to other groups. However, the genera recognized in this report as Pseudoparrellidae have characters in common which distinguish them from all other groups of foraminifera.

Procedure: Primary types and, where possible, topotype and other material were studied to ascertain the range of variability for each species. Specific limits were established using several hundred specimens from various localities. The species were then

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grouped into genera. These genera were defined on the basis of external morphology and microstructure of the type species (or when material for the type species was inadequate, other similar species were utilized). The microstructure of the test wall was studied in thin section using transmitted and polarized light with magnifications up to 1000.

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III. REVISION OF THE PSEUDOPARRELLIDAE

Superfamily DISCORBACEA Ehrenberg, 1838
Family PSEUDOPARRELLIDAE Voloshinova, 1952

Family Pseudoparrellidae SUBBOTINA, 1959, in RAUZER-CHERNOUSOVA and FURSENKO, 1959, *Osnovy Paleontologii*, v. 1, p. 272 (*partim*). [*nom. correct.* and *nom. transl. ex. subfamily* Pseudoparrellinae Voloshinova, 1952.]

Subfamily Pseudoparrellinae VOLOSHINOVA in VOLOSHINOVA and DAIN, 1952, *Trudy VNIGRI*, nov. ser., vyp. 63, p. 81.

Subfamily Epistominellinae REISS, 1963, *Geol. Surv. Israel Bull.* 35, p. 54 (*partim*).

Type genus: *Pseudoparrella* Cushman and ten Dam, 1948, *Contr. Cushman Lab. Foram. Res.*, vol. 24, pt. 3, p. 49.

Description: Test free, trochospiral or initially trochospiral, biconvex to convex on one side only. Wall calcareous, hyaline, perforate, crystal structure radial, septa monolamellar. Aperture a vertical slit in

face of last chamber, parallel to periphery of test, basal, may tend to become areal.

Discussion: The family Pseudoparrellidae was defined originally on external morphology as a subfamily of the Cassidulinidae (see Voloshinova, 1952, p. 81). A close relation between *Pseudoparrella* and *Cassidulina* was first suggested by Cushman (1926) when he established *Palvulinella* [= *Pseudoparrella*]. In describing the genus Cushman reported an "apertural tooth" projecting from the side of the aperture, similar to that of *Cassidulina*. The type species, *Pseudoparrella subperuviana* (Cushman) and other Recent Pacific species have a straight or slightly bent apertural slit extending up the face of the last chamber, but no projecting tooth. Reiss (1963, p. 54) believed the "Cassidulinid toothplate" (in the sense of Hofker, 1951), described by Haynes (1956) and Hofker (1957) for species of so-called *Pseudoparrella*, also indicated a close relationship to the Cassidulinidae. However, Holker's (1957, p. 382) figures of *Pseudoparrella toulmani* (Brotzen) distinctly show a low interiomarginal aperture extending along the basal suture of the last chamber from near the umbilicus to near the periphery. Hofker's specimens are therefore not true *Pseudoparrella*. Haynes (1956, p. 88) described internal toothplates extending between succeeding apertures in Paleocene specimens, identified as *Epistominella vitrea* Parker [= *Pseudoparrella vitrea*]. He described and figured a loop-shaped aperture although *P. vitrea*, described from Recent sediments, has a typical *Pseudoparrella* slit-like aperture parallel to the periphery (Parker in Parker, Phleger and Peirson, 1953, p. 9). Haynes' specimens belong to another genus and species. Neither the type nor other species of *Pseudoparrella* have toothplates which extend from a former aperture to the next. The apertures are folded inward slightly around the entire margin. Although Hofker (1951) attaches great importance to these and similar structures ("toothplates" or their "homologous" parts), the function in the living animal is unknown and thus the biologic significance remains uncertain. Apertural modifications such as those in the Pseudoparrellidae probably serve to strengthen the apertural opening mechanically.

Reiss (1963) considered the Epistominellinae [= Pseudoparrellidae] closely related to the cassidulinids and placed his sub-

family in the Cassidulinidae. He placed little importance on the crystal structure of the test wall, but instead relied on the lamellar character of the septa as indicative of true relations. Hence, he grouped monolamellid, radial forms with the monolamellid, granular cassidulinids. However, as crystal structure of the test wall appears to be of primary significance in the determination of natural groups of foraminifera (Loeblich and Tappan, 1964, p. C153), the radial-walled *Pseudoparrellidae* are not closely related to the granular-walled Cassidulinidae. Thus there is neither gross nor microstructural evidence for relating the *Pseudoparrellidae* to the Cassidulinidae.

Loeblich and Tappan (1961, p. 316) placed the *Pseudoparrellinae* in synonymy with the granular-walled *Alabaminidae*, but later (1964, p. C572) recognized the true radial-walled construction of the nominal genus, and placed the subfamily in synonymy with the *Discorbinae*.

Reiss (1963, p. 54) proposed the subfamily *Epistominellinae* as a new name for *Pseudoparrellinae* Voloshinova, as the genus *Epistominella* was considered a senior synonym of *Pseudoparrella*. This name is invalid because after 1960 a family-group name based on a junior synonym "is not to be changed, but continues to be the valid name of the family-group taxon that contains both the senior and junior synonyms" (Internat. Code of Zoological Nomenclature, art. 40). Furthermore, both *Pseudoparrella* and *Epistominella* are shown to be distinct and valid genera.

The *Pseudoparrellidae* is recognized as a distinct family on the basis of its radially-built, hyaline calcite walls, monolamellid septa, and aperture parallel to the periphery of the test, extending up the face of the last chamber.

Distribution: *Pseudoparrellidae* are known from the Oligocene (questionably) to the Recent (Figure 1) although they have been reported from rocks as old as Early Cretaceous (Kaptarenko-Chernousova, 1959). All species in Ellis and Messina (1940, *et seq.*) and most species from Soviet literature included in genera of *Pseudoparrellidae* were evaluated. All species older than Oligocene were assignable to other families. Some very similar, but still questionable species were described from Oligocene rocks. Species definitely known to belong to this family

GENUS \ AGE		GENUS					
		<i>Pseudoparrella</i>	<i>Epistominella</i>	<i>Ambitropus</i>	<i>Megastomella</i>	<i>Concavella</i>	<i>Stetsonia</i>
RECENT							
PLEISTOCENE							
PLIOCENE							
MIOCENE	UPPER						
	MIDDLE						
	LOWER						
OLIGOCENE		?					

Figure 1. Stratigraphic distribution of the genera of *Pseudoparrellidae*.

are Miocene or younger; older records should be critically re-examined.

The *Pseudoparrellidae* generally are found in deeper water on fine-grained substrates throughout the world. Many species have restricted geographic distributions while others, such as *Pseudoparrella exigua* (Brady), are apparently distributed in deep water throughout the world.

Genera: The *Pseudoparrellidae*, as originally defined (Voloshinova, 1952), contained only the genus *Pseudoparrella*, but some of the species then included are correctly referred to *Epistominella* and *Osangularia* Brotzen. On the basis of external morphology, Subbotina (*in* Rauser-Chernousova and Fursenko, 1959, p. 272) also included therein the genera *Pseudoparrella*, *Alabama* Toulmin and *Cribroparrella* ten Dam. Reiss (1963, p. 54) placed *Epistominella* and

Coleites Plummer in the Epistominellinae [=Pseudoparrellidae]. However, *Osangu-laria*, *Alabama*, *Cribroparrella*, and *Cole-ites* have granular walls (see Loeblich and Tappan, 1964) and must be excluded from the Pseudoparrellidae.

As redefined, six genera, two of which are new, comprise the Pseudoparrellidae. These genera and their type species are herein redescribed and illustrated.

Genus PSEUDOPARRELLA Cushman and ten Dam, 1948

Pseudoparrella CUSHMAN and TEN DAM, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 3, p. 49.

Pulvinulinella CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 3, p. 62 (NOT *Pulvinulinella* Eimer and Fickert, 1899).

Pseudoparella VOLOSHINOVA, in VOLOSHINOVA and DAIN, 1952, Trudy VNIGRI, nov. ser., vyp. 63, p. 81.

Type species: *Pulvinulinella subperuviana* Cushman, 1926. Fixed by original designation and monotypy.

Description: Test free, small to medium in size, trochospiral, biconvex, outline nearly circular to slightly oval, slightly or not umbilicate, tightly coiled. Chambers rhomboid or nearly so, all visible from spiral side, only those of last formed whorl visible from umbilical side. Periphery sharp to rounded, unkeeled. Sutures radial or slightly curved on umbilical side, directed backward on spiral side. Wall calcareous, radially-built, monolamellid septa, finely perforate. Aperture a narrow basal slit extending up the face of the last chamber, parallel to periphery of test, on umbilical side, bordered by a slight lip which curves inward.

Discussion: This genus differs from other genera of Pseudoparrellidae in having a biconvex test, nearly circular outline, rhomboid-shaped chambers on the spiral side, and in lacking a peripheral keel. *Pseudoparella* is similar to *Megastomella*; their distinguishing characters are listed below:

Pseudoparella

Test: biconvex

Chambers: increasing slowly in height with growth; rhomboid in spiral view.

Outline: circular

Aperture: on umbilical side; narrow

Megastomella

Test: flattened; concave on umbilical side. Chambers: increasing rapidly in height with growth; elongate in spiral view.

Outline: oval

Aperture: peripheral to slightly on umbilical side; wide in mature individuals.

Pseudoparella has been regarded as a synonym of *Epistominella* Husezima and Maruhasi, 1944. The similarity between the two was recognized by Husezima and Maruhasi (1944, p. 397) when they established *Epistominella*. However, the lack of a peripheral keel, the biconvexity of the test, and the straight, rather than sharply bent aperture of *Epistominella*, are sufficient to distinguish *Pseudoparella* as a separate genus.

Pseudoparella is known from all parts of the world in Miocene to Recent deposits and may also occur in Oligocene rocks.

Genus AMBITROPUS Lipps, gen. nov.

Type species: *Epistominella evax* Bandy, 1953, Jour. Paleontology, vol. 27, no. 2, p. 179, pl. 23, figs. 1a-c.

Description: Test free, trochospiral, flattened with the spiral side about equally as convex as the umbilical side, periphery keeled, keel bifurcating around aperture. Chambers generally crescent-shaped, increasing rapidly in size in later stages giving test an oval outline. Wall calcareous, smooth, perforate, crystalline structure radial, septa monolamellid. Aperture basal, a long, wide opening in periphery of last chamber.

Discussion: *Ambitropus* differs from other Pseudoparrellidae in its peripheral aperture and keel. *Epistominella* is most similar but its aperture is always on the umbilical side of the test and is slightly bent, and its test is more nearly circular in outline. Other genera with peripheral apertures, *Megastomella* and *Stetsonia*, are never carinate.

Species assigned to this genus range from early Miocene to Recent in age and have been found only in the Eastern Pacific Ocean or adjacent fossil deposits. *Ambitropus evax* (Bandy) was described from Recent sediments off San Francisco and *A. thalmani*

TABLE 1

Key to the Genera of Pseudoparrellidae

1. a. Peripheral keel present	2
b. Peripheral keel absent	4
2. a. Aperture on umbilical side (1a)	3
b. Aperture peripheral (1a)	<i>Ambitropus</i>
3. a. Spiral side strongly concave (2a)	<i>Concavella</i>
b. Umbilical side strongly convex (2a)	<i>Epistominella</i>
4. a. Generally oval in outline, aperture peripheral (1b)	5
b. Generally circular in outline, aperture on umbilical side (1b)	<i>Pseudoparella</i>
5. a. Test distinctly trochospiral (4a)	<i>Megastomella</i>
b. Test nearly involute (4a)	<i>Stetsonia</i>

(Strainforth and Stevenson) was described from the Lower Miocene of Ecuador.

The generic name is from the Latin, *ambio*, *-itus*, meaning "around", and *tropis*, *-eos*, *-idos*, meaning "keel", referring to the peripheral keel around the entire test margin. Gender: Masculine.

Genus *CONCAVELLA* Lipps, gen. nov.

Type species: *Pulvinulinella gyroidinaformis* Cushman and Goudkoff, 1938, Contr. Cushman Lab. Foram. Res., vol. 14, pt. 1, p. 2, pl. 1, figs. 1a-2c.

Description: Test free, trochospiral, concavo-convex, spiral side concave in adult, umbilical side generally strongly convex, outline oval to circular, periphery broadly rounded, keeled at juncture with spiral side. Chambers inflated on umbilical side. Wall calcareous, hyaline, crystalline structure radial, septa monolamellid. Aperture basal or areal in larger specimens, a narrow slit in face of last chamber on umbilical side of test.

Discussion: This genus is distinguished by its concave spiral side, large broadly rounded chambers, a keel at the juncture of the spiral side and periphery, and a tendency for the aperture to become areal in large specimens. The early stages are similar to small specimens of *Epistominella*, but in later stages the typical characters of *Concavella* are developed.

This genus is monotypic. *Concavella gyroidinaformis* (Cushman and Goudkoff) is known from the Luisian and Mohnian Stages of California.

The generic name is from the Latin *con-cavus*, meaning hollowed or arched inward; *-ella*, a diminutive. Gender: Feminine.

Genus *EPISTOMINELLA* Husezima and Maruhasi, 1944

Epistominella HUSEZIMA and MARUHASI, 1944, Jour. Sigenkagaku Kenkyusyo, vol. 1, no. 3, p. 397.

Type species: *Epistominella pulchella* Husezima and Maruhasi, 1944. Fixed by original designation and monotypy.

Description: Test free, small to medium in size, trochospiral, planoconvex, or with spiral side slightly convex, umbilical side strongly convex, periphery keeled. Chambers trigonal on umbilical side, rhomboid to lunate on spiral side. Wall calcareous, smooth, perforate, crystalline structure radial, septa monolamellid. Aperture basal, a narrow slit in face of last chamber, on umbilical side of test.

Discussion: This genus is differentiated by its peripheral keel, convex umbilical side, and nearly flat spiral side. The genus is similar to *Concavella* but does not have a keel on the spiral side of the periphery, large, broadly rounded chambers, nor a concave spiral side.

Species of *Epistominella* are abundant in the North Pacific Ocean basin and adjacent fossil deposits. Some fossil species also have been reported from the Mediterranean area. The genus is also reported from Recent deposits of the Arctic Ocean. *Epistominella* ranges from the early Miocene to Recent.

Genus *MEGASTOMELLA* Faulkner, de Klasz, and Rérat, 1963

Megastomella FAULKNER, DE KLASZ, and RÉRAT, 1963, Revue Micropaléontologie, vol. 6, no. 1, p. 19.

Type species: *Megastomella africana* Faulkner, de Klasz, and Rérat, 1963. Fixed by original designation.

Description: Test free, small to medium in size, trochospiral, flattened to slightly biconvex, outline oval, periphery broadly to sharply rounded. Chambers long, narrow, crescent-shaped, generally more than twice as high as wide. Sutures radial, depressed. Wall calcareous, smooth, perforate, crystalline structure radial, septa monolamellid. Aperture basal, a long wide slit in face of final chamber, generally peripheral or slightly on umbilical side of test.

Discussion: *Megastomella* differs from other genera in its wide, peripheral aperture, elongate chambers typically three times as high as wide, and non-carinate periphery. *Megastomella* resembles *Pseudoparrella* and their differing characters are listed in the discussion of *Pseudoparrella*. *Megastomella* differs from *Stetsonia* in being trochospiral throughout ontogeny.

The type species, *Megastomella africana*, was described from pyrite casts found in Africa (Faulkner, de Klasz, and Rérat, 1963). A single topotype, also a pyrite cast, given to A. R. Loeblich by de Klasz, is figured (Plate III, figures 3a-c). Because of the preservation, the characters of the test wall could not be determined for the type species. In the morphologically similar California species, *M. capitaneus* (Cushman and Klempell), the crystalline structure of the wall is radial and the septa are monolamellid.

The genus is known from the lower Miocene in Africa and the upper Miocene in

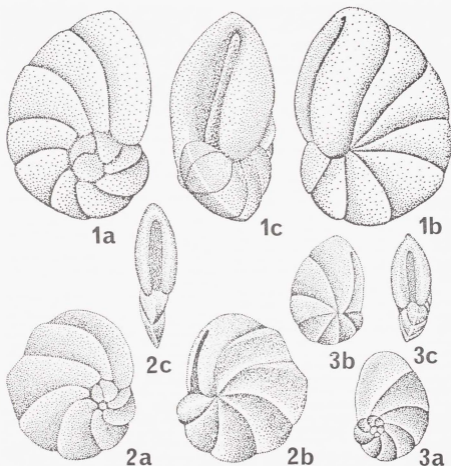


Figure 2. Variation in the type species of *Megastomella*: *M. africana*. 1. *Megastomella africana africana* Faulkner, de Klasz and Rérat, Holotype, Miocene, Gabon. 2 and 3. *M. africana compressa* Faulkner, de Klasz and Rérat, Miocene, Nigeria, Paratype (2) and Holotype (3). All figures X40, after Faulkner, de Klasz and Rérat, 1963.

California. It is generally found in fine-grained sediments.

Genus *STETSONIA* F. L. Parker, 1954

Stetsonia F. L. Parker, 1954, Mus. Comp. Zool., Harvard, Bull., vol. 111, no. 10, p. 534.

Type species: *Stetsonia minuta* F. L. Parker, 1954, Mus. Comp. Zool., Harvard, Bull., vol. 111, no. 10, p. 534, pl. 10, figs. 27-29. Fixed by original designation and monotypy.

Description: Test free, small, initially trochospiral, involute in later stages, biconvex, outline circular to oval, periphery broadly rounded. Chambers increasing in height with growth, crescent-shaped. Wall

calcareous, smooth, finely perforate, crystalline structure radial, septa monolamellid. Aperture basal, a peripheral slit parallel to test margin or slightly to one side of periphery, in face of last chamber.

Discussion: This genus can be differentiated from other Pseudoparrellidae by its nearly planispiral test in the adult, and by the peripheral aperture.

Two species of *Stetsonia* have been described to date, the type species, *S. minuta*, from the Gulf of Mexico, and *S. borvatbi* Green from the Arctic Ocean (Green, 1960).

This small genus is more abundant in

deeper water but also occurs in shallow water.

IV. CALIFORNIA SPECIES

Species of *Pseudoparrellidae* are common constituents of fossil and living foraminiferal faunas in the California region. Because the same or similar species are living today, many are useful paleoenvironmental indicators. Some extinct forms may be useful stratigraphic markers. Nineteen species and two varieties reported from California have been assigned to genera of the *Pseudoparrellidae*. Four of these species are not *pseudoparrellids* and four are synonymous with other species. The remaining thirteen species are considered valid and represent five of the six genera of *Pseudoparrellidae*. The species previously reported from California are summarized in Table 2, together with their specific and generic reassignment, and the valid species of *Pseudoparrellidae* from California are described below in section V.

Species erroneously reported as Pseudoparrellidae in California: The species from California reported incorrectly as *Pseudoparrellidae* are discussed below and excluded from the family.

Pulvinulinella culter: This species was recorded from the Eocene in Fresno County

(Martin, 1943) and questionably from the lower Zemorrian in the Santa Cruz Mountains (Kleinpell, 1938, p. 327). Kleinpell's figure (1938, pl. 5, fig. 15) of the apertural view shows a small, wide, areal aperture unlike any *Pseudoparrellidae* but more closely resembling certain *Ceratobuliminidae* and *Anomalinidae*. The specimen is broken and positive identification is difficult. Martin's specimens were assigned to *Parrella* [= *Osangularia*] by Mallory (1959, p. 239).

Pulvinulinella cf. *P. danvillensis:* This designation was given a specimen figured from the Eocene Kreyenhagen Shale by Mallory (1959, p. 240). Mallory states that his specimen has a more rounded periphery than do the type specimens of the species. In addition the apertural position is quite distinct and unlike the holotype, which is an *Alabamina* (see Howe and Wallace, 1932, pl. 13, fig. 7). Unfortunately the last chambers of Mallory's specimen are broken away and generic identification is not possible. The aperture appears to extend vertically up the chamber face and has a projection similar to species of *Eponidella* Cushman and Hedberg.

Epistominella levicula: The generic position of this Recent Californian species has been uncertain in the past. It has been placed

TABLE 2

Summary and revised assignment of species reported from California as *Pseudoparrellidae*. Arranged alphabetically by reported specific designation. Species which are not *Pseudoparrellidae* are marked with an asterisk.

Reported generic assignment	Reported specific assignment from California	Revised generic and specific assignment
<i>Pulvinulinella</i>	<i>bradyana</i>	<i>Pseudoparrella subperuviana</i>
<i>Pulvinulinella</i>	<i>capitanensis</i>	<i>Megastomella capitanensis</i>
<i>Pulvinulinella</i>	<i>culter</i>	<i>Osangularia culter</i> *
<i>Pseudoparrella</i>	cf. <i>P. danvillensis</i>	genus and species undetermined*
<i>Epistominella</i>	<i>discorbisoides</i>	<i>Pseudoparrella?</i> <i>discorbisoides</i>
<i>Epistominella</i>	<i>evax</i>	<i>Ambitropus evax</i>
<i>Pulvinulinella</i>	<i>exigua</i>	<i>Pseudoparrella exigua</i>
<i>Pulvinulinella</i>	<i>gyroidinaformis</i>	<i>Concavella gyroidinaformis</i>
<i>Epistominella</i>	<i>levicula</i>	<i>Eilohedra levicula</i> *
<i>Epistominella</i>	<i>nova</i>	<i>Pseudoparrella garrisoni</i>
<i>Pulvinulinella</i>	<i>pacifica</i>	<i>Epistominella pacifica</i>
<i>Pulvinulinella</i>	<i>parva</i>	<i>Epistominella pacifica</i>
<i>Pulvinulinella</i>	cf. <i>P. pontoni</i>	<i>Pseudoparrella californica</i>
<i>Epistominella</i>	<i>pontoni</i> var. <i>californica</i>	<i>Pseudoparrella californica</i>
<i>Pulvinulinella</i>	<i>purisima</i>	<i>Megastomella purisima</i>
<i>Pulvinulinella</i>	<i>relizensis</i>	<i>Pseudoparrella relizensis</i>
<i>Epistominella</i>	<i>sandiegoensis</i>	<i>Pseudoparrella exigua</i>
<i>Pulvinulinella</i>	<i>smithi</i>	<i>Epistominella smithi</i>
<i>Pulvinulinella</i>	<i>subperuviana</i>	<i>Pseudoparrella subperuviana</i>
<i>Pulvinulinella</i>	<i>subperuviana</i> var. <i>minuta</i>	<i>Pseudoparrella minuta</i>
<i>Pulvinulinella</i>	<i>tenuicarinata</i>	<i>Osangularia tenuicarinata</i> *

in *Epistominella* or *Eponides*, and Uchio suggested (1960, p. 67) that it was an *Alabama*. However, the species has a radial crystalline wall structure and bilamellid septa, thus excluding it from *Epistominella* or *Alabama* and allying it with the Eponididae Hofker. The apertural characters and gross test morphology differ from previously described genera of Eponididae, hence a new genus is erected.

Family EPONIDIDAE Hofker, 1951

Genus EILOHEDRA Lipps, gen. nov.

Type species: *Epistominella levicula* Resig, 1958, *Micropaleontology*, vol. 4, no. 3, p. 304, text-fig. 16a-c.

Description: Test free, small, trochospiral with numerous whorls, tightly coiled, spiral side convex, umbilical side flattened and depressed in umbilical area, outline circular, periphery broadly rounded. Chambers wide, rhomboid in spiral view, trigonal in umbilical view. Sutures radial, recurved on umbilical side. Wall calcareous, hyaline, perforate, crystalline structure radial, septa bilamellid. Aperture extending along basal suture of last chamber between umbilicus and periphery, extending vertically up face of last chamber near periphery, bordered by lip, depressed in apertural face of chamber.



Figure 3. *Epilohedra levicula* (Resig) showing distinctive aperture depressed in face of last chamber.

Discussion: This new genus is distinguished from all other genera with radially constructed test walls and bilamellid septa by the small, tightly coiled test with broadly rounded periphery and distinctive aperture (Figure 3). It is placed in the Eponididae because of the trochospiral test and apertural position.

Epilohedra is very similar to *Syratkina* Pokorny, whose wall structure is unknown, but

differs primarily in lacking a tuberculated surface.

The generic name is from the Greek *eilo* meaning "roll up, twist"; *+bedra* meaning "abode, dwelling", in reference to the tightly coiled test. Gender: Feminine.

Pulvinulinella tennicarinata: Cushman and Siegfus (1935, p. 95) originally described this species from the Eocene Kreyenhagen Shale in Fresno County, California. It was transferred to *Parrella* [= *Osangularia*] by Mallory (1959, p. 240).

V. DESCRIPTIONS OF TYPE AND CALIFORNIA SPECIES

The type species of the genera described in sections III and IV and the valid species recognized as Pseudoparrellidae in California are described in alphabetical order by genus and species. In order to record their distribution, the synonymies include all known references to occurrences of these species, except for some widely distributed species reported from many places throughout the world. Except where specimens were adequately illustrated or reexamination was possible, no attempt was made to determine the validity of the reports, and each author's identification is assumed to be accurate. The age of each California Miocene record is given in local stage names. Previous inter-regional correlation of these stages has recently been questioned (Lipps, 1964, p. 114). Therefore, the assignments given by Kleinpell (1938) are used tentatively in this report. These are as follows: Zemorrian = lower lower Miocene; Saucian = upper lower Miocene; Relizian = lower middle Miocene; Luisian = upper middle Miocene; Mohnian = lower upper Miocene; Delmonian = upper upper Miocene.

Family PSEUDOPARRELLIDAE Voloshinova

Genus AMBITROPUS Lipps

AMBITROPUS EVAX (Bandy)

Pl. I, figs. 11a-c

Epistominella evax BANDY, 1953, *Jour. Paleontology*, vol. 27, no. 2, p. 179, pl. 23, figs. 1a-c (Recent, off San Francisco, at 1800 ft.).

Epistominella thalmani (Stainforth and Stevenson). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487, pl. 5, figs. 9-11 (Mohnian, San Juan Capistrano area). (NOT *Palmeriella thalmani* Stainforth and Stevenson, 1948.)

Epistominella cf. *E. evax* Bandy. SMITH, P. B., in Winterer and Durham, 1962, U. S. Geol. Survey, Prof. Paper 334-II,

p. 288 [table] (u. Miocene, S. E. Ventura basin).

Description: Test free, medium in size, trochospiral, flattened, of about $2\frac{1}{2}$ whorls, outline oval, lobate, periphery carinate, keel of varying width, sharply rounded. Spiral side flat, all whorls, chambers, and proloculus visible, initial whorl raised, second whorl depressed, final part elevated above preceding whorls. Umbilical side low, slightly convex in varying degrees, last whorl and 6 to 7 chambers visible. Chambers about 17 in number, inflated, crescent-shaped on both sides, increasing rapidly in size in last whorl, curved back over preceding chambers, overlapping preceding whorls completely on umbilical side and slightly on spiral side, proloculus globular. Sutures distinct, limbate, strongly curved backward on both sides of test. Wall calcareous, finely perforate, surface smooth, crystal structure radial, septa monolamellid. Aperture basal, equatorial, a wide vertical slit in final chamber face, top pointed, both sides bordered by a rim formed by the peripheral keel bifurcating around aperture.

Discussion: This species is the type for *Ambitropus*, to which one other species, *Palmerinella thalmanni* Stainforth and Stevenson, 1948 = *A. thalmanni* (Stainforth and Stevenson), can be assigned. Smith (1960, p. 487) stated that specimens from the San Juan Capistrano area in Southern California were identical to the types of *A. thalmanni* from the lower Miocene of Ecuador. Comparisons of Smith's specimen (USNM 624843) with a large number of *A. evax* from rocks of the same age at Newport Bay, California, and with the type specimens of *A. evax* and *A. thalmanni*, indicate that the California specimens are distinct from those of Ecuador. Variants identical to Smith's specimens and the type specimens of *A. evax* are present in the Newport Bay assemblage, yet none of the specimens closely resembled the types of *A. thalmanni*. *Ambitropus evax* is differentiated from *A. thalmanni* by its more curved sutures, more rapidly increasing chamber size resulting in an oval rather than circular test outline, and by the larger size.

Type locality and occurrence: This species was originally described from the south side of Cordell Bank off San Francisco. The only fossil record is from the upper Miocene of California. The species apparently lives in depths greater than 567 m, at low temperature (5.2°C to 5.5°C) and oxygen content ($0.4^{\theta}/\infty$), and at normal salinity (Bandy, 1953).

Genus CONCAVELLA Lipps

CONCAVELLA GYROIDINAFORMIS (Cushman and Goudkoff)

Pl. II, figs. 1a-3b

Pulvinulinella gyroidinaformis CUSHMAN and GOUDKOFF, 1938, Cushman Lab. For. Res., Contr., vol. 14, pt. 1, p. 2 (l. Mohnian, east and west sides San Joaquin Valley; Mohn Spring, Santa Monica Mts.; San Jose Hills west of Pomona; Palos Verdes Hills). KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 328, pl. 18, figs. 17, 18, 19 (u. Luisian, u. and l. Mohnian, eastern Santa Monica Mts., Round Mountain area, eastern Kern Co.; San Pablo Creek, Contra Costa Co.). FERGUSON, 1943, Calif. Div. Mines, Bull. 118, p. 246, fig. 98, 5a-c (Tertiary, east side San Joaquin Valley). GOUDKOFF, 1943, Calif. Div. Mines, Bull. 118, p. 251, figs. 99a-b [charts] (l. Mohnian, west side San Joaquin Valley). KLEINPELL in Woodring, Bramlette and Kew, 1946, U. S. Geol. Survey, Prof. Paper 207, p. 33 [list] (Palos Verdes Hills). SAN JOAQUIN GEOL. SOC., 1959, Guidebook Chico Martinez Creek area field-trip, p. 4, 13 (l. Mohnian, Chico Martinez Creek, San Joaquin Valley). HUGHES, 1963, Amer. Assoc. Petrol. Geol. and Soc. Econ. Paleont. and Mineral., Pacific Sect., Guidebook Geology Salinas Valley and San Andreas Fault, 1963, p. 94, 95 (l. Mohnian, Salinas Valley).

Pulvinulinella gyroidinaformis Kleinpell MS. CANFIELD, 1939, Amer. Assoc. Petrol. Geol., Bull., vol. 23, no. 1, p. 64, 65 (m. Miocene, Santa Maria Valley).

Pseudoparrella gyroidinaformis (Cushman and Kleinpell). CROUCH, 1952, Amer. Assoc. Petrol. Geol., Bull., vol. 36, no. 5, p. 816 (Miocene, West Cortez Basin, off California).

Epistominella gyroidinaformis (Cushman and Goudkoff). NATLAND and ROTHWELL, 1954, Calif. Div. Mines, Bull. 170, chap. 3, p. 34, fig. 2, no. 13 (l. Mohnian, Topanga Canyon). NATLAND, 1957, Geol. Soc. America, Mem. 67, vol. 2, pl. 6 (following p. 572) [list] (Mohnian, southern San Joaquin Valley). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487 (u. Luisian, l. Mohnian, Santa Ana Mts.; San Juan Capistrano area). COOPER, 1961, Cushman Found. For. Res., Contr., vol. 12, pt. 2, table 2 (reworked into Recent beach sands, Half Moon Bay). BANDY and KOLPACK, 1963, Micropaleontology, vol. 9, no. 2, p. 163, tables (l. Mohnian, Santa Ynez Mts.). MARTIN, 1963, Amer. Assoc. Petrol. Geol., Bull., vol. 47, no. 3, p. 443 (late Miocene, west of Bakersfield).

Epistominella ("Pulvinulinella") gyroidinaformis (Cushman and Goudkoff). NATLAND and ROTHWELL, 1954, Calif. Div. Mines, Bull. 170, chap. 3, p. 35.

Epistominella "*Pulvinulinella*" *gyroidinaformis* (Cushman and Goudkoff). MARTIN, 1963, Amer. Assoc. Petrol. Geol., Bull., vol. 47, no. 3, p. 441, 444. MARTIN, 1963, Amer. Assoc. Petrol. Geol., Bull., vol. 47, no. 9, p. 1773 (late Miocene, west of Bakersfield).

Description: Test free, small to medium in size, trochospiral, concave-convex, about 2 whorls, outline generally round or may tend to be oval, in some specimens last few chambers tend to uncoil, or coil onto umbilical side of test, periphery broadly rounded, spiral edge of periphery keeled, keel of variable width, round, raised. Spiral side concave in varying degrees, all whorls, chambers and proloculus visible, chambers on spiral side crescent-shaped, flattened, strongly overlapping previous chambers. Umbilical side generally strongly convex, final and part of penultimate whorls visible, umbilicus open, chambers on umbilical side strongly inflated, trigonal to square, slightly overlapping previous chambers. Sutures distinct, radial and depressed on umbilical side, limbate and strongly curved back on spiral side. Wall hyaline, calcareous, finely perforate, crystalline structure radial, septa monolamellid. Aperture a narrow slit, depressed in face of last chamber, bordered by a very slight raised and in-turned rim, parallel to periphery of test on umbilical side, basal in position with lower $\frac{1}{4}$ to $\frac{1}{2}$ of slit slanted toward umbilical side, upper part slanted toward spiral side, more rarely aperture may tend to become areal.

Discussion: *Concavella gyroidinaformis* is differentiated from all other species of Pseudoparrellidae by its concave spiral side, by a tendency for the last chambers to uncoil, and by an areal aperture in some specimens. Assemblages with specimens that have uncoiling final chambers and an areal aperture (Pl. II, figs. 2a-c) occur somewhat higher in the lower Mohnian than assemblages consisting of only typically enrolled forms (Pl. II, figs. 1a-c, 3a-c). However, typical specimens occur in the same samples and intergrade with those having areal apertures. Therefore the two forms are considered conspecific.

Type locality and occurrence: This species was originally described from the Shale Hills (Sec. 10, T. 27 S., R. 18 W.) in Kings County, California. It is known in California from Contra Costa County (38°N. Lat.) south to Orange County (33.5°N.), occurring in very fine-grained sediments with other foraminifera indicative of water deeper than 1500 m. (see Brandy and Kolpack, 1963, text-fig. 35).

Concavella gyroidinaformis is considered

indicative of the lower part of the Mohnian Stage, although it has also been reported from the upper Luisian (Kleinpell, 1938; Smith, 1960) and the upper Mohnian (Kleinpell, 1938).

Genus EPISTOMINELLA Husezima and Marubasi

EPISTOMINELLA PACIFICA (Cushman)

Pl. II, figs. 5a-c, 7a-c

Pulvinulinella pacifica CUSHMAN, 1927, Calif. Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 1, no. 10, p. 165, pl. 5, figs. 14, 15 (Recent, off Oregon, central and southern California, Gulf of Panama). CUSHMAN, STEWART, and STEWART, 1930, San Diego Soc. Nat. Hist. Trans., vol. 6, no. 2, p. 73, pl. 6, figs. 5a-c (Miocene and Pliocene, Humbolt Co.). STEWART and STEWART, 1930, Amer. Assoc. Petrol. Geol., Bull., vol. 14, no. 11, p. 1448 (u. DeMontian, Puente Hills). ADAMS, 1932, Micropaleontology Bull., Stafford, vol. 3, no. 4, pl. 1, figs. 5a-c; pl. 3, figs. 2a-c (Pliocene, Orange Co.). NATLAND, 1933, Calif. Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 3, no. 10, p. 228 (Recent, off Los Angeles; Pliocene, Hall Canyon, Ventura Co.). STEWART and STEWART, 1933, San Diego Soc. Nat. Hist., Trans., vol. 7, no. 21, p. 267 (upper Pliocene, Seven Mile Beach, San Mateo Co.). WOODRING, BRAMLETTE and KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 141 (u. Mohnian, Palos Verdes Hills). KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 328 (l. Relisian—Pliocene, California). KLEINPELL in Woodring, Bramlette and Kew, 1946, U. S. Geol. Survey, Prof. Paper 207, p. 33 (Miocene, Palos Verdes Hills).

Pulvinulinella pacific NATLAND, 1933, Calif. Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., v. 3, no. 13, chart.

Pseudoparrella pacifica (Cushman). CUSHMAN, 1948, Foraminifera their classification and economic use, Harvard, p. 544, pl. 33, figs. 2a-b (refigured). CROUCH, 1952, Amer. Assoc. Petrol. Geol., Bull., vol. 32, no. 5, p. 836, pl. 6, fig. 1 (Recent, off Southern California, Mexico; Pliocene, Los Angeles basin). MARTIN, 1952, Cushman Found. Forum. Res., Contr., vol. 3, pt. 3-4, p. 116, table 3. SHCHEDRINA, 1953, Trudy Zool. Inst., Akad. Nauk SSSR, vol. 13, p. 16, 30 (Recent, SE part of Okhotsk Sea). CROUCH, 1954, Jour. Sed. Petrol., vol. 24, no. 3, p. 189, table (Miocene to Recent, Southern California). SUBBOTINA in Rauzer-Chernousova and Fursenko, 1959, Osnovy Paleontologii, Obshchaya Chast', Prosteyshie, Akad. Nauk SSSR, p. 272, text-figs. 497a-c (m. Miocene, Sakhalin). SAIDOVA, 1961, Trudy Inst. Okeano., Akad. Nauk SSSR, vol. 45, p. 65 (Recent, NE Pacific Ocean).

- SAIDOVA, 1961, *Ekologiya foraminifer i paleogeografiya dnevnoostochnykh morey SSSR, i severo-zapadnoy chasti Tikhogo Okeana*, Inst. Okeano., Akad. Nauk SSSR, p. 65, pl. 20, fig. 135 (Recent, Bering Sea, NW Pacific Ocean, Okhotsk Sea; pre-Recent, Sea of Japan).
- SAIDOVA, 1962, *Voprosy Mikropaleontologii*, vyp. 6, p. 37, 58, 62 (Recent, E. side of Kamchatka Peninsula).
- MALLORY, in Moore, 1963, U. S. Geol. Survey, Prof. Paper 419, p. 86, 87 (lower Miocene, Astoria, Oregon).
- SAIDOVA, 1964, Trudy Inst. Okeano., Akad. Nauk SSSR, vol. 48, p. 102 (Recent, NE Pacific Ocean).
- Epistominella pacifica* (Cushman). MARTIN, 1952, Cushman Found. Foram. Res., Contr., vol. 3, pt. 3-4, p. 136, pl. 24, figs. 8a-c (upper and lower Pliocene, Los Angeles basin).
- BANDY, 1953, Jour. Paleontology, vol. 27, no. 2, p. 177, pl. 23, figs. 2a-c (Recent, off San Francisco and Point Arguello).
- BANDY, 1953, Jour. Paleontology, vol. 27, no. 2, p. 201, 202 (upper Miocene, Wheeler Canyon; Pliocene, Ventura Co.).
- NATLAND and ROTHWELL, 1954, Calif. Div. Mines Bull. 170, chap. 3, p. 34, fig. 2, no. 7 (Pliocene and upper Miocene, Los Angeles and Ventura basins).
- BANDY, 1955, Cushman Found. Foram. Res., Contr., vol. 6, pt. 2, p. 77 (Pliocene, Purisima Fm., Santa Cruz).
- HARRINGTON, 1955, Cushman Found. Foram. Res., Contr., vol. 6, pt. 4, p. 125, 126 (Pliocene, Purisima Fm., Half Moon Bay).
- ZALESNY, 1959, Micropaleontology, vol. 5, no. 1, p. 124 (Recent, Santa Monica Bay).
- BANDY, 1960, Jour. Paleontology, vol. 34, no. 4, p. 678, text-figs. 6, 7 [charts] (Pliocene, Ventura basin).
- BANDY and ARNAL, 1960, Amer. Assoc. Petrol. Geol., Bull., vol. 44, no. 12, p. 1927 (Miocene).
- SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487, pl. 58, figs. 12-14 (Mohnian, Santa Ana Mts., San Juan Capistrano area).
- SMITH, in Winterer and Durham, 1962, U. S. Geol. Survey, Prof. Paper 334-II, p. 295 [table], p. 313 [list], pls. 48, 49 [tables] (upper Miocene to Pliocene, SE Ventura basin).
- VELLA, 1962, Tuatara, vol. 10, no. 1, p. 31 [chart].
- COCKBAIN, 1963, Cushman Found. Foram. Res., Contr., vol. 14, pt. 2, table 2 (Recent, Juan de Fuca Strait, Strait of Georgia, British Columbia).
- NATLAND, 1963, Jour. Paleontology, vol. 37, no. 4, p. 949, figs. 2, 3 [charts] (upper Pliocene, Hall Canyon, Ventura Co.).
- SMITH, P. B., 1963, U. S. Geol. Survey, Prof. Paper 475-C, art. 79, p. C75, C76 [tables] (Recent; Pleistocene, Gulf of Alaska).
- BANDY and RODOLFO, 1964, Deep-Sea Res., vol. 11, no. 5, table 4 (fossil?, Peru-Chile Trench).
- Pseudoarrella pacifica* (Cushman). VOLOSHINOVA in Voloshinova and Dain, 1952, Trudy VNIGRI, nov. ser., vyp. 63, p. 83, pl. 1, figs. 4a-c (middle to upper Miocene, Sakhalin; middle to upper Miocene, Pliocene, California; Recent, Pacific Ocean).
- SAIDOVA, 1960, Mezhdun. Geol. Kongr., 21 sess., 1960, Dokl. Sov. Geol., p. 62, 63 (Recent, North Pacific Ocean).
- SAIDOVA, 1960, Trudy Inst. Okeanol., Akad. Nauk SSSR, vol. 32, p. 128, 136, 137, 140, 141, 145 (Recent, Sea of Okhotsk, off SW Kamchatka Peninsula).
- SAIDOVA, 1961, Trudy Inst. Geol., Akad. Nauk Estonskoi SSR, vol. 8, p. 200 (Recent, North Pacific Ocean).
- Paleovulvinella (Epistominella) pacifica* (Cushman). NATLAND, 1952, Pacific Petrol. Geol., vol. 7, no. 2, p. 2 [chart] (Wheelerian = Pliocene).
- "*Paleovulvinella*" *pacifica* (Cushman). MALLORY in Moore, 1963, U. S. Geol. Survey, Prof. Paper 419, p. 86.
- Paleovulvinella parva* CUSHMAN and LAIMING, 1931, Jour. Paleontology, vol. 5, no. 2, p. 115-116, pl. 13, figs. 5a-c (lower Miocene, Los Sauces Creek, Ventura Co.).
- KLEINFELD, 1938, Miocene stratigraphy of California, Tulsa, p. 329 (lower Miocene, Chico Martinez Creek, Kern Co.; Astoria, Oregon, Rich's Passage, Washington).
- CUSHMAN, STEWART and STEWART, 1947 [1948], Oregon Dept. Geol. and Mineral Indust., Bull. 36, pt. 2, p. 48, pl. 6, figs. 5a-c (Miocene, Agate Beach, Oregon).
- PAU, 1948, Jour. Paleontology, vol. 22, no. 6, p. 780, pl. 119, figs. 12-14 (lower to middle Miocene, Grays Harbor, Washington).
- STEWART, 1956, The Ore-bin, vol. 18, no. 1, p. 4.
- Pseudoarrella zarva* (Cushman and Laiming). RAU, 1951, Jour. Paleontology, vol. 25, no. 4, p. 449, pl. 67, figs. 1, 2 (lower Miocene, Willapa Valley, Washington).
- STEWART, 1956, The Ore-bin, vol. 18, no. 1, p. 5, 6 (lower Miocene, Depoe Bay south to Newport, Oregon; Agate Beach, Oregon).
- STEWART, 1956, The Ore-bin, vol. 18, no. 7, p. 58. MALLORY in Moore, 1963, U. S. Geol. Survey, Prof. Paper 419, p. 87 (lower Miocene, Yaquina Head area, Oregon).
- Epistominella parva* (Cushman and Laiming). RAU, 1958, U. S. Geol. Survey, Oil and Gas Chart, O. C. 57, chart 2 (lower Miocene, Willapa Valley, Washington).
- KLEINFELD and WEAVER, 1963, Univ. Calif. Pubs. Geol. Sci., vol. 43, no. 1, fig. 4, chart (Zemorian and Saucian, Los Sauces Creek, Ventura Co.).
- RAU, 1964, U. S. Geol. Survey, Prof. Paper 374-G, p. G5. MALLORY in Moore, 1963, U. S. Geol. Survey, Prof. Paper 419, p. 86. SNAVELY, RAU and WAGNER, 1964, The Ore-bin, vol. 26, no. 8, p. 146 [list], (lower Miocene, Yaquina Bay area, Oregon).
- Epistominella pacifica parva* (Cushman and Laiming). BANDY and KOLPACK, 1963, Micropaleontology, vol. 9, no. 2, p. 163 (lower Miocene, Tecolote Tunnel, Santa Ynez Mts., Santa Barbara Co.).
- Description:* Test free, small to medium in size, trochospiral, $2\frac{1}{2}$ to $3\frac{1}{2}$ whorls,

outline circular to slightly ovate, margin even to slightly lobate, periphery carinate, keel narrow, rounded, raised, finely perforate. Spiral side flat to slightly convex, initial stages raised in differing degrees, last whorl flattened to slightly convex, all whorls, chambers and proloculus visible. Umbilical side very strongly convex, 5 to 8 chambers and last whorl visible, umbilicus open or closed, deep and bordered by a keeled edge when open. Chambers 23 to 26 in number, increasing gradually in size with growth, rhomboid on spiral side, 2 to 3 times as wide as high, narrower at base, early chambers square, curved back over preceding chamber, on umbilical side wedge-shaped, curved backward, narrow at base, broad at top, commonly slightly inflated, extension toward umbilicus commonly covering it, overlapping fore-edge of previous chambers, completely overlapping previous whorl. Sutures distinct, limbate, raised and tending to be tangential on spiral side, slightly depressed and curved backward on umbilical side. Wall calcareous, finely perforate, surface smooth, crystalline structure radial, septa monolamellid. Aperture a narrow vertical slit, basal, extending to near top of final chamber face, arched toward umbilical side with bend about $\frac{1}{4}$ of length of aperture, top pointed, wider at base, opening bordered by a narrow rim, apertural face flat, bordered by peripheral keel on spiral edge, very acute or commonly keeled top edge extending from periphery to umbilicus, top edge straight, curved sharply down to umbilicus, lower margin straight, indented to join aperture.

Discussion: *Epistominella pacifica* is distinguished by its nearly circular outline, strongly umbilico-convex test, and nearly flattened or slightly convex spiral side.

Epistominella parva is placed in synonymy with *E. pacifica* as it differs only in size. The holotype of *E. parva* is identical to smaller specimens of *E. pacifica*. Assemblages of both forms intergrade and are indistinguishable. Lewis Martin (1952, p. 136) noted that *E. smithi* may be conspecific with *E. pacifica*; however, *E. smithi* differs in its more rapidly increasing chamber size with growth, resulting in an oval outline, and in the less convex test.

Epistominella carinata Voloshinova, 1960, *E. troptunensis* Voloshinova, 1960, from the Miocene of Sakhalin and *E. pulchella* Husezima and Maruhasi, 1944, from the Pliocene of Japan are similar to *E. pacifica* and may prove synonymous.

Type locality and occurrence: Cushman (1927, p. 165) originally described *Epistominella pacifica* from Recent sediments off central California (Lat. $36^{\circ}50'$ N; Long.

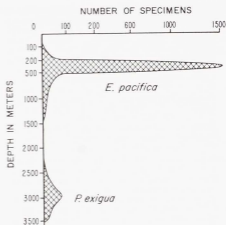


Figure 4. Quantitative distribution of *Epistominella pacifica* (Cushman) and *Pseudoparrella exigua* (Brady) with depth in the Bering Sea and Western North Pacific Ocean. (From Saidova, 1961, text-fig. 19)

$122^{\circ}15'$ W; 735 fathoms). It has since been reported from lower Miocene to Recent deposits on both sides of the North Pacific Ocean. On the east side, the species has been reported from Panama to the Gulf of Alaska, but as a fossil only from Southern California northward. On the west side, it lives in the Bering Sea south to the Okhotsk Sea. The species has also been found in sediment cores throughout the same area and in the Sea of Japan (Saidova, 1961). It was reported in the Miocene deposits of Sakhalin (Voloshinova, 1952). The smaller form given the name *E. parva*, originally described from Los Sauces Creek, Ventura County, California (Cushman and Laiming, 1931), has been recorded from elsewhere in California, and from Oregon and Washington. This name has been given to specimens occurring in the lower Miocene.

Epistominella pacifica has been found in Recent sediments from 34 m to 2300 m in depth (see Table 3) although it occurs most abundantly between 150 m and 600 m (Figure 4; Saidova, 1961; Natland, 1933). The occurrence of *E. pacifica* in abundance is discontinuous in the western Pacific Ocean (Saidova, 1962, p. 37) and probably also in the eastern Pacific. Apparently factors other than depth are important in the distribution of this species, but detailed information has not been recorded. The spe-

cies has been found on silt- to fine sand-sized sediment in waters of about normal salinity and commonly 2° to 7°C.

EPISTOMINELLA PULCHELLA Husezima and Maruhasi

Pl. II, figs. 4a-c

Epistominella pulchella HUSEZIMA and MARUHASI, 1944, Jour. Sigenkagaku Kenkyusyo, vol. 1, no. 3, p. 398, pl. 34, figs. 10a-b.

Epistominella pulchella IWASA, 1955, Jour. Geol. Soc. Japan, vol. 61, no. 712, p. 6.

Description: Test free, small, trochospiral, inequally biconvex, consisting of three whorls, outline circular, very slightly lobate, periphery carinate, with narrow, slightly raised, rounded keel. Spiral side low, convex, all chambers, whorls, and proloculus visible, initial portion of spire is highest part, below center of test. Umbilical side convex, last whorl of six chambers, edge of aperture toward spiral side visible, umbilicus closed. Chambers 16 in number, opaque, curved back over top of preceding chambers, on spiral side rectangular, width greater than height, on umbilical side narrow at base widening at top, overlapping preceding chamber, inflated with wide extension toward umbilicus, proloculus rounded. Sutures distinct, narrow, of differing width, translucent, flush with surface of test and curved back slightly on spiral side, depressed and at first radial on umbilical side, then curved backwards in middle of chamber height. Wall calcareous, smooth, thickest in center of test, finely perforate. Aperture a narrow slit, in a depression on umbilical side of test, extending from base to top of chamber, basal one-fourth at angle away from spiral side, curved sharply back toward spiral side thence straight to top, top rounded, edge toward spiral side partly beneath peripheral keel, apertural face bordered by peripheral keel on spiral side with lower margin indented to join

aperture, otherwise straight, and edges smoothly rounded.

Discussion: This species is similar to *E. pacifica* but differs in the lenticular test. However, examination of a large series of the Japanese species may show it to be synonymous. As previously noted, specimens of several other species from eastern Russian and Japan also should be compared with *E. pulchella*.

Type locality and occurrence: *Epistominella pulchella* was described from the Pliocene lower Haizume Formation at 214 m in a core in the Kasiwazaki Oil Field, Niigata-Ken, Japan. The species was reported also from the Miocene (Fujita and Ito, 1957, p. 502) and the Recent (Takayanagi, 1953, p. 84) in 40 m on a silt and clay bottom.

EPISTOMINELLA SMITHI (R. E. and

K. C. Stewart)

Pl. II, figs. 6a-c

Pulvinulinella smithi R. E. and K. C. STEWART, 1930, Jour. Paleontology, vol. 4, no. 1, p. 70, pl. 9, figs. 4a-c (Pliocene, Ventura, Calif.). CUSHMAN and MOYER, 1930, Cushman Lab. For. Res., Contr., vol. 6, pt. 3, p. 60 (Recent, off San Pedro, Calif.).

Pseudoparrella smithi (R. E. and K. C. Stewart). CROUCH, 1951, Cushman Found. For. Res., Contr., vol. 2, pt. 1, p. 10 (lower Pliocene, west side Newport Lagoon, Calif.). PHLEGER, 1951, Soc. Econ. Paleon. and Mineral., Spec. publ. no. 2, p. 68, 69 [tables] (Recent? cores, San Diego Trough). CROUCH, 1952, Amer. Assoc. Petrol. Geol., Bull., vol. 32, no. 5, p. 836, pl. 6, figs. 2-3. (Recent, basins off Southern California; Pliocene, Los Angeles basin).

Epistominella smithi (R. E. and K. C. Stewart). BANDY, 1953, Jour. Paleontology,

TABLE 3
Some reported ecologic data for *Epistominella pacifica* (Cushman)

Locality	Depth (M)	Temperature (°C)	Salinity (‰)	Reference
Off Panama	1410 to 2124	—	—	Cushman, 1927
Off Baja California, Mexico	2640	—	—	Cushman, 1927
Off So. California	252 to 1104	—	—	Cushman, 1927
Off San Pedro, California	253 to 2535	11 to 2.9	—	Natland, 1933
Santa Monica Bay, California	600 to 920	5 to 6	34.4 to 34.45	Zalesny, 1959
Off Point Arguello, California	600 to 800	4.0 to 5.5	34.2 to 34.4	Bandy, 1953
Off Central California	870 to 1632	—	—	Cushman, 1927
Off San Francisco, California	2000 to 2500	1.9 to 2.2	34.6 to 34.7	Bandy, 1953
Juan de Fuca Strait, Canada	34 to 184	6.7 to 7	32.5 to 34.0	Cockbain, 1963
Gulf of Alaska	230 to 810	—	—	Smith, 1963
Western Bering Sea	136 to 1201	—	—	Saidova, 1961, 1962
Off SE Kamchatka	126 to 1700	—	—	Saidova, 1961, 1962
West-central Okhotsk Sea	600 to 1000	2.0	33.5	Saidova, 1960, 1961, 1962

vol. 27, no. 2, p. 177, pl. 23, figs. 7a-c (Recent, off Point Arguello, Calif.). WALTON, 1955, Jour. Paleontology, vol. 29, no. 6, p. 1008, pl. 103, figs. 22, 23 (Recent, Todos Santos Bay, Baja Calif., Mexico). WHITE, 1956, Jour. Paleontology, vol. 30, no. 2, p. 257, pl. 32, figs. 1a-c (Pliocene, Capistrano Beach, Calif.). PIERCE, 1956, Jour. Paleontology, vol. 30, no. 6, p. 1300, pl. 139, figs. 14a-c (lower and upper Mohnian, Benedict Canyon, Los Angeles). BANDY and ARNAL, 1957, Amer. Assoc. Petrol. Geol., Bull., vol. 41, no. 9, p. 2041, 2042, 2051 [tables] (Recent, off Central America). RESIG, 1958, Micropaleontology, vol. 4, no. 3, p. 306 (Recent, Santa Cruz Basin, Calif.). ZALESNY, 1959, Micropaleontology, vol. 5, no. 1, p. 124 (Recent, Santa Monica Bay, Calif.). GREEN, 1960, Micropaleontology, vol. 6, no. 1, p. 74 (Recent, Arctic Ocean). BANDY, 1960, Jour. Paleontology, vol. 34, no. 4, text-fig. 7 [chart] (Pliocene-Pleistocene, Ventura basin). UCHIO, 1960, Cushman Found. For. Res., Spec. publ. no. 5, tables, pl. 9, figs. 8-10 (Recent, off San Diego). BANDY, 1961, Micropaleontology, vol. 7, no. 1, p. 15, pl. 5, figs. 6a-c (Recent, Gulf of California). HARMAN, 1964, Micropaleontology, vol. 10, no. 1, p. 95 (Recent, Santa Barbara basin, Calif.). SMITH, P. B., 1964, U. S. Geol. Survey, Prof. Paper 429-B, p. B44 (Recent, off El Salvador).

Epistominella pacifica smithi (R. E. and K. C. Stewart). BANDY, 1964, Jour. Paleontology, vol. 38, no. 1, p. 141 (Recent-sub-Recent, Santa Monica and San Pedro basins, Calif.). BANDY and RODOLFO, 1964, Deep-Sea Res., vol. 11, no. 5, tables 3, 4, fig. 5a (Recent, Peru-Chile Trench, 796 m).

Not *Pulvinulinella smithi* Stewart. SACAL and DEBOURLE, 1957, Mém. Soc. Geol. France, no. 78, p. 47, pl. 21, fig. 4.

Description: Test free, medium in size, trochospiral, inequally biconvex, consisting of two and one-half whorls, outline ovate, margin lobate, periphery carinate, keel of variable width, normally narrow, rounded, slightly raised. Spiral side low, convex, all whorls, chambers and proloculus visible, initial part of spire elevated, below center of test, last whorl flattened. Umbilical side strongly convex, five to six chambers visible in last whorl, umbilicus open or closed, deep when open, commonly rimmed by ridges on chambers. Chambers fifteen in number, on spiral side crescent-shaped, upper edge an arc, lower edges form two intersecting arcs, width greater than height, curved back over preceding chamber for half its width, narrow at base becoming broad at top on umbilical side, inflated,

with umbilical extension overlapping forward part of preceding chamber, some specimens with short low ridges on umbilical extension, proloculus rounded. Sutures distinct, narrow, limbate, flush on spiral side, deeply incised on umbilical side, strongly curved backwards. Wall calcareous, smooth, finely perforate. Aperture a narrow slit nearly parallel to periphery but curved slightly toward spiral side, in a depression on face of last chamber, extending from base to top of chamber, upper margin rounded, bordered by narrow rim, apertural face triangular, bordered by peripheral keel on spiral side, sharply rounded on others, lower margin of last chamber indented and joins aperture.

Discussion: *Epistominella smithi* is characterized by curved sutures on the spiral side and the rapidly increasing chamber size in later stages, resulting in an oval outline.

Type locality and occurrence: The type locality of *E. smithi* is in the upper Pico Formation (Pliocene) in the "mud pits at the Dent Mud Plant about 1½ miles north of Ventura and ½ mile east of Ventura Avenue at the head of Franklin Lane, Ventura County, California" (Stewart and Stewart, 1930). The type area is now covered by an avocado tree grove, and no specimens of *E. smithi* were found in samples taken farther east of the head of Franklin Lane.

This species has a geologic range from lower upper Miocene to Recent. It is reported as a fossil only from Southern California, with two doubtful exceptions: Malory (in Moore, 1963) listed *Parrella* cf. *P. smithi* (R. E. and K. C. Stewart) from the lower Miocene Astoria Formation in Oregon; and Iwasa and Kikuchi (1954) identified specimens from the Middle Miocene Sugota Formation in the Dewa Hills, Akita Prefecture, Japan, as *Epistominella smithi*. *Epistominella smithi* is recorded in Recent seas from Southern California southward to South America. It was also reported from the Arctic Ocean northwest of Ellesmere Island (Green, 1960) but, as it has not otherwise been recorded living north of Point Arguello, California, this report may be incorrect.

The species lives in water of 8.5° to 4.0°C and rarely at cooler temperatures (Crouch, 1952), in depths ranging from about 67 to 2734 m (see Table 4), and on finer-grained substrates.

Genus MEGASTOMELLA Faulkner, de Klasz and Rérat

MEGASTOMELLA AFRICANA Faulkner, de Klasz and Rérat

Pl. III, figs. 3a-c; text-fig. 2

Megastomella africana FAULKNER, DE KLASZ and RÉRAT, 1963, *Revue de Micropaléontologie*, vol. 6, no. 1, p. 20, pl. 1, figs. 1a-c.

Description: Test free, medium to large in size, trochospiral, flattened, consisting of 2 whorls, outline ovate, slightly lobate, periphery acute. Spiral side convex, apex of spire highest part, both whorls, proloculus, and all chambers except first few following proloculus are visible from exterior. Umbilical side increasing in height toward last-formed chambers, umbilicus in center, covered, the opposite margin of aperture, last whorl and nine chambers visible on umbilical side. Chambers elongate, narrow in axial region, broadened toward periphery, very slightly inflated, somewhat overlapping previous chambers, nearly completely overlapping previous whorl on spiral side and entirely on umbilical side, with inflated chamber extensions covering umbilicus. Sutures distinct, narrow, of constant thickness, depressed slightly on spiral side, more so on umbilical side, curved gently backward. Aperture a slit from base to top of chamber, parallel to periphery, pointed at top, widest at base, extending slightly toward umbilicus under umbilical extension, curved in middle toward spiral side, apertural margin sharply rounded on spiral side, broadly rounded on umbilical side.

Discussion: *Megastomella africana* is characterized by large size and a wide aperture which tends to lie on the umbilical side. The subspecies *M. africana compressa* Faulkner, de Klasz and Rérat, 1963, differs in having

a more compressed test and a peripheral aperture (Figure 2).

Type locality and occurrence: The type locality is at 1130 m in bore hole L0 9, 8 km. WNW of Port-Gentil, Gabon, Africa. The species is known only from the lower Miocene Mandorové Formation in the western part of the Gabon basin, Africa.

MEGASTOMELLA CAPITANENSIS (Cushman and Kleinpell)

Pl. III, figs. 1a-2c

Palvulinella capitansensis CUSHMAN and KLEINPELL, 1934, *Cushman Lab. Foram. Res., Contr.*, vol. 10, pt. 1, p. 18, pl. 3, figs. 3a-c (Miocene, west of Dos Pueblos Creek, Santa Barbara County, Calif.). KLEINPELL, 1938, *Miocene stratigraphy of California*, Tulsa, p. 327 (l. Mohnian, Santa Monica Mountains, Calif.; u. Mohnian, Palos Verdes Hills). CANFIELD, 1939, *Amer. Assoc. Petrol. Geol., Bull.*, vol. 23, no. 1, p. 65 (m. Miocene, Santa Maria Valley oil field). CAMPBELL and CLARK, 1944, *Geol. Soc. America, Spec. paper* 51, p. 2. KLEINPELL in Woodring, Bramlette and Kew, 1946, *U. S. Geol. Survey, Prof. Paper* 207, p. 36 [table] (u. Mohnian, Palos Verdes Hills).

Epistominella capitansensis (Cushman and Kleinpell). DOWNS, 1955, *So. Calif. Acad. Sci., Bull.*, vol. 54, pt. 2, p. 49 (Miocene, San Joaquin Hills, Orange Co., Calif.).

Epistominella sp. PARKER, 1964, *Jour. Paleontology*, vol. 38, no. 4, p. 625, pl. 99, figs. 39a-c (lower Mohnian, off Guadalupe Island, Mexico).

Description: Test free, small to medium in size, flattened, trochospiral, ovate in outline, margin lobate, periphery rounded. Spiral side flattened, first formed whorls depressed, all whorls, proloculus and chambers and opposite edge of aperture visible

TABLE 4

Some reported ecologic data for *Epistominella smithi* (R. E. and K. C. Stewart).

Locality	Depth (M)	Temperature (°C)	Salinity (‰)	Reference
Off Point Arguello, California	600 to 800 m	4.0 to 5.5	34.2 to 34.4	Bandy, 1953
Basins off So. California	100 to 666-2/3	4.0 to 8.5	34.2 to 34.66	Crouch, 1952
Santa Barbara Basin, California	372 to 563	—	—	Harman, 1964
Santa Cruz Basin, California	700 to 2000	4.1 to 5.0	—	Resig, 1958
Santa Monica Bay, California	226 to 920	5 to 7	34.45 to 34.55	Zalesny, 1919
Off San Pedro, California	133-1/3	—	—	Cushman & Moyer, 1930
Off San Diego, California	514 to 1230	—	—	Uchio, 1960
Todos Santos Bay, Baja California	66-2/3 to 133-1/3	—	—	Walton, 1955
Gulf of California	610 to 2743	4.5 to 6.0	—	Bandy, 1961
Off Central America	68 to 1750	3.5 to 7.5	34.7	Bandy & Arnal, 1957
Off El Salvador	450 to 1700	3 to 5	34.56 to 34.61	Smith, 1964

from spiral side. Umbilical side convex, umbilicus covered. Chambers twelve to thirteen in number, eight in last whorl, three to four times as high as wide, increasing in height with growth, somewhat inflated, curved over previous chambers, with downward extensions on both sides of base overlapping preceding whorl, narrow at base and expanded at top. Sutures thin, radial at first, curved backward in middle of chamber height. Wall calcareous, smooth, finely perforate, opaque to nearly translucent, crystalline structure radial, septa monolamellid. Aperture a long, equatorial slit, extending from base to top of chamber face, about four or five times as long as wide, curved slightly in middle, bent toward spiral side at base, top curved, apertural margins very slightly raised, rounded, smoothly joining sides of chamber.

Discussion: This species is small and has a narrow aperture. The holotype (Pl. 3, figs. 1a-c) is unlike most specimens of this species, which do not attain such a large size. The species can be differentiated from *M. purissima* by the straighter sutures and more oval outline.

Type locality and occurrence: *Megastomella capitaneensis* was originally described from lower Mohnian (upper Miocene) strata "232 feet stratigraphically above the top of 10 foot thick, prominent chert bed exposed at base of ocean bluffs immediately east of Dos Pueblos Creek, west of Naples" (Cushman and Kleinpell, 1934, p. 18). It was reported from Santa Maria Valley southward to near Guadalupe Island, Mexico. Parker's (1964) figured specimen from the latter locality is identical to small topotypes of *M. capitaneensis*.

MEGASTOMELLA PURISSIMA (Bramlette)

Pl. III, figs. 4a-c

Pulvinulinella purissima BRAMLETTE, 1950 [1951], U. S. Geol. Survey, Prof. Paper 222, p. 60, pl. 23, figs. 10-15 (Delmontian?, Topanga Canyon, Los Angeles Co.; Santa Maria District; Puente Hills).

Pseudoparrella purissima (Bramlette), ELIS and MESSINA, 1951, Catalog of Foraminifera, suppl. 1951, no. 3.

Description: Test free, medium in size, flattened, trochospiral, ovate in outline, margin slightly lobate, periphery sharply rounded. Spiral side slightly convex, depressed in area of early whorl, parts of all whorls, 20 to 21 chambers, and proloculus visible. Umbilical side convex, umbilicus covered by chamber extensions, part of apertural margin and last whorl with nine chambers visible. Chambers 20 to 21 in number, three times as high as wide, becoming relatively higher in later chambers, slightly inflated, curved backwards over

previous chambers, with a sharper bend in middle of younger chambers, overlapping edges of previous chamber and previous whorl on spiral side, completely overlapping those of previous whorl on umbilical side, umbilical extension inflated, proloculus round, raised. Sutures distinct, appearing as a thin depressed line, radial near center, curved back toward margin. Wall calcareous, smooth, finely perforate, translucent. Aperture a peripheral slit, parallel to periphery, curved, narrow, long, extending from base to rounded top of chamber face, and toward umbilicus at lower edge of umbilical extension, apertural margins rounded, smoothly joining sides of chamber.

Discussion: This species is characterized by its wide aperture, long chambers, and strongly curved sutures. Some specimens have a tendency for final chambers to coil onto the umbilical side of the test. Specimens may be concave on either side of the test as a result of the irregular coiling.

Type locality and occurrence: The type locality of *M. purissima* is "in the Monterey formation (Modelo formation of some geologists) on the east slope of the spur 0.35 mile, S. 30° E. from the intersection of Ventura Boulevard and Topanga Canyon Avenue, near Woodland Hills (formerly known as Girard) on the north slope of the Santa Monica Mountains, Los Angeles County, California" (Bramlette in Woodring and Bramlette, 1950). Bramlette also recorded the species from upper Miocene sediments in the Santa Maria district and Puente Hills.

Genus PSEUDOPARRELLA Cushman and ten Dam

PSEUDOPARRELLA CALIFORNICA (White)

Pl. I, figs. 6a-c

Epistominella pontoni californica WHITE, 1956, Jour. Paleontology, vol. 30, no. 2, p. 257, pl. 31, figs. 9a-c (upper Miocene, Capistrano Beach, Calif.).

Pulvinulinella cf. *P. pontoni* Cushman. KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 329, pl. 16, figs. 5a-c (lower Delmontian, Reliz Canyon, Monterey Co., Calif.).

Epistominella californica White. BANDY and ARNAL, 1957, Amer. Assoc. Petrol. Geol., Bull., vol. 41, no. 9, p. 2041, 2051 (Recent, off Acapulco, Mexico).

Epistominella subpersuviana californica White. BANDY and KOLPACK, Micropaleontology, vol. 9, no. 2, p. 163 (Relizian to lower Mohnian, Santa Ynez Mountains, Santa Barbara Co., Calif.).

Description: Test free, small in size, biconvex, trochospiral, consisting of 2½

whorls, outline circular to suboval, lobulate, periphery rounded. Spiral side of differing convexity, generally smoothly convex but commonly somewhat flattened, all whorls, chambers and proloculus visible. Umbilical side evenly convex, umbilical region depressed, six to nine chambers and last whorl visible, umbilicus closed. Chambers 18 to 22 in number, slightly inflated; on spiral side rhomboid in outline throughout or increasing in relative height in last whorl, lower margin lobed, extending onto previous whorl; on umbilical side wedge-shaped, narrow at base, broadening toward top of chamber, overlapping front part of previous chamber, with inflated umbilical extension; proloculus rounded. Sutures distinct, slightly limbate, depressed, radiate on umbilical side, slanted backwards on spiral side. Wall calcareous, radially-built, surface smooth, perforations numerous and obvious. Aperture a very narrow slit, slightly oblique to periphery, in a deep depression on apertural face, extending from base to top of chamber, bordered by a very narrow raised rim. Apertural face smoothly rounded from aperture joining sides of chamber, lower margin indented to join apertural margin.

Discussion: *Pseudoparrella californica* differs from other California species in the straighter sutures, more rounded periphery, thicker test, more inflated chambers which are square in spiral view, and in the smaller size. The species differs from the holotype of *P. pontoni* in the lower spire, more circular outline and rounded periphery.

Type locality and occurrence: The type locality is 1.8 miles south of the intersection of U.S. Hwy. 101 S, Alt., and U.S. 101 N on former U.S. 101, $\frac{2}{3}$ the distance up cliff, in a small gully containing a drainage pipe just below a 10 inch chert bed, Capistrano Beach, California (USC loc. 150=UCLA loc. 4719).

Pseudoparrella californica has been reported from Relizian (lower middle Miocene) to Recent deposits from Santa Barbara County southward to off Acapulco, Mexico, where it was collected in 1750 m of water at 2.6 to 3.8°C and a salinity of 34.7‰.

PSEUDOPARRELLA EXIGUA (Brady)

Pl. I, figs. 9a-c

Pulvinulina exigua BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 696, pl. 103, figs. 13a-14c (Challenger Stations 332 and 160, South Atlantic Ocean and Southern Ocean).

Pulvinulinella exigua (Brady). HANNA and CHURCH, 1927, Jour. Paleontology, vol. 1, no. 3, p. 200 (Recent, off Farallon Islands, Calif.).

Pseudoparrella exigua (Brady). PHLEGER,

1951, Soc. Econ. Paleont. and Mineral, Spec. publ. no. 2, p. 69 [chart] (Recent, San Diego Trough, Calif.).

Epistominella sandiegoensis UCHIO, 1960, Cushman Found. Foram. Research, Spec. publ. no. 5, p. 68, pl. 9, figs. 6, 7 (Recent, off San Diego, Calif.; Sebastian Vizcaino Bay, Mexico).

Not *Exponides exigua* (Brady). BARBAT and JOHNSON, 1934, Jour. Paleontology, vol. 8, no. 1, p. 16, pl. 1, figs. 5-7. KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 318, pl. 20, figs. 6, 10, 12.

Description: Test free, small, biconvex, trochospiral, of 3½ whorls, outline circular, margin slightly lobate, periphery acutely rounded. Umbilical side flattened, 6 chambers of last whorl visible, umbilicus covered. Spiral side convex, all chambers and proloculus visible, center of spire very nearly in center of test. Chambers 22 in number, on spiral side rhomboid in shape, about twice as wide as high, and curved back over previous chamber, on umbilical side wedge-shaped and covering previous whorl completely, proloculus round. Sutures distinct, on spiral side slightly limbate, flush and bent obliquely backwards, on umbilical side very slightly depressed and curved forward at first, then back slightly and then recurved forward. Wall calcareous, finely perforate, thin and translucent. Aperture a slit parallel to periphery on umbilical side, in slight depression on apertural face, basal, extending to top of chamber, narrower at top, bordered by narrow rim. Apertural face sharply rounded.

Discussion: This small species has been assigned to several different genera in the past although it possesses the characters of *Pseudoparrella*. It is distinguished from other species by its small size, acute periphery, and recurved sutures on the umbilical side of the test. *Epistominella sandiegoensis* Uchio is identical to the original figures of this species, hence it is considered a junior synonym.

Barbat and Johnson (1934) and Kleinpell (1938) erroneously assigned to this species specimens which have basal sutural apertures.

Occurrence: *Pseudoparrella exigua* originally was described from deep-water samples collected in the South Atlantic and Southern Oceans and has since been reported throughout the world. It occurs along the entire eastern side of the North Pacific Ocean, but only California records are included in the synonymy above.

The species is commonly recorded on fine-grained sediments in deep water (see Figure 4) although it is found also in shallow

water in decreased abundance. Hofker (1951) believed the species was pelagic in life because of its thin test walls, inflated chambers, widespread distribution and occurrence in *Globigerina* oozes. However, many deep-water benthonic species of foraminifera have thin walls, are widely distributed, and are found in *Globigerina* oozes. *Pseudoparrella exigua* is not found in plankton tows but is recorded as living on the bottom (see Uchio, 1960). There is no evidence to suggest a pelagic habitat.

PSEUDOPARRELLA GARRISONI Lipps,
nom. nov.

Pl. I, figs. 4a-c

Epistominella nova GARRISON, 1959, Jour. Paleontology, vol. 33, no. 4, p. 669, pl. 85, figs. 11a-c (lower Miocene, Saucian, west side of San Joaquin Valley, Calif.). Not *Pseudoparrella nova* PISHVANOVA, 1959, Ukr. NIGRI, Minist. Geol. Okhrany nedr. SSSR, Trudy, vyp. 1, p. 12, pl. 6, figs. 2a-c.

Description: Test free, small, trochospiral, flattened, consisting of nearly 2 whorls, outline suboval, margin slightly lobate, periphery rounded. Spiral side flattened, all whorls, chambers, and proloculus visible. Umbilical side flattened, six chambers visible, slightly depressed in umbilical area, umbilicus closed. Chambers wedge-shaped on umbilical side, rhomboid to quadrate on spiral side, slightly inflated, increasing in size in last whorl, lower margin lobed, overlapping previous whorl and front part of previous chambers, with broad umbilical extensions. Sutures obscure, thin, depressed, curved backwards. Wall calcareous, smooth, perforations obscured, surface grainy in appearance. Aperture a short, narrow slit extending from base of last chamber parallel to periphery, on umbilical side of test, bordered by very narrow rim, slightly depressed. Apertural face smoothly joins chamber sides without sharp differentiation.

Discussion: This species is known from one specimen, the only one on the slide containing Garrison's type specimens which matched the description of the species. However, the original illustrations (Garrison, 1959, pl. 33, figs. 11a-c) are reversed images of this specimen. As none of Garrison's other figures are reversed, the identity of this specimen as the holotype is questionable.

The specimen has been leached or recrystallized and is not well preserved. An examination of a large sample from the type locality failed to yield additional specimens. It is placed in *Pseudoparrella* because of the rounded periphery, short rhomboid to quad-

rate chambers and an aperture on the umbilical side of the test. This species is separated from other species of *Pseudoparrella* by its flattened test, fewer chambers, and small size. It is similar to *Megastomella* in its flattened test.

As the specific name proposed by Garrison (July 14, 1959) is preoccupied by *Pseudoparrella nova* Pishvanova (June 24, 1959), the California species is renamed in honor of L. E. Garrison of Sacramento, California.

Type locality: *Pseudoparrella garrisoni* was originally described from the 2950 to 2976 foot cored interval of the Seaboard-Welsh no. 1 well, north of Coalinga, Fresno County, California. Garrison (1959, p. 664) inferred that the sediments were deposited in "depths down to approximately 200 feet."

PSEUDOPARRELLA MINUTA (Cushman and Laiming)

Pl. I, figs. 5a-c

Pulvinulinella subperuviana minuta CUSHMAN and LAIMING, 1931, Jour. Paleontology, vol. 5, no. 2, p. 116, pl. 13, figs. 6a-c (lower Miocene, Los Saucos Creek, Ventura Co., Calif.). BARBAT and VON ESTORFF, 1933, Jour. Paleontology, vol. 7, no. 2, p. 165 (lower Miocene, 7½ mi. SE of Maricopa, Calif.). KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 331.

Epistominella subperuviana minuta Cushman and Laiming. KLEINPELL and WEAVER, 1963, Univ. Calif. Publ. Geol. Sci., vol. 43, no. 1, fig. 4 [chart], (Saucian, Los Saucos Creek, Ventura Co., Calif.).

Description: Test free, small, trochospiral, unevenly biconvex, spiral side lower than umbilical side, outline circular, periphery subacute. Spiral side flattened, raised in apical region by thick deposits of calcite which obscure early whorls and chambers. Umbilical side sharply convex, acute in umbilical area, umbilicus covered by deposits of clear calcite, 6 to 9 chambers visible in last whorl. Chambers rhomboid to lunate on spiral side, trigonal, slightly inflated and overlapping previous whorl on umbilical side. Sutures distinct, limbate, wide, flush with test surface, radial, curved back slightly. Wall calcareous, smooth, thickened in axial regions, finely perforate. Aperture a narrow vertical slit parallel to periphery, basal, occurring in depression on umbilical side of test, apertural face flattened, margin sharply rounded.

Discussion: The original illustrations of the holotype of *Pseudoparrella minuta* show six chambers in the last whorl, whereas the

specimen on the type slide has nine, hence this specimen may not be the holotype.

Pseudoparrella minuta is similar to some specimens of *P. subperuviana* but differs in the smaller size, more flattened spiral side, and thickened walls in the axial region. A large series of topotypes of both species show them to be distinct; *P. minuta* therefore is elevated to specific rank.

Type locality and occurrence: This species was originally described from lower Miocene Strata exposed in Los Sauces Creek, Ventura County, California. It has since been recorded from contemporaneous strata in the Santa Ynez Mountains and the southwestern San Joaquin Valley, California.

PSEUDOPARRELLA RELIZENSIS
(Kleinpell)

Pl. I, figs. 7a-8c

Pulvinulinella relizensis KLEINPELL, 1938, Miocene stratigraphy of California, p. 329, pl. 10, figs. 10a-c (upper Saucian to upper Luisian, Reliz Canyon, Monterey Co., Calif.; Adelaida Quad., San Luis Obispo Co., Calif.). NATLAND, 1950, Geol. Soc. America, Mem. 43, pt. 4, p. 33, pl. 9, figs. 4a-c (Pliocene, Carmen Island, Baja California, Mexico).

Epistominella relizensis (Kleinpell). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487 (Mohnian, Santa Ana Mts., San Juan Capistrano Area, Orange Co., Calif.).

Description: Test free, small to medium in size, biconvex, trochospiral, about 2½ whorls, outline circular to suboval, periphery rounded to subacute. Spiral side flattened, edges rounded, all chambers and proloculus visible. Umbilical side slightly convex, commonly depressed in umbilical area, about 9 chambers visible, umbilicus closed. Chambers about 21 in number, slightly inflated, each curved back over that preceding, chambers rhomboid and slightly overlapping those of previous whorl on spiral side, chamber height on spiral side 2 to 3 times the width, on umbilical side chambers are wedge-shaped, narrow at base, widening at top and with flattened umbilical extension, proloculus round. Sutures distinct, thin, slightly depressed and curved backwards. Wall calcareous, smooth, finely perforate. Aperture basal, narrow, elongate vertical slit parallel to periphery, equatorial or slightly on umbilical side of test, depressed, bordered by very narrow rim.

Discussion: The holotype of this species was deposited at Stanford University but is no longer in the collections according to A. Myra Keen and J. J. Graham.

The aperture of *P. relizensis* varies in

position from peripheral to extraumbilical. The final chamber of some specimens is shortened (Pl. I, fig. 7a-c), as in the holotype.

Pseudoparrella relizensis resembles *Megastomella* in its commonly equatorial aperture and curved sutures. It is placed in *Pseudoparrella* because of the short rhomboid chambers, circular to suboval outline, and biconvex test.

The species is distinguished from *P. subperuviana* by the more rounded periphery, more evenly biconvex test, and nearly peripheral aperture. It is separated from *P. californica* by the larger size, relatively thinner test and chambers, and curved sutures.

Type locality and occurrences: The type locality of *P. relizensis* is on a ridge projecting east, approximately 3800 feet north-east of the Reliz Canyon Camp Ground, Reliz Canyon, Monterey County California. It is "580 feet above the top of the Vaqueros sandstone" (Kleinpell, 1938, p. 330) in the Monterey Shale of the middle Relizian stage. *Pseudoparrella relizensis* occurs abundantly in Reliz Canyon. It is reported from upper Miocene rocks in Orange County, Calif., and from Pliocene sediments of Carmen Island, Baja California, about 850 miles south of the type locality.

PSEUDOPARRELLA SUBPERUVIANA
(Cushman)

Pl. I, figs. 1a-3c

Pulvinulinella subperuviana CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 3, p. 63, pl. 9, figs. 9a-c (middle Miocene, Highland District, San Luis Obispo Co., Calif.). CUSHMAN, STEWART and STEWART, 1930, San Diego Soc. Nat. Hist., Trans., vol. 6, no. 2, p. 73 (middle Miocene, Bear River, Humboldt Co., Calif.). DORN, 1932, Micropaleontology Bull., Stanford, vol. 3, no. 2, p. 29 (Miocene, Salinas Valley, Calif.). WOODRING, BRAMLETTE and KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 133 (middle Miocene, Palos Verdes Hills, Calif.). KLEINPELL, 1938, Miocene stratigraphy of California, p. 330 (lower Saucian to upper Luisian, Nipomo Quad., San Luis Obispo Co.; Chico Martinez Creek, Kern Co.; Carneros Creek, Kern Co.; Concord Quad., Contra Costa Co., Calif.). WOODRING, BRAMLETTE and LOHMAN, 1943, Amer. Assoc. Petrol. Geol., Bull., vol. 27, no. 10, p. 1344, 1346 (Relizian, Santa Maria District, Santa Barbara Co., Calif.). KLEINPELL in Woodring, Bramlette and Kew, 1946, U. S. Geol. Survey, Prof. Paper 207, p.

- 19 [table] (Miocene, Palos Verdes Hills, Calif.).
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- Epistominella subperuviana* (Cushman). PIERCE, 1956, Jour. Paleontology, vol. 30, no. 6, p. 1300, pl. 140, figs. 1a-c (Mohnian, Benedict Canyon, Los Angeles Co., Calif.). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487 (upper Luisian to lower Mohnian, Santa Ana Mts. and San Juan Capistrano areas, Calif.). BANDY and ARNAL, 1960, Amer. Assoc. Petrol. Geol., Bull., vol. 44, no. 12, p. 1927 (Miocene, southern San Joaquin Valley, Calif.). SMITH, P. B. in Winterer and Durham, 1962, U. S. Geol. Survey, Prof. Paper 334-H, p. 288, 295, 313, pl. 48, 49 [tables] (upper Miocene to Pliocene, southeastern Ventura Basin, Calif.). LOEBLICH and TAPPAN, 1964, Treatise Invert. Paleontology, pt. C, Protista 2, vol. 2, p. C578, fig. 453, no. 5a-e (Holotype refigured).
- Epistominella subperuviana subperuviana* (Cushman). BANDY and KOLPACK, 1963, Micropaleontology, vol. 9, no. 2, p. 153 (Refugian to Mohnian, Tecolote Tunnel, Santa Ynez Mts., Santa Barbara Co., Calif.).
- NOT *Palvulinella subperuviana* Cushman. SACAL and DEBOURLE, 1957, Soc. Géol. France, Mém., no. 78, p. 47, pl. 21, fig. 1.
- Description:* Test free, trochospiral, medium in size, inequally biconvex, about 2½ whorls, outline circular to slightly oval, periphery acute. Spiral side convex, flattened on last whorl, raised in center, all whorls and chambers visible. Umbilical side evenly convex, commonly depressed in center, umbilicus closed, covered by chamber extensions. Chambers about thirty in number, ten in last whorl, increasing in relative height with growth, about half as wide as high, narrow in axial region becoming wider at margin on umbilical side, with extension toward but not always covering umbilicus, proloculus circular. Sutures distinct, thin, slightly raised, curved smoothly backward. Wall calcareous, smooth, finely perforate, early whorls thickened and opaque when dry, last whorl thinner and translucent, crystal structure radial, septa monolamellid. Aperture a very narrow slit, parallel to periphery, on umbilical side of last chamber, elongate, extending from base to near top of chamber, depressed in apertural face, bordered by a very narrow rim.
- Discussion:* The holotype (Pl. 1, figs. 1a-c) of *Pseudoparrella subperuviana* is damaged. Its final chamber is missing and one

of the remaining chambers is broken on the spiral side (not shown on Pl. 1). Material remaining from the broken final chamber gives the apertural face a more pronounced and wide appearance. The holotype of *P. bradyana* (Pl. 1, figs. 3a-c) is identical to topotype specimens of *P. subperuviana*.

This species is characterized by its flattened final whorl, acute periphery, moderately large size, and limbate sutures. The aperture is always definitely on the umbilical side of the test. In some specimens the apex of the spire is more elevated and the final whorl more flattened, and the sutures on the umbilical side of the test may curve back.

Sacal and Debourle (1957) figured *P. subperuviana* from the Aquitaine Basin in France, but their specimen does not belong to *Pseudoparrella*, the aperture being typical of *Alabamina*.

Type locality and occurrences: *Pseudoparrella subperuviana* was originally described from Luisian rocks in Sec. 24, T.28S., R.14E., Mt. Diablo Base and Meridian, Highland District, San Luis Obispo County, California. *P. bradyana* was described from Recent sediments at Latitude 7°01'N and Longitude 81°48.7'W off Panama, Central America.

The species occurs from Washington southward to Ecuador in deposits ranging from Oligocene (?) to Recent. In general, specimens from Pliocene or younger rocks were previously designated *P. bradyana*, whereas those from older rocks were called *P. subperuviana*.

PSEUDOPARRELLA? DISCORBISOIDES

(Pierce)

Pl. I, figs. 10a-c

Epistominella discorbisoides PIERCE, 1956, Jour. Paleontology, vol. 30, no. 6, p. 1304, pl. 139, figs. 13 (Mohnian, Benedict Canyon, Los Angeles Co., Calif.).

Description: Test free, trochospiral, of medium size, inequally biconvex, about 2½ whorls, outline circular, periphery acute, carinate. Spiral side strongly convex, tending to become flattened on last whorl, all whorls, chambers and proloculus visible. Umbilical side flattened to very slightly convex, depressed in umbilical area, only last whorl visible. Chambers lunate on spiral side, slightly inflated and partially covering previous whorls on umbilical side, increasing rapidly in relative height with growth. Sutures curved slightly back on spiral side, initially directed forward then strongly curved back on umbilical side. Wall calcareous, smooth, finely perforate,

crystal structure radial. Aperture a narrow basal slit parallel to periphery on umbilical side of test.

Discussion: The type slide of this species contained the holotype, three paratypes and one *Buccella*. As the final chambers of all specimens were broken away and the apertural region damaged, the apertural characters are not clear. Additional specimens could not be found in samples collected from the type area nor in samples provided by R. L. Pierce.

The generic assignment of these specimens is questionable. The microstructure of the test could not be completely determined as the technique for determining lamellar characters of the septa requires sectioning, and only type material was available. The specimens were studied with polarized light, which revealed a radial crystalline wall structure. The species is tentatively assigned to *Pseudoparrella* because of similarities to aberrant specimens of *P. subperuviana* from the Monterey Formation near Carmel, California. The type specimens of *P. discorbisoides* may actually represent aberrant *P. subperuviana*.

Type locality: The type locality of *P. discorbisoides* was not precisely stated in the original description. The type slide is labeled USC 261 which corresponds to Pierce's locality 100. It is approximately 200 feet north of Mulholland Drive on the Davana Fire Road. The species was listed from 11 samples ranging from lower to upper Mohnian, from Benedict Canyon, Los Angeles County, California (Pierce, 1956).

Genus STETSONIA F. L. Parker

STETSONIA MINUTA F. L. Parker

Pl. II, figs. 8a-c

Stetsonia minuta F. L. Parker, 1954, Mus. Comp. Zool., Harvard, Bull., vol. 111, no. 10, p. 534, pl. 10, figs. 27-29.

Description: Test free, small, involute in later stages, slightly trochospiral in early stage, biconvex, outline nearly circular, lobate, periphery rounded. Chambers of last whorl 10, completely overlapping previous whorls, crescent-shaped, increasing in height with growth, slightly inflated, overlapping front of previous chamber. Sutures distinct, thin, depressed, curved smoothly back. Wall calcareous, smooth, finely perforate, thin, crystalline structure radial, septa monolamellar. Aperture a narrow slit extending from base of face to top of last chamber, depressed, tending to slant toward one side of test, bordered by narrow rim, apertural face rounded.

Discussion: This species, the type for the genus, differs from *S. borvatbi* Green in having nearly twice as many chambers in the last whorl and a slightly asymmetrical aperture.

Type locality: *Stetsonia minuta* was described from the northeastern part of the Gulf of Mexico at Latitude 29°40'N, Longitude 88°28.5'W, at a depth of 42 m. It occurs in samples taken in 20 to 3251 m.

Genus EILOHEDRA Lipps
EILOHEDRA LEVICULA (Resig)

Pl. III, figs. 5a-c, text-fig. 3

Epistominella levicula RESIG, 1958, Micropaleontology, vol. 4, no. 3, p. 304, text-figs. 16a-c (Recent, Santa Cruz Basin, Calif.). MCGLOSSON, 1959, Micropaleontology, vol. 5, no. 2, p. 236 (Recent, off Santa Catalina Island, Calif.). BANDY, 1961, Micropaleontology, vol. 7, no. 1, p. 15 (Recent, Gulf of California). BANDY and RODOLFO, 1964, Deep-Sea Res., vol. 11, no. 5, table 4, fig. 5a (Recent, Peru-Chile Trench).

Eponides leviculus (Resig). UCHIO, 1960, Cushman Found. Foram. Res., Spec. publ. no. 5, p. 67, pl. 10, figs. 23-25 (Recent, off San Diego, Calif.). PHLEGER, 1964, Amer. Assoc. Petrol. Geol., Mem. 3, p. 383, pl. 2, figs. 20, 21 (Recent, Gulf of California).

Eponides sp. A. CROUCH, 1952, Amer. Assoc. Petrol. Geol., Bull., vol. 36, no. 5, p. 836, pl. 5, figs. 10-11 (Recent, East Cortes, Long Basins, off Southern California; Pliocene, Los Angeles Basin, Calif.).

Description: Test free, small, inequally biconvex, trochospiral, outline circular, slightly lobate, periphery rounded. Spiral side strongly convex, all whorls, chambers and proloculus visible. Umbilical side slightly convex, depressed in umbilical area, only last whorl visible around the open umbilicus. Chambers slightly inflated, curved back over that preceding, rhomboid to rectangular in spiral view, trigonal in umbilical view, broadly rhomboid in edge view. Sutures distinct, thin, slightly depressed, radial, directed straight back on spiral side, arched back on umbilical side. Wall calcareous, finely perforate, thin, transparent, surface smooth, crystalline structure radial, septa bilamellid. Aperture basal, low, extending from near umbilicus to near periphery, with short vertical extension up face of final chamber near periphery, depressed.

Discussion: This species is distinguished from similar species in other genera by its characteristic aperture, small size, and numerous chambers.

Type locality and occurrences: *Eilohedra levicula* was originally described from Recent

deposits in Santa Cruz Basin, off California, but an exact locality was not given.

The species occurs between 42 and 5929 m and is most abundant in deeper waters below sill depth in basins off Southern California. It also is reported living between 122 and about 565 m in the Gulf of California, and as fossil from the Pliocene of the Los Angeles Basin. *Eilohedra levicula* is reported from the Peru-Chile Trench off South America.

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PLATES I-III

All Figures: a, Spiral View; b, Umbilical View; and c, Apertural View. All are shaded camera lucida drawings.

Abbreviations: UCLA=Type collections, Department of Geology, University of California, Los Angeles; USNM=U. S. National Museum; USC=University of Southern California.

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Drawings: Figs. 2, 4, 6-8, 11 by Margaret Rogers; 3, 5, 9-10 by Helen Tappan Loeblich; 1 by Lawrence B. Isham.

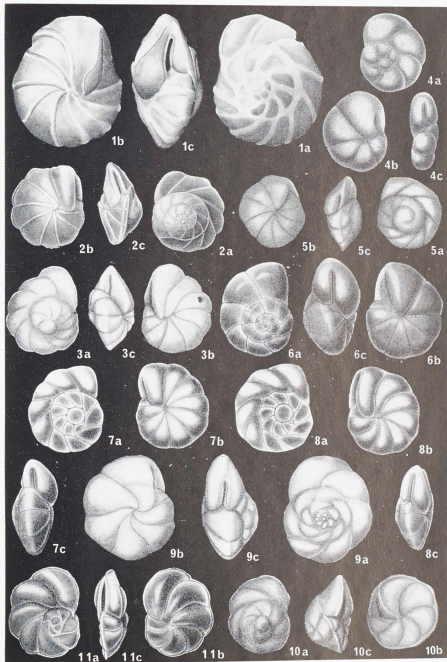


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Drawings: Figs. 1-4, 7 by Margaret Rogers; 5-6 by Helen Tappan Loeblich; 8 by Lawrence B. Isham.

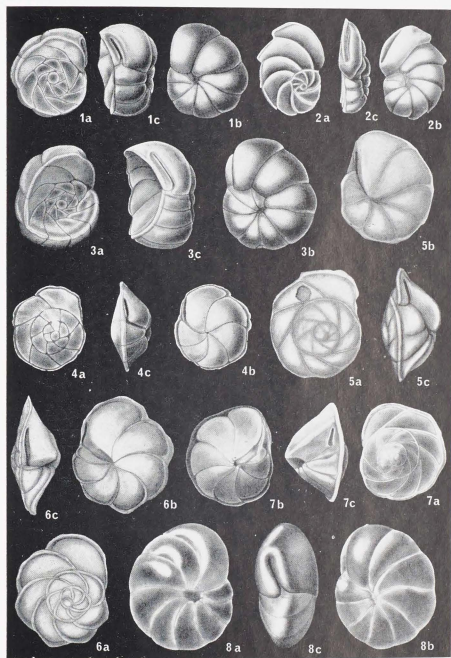


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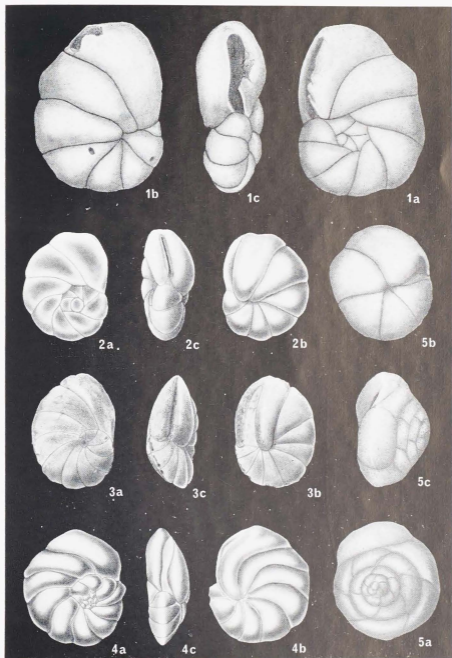


PLATE III

ERRATA

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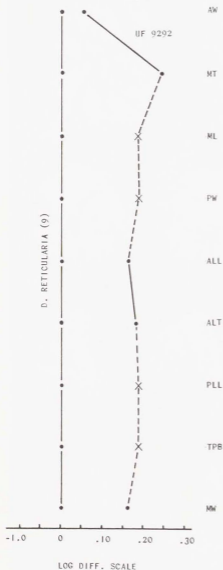


Figure 2. Ratio diagram comparing various dimensions of fossil *Deirochelys* (UF 9292) and a series of Recent *D. reticularia*. Abbreviations same as in Fig. 1. X - estimated dimension.

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