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ABSTRACT

The internal structure of toptypes of Camerin a catenula (Cushman) and Eoconuloides parvulus (Cushman) and of specimens of Eoconuloides wellsi (Cushman) and of specimens of Heliostegillina polyseptata (Barker) is discussed and illustrated and notes are given on their stratigraphic ranges. In the introductory remarks a postulate by Hofker (1968) concerning the phylogenetic relationship of the genus Lepidocyclina and related genera is rejected. Lepidocyclina ecuadorensis Hofker is without question a synonym of Heliolepidina spiralis Tobler. The phylogenetic relationships proposed by Barker and Grimsdale (1936) for the lepidocycline and heliolepidine lineages are maintained and re-emphasized.

INTRODUCTION

This article is an attempt to clarify certain misconceptions concerning the internal structure and stratigraphic range of several species of American Eocene Foraminifera. Such data are essential to an understanding of the phylogenetic relationships which have been postulated. Barker and Grimsdale (1936, p. 244) proposed a phylogenetic scheme in which the subgenus Polyplepidina of the genus Lepidocyclina was derived from the Heliolepidina lineage. Heliolepidina was also a coeval ancestor of actinosiphonid s such as Polyplepidina, Polyplepidina antilea Cushman. Moreover, in my 1960a article (p. 62) cited by Hofker (1968, p. 22) I wrote: "During the upper middle Eocene the first subgenus, Polyplepidina, of the genus Lepidocyclina was derived . . . The middle Eocene age of Lepidocyclina (Polyplepidina) antilea has long been established in surface outcrop (Cole, 1956, Table 4; 1958a, p. 190; Grimsdale, 1959, p. 17) and in wells (Cole, 1938, p. 48; 1944, p. 34; Gravell and Hanna, 1938, p. 1007).

The specimens which Hofker (1968, p. 22) identified as Lepidocyclina ecuadorensis are strikingly similar to specimens from northwest Peru which L. Rutten (1928, p. 945) named Lepidocyclina vichayalensis. M. G. Rutten (1935, p. 544) transferred this species to the genus Actinosiphon. Cole (1960a, p. 60) stated " . . . Lepidocyclina vichayalensis Rutten (1928, p. 945) was based on specimens of Heliolepidina nortoni Vaughan." Later, Cole (1962, p. 147) concluded that H. nortoni was a synonym of Heliolepidina spiralis Tobler.

The specimens illustrated by Hofker (1968, pl. 11, fig. 3; pl. 14, fig. 2) as Lepidocyclina ecuadorensis should be compared with toptypes of Heliolepidina nortoni (Cole, 1962, pl. 24, figs. 1-3). All of these specimens have Type III prezygotic embryonic apparatuses (Cole, 1962, p. 146), which is characteristic of upper Eocene specimens (Cole, 1962, p. 147) of Heliolepidina spiralis. One specimen (Hofker, 1968, pl. 14, fig. 2) shows the row of spiral chambers (about two rows below the second embryonic chamber and continuing across the illustration to the right) best, but the spiral chambers also appear in figure 1, plate 14 (Hofker, 1968) to the right of the embryonic chambers.

The embryonic apparatus, the possession of a sequence of spiral chambers beyond the embryonic apparatus, and the shape and alignment of the equatorial chambers in Lepidocyclina ecuadorensis are characteristic of Heliolepidina, not Lepidocyclina.

In unit 4 assigned by Cushman and Stainforth (1951, p. 34) to a reefal facies of upper middle Eocene age, Hofker (1968, pl. 8, fig. 4) found specimens which he correctly identified as Heliolepidina spiralis in association with abundant specimens.
which he referred incorrectly to the genus Lepidocyclina (his Lepidocyclina ecuadorensis = Helicolepidina spiralis). Other specimens in unit 4 were identified as Helicolepidina paucispire, a species placed by Cole (1960a, p. 59) in the synonymy of Helicostegina polygyralis (Barker).

Hofker (1968, p. 21) in one place correctly observed that unit 4 is upper Eocene. However, he modified this statement by writing: "...Van der Vlerk (see later) believes that unit 4 is from the uppermost part of the Middle Eocene." Unfortunately, Hofker and Van der Vlerk identified Lepidocyclina ecuadorensis (= Helicolepidina spiralis) incorrectly. Therefore, the statistics (Vlerk, in Hofker, 1968, p. 27, 28) upon which Van der Vlerk based the middle Eocene age of unit 4 are meaningless, as his statistical method is based on an analysis of the embryonic chambers of Lepidocyclina, whereas the measurements given were made on Helicolepidina.

Hofker (1968, p. 22) wrote: "...Lepidocyclina ecuadorensis is somewhat older than L. antillea and may have been ancestor to it; this also points to an upper Middle Eocene age of unit 4 of Ecuador, where the species is abundant." Lepidocyclina antillea is definitely a middle Eocene species, Helicostegina polygyralis (Hofker's Helicolepidina paucispire) is not known to occur below the upper Eocene, and Helicolepidina spiralis with a Type IIIb embryonic apparatus is assumed to be characteristic of the upper Eocene. Therefore, on stratigraphic position "Lepidocyclina ecuadorensis" cannot be the ancestor of Lepidocyclina antillea.

These misconceptions demonstrate that an additional analysis of certain species which are the logical ancestors of the lepidocyclines is needed. Therefore, Eoconuloides parvulus (Cushman) (= Amphistegina lopeztrigoi), Eoconuloides welsi Cole and Bermudez, and Helicostegina polygyralis (Barker) are discussed and illustrated. Additional notes are given on Camerina catenula (Cushman and Jarvis) as the internal structure of toptypes of this important Paleocene-lower Eocene species have not been illustrated by a sufficient number of specimens to show the variation between individuals.

In summary, the concept of Barker and Grimsdale (1936, p. 244; Cole, 1960a, p. 62) that Eoconuloides parvulus (= Amphistegina lopeztrigoi) by its internal structure and stratigraphic position is the logical ancestor both of the lepidocycline and helicopelidine lineage is strengthened by additional data presented here. Helicostegina, a mutant derived from the ancestor species, interconnects Eoconuloides with the more advanced lineages. In one lineage, the helicopelidines, the spiral chambers which characterize Helicostegina, although reduced, are maintained, whereas, in the other lineage, the lepidocyclines, the spiral chambers are so reduced that they are confined to a short spiral encircling the embryonic chambers.

Localities of the Figured Specimens

Cuba

Loc. 1—"Maraguán, Rio Maraguanito, cruce del camino de Camaguey a Maraguán, Camaguey Prov., Bermudez sta. 284, toptypes, Amphistegina lopeztrigoi D. K. Palmer;" 6 specimens through the courtesy of Pedro J. Bermudez.

Loc. 2—N. W. of Sibanicu, 23.3-4 km., on Maragua-Camaguey road; toptypes; courtesy of the late Mrs. D. K. Palmer and the late Donald W. Gravell; toptypes.

Loc. 3—Asphalt seep and quarry on Rancho Peñón, 7 km.s. south of Martí (Hato Nuevo) and 850 m. northwest of the little settlement of Peñón, Matanzas Province; Donald W. Gravell and J. B. Klecker, collectors (reference: Cole and Gravell, 1952, p. 708).

Florida

Loc. 4—St. Mary's River Oil Corporation, Hilliard Turpentine Company well No. 1 (W-336), Nassau County, Florida, at a depth of 1285-1295 feet. (Cole, 1944, p. 18, 34).

Trinidad

Loc. 5—Maerky's original sample 102b, III; for location and discussion of this sample, see: Cushman and Renz, 1946, p. 1-11; material lent through the courtesy of J. B. Saunders.

Loc. 6—K. R. 25684; steep bank on east (waiting rooms) side of San Fernando Railway Station (coordinates N: 237060 links; E: 356425 links); dark grey-brown calcareous silt; J. B. Saunders, collector.

St. Bartholomew

Loc. 7—Promontory separating Anse des Lézards and Anse des Cayes on the north coast; marly tuff 0.2 m. thick with abundant larger Foraminifera forming a transition zone between the lower horizon of cross-bedded tuffs and the overlying limestone; A. Senn, collector, S. B. 12.

DISCUSSION OF GENERA AND SPECIES

Family CAMERINIDAE

Genus Camerina Bruguier, 1792

(For a discussion of this generic name, see Cole, 1966, p. 236-238.)

Camerina catenula (Cushman and Jarvis)

Plate 17, figures 1-4, 6, 8

1932. Operculina catenula CUSHMAN and JARVIS,
U. S. Nat. Mus., Proc., v. 80, art. 14, p. 42, pl. 12, figs. 13a, b.


This species, including species which are considered to be synonymous with it, has been assigned to the genera *O perculina* (Cushman and Jarvis, 1932, p. 42; D. K. Palmer, 1934, p. 34); *Pellati­ spir ella* (Hanzawa, 1937, p. 116); *Cam erina* (Bar­ ker, 1939, p. 325; COLE, 1960b, p. 193); *Micel­ lanaea* (Vaughan and COLE, 1941, p. 32; Vaughan, 1945, p. 23); *R anikothalia* (Caudri, 1944, p. 17; Hanzawa, 1962, p. 161); and *O perculinoides* (COLE, 1953, p. 32, 35; 1958b, p. 270; COLE and Herrick, 1953, p. 52; Sachs, 1957, p. 107). In addition, it has been placed in two subgenera *Nummulites* (*Nummulites* (Cizancourt, 1948, p. 10) and *Nummulites* (*Chordoperculinoides*) (Arni, 1963, p. 26).

The generic classification of *Cam erina catenula* has been discussed (COLE, 1960b, p. 192, 193) and will not be repeated.

Discussion.—Cushman and Jarvis (1932, p. 42) described a single specimen from supposed “... Upper Cretaceous of pit at Lizard Springs near Guayaguare, southeast Trinidad, British West Indies” as *O perculina catenula*. The description was brief and the specimen was illustrated by two drawings. COLE (1953, pl. 3, fig. 1) published a photograph of the type and wrote (p. 37) “... *O perculi­ noides catenula* is similar to *O. bernudezi*. ... Unless more specimens are collected and thin sections made, it is impossible to do more than indicate the similarity between the two species.”

In 1959 through the courtesy of Dr. H. G. Kugler I received some matrix-free specimens from the Lizard Springs area concerning which Mr. John B. Saunders (letter dated 25 March 1960) wrote “The sample Maerky 102b III from Lizard Springs we consider to be the same locality as the Cushman and Jarvis one. There is some slight confusion amongst the old samples of the Ampelu Ravine area but this is the only locality just there from which larger forams have been found ... we have called this sample the type locality for *O. catenula.*”

Two thin sections (COLE, 1960b, pl. 25, fig. 6; pl. 26, fig. 1) made from these specimens (Maerky 102b, III) which are assumed to be topotypes of *O. catenula* were published in connection with a study of the genus *Cam erina*. COLE (1960b, p. 193) assigned “*O perculina* catenula” to the genus *Cam erina*, stating: “The description of the structure of *Cam erina* is identical with that given by COLE and Herrick (1953, p. 53) for *O perculinoides geor­ gianus* (= Ranikothalia of Nagappa, 1959, p. 159 = *Cam erina catenula*).”

Sachs in 1957 (p. 107-113) had studied a large suite of topotypes of *O perculina bernudezi* D. K. Palmer (1934, p. 238) in which he demonstrated by measurements and an excellent series of illustrations of external views and thin sections the variation which occurs between specimens. Moreover, he was able to show conclusively that a number of species proposed by Hanzawa (1937), Barker (1939), Mrs. Cizancourt (1944, 1951), Vaughan and COLE (1941), Vaughan (1945), and COLE and Herrick (1953) were synonyms of *O perculina bernudezi*.

However, at that time Sachs could not analyze *O perculina catenula* Cushman and Jarvis, as topotype material was not available. COLE (1958b, p. 270) restudied and published notes on many American species of camerinids, stating: “Although *O. catenula* is known only from its external appearance, it so resembles typical specimens of *O. bernudezi* that these species cannot be separated.”

In 1959 COLE discussed briefly the geographic distribution and stratigraphic position of *O perculina catenula* and associated larger Foraminifera.

Although by 1960 there was sufficient evidence to demonstrate that “*O perculina* bernudezi was a synonym of *Cam erina catenula*, Hanzawa (1962, p. 161) retained “*O.* bernudezi” as a valid species, but assigned it to the genus *R anikothalia* (Caudri, 1944, p. 266). COLE (1960b, p. 192) concluded that *R anikothalia* was a synonym of *Cam erina*. ARNI (1963, p. 26) designated *O perculina bernudezi* the type species of a new subgenus *Chordoperculinoides* of *Cam erina* (= *Nummulites* of authors - see: COLE, 1966, p. 236).

Additional illustrations (pl. 17, figs. 1-4, 6, 8) of topotypes of *Cam erina catenula* are presented to show variation and reinforce the conclusion that “*O perculina* bernudezi is indeed a synonym of *Cam erina catenula*.

Stratigraphic range.—A detailed discussion of the stratigraphic and geographic distribution of *C. catenula* has been published (COLE, 1959) and ad-
ditional notes have been given recently (Cole, 1969, p. 34-37).

Family AMPHISTEGINIDAE

Genus Eoconuloides Cole and Bermudez, 1944

Type species, Eoconuloides wellsi Cole and Bermudez, 1944


The internal structure of toptypes (Pl. 16, figs. 1, 3, 5-7; Pl. 17, fig. 5) of Amphistegina lopeztrigoi D. K. Palmer are illustrated. These specimens show all the structures which characterize the genus Tremastegina Brönnimann, 1950, including the basal pores (Pl. 16, fig. 1).

As the structure of Tremastegina appeared to be similar to that of specimens assigned to the genus Eoconuloides Cole and Bermudez, 1944, the type of this genus, E. wellsi Cole and Bermudez (1944, pl. 27, figs. 4-10), was re-examined, and additional preparations (Pl. 16, figs. 2, 4, 8, 9; Pl. 17, fig. 7) were made of specimens from Peñon Seep, Matanzas Province, Cuba, which had been identified by Cole and Gravell (1952, p. 713) as E. wellsi.

Eoconuloides (Pl. 16, fig. 2) has the same kind of apertures as those developed by Tremastegina (Brönnimann, 1950, text fig. 6). These apertures are present also in one of the type illustrations (Cole and Bermudez, 1944, pl. 27, fig. 6) of Eoconuloides, although they do not show as well as in the preparations of the specimens from Peñon Seep. Moreover, many of the specimens of Eoconuloides have basal pores similar to those of Tremastegina.

As the structures which supposedly characterize the genus Tremastegina are identical to those of Eoconuloides, Tremastegina Brönnimann, 1950, is a synonym of Eoconuloides Cole and Bermudez, 1944.

The internal structures of transverse sections of Eoconuloides resemble those of Helicostegina (compare figs. 4, 8, 9, Pl. 16 with those of Helicostegina dimorpha Barker and Grimsdale, figs. 11-14, pl. 92, Cole and Gravell, 1952). The major difference between these two genera is shown by median sections (compare fig. 2, Pl. 16 with those of Helicostegina, figs. 16-19, pl. 92, Cole and Gravell, 1952) in which well-developed chambers are formed in the final volutions of Helicostegina.

Some median sections of Eoconuloides (Cole and Gravell, 1952, pl. 92, fig. 9) have small, irregular chambers in the final volutions. These were noted in the types (Cole and Bermudez, 1944, p. 340) as well as in the specimens from Peñon Seep. Therefore, Helicostegina differs mainly from Eoconuloides in the greater development of the chambers which are formed in a peripheral flange of Helicostegina.

Although the two genera are retained, continued analysis may prove that Eoconuloides is a synonym of Helicostegina Barker and Grimsdale, 1936.

Eoconuloides parvulus (Cushman)

Plate 16, figures 1, 3, 5-7, 10, 12; plate 17, figure 5

1919. Nummulites parvula CUSHMAN, Carnegie Inst. Washington, Publ. 291, p. 51, pl. 4, figs. 3, 6, probably fig. 4, not fig. 5.


1936. Amphistegina lopeztrigoi Palmer. BARKER and GRIMSDALE, Jour. Paleontology, v. 10, no. 4, p. 233, pl. 30, figs. 1, 2; pl. 32, figs. 1-3; pl. 34, fig. 1; pl. 38, fig. 3.

1942. Amphistegina lopeztrigoi D. K. Palmer. COLE, Florida Geol. Survey, Bull. 20, p. 33, 34, pl. 15, figs. 2, 3; pl. 16, fig. 11.

1944. Amphistegina lopeztrigoi D. K. Palmer. COLE, ibid., Bull. 26, p. 55, pl. 1, fig. 17; pl. 8, fig. 16; pl. 9, figs. 10-13.


Two specimens (Pl. 16, figs. 10, 12) of Eoconuloides parvulus, one from St. Bartholomew and the other from a well in Florida, are illustrated, not only for comparison with the toptypes of “Amphistegina lopeztrigoi,” but also to supplement other illustrations of E. parvulus.

Cole (1958a, pl. 25, figs. 17, 18) illustrated two transverse sections of E. parvulus from St. Bartholomew. A specimen (Pl. 16, fig. 12) from the same locality shows the apertures which are identical to those in “Amphistegina lopeztrigoi” (Pl. 16, fig. 3; Pl. 17, fig. 5).

Another specimen (Pl. 16, fig. 10) is from the same sample as the specimens illustrated by Cole (1944, pl. 9, figs. 11, 13). A median section (Cole, 1944, pl. 9, fig 13) shows the typical siphonate apertures of Eoconuloides parvulus. The transverse section (Pl. 16, fig. 10) is similar to those of “Amphistegina lopeztrigoi” (Pl. 16, figs. 1, 5-7), but the walls are slightly thicker. The specimen (Cole, 1944, pl. 9, fig. 11), however, is identical to “Amphistegina lopeztrigoi.”

In general, the specimens from Florida and St.
Bartholomew have thicker walls than do those from Cuba. The specimens from Florida and St. Bartholomew are from limestone, whereas those from Cuba were embedded in a clastic matrix. The difference of environment may be the control, as specimens of *Camerina* from limestones have thicker walled tests than do those from clastic sediments (Cole, 1958a, p. 191, 195).

**History.**—*Amphistegina lopetztrigoi* D. K. Palmer (1934, p. 285) was described from Cuba from a locality assigned to the Eocene “...probably middle Eocene.” The type illustrations (Palmer, 1934, pl. 15, figs. 6, 8) are two external views. Barker and Grimsdale (1936, p. 233) referred Mexican specimens from the “Lower middle Eocene” to this species and gave the first analysis of the internal structure.

Cole (1942, p. 33) recognized this species in two wells in Levy County, Florida, and sent specimens to the late Mrs. D. K. Palmer, who confirmed the identification. Other specimens of this species (Cole, 1944, p. 55) were found in a well in Nassau County, Florida. Applin and Jordan (1945, p. 131) recorded *Amphistegina lopetztrigoi* as one of the characteristic species of the Lake City Limestone (early middle Eocene) of the subsurface section of Florida.

Cushman (in Vaughan, 1945, p. 49) described *Amphistegina sennis* from Barbados, writing: “This species differs from *Amphistegina lopetztrigoi* in its much smaller size, fewer chambers, and fewer but more prominent bosses in the umbonal region.” Brönnimann (1950) made a detailed study of *A. sennis* “...from the Middle Eocene Upper Scotland formation of Barbados” and erected the genus *Tremastegina* with *A. sennis* the type.

Cole and Gravell (1952, p. 714) identified *Amphistegina lopetztrigoi* at Peñón Seep, Matanzas Province, Cuba, writing that it is “...impossible to distinguish between the smaller topotype specimens of *A. lopetztrigoi* and the larger (diameter up to 1.10 mm.) specimens of *A. sennis*. It is logical, therefore, to combine these species.”

Cole (1958a, p. 201) studied abundant material from the middle Eocene of St. Bartholomew, French West Indies, and decided that *Amphistegina lopetztrigoi* was a synonym of “Nummulites” *parvula* Cushman (1919, p. 51). He (Cole, 1958a, p. 201) wrote “Cushman’s illustrations of *Nummulites parvula* show clearly that it should be referred to the genus *Amphistegina* ... It is impossible to distinguish these specimens from St. Bartholomew from topotype specimens of *A. lopetztrigoi* from Cuba, therefore, the two species are combined.”

**Stratigraphic occurrence.**—*Eoconuloides parvulus* (Cushman) was described from surface outcrops (USGS loc. 6903) on St. Bartholomew in association with *Lepidocyclina antillea* Cushman (1919, p. 24, table). Cole (1958a, p. 190) and Hanzawa (1959, p. 843, 844) confirmed the association of these two species and, in addition, reported that *Eoconuloides wellsi* and *Helicostegina dimorpha* Barker and Grimsdale (identified as *H. gyralis*) occurred in the same thin sections from St. Bartholomew.

Cole (1938, p. 46) reported *Lepidocyclina antillea* (identified as *L. gardnerae* Cole) from a well in Jackson County, Florida, in sediments assigned to the Claiborne, middle Eocene. Gravell and Hanna (1938, p. 1007) were able to trace the occurrence of the zone of *Lepidocyclina (Polyplepidina)* in wells from Texas to Florida. They (Gravell and Hanna, 1938, p. 987) placed this zone near the base of the Cook Mountain Formation (middle Eocene).

Barker and Grimsdale (1936, p. 233) found *Eoconuloides parvulus* (identified as *Amphistegina lopetztrigoi*) in association with *Lepidocyclina antillea*, a species which is diagnostic of the Cook Mountain Formation of Texas and the Lake City Limestone of Florida (Applin and Jordan, 1945, p. 131; Cole and Applin, 1964, p. 20).

Cole and Gravell (1952, p. 714) reported *Eoconuloides parvulus* (identified as *Amphistegina lopetztrigoi*) at Peñón Seep, Matanzas Province, Cuba, with numerous species of Foraminifera including *Eoconuloides wellsi* Cole and Bermudez and *Helicostegina dimorpha* Barker and Grimsdale (identified as *H. gyralis* Barker and Grimsdale). Beckmann (1958, p. 417), by planktonic Foraminifera, assigned the fauna of Peñón Seep to the “... *Hantkenina aragonensis* zone of lower Middle Eocene age (Bolli 1957) ...”

The *Hantkenina aragonensis* zone is placed in the lower part of the middle Eocene (Bolli, 1957, p. 159; Brönnimann and Rigassi, 1963, pl. 1). Beckmann (1958, p. 420) suggested that in Cuba specimens which resemble *Lepidocyclina antillea* “... occur in the upper part of the Globigerina kugleri zone and in the lower part of the Globorotalia lehneri zone.” Cole and Applin (1964, p. 19) wrote: “Although *Lepidocyclina (Polyplepidina)* has not been reported from Peñón Seep, species of larger Foraminifera, such as *Pseudophragmmina flintensis* and *Asterocyclina monticellensis*, do occur there. As these species are associated with *Lepidocyclina (Polyplepidina)* *antillea* elsewhere, we suggest that Peñón Seep might as reasonably be cor-
related with the Globigerapsis kugleri zone of Trinidad."

This suggestion of Cole and Apelin (1964, p. 19) is substantiated by an observation by Bermudez (1963, p. 35) that Beckmann (1958, p. 418) recovered the planktonic Foraminifera from beds of soft marl and sands which underlie the zone with larger Foraminifera at Peñon Seep. Bermudez (1963, p. 35) wrote that the planktonic Foraminifera reported by Beckmann "... indicate a stage of the lower Eocene equivalent to the Universidad Formation, whereas the beds above indicate a stage of the middle Eocene low in the section equivalent to the Loma Candela Formation. ... It is possible that between the zone with the orbitoidal fauna and the zone with the planktonic fauna there is a hiatus ..."

Levin (1957) established that in a well in Levy County, Florida, Eoconuloides parvulus (identified as Amphistegina lopezrigoi) and Helicostegina dimorpha (identified as H. gyralis) occur in association with Pseudophragmina cedrakeyensis Cole in the Oldsmar Limestone (lower Eocene). Butterlin (1967, p. 549) identified Pseudophragmina cedrakeyensis, P. stephensi, Eoconuloides parvulus (as Amphistegina) and Helicostegina dimorpha in association in the Corinto No. 1 well, State of Campeche, Mexico.

Cole (1944, p. 34) reported that Pseudophragmina cedrakeyensis was associated with P. stephensi (Vaughan) (identified as Pseudophragmina cookii) in a well in Nassau County, Florida. P. stephensi is diagnostic of the Salt Mountain Limestone of Alabama and is one of the characteristic species of the Camerina catenula zone (Cole, 1959; Cole, 1969, p. 31-37).

Beckmann (1958, p. 417) gave the stratigraphic range of Eoconuloides parvulus (his Amphistegina lopezrigoi) in Cuba as Paleocene into the middle Eocene (Globorotalia velascoensis - G. pseudomenardii planktonic zone to the Globigerapsis kugleri zone).

Brönimann and Rigassi (1963, p. 292, 309) reported "Amphistegina lopezrigoi (= Eoconuloides parvulus) from the Apolo and Alkázár Formations in the vicinity of Habana, Cuba. They (Brönimann and Rigassi, 1963, Table 1) assigned these beds to the "Operculina" catenula zone, or in terms of planktonic Foraminifera, the Globorotalia angulata and Globorotalia velascoensis - G. pseudomenardii zones.

These data suggest that Eoconuloides parvulus has a long stratigraphic range from Paleocene into the base of the upper middle Eocene.

Eoconuloides wellsi Cole and Bermudez
Plate 16, figures 2, 4, 8, 9; plate 17, figure 7
1944. Eoconuloides wellsi COLE AND BERMUDEZ, Bull. Amer. Paleontology, v. 28, no. 113, p. 341, 342, pl. 27, figs. 4-10.


The types of this species have a high conical form. Specimens from Peñon Seep, Matanzas Province, Cuba, although conical, vary from compressed (Pl. 16, fig. 9) to elongate (Pl. 17, fig. 7; Cole and Gravel, 1952, pl. 92, fig. 3).

Although there is similarity in form and structure in E. wellsi and E. parvulus, the two species can be separated. In median section E. parvulus normally has more expanded chambers (Pl. 16, fig. 3; Cole and Gravel, 1952, pl. 91, fig. 7) than E. wellsi (Pl. 16, fig. 2; Cole and Gravel, 1952, pl. 92, figs. 7, 8, 10). In transverse section E. wellsi has many more subdivisions in the final volution (Pl. 16, figs. 4, 8, 9) than does E. parvulus (Pl. 16, figs. 1, 5-7, 10).

History.—Cole and Bermudez (1944, p. 340) described small conical specimens from the middle Eocene of Habana Province, Cuba, as Eoconuloides wellsi, new genus and species. They stated: "Eoconuloides is related to Helicostegina Barker and Grimsdale (1936, p. 233)." Cushman and Stainforth (1946, p. 118) named similar specimens from the middle Eocene of Ecuador Amphistegina elliotti, stating: "This species differs from Amphistegina lopezrigoi Palmer from the Eocene of Cuba in the more conical form and the smaller papillae."

The illustrations (Cushman and Stainforth, 1946, pl. 20, figs. 3, 4, 6) of A. elliotti clearly show that the final coil of chambers is subdivided into chamberlets of the same kind that characterize Helicostegina. Cole and Bermudez (1944, p. 340) stated concerning Eoconuloides wellsi "... the most primitive species of Helicostegina has well-developed subsidiary chamberlets. These are not found in Eoconuloides although there is a suggestion of the development of this type of chamberlet." Later, Cole and Gravel (1952, pl. 92, fig. 9) illustrated a specimen identified as Eoconuloides wellsi from Peñon Seep, Matanzas Province, Cuba, which has chamberlets in the final volution similar to those of Amphistegina elliotti.

Stratigraphic range.—The types (Cole and Bermudez, 1944, p. 333) are from a "Cut in road from Managuaco to Nazareno, Habana Province, Cuba (Bermudez sta. 222)." Bermudez (1950, p. 340) gave its stratigraphic range in Cuba from the Lucero member of the Capdevila formation (lower Eocene) into the Loma Candela formation (middle Eocene). Beckmann (1958, p. 417) gave a prob-
able stratigraphic range of this species from the *Globorotalia velascoensis* planktonic zone (Paleocene) into the *Hantkenina aragonensis* zone (lower middle Eocene).

Bradinmann and Rigassi (1963, p. 321) reported *Eoconuloides wellsi* appeared first in the *Globorotalia rex* planktonic zone in the vicinity of Habana, Cuba. Cole (1958a, p. 190) reported it in association with *Lepidocyclina antillaea* Cushman on St. Bartholomew, West Indies.

The stratigraphic range of *E. wellsi* in the Caribbean region is from the lower Eocene into the base of the upper middle Eocene.

**Family DISCOCYCLINIDAE**

Genus *Discocyclina* Gumbel, 1870

*Discocyclina (Discocyclina) barkeri*

Vaughan and Cole

Plate 16, figure 11

1941. *Discocyclina (Discocyclina) barkeri* Vaughan and Cole, Geol. Soc. Amer., Sp. Paper 30, p. 57, 58, pl. 18, figs. 4-7; pl. 21, figs. 1, 2.


This species is associated with *Camerina catenula* (Cushman and Jarvis) in Trinidad, Cuba, Venezuela, and Barbados. Several specimens were found at locality 5 (Maerky 102b III) in association with *C. catenula*. The best vertical section of *D. barkeri* is illustrated.

**Family LIPIDOCYCLINIDAE**

Genus *Helicostegina* Barker and Grimsdale, 1936

*Helicostegina polygyralis* (Barker)

Plate 17, figures 9-11

1932. *Helicolepidina polygyralis* Barker, Geol. Mag., v. 69, p. 309, 310, pl. 22, fig. 5; text fig. 4.


1936. *Helicolepidina polygyralis* Barker. Barker and Grimsdale, *ibid.*, v. 10, no. 4, p. 241, 243, pl. 36, fig. 2; pl. 38, figs. 1, 2.

1936. *Helicolepidina paucispira* Barker. Barker and Grimsdale, *ibid.*, v. 10, no. 4, p. 243, pl. 31, figs. 11, 12; pl. 33, figs. 4-6; pl. 36, figs. 1, 3; pl. 38, fig. 4.


1945. *Helicolepidina paucispira* Barker and Grimsdale. Cole, Florida Geol. Survey, Bull. 28, p. 46-49, pl. 1, figs. 1-11; pl. 4, fig. 1; pl. 8, fig. 4.


1968. *Helicolepidina paucispira* Barker and Grimsdale. Hofker, Senior, Palaeontographica, v. 130, sec. A, p. 21, 22, pl. 8, fig. 5; pl. 11, figs. 1, 2.


In the type description of *Helicolepidina paucispira*, Barker and Grimsdale (1936, p. 243) described and illustrated only megalospheric specimens. Cole (1945, p. 46) recovered from a well in Leon County, Florida, megalospheric specimens which are identical to the types of *H. paucispira*. In this sample there were microspheric specimens which could be correlated with the megalospheric specimens, as the only other components of this sample were species of *Lepidocyclina*.

In 1960a, Cole (p. 59) prepared a number of thin sections of specimens from Trinidad which Grimsdale (in Vaughan and Cole, 1941, p. 86) described as *Helicostegina soldadensis*. Additional thin sections of *H. soldadensis* were prepared in 1963 (Cole, p. 42, pl. 10, figs. 5-8; pl. 11, all figs.) in which microspheric specimens were found.

Dr. R. Wright Barker (letter, dated 9 July, 1963) generously sent me excellent photographs of topotypes of *Helicolepidina paucispira*, *Helicostegina soldadensis* and *Helicolepidina polygyralis*. All this material has been restudied.

One of the critical points is the kind of aperture possessed by these specimens, as the apertures of *Helicostegina* are different from those of *Helicolepidina*. Grimsdale (in Vaughan and Cole, 1941, p. 87) recognized the difficulty of observing apertures even in well-oriented median sections of *Helicostegina* writing "The split apertures in the primary septa [have] ... counter septa which are very short and not developed in the equatorial plane; for this reason they are seldom visible in equatorial sections."

Although many of the preparations of *Helicostegina soldadensis* do not show the apertures,
one of the microspheric specimens from Trinidad (Cole, 1963, pl. 11, fig. 3) has such apertures (Pl. 16, fig. 10). Similar apertures were found in a microspheric specimen from Florida (Cole, 1960a, pl. 10, fig. 8) which had been identified as *Helicolepidina paucispira*. These may be observed if the illustration (Cole, 1960a, pl. 10, fig. 8) is examined with a low-power magnifying glass.

The only available illustration (Barker and Grimsdale, 1936, pl. 36, fig. 2; pl. 38, fig. 2) of a microspheric specimen of *Helicolepidina polygyralis* is not well oriented. However, this specimen (Barker and Grimsdale, 1936, pl. 38, fig. 2, upper right) does possess apertures which have counter septa of the kind found in *Helicostegina*.

This evidence suggests that *Helicolepidina paucispira* and *Helicolepidina polygyralis* should be transferred to the genus *Helicostegina*. This conclusion is reinforced by the structure of the megalospheric test. Cole (1960a, p. 59) wrote: "The vertical sections of *Helicostegina* are markedly different from those of *Helicolepidina* (fig. 11, pl. 11) in that the equatorial zone in *Helicolepidina* is continuous to the embryonic chambers, whereas this zone in *Helicostegina* is not."

If all the illustrations of *Helicostegina paucispira*, *H. polygyralis* and *H. soldadellensis* are compared, the only difference which can be observed either in megalospheric or microspheric specimens is the development of the sequence of spiral chamberlets in the median plane.

However, the length and strength of the spiral vary between specimens from the same sample. One specimen (Pl. 16, fig. 9) has a short spine of the "paucispira" kind which cannot be traced to the periphery of the test, whereas another specimen (Pl. 16, fig. 11) has a longer spine of the "soldadellensis" kind which can be followed to the periphery of the test. This same arrangement is shown (Cole, 1960a, pl. 10, figs. 3, 5) in specimens from another locality.

The development of the spiral wall and the number of chamberlets which are inserted following the initial coil of chambers are as variable as the length of the spiral whorl in specimens from the same sample. As there are seemingly no valid criteria by which these specimens can be separated, only one species, *Helicostegina polygyralis* (Barker), is recognized.

**Stratigraphic range.—** The types of *Helicostegina polygyralis*, by associated larger Foraminifera, are from the upper Eocene (Cole, 1986, p. 42, 43) of Ecuador. *Helicostegina polygyralis* (identified as *Helicolepidina paucispira*) occurs in the upper Eocene *Lepidocyclina* chaperi zone of Florida (Cole, 1945, p. 17) and, in Trinidad, in the *Globorotalia cerroazulensis* planktonic zone (Cole, 1960a, p. 57). Under the name *Helicolepidina paucispira* it is known from the upper Eocene of the Tampico Embayment area of Mexico (Barker and Grimsdale, 1936, p. 244).

**LITERATURE CITED**


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**EXPLANATION OF PLATE 16**

<table>
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<tr>
<th>Figs.</th>
<th>Page</th>
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<tr>
<td>1, 3, 5-7, 10, 12. <em>Eoconuloides parvulus</em> (Cushman).</td>
<td>80</td>
</tr>
<tr>
<td>1, 5-7, 10. Transverse sections; 1, 5, 7, 10, ×40; 6, ×20; 1, 7, loc. 1; 3, 5, 6, loc. 2; 10, loc. 4</td>
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<tr>
<td>3. Median section, ×20; loc. 2.</td>
<td></td>
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<tr>
<td>12. Part of a median section, ×40; loc. 7.</td>
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<td>2, 4, 8, 9. <em>Eoconuloides wellsi</em> Cole and Bermudez.</td>
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<td></td>
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<td></td>
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<td>11. <em>Discocyclina</em> (<em>Discocyclina</em>) <em>barkeri</em> Vaughan and Cole.</td>
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<td>Vertical section, ×40; loc. 5.</td>
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</table>
Cole: Studies on American Eocene Foraminifera
Cole: Studies on American Eocene Foraminifera


---, 1958b, Names of and variation in certain American larger Foraminifera, particularly the camerinids - no. 2: Bull. Amer. Paleontology, v. 38, no. 173, p. 261-284, pls. 32-34.


---, 1967, Contributions from the Cushman Foundation for Foraminiferal Research 85

EXPLANATION OF PLATE 17

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3, 8. Median sections; 3, ×40; 8, ×20; loc. 5.

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Median section; ×20; loc. 1.

7. Eoconuloides wellesi Cole and Bermudez. .................. 82

Transverse section, ×20, by reflected light; loc. 3.

9-11. Helicostegina polygyralis (Barker). ....................... 83

9-11. Median sections, ×40, of megalospheric specimens; loc. 6.

10. Central part, ×210, of a median section of a microspheric specimen; entire median section illustrated as fig. 3, pl. 11, Cole, 1963; loc. 6.

---, 1949, Contributions from the Cushman Foundation for Foraminiferal Research 85


---, 1959, Occurrence of the foraminiferal species Acervulina linearis Hanzawa from St. Bartholomew Island, French West Indies: Jour. Paleontology, v. 33, no. 5, p. 843-845, pl. 117.


367. SEASONAL OCCURRENCES, STANDING CROP AND PRODUCTION IN BENTHIC FORAMINIFERA OF PUERTO DESEADO

ESTEBAN BOLTOVSKOY and HAYDÉE LENA

ABSTRACT

A quantitative study of populations of Buliminella elegantissima, Elphidium articulate, Epistominella exigua and Rotalia beccarii collected weekly (February to March, 1966) in the Quinta Island area, Puerto Deseado, Patagonia, revealed that these species had their main bloom in the winter of 1964. The whole foraminiferal fauna of this area also exhibited outbursts at the same time. However, Buceella frigida exhibited outbursts in the spring of 1964 and the summer of 1965/66, and Elphidium gunteri showed well-pronounced peaks during the summer months. Young individuals of Buliminella elegantissima, Elphidium articulate, Epistominella exigua, Elphidium gunteri and Rotalia beccarii were found practically every month; this indicates that their reproduction occurs throughout the year. It is supposed that Buceella frigida reproduces once a year. The standing crop of the benthic foraminiferal fauna was found to be 9.24 specimens per sq. cm. The annual production of the whole foraminiferal fauna was calculated to be 1,056,600 specimens per sq. meter. The annual production in a sq. meter, expressed in terms of dry weight, was calculated to be 4.65 grams.

INTRODUCTION

Two papers have been previously published on the seasonal occurrence of benthic Foraminifera in Deseado Creek (Bolovskoy, 1964, 1965a). For those studies weekly collections were made for two years (1961 and 1962) in the vicinity of “Dos Hermanas” rock. The study of this area enabled the author to reveal the life cycle of only the few most abundantly represented species. Most of the species were too limited in number for a quantitative examination.

We subsequently looked for another place on the same creek that would yield sufficient specimens for a study of seasonal occurrences. Thus we can consider this study in some degree to be a continuation of the earlier ones. In order to save space, various data which can be easily found in those papers (previous works on the seasonal occurrences of Foraminifera, description of the area studied, etc.) are not given here. The systematic description and figures of the species discussed and of the entire foraminiferal fauna of the area under study, not repeated here, were published by the same authors elsewhere (Bolovskoy, 1963; Bolovskoy and Lena, 1966).

The use of another type of sampling gear enabled us to attack not only the problem of seasonal changes but some other aspects of foraminiferal biology as well, namely, the foraminiferal standing crop and production.

MATERIAL

The material studied was collected in the small area (15 sq. meters approximately) situated between the left coast of Deseado Creek and Quinta Island. The sampling gear used was a Lankford coring tube having an inner diameter of 32.4 mm. and a cross section of 8.24 sq. cm. Its description can be found elsewhere (Bolovskoy, 1965b).

The short cores were collected every week from February 1964 to March 1966. Only the top two centimeters of the sediments from each core were utilized for the investigation. This portion was removed from the core upon arriving in the laboratory of the Puerto Deseado Marine Biological Station (situated about two km. from the sampling area) and immediately subjected to the following treatment: fixed in a 5-10% solution of formalin; washed in a no. 250 sieve (mesh size 0.061 mm.); colored with Rose Bengal solution; washed again to remove excess Rose Bengal; dried, and treated with carbon tetrachloride. Specimens were separated, mounted on slides and identified, and all necessary measurements were made in the Foraminiferal Laboratory of the Museo Argentino de Ciencias Naturales “B. Rivadavia,” Buenos Aires.

All the specimens that were alive at the moment of their capture (those containing protoplasm colored with Rose Bengal) were picked from each sample; in all, these totalled about 9,000. The number of dead specimens was, on the average, approximately three times greater, but dead specimens were picked from every fourth sample only (i.e., once a month).

METHOD FOR DETERMINING SEASONAL CHANGES

In order to determine the reproductive rhythm of each species, young specimens were separated from adult ones, different criteria being used for separating each species, as described in the subsequent discussion of the species. We should empha-
size, however, that for some species the percentage of the young individuals was probably somewhat higher than that calculated, because some small young specimens, mainly of *Buliminella elegantissima* and *Epistominella exigua*, passed through the sieve. However, we did check several samples without washing them and found that if specimens were lost their number was quite insignificant.

**SEASONAL CHANGES**

**PARTICULAR SPECIES**

The total number of living species found in the Quinta Island area was about 50, but only the following four were considered to be sufficiently abundant for a study of their seasonal changes: *Buliminella elegantissima* (27.37%), *Elphidium articulatum* (8.69%), *Epistominella exigua* (5.50%) and *Elphidium gunteri* (4.97%). Their average abundance in the whole foraminiferal assemblage of the area studied is given in parentheses. The seasonal occurrences of *Rotalia beccarii* and *Buccella frigida* were studied, but these were less abundant (3.42 and 2.74%, respectively), so conclusions concerning them are less reliable.

**TABLE 1**

Seasonal changes in the most abundant species in the Quinta Island area

A. Number of specimens found each month
B. Percentage of young specimens in the total population of that species
**Buliminella elegansisima** (d’Orbigny)

It was difficult to decide what criterion should be used in separating young specimens from adult ones. Certainly the best would be the number of chambers, but to determine this would require sections. Since sectioning is a long procedure and since more than 2,500 specimens were involved, we were forced to abandon this and to take as a criterion the size of the test. We believe this to be a valid decision, since a direct relationship between the number of chambers and the length of a test was observed. All tests larger than 0.150 mm. were considered to be adults. The largest adult individuals were 0.426 mm. in length.

Table 1, fig. 1A shows the abundance of *B. elegansisima* calculated for each month. Fig. 1B shows the percentage of young specimens in the total population. *B. elegansisima* was most abundant in the winter of 1964. In addition some peaks were observed at other times, but they were not as high.

An analysis of this table reveals that young specimens of the species discussed are present throughout the year; hence the reproduction of this species has no annual periodicity, but occurs throughout the year.

**Elphidium articulatum** (d’Orbigny)

Size was considered as a criterion for separating this species. All specimens larger than 0.23 mm. were considered to be adults. Table 1, fig. 2A shows the total number of specimens per month, and fig. 2B the percentage of young individuals. The greatest development occurred in the winter months of 1964 and 1965. The bloom of 1965 was much smaller than that of 1964.

New broods appeared practically throughout the year. Thus the life cycle of this species is undoubtedly shorter than a year.

**Epistominella exigua** (Brady)

Table 1, fig. 3A gives the total number of specimens collected during different months. Several peaks can be observed, the greatest of which was in 1964 (in the winter months and in November). Fig. 3B shows the percentage of young individuals. Those whose greater diameter was equal to or smaller than 0.114 mm. were considered to be young specimens.

*E. exigua* evidently reproduces throughout the year. Although during some months no young specimens were encountered, we believe this to be accidental and probably explained by an insufficient number of living specimens found during these months. The largest specimen of *E. exigua* was 0.227 mm.

**Elphidium gunteri** Cole

Table 1, fig. 4 illustrates the total number of living specimens collected each month (A) and the percentage of young specimens (B). All tests smaller than 0.2 mm. were considered to be young. The maximum size of adult individuals in the area studied was 0.568 mm.

An analysis of both figures reveals that this species had its greatest bloom in warm months, namely, summer-fall of 1964, summer of 1964/65 and summer of 1965/1966. Unlike the species described above, it did not show a high standing crop in the winter of 1964. As young individuals appeared almost every month, the periodicity of its reproduction should be considered shorter than a year.

**Rotalia beccarii** (Linne)

In this species the separating criterion was the number of chambers. In the microspheric population, all specimens having ten chambers or less (including the proloculus) were considered to be young. In the microspheric population this number was increased to 15 chambers.

Table 1, fig. 5A illustrates the changes in the whole population; fig. 5B shows the percentage of young specimens. Those portions of the bars of the histogram that are black represent the microspheric specimens.

As shown there, microspheric specimens were found only in the winter and spring of 1964 and in the winter of 1965 (when they were very scarce). Microspheric young were observed only in the winter of 1964. However, we should emphasize again that the conclusions drawn concerning this species are not completely reliable, as too few specimens were found. The data obtained with respect to the periodicity of reproduction supported the conclusions reached in the previous paper (Boltovskoy, 1964), namely, that this species reproduces throughout the year.

**Buccella frigida** (Cushman)

The criterion used to separate young specimens from adult ones was test size; all tests smaller than 0.2 mm. were considered to be young. The maximum diameter of adult tests was 0.497 mm.

Table 1, fig. 6A shows the number of living specimens of this species found in different months. Fig. 6B shows the percentage of young live specimens with respect to total number of living individuals.

It can be seen that two pronounced blooms took place during the time of our study, both in warm months. In 1964 a bloom took place in November, and in 1966 in January. It is interesting to mention that the blooms of young individuals in 1964 took place in August and in 1965 in November. Thus we can conclude that the specimens of this species need about 2-3 months to change from young ones to specimens considered by us to be adults.

The analysis of the observations obtained reveals that *B. frigida* started reproduction in late winter.
and finished in early summer. Thus its period of reproductive activity is about eight months. In 1964, B. frigida began its cycle earlier than in 1965. We are inclined to consider that this species lives about a year, but, owing to the rather limited number of living specimens found, B. frigida could not be studied thoroughly enough and the graphs obtained may not be very accurate.

**FORAMINIFERAL POPULATION AS A WHOLE**

Of the species listed above, only *Elphidium gunteri* was characterized by pronounced peaks dur-

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**TABLE 2**

<table>
<thead>
<tr>
<th>Month</th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
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</thead>
<tbody>
<tr>
<td>Mean Monthly Temperature (°C)</td>
<td><img src="image" alt="Graph of Mean Monthly Temperature" /></td>
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<td></td>
</tr>
<tr>
<td>Number of Living Specimens</td>
<td><img src="image" alt="Graph of Number of Living Specimens" /></td>
<td></td>
<td></td>
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</tbody>
</table>

Mean monthly temperature and seasonal quantitative variations of the entire foraminiferal population in the Quinta Island area.
ing the warm months. *Buccella frigida* had only a secondary bloom during the summer of 1965/66, however, the first one occurring in the spring of 1964. The histograms of the development of the other species are not absolutely uniform, but they nevertheless show the greatest outburst in the winter of 1964.

According to data in the literature (see Boltovskoy, 1964, p. 136) and the results obtained in the previous study of a nearby locality (Boltovskoy, 1965a, text fig. 1), the bloom of benthic Foraminifera takes place in the summer months and/or (much fewer data) in the spring and fall. Thus, the quantitative abundance in the winter of 1964 seems unusual and rather strange.

Table 2 shows the seasonal quantitative variations of the entire foraminiferal population in the area studied. The greatest number of specimens was found also during the winter months of 1964. In the summer of 1964/65, the foraminiferal fauna was quantitatively poor. In the summer of 1965/66 another bloom took place, but this was considerably smaller than that of the winter of 1964. Thus, the data concerning the whole foraminiferal fauna coincide very well with the data obtained on the species cited above, although they do not agree well with that in the literature.

Unfortunately, with the data available we cannot give an exact explanation of the difference found between the seasonal changes in benthic Foraminifera of the Quinta Island area observed by us in 1964-1966 and the results obtained by previous authors for other areas. We can suppose that the peculiar aspect of the Quinta Island foraminiferal development could be caused either by the specific content of the fauna in the area mentioned or by some local factors acting during the winter of 1964.

As for the former supposition, it can be admitted that there are some species which usually have their bloom in winter months. There are, for instance, even observations confirming a winter maximum abundance of planktonic Foraminifera (Cheng & Cheng, 1964). But we do not think that this is the case for all the Foraminifera in the Quinta Island area that showed an outburst in the winter of 1964. *Rotalia beccarii*, at least, probably belongs to a group of species which is characterized by a bloom in summer months. From the previous study (Boltovskoy, 1964) we know that just such a bloom (and really well pronounced) was observed in this species in 1962 and 1963. Thus, the winter bloom of *Rotalia beccarii* found in this study perhaps is explained by some local factors unique for the winter of 1964.

Concerning the supposition that local factors unique for 1964 created that bloom, unfortunately we have no data about the environmental conditions during the different months and seasons of our study. The only information we have is on monthly mean temperatures (see table 2, A). However, no correlation between the temperatures and the unusual bloom of the winter of 1964 exists. Certainly many other unknown factors could play decisive roles, as, for instance, decrease in the quantity of certain enemies of Foraminifera, or the high mortality of some groups of organisms which are not real enemies of Foraminifera but whose removal allowed the more abundant development of Foraminifera. At any rate it seems that one or more unknown factors conditioned the bloom. We cannot credit the abundance of foraminiferal specimens found in the winter of 1964 to an error in sampling. Collections were made regularly and by experienced technicians. Eight samples taken monthly are, we believe, sufficient to produce reliable data on the foraminiferal population taken as a whole.

**STANDING CROP**

**Generalities**

The term "standing crop" (or "standing stock") for the benthos is used to denote the organisms that live at a given time in a determined area on the bottom. It is important to know the standing crop, because the areas with a large standing crop are those where productivity is also high. All the groups of the organic world are related to each other, and knowledge of the standing crop of one group gives some idea of the general standing crop of the area in question. The standing crop changes according to the seasons of the year, months, or even shorter periods, but it is always possible to calculate the average standing crop in terms of the number of specimens, in biomass (live weight), dry weight, volume, etc.

The benthic Foraminifera can easily be utilized to calculate the standing crop, since they live in almost all marine environments, including areas of low salinity, and inhabit all depths. To calculate the standing crop of the benthic Foraminifera is of interest not only in the study of productivity, but also for geological purposes. To understand better the calcium regime in oceanic waters, we need to study the rate of accumulation of foraminiferal tests on the bottom, inasmuch as these represent an important source of calcareous material on the sea floor. Moreover, by studying this rate we are able to draw other conclusions of a marine geological character.

The calculation of the foraminiferal supply has been carried out by different authors by counting the living Foraminifera per unit volume of sediment, specifically the number of Foraminifera in a sample (sediment saturated with water) which had a volume of 10 ml. Phleger (1960) established that in the majority of the samples this number fluctuated between 50 and 200. However, in some places it was higher than 1,000, and even could
reach 3,500 (Mississippi River delta). Although these data give a general idea of the quantity of the benthic Foraminifera, they do not reveal the real standing crop.

The calculation made by Walton (1955) comes closer to the correct representation of a standing crop. He counted the quantity of living specimens in a determined volume and related this number to a specified area of bottom surface.

Lankford (1959), Phleger (1960, 1964), Lynts (1966) and Saidova (1967) counted the number of living specimens per square centimeter or square meter. Since they took into consideration only the one or two upper centimeters of sediment, however, their results do not represent a real standing crop. Boltovskoy (1966) has shown that benthic Foraminifera can survive within the sediments to depths of 16 cm. beneath the surface of sediments on the sea floor, so to calculate the standing crop of the benthic Foraminifera one must study the sediments at least to that depth.

**METHOD FOR MEASURING THE STANDING CROP**

We started the calculation of the standing crop in the area studied by counting the Foraminifera in each sample. The following are the average number of living specimens per sample gathered in different months:

<table>
<thead>
<tr>
<th>Depth s In Core</th>
<th>Specimens per cc</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Numbers Of Specimens At Different Depths In Core</strong></td>
<td><strong>(According to Boltovskoy, 1966)</strong></td>
</tr>
<tr>
<td><strong>Depth in cm.</strong></td>
<td><strong>Specimens per cc</strong></td>
</tr>
<tr>
<td>0 - 2</td>
<td>1.06</td>
</tr>
<tr>
<td>4 - 6</td>
<td>0.36</td>
</tr>
<tr>
<td>8 - 10</td>
<td>0.26</td>
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<tr>
<td>12 - 14</td>
<td>0.23</td>
</tr>
<tr>
<td>16</td>
<td>0.08</td>
</tr>
</tbody>
</table>

The monthly average is 23.67 specimens per sample. Since the sampling tube had a transverse section equal to 8.24 square centimeters, in one square centimeter there are 2.87 specimens (23.67 ÷ 8.24). This number takes into account only the two uppermost centimeters of each sample. To calculate the real standing crop, one must count the living specimens more deeply buried. For this operation we used the table given by Boltovskoy (1966), which shows the number of living Foraminifera found to a depth of 16 cm. in the cores from the top to 16 cm. This table, reproduced below, was prepared on the basis of the material extracted in Puerto Deseado, mainly in the Quinta Island area, so the data can be used in the present calculation.
lent to the annual productivity. If a species reproduces more than once a year, to determine the annual productivity it is necessary to multiply standing crop by the number of periods of reproduction. Certainly this is only a very generalized scheme. As Murray discusses later, the exact calculation of productivity is much more complicated, because productivity depends on the following four main factors: "The initial size of the standing crop, the proportion of individuals which reproduce, the frequency of reproduction, and the number of new individuals resulting from each reproductive phase" (Murray, 1967, p. 62).

We are still too far from understanding these four factors in regard to the benthic Foraminifera. Therefore the considerations on benthic foraminiferal production discussed below are only the first step, and the figures obtained are in no way exact.

Foraminiferal Production
In the Quinta Island Area

Method and Results
As determined above, the average standing crop in the Quinta Island area is 9.24 specimens of Foraminifera per square cm. Only a few species there reproduce once a year (Buccella frigida, Elphidium macellum, Quinqueloculina seminulum, and probably a few others), and their representatives are not numerically conspicuous. We can conclude (admittedly arbitrarily) that they probably compose about 6% of the total population (0.55 specimens of the standing crop). The remaining 94% (8.69 specimens of the standing crop) is composed of species with reproductive cycles of shorter periodicity. The periodicity in reproductive cycles of Foraminifera is not well known, but it has been observed generally to be shorter in species of smaller size. The foraminiferal fauna of the Quinta Island is almost exclusively of small forms. For the present calculations we can accept that on the average the period of the reproductive cycle of the species that compose 94% of the total population (8.69 specimens of the standing crop) is one month. Thus, the annual production per square cm. on the bottom in the Quinta Island area is 0.55 + (8.69 \times 12) = 104.83, or approximately 105 specimens per square cm. per year. For a square meter the annual production of benthic Foraminifera in the Quinta Island area would then be about 1,050,000 specimens.

To calculate productivity in terms of biomass, we did the following: 2,800 specimens of Rose Bengal-stained Foraminifera were successively picked from dry bottom sediments taken in the Quinta Island area. They were weighed, calcined at a temperature of about 500°C, and weighed again. The difference between the two weights was 12.4 mg.; this, then, being the weight of the dry protoplasm of the 2,800 tests. Consequently the weight of protoplasm of 1,050,000 specimens is equal to 4,650 gr. Thus, we can conclude that the annual productivity of benthic Foraminifera in one square meter in the Quinta Island area, expressed in terms of dry biomass, is 4,650 gr. We must emphasize once more, however, that the above calculation does not pretend to be exact and represents only a rough estimate of annual production. With these data we wished only to indicate one of the possible approaches to the problem of productivity in benthic Foraminifera.

RELATIONSHIP BETWEEN LIVING AND DEAD SPECIMENS
An examination of the relationship between the number of living specimens and the number of dead (or the total number of specimens) can give an idea about the rate of sedimentation. If productivity is known, the rate of sedimentation can be calculated, but if productivity is unknown, the relationship to be discussed here can give ideas about the relative depositional rate in various places. Usually this relationship is expressed by the letter "R" and the result, for convenience, is multiplied by 100. Thus, the entire formula is:

\[ R = \frac{\text{number of living Foraminifera}}{\text{number of dead Foraminifera}} \times 100 \]

A large "R" signifies fast, a small "R" slow deposition. This problem is discussed in detail by Walton (1955) and Phleger (1960, 1964).

The following are monthly values for "R" for the Foraminifera from the Quinta Island area:

<table>
<thead>
<tr>
<th>Month</th>
<th>1964</th>
<th>1965</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>February</td>
<td>February</td>
</tr>
<tr>
<td>March</td>
<td>23.4</td>
<td>15.1</td>
</tr>
<tr>
<td>April</td>
<td>30.5</td>
<td>5.6</td>
</tr>
<tr>
<td>May</td>
<td>43.5</td>
<td>9.4</td>
</tr>
<tr>
<td>June</td>
<td>31.8</td>
<td>26.3</td>
</tr>
<tr>
<td>July</td>
<td>27.2</td>
<td>28.6</td>
</tr>
<tr>
<td>August</td>
<td>32.1</td>
<td>6.7</td>
</tr>
<tr>
<td>September</td>
<td>19.1</td>
<td>14.6</td>
</tr>
<tr>
<td>October</td>
<td>12.1</td>
<td>4.2</td>
</tr>
<tr>
<td>November</td>
<td>26.2</td>
<td>11.3</td>
</tr>
<tr>
<td>December</td>
<td>28.9</td>
<td>7.4</td>
</tr>
<tr>
<td>January</td>
<td>50.0</td>
<td>28.2</td>
</tr>
</tbody>
</table>

The results here presented are rather contradictory: "R" appears to be quite different in different months, and monthly average values of 1964 do not correspond to those of 1965. Therefore, we prefer not to draw conclusions with respect to the sedimentation rate on the basis of the "R" values obtained. However, the table presented above is of some interest and, perhaps, can be used in future investigations.
SUMMARY

The material studied for this paper was collected weekly during a two-year period (February, 1964 to March, 1966) with a Lankford coring tube in the Quinta Island area, Puerto Deseado, Patagonia. All specimens containing protoplasm—in all about 9,000—were picked out, identified and counted. In order to get an idea about reproductive rhythms, the young individuals were separated from the adult ones in the most abundant species. Histograms of the whole population by month and of the percentages of the young individuals were drawn for the following six species: *Balaminella elegantissima*, *Elphidium articulatum*, *Epistominella exigua*, *Elphidium gunteri*, *Rotalia beccarii* and *Buccella frigida*. A histogram that represents the changes in the total number of the entire foraminiferal assemblage of the area under study was also prepared.

It was found that all the species cited above, except *Elphidium gunteri* and *Buccella frigida*, showed the greatest bloom in the winter of 1964. The same was observed in the foraminiferal assemblage taken as a whole. *Elphidium gunteri* showed pronounced peaks during the warm months, *Buccella frigida* exhibited outbursts in the spring of 1964 and in the summer of 1965/66. Winter blooms in benthic Foraminifera are unusual and had previously not been recorded. Unfortunately, it was impossible to explain them, as the data available concerning environmental conditions were inadequate. However, the possibility cannot be excluded that several foraminiferal species are more numerous during the cold months.

It was established that young specimens of *Balaminella elegantissima*, *Elphidium articulatum*, *Epistominella exigua*, *Elphidium gunteri* and *Rotalia beccarii* were found practically every month. This indicates that these species reproduce throughout the year. *Buccella frigida* apparently reproduces but once a year.

The standing crop was determined for the whole benthic foraminiferal assemblage by taking into account the maximum depth to which living Foraminifera can penetrate in sediments. The average standing crop in the Quinta Island area is 9.24 specimens per square centimeter.

The annual production per square meter on the bottom was calculated to be 1,050,000 specimens. Although this number is only approximate, we considered it of interest. Undoubtedly more attention should be given to the study of foraminiferal production. Recent investigations have revealed that this group plays a very important role in the biological production of the ocean, at least in some areas (for instance, at great depths). The annual production in one square meter, expressed in terms of dry weight, was calculated to be 4.650 gr.

The relationship between living and dead specimens was determined for each month. It fluctuated from 5.6 to 50.

ACKNOWLEDGEMENT

Grateful acknowledgement is made of the assistance of Mr. P. Medina and Mr. I. Zizich, technicians of the Puerto Deseado Marine Biological Station, for collecting all the samples during the two-year period of this study.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XX, PART 3, JULY 1969

368. *TOSAIA LOWMANI*, A NEW SPECIES FROM OFF THE
PACIFIC COAST OF PANAMA

GEORGE A. SEIGLIE and PEDRO J. BERMÜDEZ

INTRODUCTION

The purpose of this note is to describe a new species of the genus *Tosaia*. This paper is part of the project on Panama of the Marine Biology Program, Puerto Rico Nuclear Center.

This small foraminifera has, at first glance, the appearance of a planktonic foraminifer resembling *Globigerinita uvula* (Ehrenberg) in shape. However, no planktonic foraminifera occurred in the sediment of the station where the sample was collected or in the plankton samples of the same station.

Thanks are given to Dr. John H. Martin, Marine Biology Program, Puerto Rico Nuclear Center, for the plankton samples of station 45 and to Miss Vicki Weber, Temple University, Philadelphia, for her help in translating this paper.

SYSTEMATICS

*Tosaia lowmani* Seiglie and Bermúdez

Text figures 1 to 15

Description.—Test small, the shape that of a bunch of spiny spheres.

Megaspheric form: diameter greater than height, trochospiral, two to three whorls with four chambers per whorl; proloculus relatively large, diameter from 0.022 to 0.034 mm.; wall calcareous, finely perforated and hispid; aperture a small arch or slit provided with a poorly defined lip, in some specimens the aperture appears to be partly closed; height from 0.085 mm. to 0.0144 mm.

Microspheric form: test elongated, early portion trochospiral, with one to one and a half whorls, then triserial, with a total of three to six chambers; proloculus relatively small, diameter from 0.017 to 0.027 mm.; wall calcareous, finely perforated and hispid; aperture, a small slit provided with a lip projecting as a pointed flap from the aperture; length from 0.137 to 0.187 mm., width from 0.115 to 0.155 mm.

Age.—Recent.

Types.—The holotype (text figure 1a-b) and ten paratypes (text figures 2 to 11) were deposited at the U. S. National Museum, and four paratypes (text figures 12 to 15) were deposited at the American Museum of Natural History.

Type locality.—The type locality is station 45, Nuclear Center of Puerto Rico project on Panama, southwest off the mouth of Tapia River, Panama: 8°58′15″ North Latitude and 79°25′15″ West Longitude, Pacific Ocean, at a depth of 5.6 meters. Surface temperatures were from 22.5°C to 28.0°C, and surface salinities from 28.0 to 34.4 parts per thousand.

Remarks.—This species differs from *Tosaia weaveri* Seiglie and Bermúdez in its hispid surface.

EXPLANATION OF TEXT FIGURES 1-15

1a-b. Holotype, microspheric form, length 0.187 mm., width 0.155 mm., prolocular diameter 0.024 mm.
2. Paratype, megalospheric form, maximum diameter 0.114 mm., height 0.085 mm.
3. Paratype, microspheric form, width 0.137 mm.
4. Paratype, megalospheric form, maximum diameter 0.113 mm., prolocular diameter 0.034 mm.
5. Paratype, microspheric form, length 0.172 mm.
6. Paratype, megalospheric form, maximum diameter 0.114 mm., prolocular diameter 0.022 mm.
7. Paratype, microspheric form, length 0.115 mm., prolocular diameter 0.020 mm.
8. Paratype, megalospheric form, maximum diameter 0.102 mm., height 0.096 mm.
9. Paratype, megalospheric form, maximum diameter 0.141 mm.
10. Paratype, maximum diameter 0.113 mm., height 0.085 mm.
11. Paratype, megalospheric form, maximum diameter 0.130 mm.
12. Paratype, megalospheric form, maximum diameter 0.137 mm., length 0.137 mm., prolocular diameter 0.025 mm.
13. Paratype, microspheric form, width 0.145 mm.
14. Paratype, microspheric form, width 0.146 mm.; prolocular diameter 0.017 mm.
15. Paratype, microspheric form, width 0.153 mm., length 0.187 mm., prolocular diameter 0.022 mm.
differentiation of megalospheric and microospheric forms, and its somewhat larger size. It differs from *T. hanzawaia* Takayanagi and from *T. loeblichii* Souaya in its hispid surface, its lack of a biserial stage, and its smaller size.

The oldest of the three known species of the genus is *Tosaia weaveri*, from which evolved a deep water species, *T. hanzawaia*, and a shallow one, *T. lowmani*, sp. n. A trend in the evolution of these species is from no differentiation of megalospheric and microospheric forms in *T. weaveri* and *T. hanzawaia* to differentiation both in the size of
the proloculus and in the arrangement of chambers in *T. lowmani*, n. sp. No comparison with *T. loeblichii* is possible until more detailed information on that species is available.

![Text Figure 16](image)

**TEXT FIGURE 16**

Relationships between the size of the proloculus and the maximum diameter (or width of the test).

Text figure 16 shows the relationships of the size of the proloculus and the width of the test for the megalospheric and microspheric forms of *Tosaia lowmani*.

The following foraminiferal fauna occurs in station 45, the type locality, (percentages are given in relation to the total foraminiferal population):

- *Reophax* sp. cf. *R. communis* Lacroix 0.3%
- *Textularia* sp. 0.3%
- *Elphidium poeyanum translucens* Natland 12.0%
- *E. spinatum* Cushman and Valentine 0.3%
- *E. sp.* 9.5%
- *Ammonia sarmientoi* (Redmond) 2.5%
- *A. sp. cf. A. tepida* (Cushman) 40.7%
- *Ammonmarginulina foliacea* (Brady) 0.3%
- *Florilus grateoloupii basispinatus* (Cushman and Moyer) 1.6%
- *Tosaia lowmani* sp. n. 32.5%

The trivial name is given in honor of Mr. Frank Lowman, Marine Biology Program, Puerto Rico Nuclear Center at Mayaguez, Puerto Rico.

**BIBLIOGRAPHY**


A solitary specimen of *Astacolus reniformis* (d'Orbigny) possessing an aperture not in its usual terminal position at the peripheral angle of the last chamber was found by the author in a sample taken by the USC & GSS Oceanographer from a station (coordinates 28°15.6' south latitude; 113°15.5' east longitude) located southwest of Gantheaume Bay off the coast of West Australia, in the Indian Ocean. The sample, serial No. 166, was taken in August, 1967, from a depth of 402 meters with a main-pipe dredge, and part of the recovery was brought back by N. S. Haile, Professor and Head, Department of Geology, University of Malaya, who was a Visiting Scientist aboard the vessel during the seventh (Penang-Fremantle) leg of the ship's global cruise.

The unusual specimen (text fig. 1) has a radiate aperture that is slightly posterior to the terminal peripheral angle of the last chamber. Common techniques of examining specimens in transmitted light enabled the author to get a clear picture of the internal structure of the specimen and to conclude that the abnormally placed aperture was present in the last chamber only.

There is no other record of such an abnormal specimen of *Astacolus reniformis* (d'Orbigny) in the literature, but there are records of abnormal specimens of *Uvigerina canariensis* d'Orbigny forma *distoma* De Amicis (1895) from the Lower Pliocene of Sicily; *Uvigerina curta* Cushman and Jarvis (1929) from the Eocene of Trinidad, and *Uvigerina cocoaeensis* Cushman, which was reported by Samuel P. Ellison, Jr. (1953) from the Upper Eocene of Mississippi.

Speculation would suggest that the peculiar development of the aperture posterior to the terminal peripheral angle of the last chamber may have been caused by some ecological factor, but the possibility that it could have resulted from an injury, disease or mutation is not ruled out.

This peculiar, teratological specimen of *Astacolus* is likely to be a problem to taxonomists, because the genus, according to Montfort (1808), or the subfamily, according to Ehrenberg (1838), are defined as possessing a terminal, radiate aperture. No category has been recognised with an aperture that is not terminal at the peripheral angle, and the author, because of the rarity of the specimen, has not been tempted into establishing a new species. Moreover, zoological nomenclatural practice does not commonly emend generic or subfamily definitions in order to include abnormal forms.

The figured specimen is R.R.C. No. 5963 in the Reference and Research Collection, Department of Geology, University of Malaya, Kuala Lumpur.

**REFERENCES**


CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION FOR FORAMINIFERAL RESEARCH
VOLUME XX, PART 3, JULY 1969

370. A NEW PLANKTONIC FORAMINIFER FROM THE LATE TERTIARY OF CAR NICOBAR ISLAND, BAY OF BENGAL
M. S. SRINIVASAN and V. SHARMA
Geology Department, Banaras Hindu University, India

ABSTRACT
The new planktonic species Globorotalia nicobarica Srinivasan and Sharma from the late Tertiary Sawai Bay Mudstone Formation is described and illustrated.

INTRODUCTION
Schwager (1866) described and illustrated numerous smaller Foraminifera from Car Nicobar Island, Bay of Bengal. The new species Globorotalia nicobarica was encountered during a detailed study of the foraminifera from a late Tertiary mudstone formation of Car Nicobar Island. This planktonic species, though rare, appears to have a short stratigraphic range and may prove useful in helping determine the Miocene/Pliocene boundary in the tropical Indo-Pacific belt.

Super Family GLOBIGERINACEA Carpenter
Family GLOBOROTALIIDAE Cushman
Subfamily GLOBOROTALINAE Cushman
Globorotalia nicobarica Srinivasan and Sharma, n. sp.

Text figures 1-6

Holotype Description.—Test free, small, low trochospiral, sinistrally coiled, the umbilical side slightly concave, equatorial periphery lobulate, axial periphery sub-angular with a very thin keel. Wall calcareous, perforate, umbilicus small, shallow, umbilical surface slightly roughened, spiral side comparatively smooth. Chambers spherical to sub-angulare in outline; five to six in the final whorl, increasing rapidly as added. Sutures both on umbilical and spiral sides radial to slightly curved and slightly depressed. Aperture a low slit, slightly arched, with a lip, interiomarginal umbilical, extrumbilical.

Dimensions of Holotype.—Length, 0.28 mm.; breadth, 0.24 mm.; thickness, 0.14 mm.

Type Specimens.—Geology Department, B.H.U., Register No. F/1, holotype and 5 paratypes - No. Fp/1.

Type Sample.—S 87 C/Mf 41, Grid ref.: 9245912; moderately hard, highly calcareous, light grey mudstone of Sawai Bay Formation; about 180 meters east of Passa Bridge, along the motor road, Car Nicobar Island. Collected by Mr. V. Sharma in 1967, and recollected by Dr. Srinivasan in 1968.

Remarks.—Although Globorotalia nicobarica is a rare species in the late Tertiary of Car Nicobar, it can easily be distinguished from other recorded species of Globorotalia by the following features:

a. Axe-shaped triangular final chamber.
b. The final chamber is nearly twice that of the penultimate chamber.

Dextrally and sinistrally coiled specimens are equally common.

Age of the Type Sample.—The planktonic foraminifera from the type sample are of particular interest because of the evidence they provide in determining the faunal relation between the Indian and Pacific tropical late Tertiary deposits. The type sample has yielded the following 32 planktonic species in addition to the new species described:

Chilougembelina globigerina (Schwager)
Candeina nitida d’Orbigny
Globigerinita glutinata (Egger)
Globigerina bulloides d’Orbigny
G. falconensis Blow
G. decoraperta Takayanagi and Saito
Globigerinella siphonifera (d’Orbigny)
Globigerinoides conglobatus (Brady)
G. obliquus Bolli
G. ruber (d’Orbigny)
G. sacculifer (Brady)
G. trilobus (Reuss)
Hastigerina pelagica (d’Orbigny)
Orbulina universa d’Orbigny
O. universa (bilobate var.)
Sphaeroidinella seminulina (Schwager)
S. multiloba Le Roy
S. subdehiscens Blow
Globoquadrina acostaensis (Blow)
G. altispira (Cushman and Jarvis)
G. conglobulata (Schwager)
G. hexagona (Natland)
G. humerosa (Takayanagi and Saito)
Pulleniatina primitiva Banner and Blow
Globorotalia cibaeensis Bermudez
G. cf. margaritae Bolli and Bermudez
G. menardii (d’Orbigny)
G. multicamerata Cushman and Jarvis
G. panda Jenkins
G. plesioutumida Banner and Blow
G. scintula (Brady)
G. tumida tumida (Brady)

In addition to the above species, the type sample contains Pulleniatina intermediate between primitiva and praecursor.

The diagnostic assemblage of Candeina nitida, Pulleniatina primitiva, Globorotalia plesioutumida, G.
CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION FOR FORAMINIFERAL RESEARCH

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ACKNOWLEDGEMENTS

Thanks are expressed to Dr. F. T. Banner for his comments on Pulleniatina from the type sample, and to Dr. D. G. Jenkins for kindly going through the manuscript and for his helpful advice. Financial support was received from the C.S.I.R., Government of India.

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371. MIOCENE FORAMINIFERA FROM HUT BAY, LITTLE
ANDAMAN ISLAND, BAY OF BENGAL
M. S. SRINIVASAN
Geology Department, University College London, U.K.

ABSTRACT

Late Tertiary sediments containing abundant smaller foraminifera are recorded for the first time from Little Andaman Island, Bay of Bengal. Eighty-six benthonic and twenty-five planktonic species are recorded from a mudstone sample of Middle Miocene (Tortonian) age. A benthonic foraminiferal assemblage including Valvulina, Karreriella, abundant Nodosaridae, Stilostomella, Osangularia, Oridorsalis prominula and abundant planktonics indicates deposition of the mudstone at approximately middle bathyal depths.

INTRODUCTION

The Andaman and Nicobar Islands, in the Bay of Bengal, trend almost north-south between 6°45' and 14° north latitudes. The islands represent peaks of a prominent oceanic rise extending from the mountain ranges of western Burma and continuing in a south-easterly direction through the Islands of Sumatra and Java.

Little Andaman Island lies between south Andaman Island and the Nicobar group and is about 96 kilometers south of Port Blair (text fig. 1). The island is approximately 43 kilometers long and 24 kilometers wide, of very low relief and covered with thick forests.

Geological investigations date back to 1859, when the Austrian frigate Novara first visited Car Nicobar, but, on the whole, the Andaman and Nicobar groups of islands have received little attention from geologists, despite the fact that the two ends of this oceanic rise (Burma in the north and Sumatra in the south-east) are potentially very rich in petroleum and natural gas.

Gee (1927) was the first geologist to visit Little Andaman. He reported an exposure in Jackson Creek, in the north-west, of fine light green, slightly micaceous sandstones resembling sediments at Port Blair, South Andaman. From the northern point of Hut Bay, in the south-east, he reported the occurrence of white and cream coloured Lithothamnion limestone and coral rock, also the first occurrence of Tertiary foraminifera and algae from these deposits, consisting of small nummulites, Textularia, and fragments of Lithothamnion.

A few samples were collected by the author from Hut Bay, Little Andaman in March, 1968, for micropaleontological study. The present paper records the occurrence of a late Tertiary mudstone formation on Little Andaman Island, similar to that observed by the writer on Long, Car Nicobar, Kamorta and Nancowry Islands. The mudstone occurred in a drill hole about 200 meters off-shore at Hut Bay, 4.3 meters below the sea floor (coral rock), where the depth of the sea was 15 meters.

Foraminifera from the mudstone are of particular biogeographic interest because of the island's position and the paucity of knowledge of Cenozoic foraminifera in the region.

The 111 species of benthonic and planktonic foraminifera found there are recorded below, the most abundant being marked with an asterisk:
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FIG. 1 LOCATION MAP

* Mudstone sample location

L. laevis (Montague)
L. cf. sulcata (Walker and Jacob)
Lagenonodosaria scalaris (Batsch)
Laticarinina pauperata (Parker and Jones)*
Marginulina sp.
Massilina sp.
Neouvigerina proboscidea (Schwager)*
Nodosaria costai Schwager
N. domaiensis Le Roy*

N. cf. exilis Schwager
N. hochstetteri Schwager
N. insecta Schwager
N. insolita Schwager
N. longiscata d'Orbigny
N. pyrula d'Orbigny
N. cf. subertenuata Schwager
N. tornata Schwager
N. aff. uniforminata Le Roy
N. vertebralis (Batsch)
Nodosaria sp.
Oridorsalis prominula (Stach)*
O. rosiculiformis (Schwager)
Osangularia bengalensis (Schwager)*
Planulina wuellerstorfi (Schwager)*
Plectofrondicularia parri Finlay
Proxiropina foliacea (Schwager)
Pullenia bulloides (d'Orbigny)*
Quinqueloculina seminulum (Linné)
Rectubolivina aff. striatula (Cushman)
Reussella sp.
Robulus foliatus (Stach)
R. rotus (Cushman)
R. nicobarenensis (Schwager)*
R. politus (Schwager)
R. aff. subumbonatus (Cushman)
Ruakirtia magadalidaeformae (Schwager)
Saracenaria italica Defrance
Semiavulina sp.*
Sigmolopsis asperula (Karrer)
Sphaeroidina bulloides d'Orbigny
Spiroloculina canaliculata d'Orbigny
Stilostomella adolphina (d'Orbigny)
S. lepidula (Schwager)*
Textularia sp.*
Trifarina halkyardi (Cushman and Edwards)
Triplasia tricarinata (LeRoy)*
Vaginulina vagina d'Orbigny
Valvulineria araucana (d'Orbigny) var. malagensis Kleinpell*
Vulvulina nicobarica (Schwager)*

PLANKTONIC FORAMINIFERA
Globigerinina glatitana (Egger)
Globigerina bullosa Le Roy
G. decoraperta Takayanagi and Saito*
G. bulboides d'Orbigny*
Globigerinella siphonifera (d'Orbigny)*
Globigerinoidea apertasuturalis Jenkins
G. bolli Blow
G. immaturus Le Roy*
G. ruber (d'Orbigny)*
G. trilobus (Reuss)*
Globorotaloides hexagona (Natland)*
Orbulina universa d'Orbigny*
O. universa d'Orbigny, bilobate var.
O. suturalis Bronnimann
Sphaeroindina multiloba Le Roy
Globorugina altispira (Cushman and Jarvis)*
G. venezuelana (Hedberg)*
Globorotalia acostaensis Blow*
Globorotalia cf. barisanensis Le Roy
G. cibaoensis Bermudez
G. opima continuosa Blow
G. mayeri Cushman and Ellisor*
G. merotumida Banner and Blow
G. scitula (Brady)*
G. aff. tumida (Brady)

AGE

The mudstone fauna closely resembles late Tertiary faunas described from Vitilevu, Fiji (Cushman, 1934), Central Sumatra and West Java (Le Roy, 1944), and from Noto Peninsula, Ishikawa Prefecture, Japan (Asano, 1953).

It contains a planktonic assemblage of Globorugina altispira (Cushman and Jarvis), Globorotalia acostaensis (Blow), Globorotalia aff. tumida (Brady), Globorotalia cf. merotumida Banner and Blow and Globorotalia opima continuosa Blow, but a lack of Pulleniata suggests that the sample was obtained from a horizon within Zone N. 16. ["Globorotalia (Turborotalia) acostaensis (S.S.) - G. (G.) merotumida partial range zone") of Banner and Blow (1965b), which they correlated with the Tortonian Stage (Middle Miocene).

Two species, Eouvigerina hispida (Schwager) and Bolivinita quadrilatera (Schwager), are of considerable value in Miocene stratigraphy of the Indo-Pacific region. Finlay (1947, table 1) pointed out that "Hopkinsina" notohispida (a member of the hispida lineage) first makes its appearance in New Zealand in beds which he correlated with the Helvetian. The distinctive and widespread hispida group was also recorded from the Burdigalian of Venezuela (Senn, 1940) and from the Middle Miocene of Japan (Asano, 1953). Records of this species in the literature suggest that the hispida group appeared in the Indo-Pacific region during Middle Miocene time, and ranges up through the Upper Miocene, accompanied by Bolivinita quadrilatera. The second form, Bolivinita quadrilatera (Schwager), a widely recorded late Tertiary Indo-Pacific species, first makes its initial appearance in the Tongaporutuan Stage (Messinian) in New Zealand. Elsewhere in Car Nicobar, the Philippines, Java, Sumatra, Fiji, and Manus Island, Papua, this species is only found associated with a late Miocene planktonic assemblage. Thus it appears to be a reliable index species for recognising the Upper Miocene in the Indo-Pacific region.

The presence of the Middle Miocene marker species Eouvigerina hispida (Schwager) and, at the same time, the absence of the Upper Miocene index species Bolivinita quadrilatera (Schwager) suggests a Middle Miocene age for the mudstone sample.

Both planktonic and benthonic foraminiferal species suggest that the mudstone sample is of Upper Middle Miocene (Tortonian) age.

PALEOECOLOGY

The most characteristic features of the mudstone microfauna are the relatively high percentage of planktonic foraminifera (constituting about 70 per cent of the specimens) and the diversity and abundance of benthonic foraminifera. Representatives of the Miliolina and the Elphidiidae, important
world-wide elements of inner-shelf faunas, are absent or sparse. The following benthonic species are common and are diagnostic of deep-water biofacies: *Vulvulina nicobarica*, *Karrerriella bradyi*, *Bolivinita elegantissima*, *Chilostomella oolina*, *Laticarinina pauperata*, *Oridorsalis prominula*, *Osangularia bengalensis*, *Planulina wuellerstorfi*, *Pullenia bulloides*, *Hoeglundina elegans*, and abundant uniserial lagenids. The assemblage is considered to indicate the semipelagic biofacies (Vella, 1962), and the depth of deposition was probably greater than 600 meters.

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INTRODUCTION

The stratigraphic implications of the Carboniferous microfacies were initially developed in the study of the Russian Platform. During the last decade, this approach has been successfully extended to Western Europe, Western Asia and Arctic Siberia, where it is now considered a routine procedure.

The rapid extension of this Lower Carboniferous in the Tethyan realm is due to two factors:

1. The uniformity of the foraminiferal populations in the Tethys and, in particular, between Europe and North Africa (Durif, 1959; Deleau et Marie, 1961; Said and Andrawis, 1961; Mamet, 1962; Chanton, 1963; Solovjeva and Krasheninnikof, 1965; Omara and Wangerov, 1965). There is no apparent discrepancy between the phylogenetic development of the thirteen known families and approximately one hundred genera of calcareous secreted foraminifers among the different basins of these regions.

2. The rapidity of evolution and, hence, the possibility of recognizing 17 zones, which range from the Latest Famennian to the earliest Namurian.

These facts certainly compensate for the facies sensitivity of the foraminifers; moreover, discrepancies due to facies influence are partially eliminated if the comparison of the stratigraphic ranges is restricted to normal marine limestones from shallow depth (Mamet and Skipp, in press.) It is a fauna of such an environment that will be discussed here.

MICROFACIES

The microfauna of the Dolomitic Limestone Formation of the Um Bogma Region was first described in 1965 by Omara and Conil and attributed to the Tournaisian-Visean passage beds.

This conclusion was of particular potential importance for the paleogeography of the Carboniferous, since marine foraminifera-bearing Tournaisian or Early Visean sediments are often scarce or absent in most of Egypt and Libya. As the published material appeared to include known Middle Visean taxa (Mamet, Choubert and Hottinger, 1966), it seemed worthwhile to restudy the assemblage.

The microfacies encountered in the original material has been supplemented by additional thinner sections which disclose the presence of 19 Tethyan taxa; they can be grouped into three assemblages (text fig. 1):

1. Microfacies elements of long stratigraphic distribution.

Brunsiola pulchra Mikhailov and Brunsiola spirilinoides Grozdilova and Glebovskaja range from the Tournaisian to Late Visean, with a peak in Late Tournaisian-Middle Visean.

Similarly, Calciophora laevis Williamson, Earlandia clavatula (Howchin), Earlandinita sp., Endothyra sp., and Eotubertimea sp. are long ranging.

Calciophora pachysphaerica (Pronina), Endothyra prisca (Rauzer-Chernousova and Reitlinger), Endothyra of the group Endothyra similis, and Tetractus sp. appear in Late Tournaisian and flourish in Visean time.

None of these taxa, are, therefore, suitable for exact dating of the formation.

2. Visean elements.

Seven characteristic Visean taxa have been observed in the Dolomitic Limestone Formation and are here listed in the order of their appearance in the Tethyan realm.

Globoendothyra emend. appears in the earliest Visean; this genus is extremely important, as it is observed at that level, not only in Eurasia, but all over the Northern Hemisphere (Mamet, 1968).

The appearance of the family Archaediscidae is also a world-wide characteristic of Early Visean time (Mamet, 1965); in particular the appearance of Planoarchaeiscus sp. and Permodiscus sp. has been reported in the early Visean of practically all basins of the Northern Hemisphere. The family appears in particular at the base of the Carrière Lambert, the stratotype for the Lower Visean. In the Donbass as well as in the Urals, primitive representatives of Archaediscidae are restricted to the Visean and have never been observed in the Tournaisian (Malakhova, 1956; Lipina, 1955; Pronina, 1963; Smirnov et al., 1963; Tcherbakho et al., 1964; Ganelina, 1966; etc.), Planoarchaeiscus sp. and Permodiscus sp. are, therefore, characteristic Viséan foraminifera; they flourished in mid-Visean time. [Recently Conil (personal communication) has observed Planoarchaeiscus aegyptiacus in the Middle Visean (V2) of Belgium.] The only exception to this range is the reported occurrence of
**Planoarchaediscus** (Bogush and Yuferev, 1962) in the latest Tournaisian of Tian-Shian; however, this downward extension is doubtful, as the microfauna associated with these Archaediscidae is by no means characteristic of the Tournaisian.

### 3. Mid-Visean elements.

Rare, primitive *Konickkopora* sp. appear in highest V I b, but their outburst is characteristic of the Middle and part of the Late Visean.


The highest stratigraphic marker observed in the Dolomitic Limestone Formation is the genus *Draffania*. The form has been tentatively assigned by Omara and Conil (1965) to *Draffania biloba* Cummings, *incertae sedis*, originally described in the Visean Dochra Limestone of Scotland (Cummings, 1957). However, this taxon appears to be characteristic of the latest part of the Visean all
over Western Europe. Indeed, it has been reported in the latest Visean beds of the Archerbeck borehole (Cummings, 1961, p. 119) and in the latest Visean Second Abden Limestone (Ferguson, 1962). *Draffania biloba* Cummings has also been observed in the latest Visean of Morocco and Algeria, where it is well displayed in the V 3 c horizon (Mamet, *et al.*, 1966); it is also found at a similar level in Germany (IIIb and IIIγ), in southern France (Mamet, 1968) and in other regions of Western Europe.

The form observed in Egypt, however, is much smaller than the original *Draffania biloba* Cummings and its outer wall and central partition are much thinner, so it should preferably be referred to *Draffania quasibiloba* Fomina, 1960, a form described in the Aleksin of the Submoscovian syncline (Fomina, 1960, p. 116). Such primitive *Draffania* are also found in the S 2-D 1 of the United Kingdom (B. Olroyd, pers. comm.), and their first appearance is distinctive of the V 2 b in Belgium. In the U.S.S.R., the form ranges from Late Middle Visean to earliest Namurian, although this upper extension must be verified.

The base of the range-zone of *Draffania* is, therefore, Zone 13. This is consequently the oldest possible age for the Dolomitic Limestone Formation. No late Visean Tethyan foraminiferal indices (such as *Endothyranopsis crassa* (Brady) or *Archaeodiscus karreri* (Brady) have been observed.

**DISCUSSION**

The brachiopod *Actinoconchus lamellosus* (L’Eveillé), never observed in Belgium above Tournaissian time, and the foraminiferal family Archaeodiscidae, characteristic of the Visean, have both been recorded in the Dolomitic Limestone Formation of Omara’s Um Bogma Terrane (1965). Although the appearance of Archaeodiscidae is probably more significant than the presence of a Tournaissian taxon, Omara and Conil gave the Dolomitic Limestone Formation a non-committal Tournaissian-Visean passage-beds assignment. However, additional microfaunal evidence indicates that the Dolomitic Limestone Formation is much younger and should be attributed to the Late Middle Visean (V 2 b). In the same formation, the Carboniferous-Permian *Neospirifer* sp. has recently been discovered. Outside Egypt, *Neospirifer* sp. is present in the Lower Carboniferous (Visean) of the Kusnitz basin (USSR) (Besnosova, 1959).

The continental coal-bearing Upper Sandstone Formation, which conformably overlies the Dolomitic Limestone Formation, has been assigned to the Visean (Omara and Schultz, 1965) on account of microspores recovered from coal seam no. 3 in Um Thora (Um Bogma area). Moreover, a more precise stratigraphic age was attributed to this formation by Synelnikov and Kollerov (1959), who indicated that the spore spectrum of the El Bedaa-Thora coal (Um Bogma area) points to a late Visean age (CV 1). This later age is in accordance with the conformably underlying Late Middle Visean Dolomitic Limestone Formation.

The Dolomitic Limestone Formation of the Um Bogma Terrane offers superficial sedimentological resemblances with the classical marine Carboniferous exposures of Wadi Araba on the Western side of the Gulf of Suez. This similarity led Kostandi (1959) and Said (1962) to include the marine carbonates from opposite sides of the Gulf of Suez in a single lithostratigraphic unit, the Um Bogma “series.” They yield, however, completely different microfaunal associations. The Wadi Araba exposure embraces at least seven marine intercalations ranging from Westphalian C (or Early Moscovian, Solovjeva and Krasheninnikov, 1965) to Lower Stephanian (Omara and Kenawy, 1966). The Dolomitic Limestone Formation is Lower Carboniferous. Therefore, the lithological correlation of the carbonate sequences on opposite sides of the Gulf of Suez and their inclusion in a single Um Bogma “series” seems unwarranted. This conclusion, reached earlier by Omara (1965) and by Omara and Kenawy (1966), is emphasized again in the present paper.

**CONCLUSION**

The oldest possible age for the microfaunas encountered in the Dolomitic Limestone Formation of the Um Bogma Terrane, Egypt, is V 2 b, Zone 13, Late Middle Visean. This age is in agreement with the known paleogeography of the surrounding basins in which the mid-Visean transgression is widespread.

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

AMATO, V., and DROOGER, C. W. How to measure the angle $\gamma$ in the Miogypsiniidae.—Rev. Española Micropaleontologia, v. 1, No. 1, 1969, p. 19-24, text figs. 1-10 (diagrams).

ARNOLD, ZACH M. The uniparental species concept in the Foraminifera.—Trans. Amer. Microscop. Soc., v. 87, No. 4, Oct. 1968, p. 431-442, figs. 1-35 (on 2 pls.).—The variation observed among living specimens suggests that some generic separations are actually only variant forms of a single species.


BANDY, ORVILLE L. Paleoclimatology and Neogene planktonic foraminiferal zonation.—Giornale Geol., Ann. Mus. Geol. Bologna, ser. 2, v. 35, 1967, fasc. 2, 1968, p. 277-290, text fig. 1 (diagram).—Waters having summer surface temperatures of $6^\circ$C or less are characterized by a sinistral pachyderma polar fauna; those of 9-18$^\circ$C by a dextral pachyderma transitional fauna; and those of $18^\circ$C or more by a Globorotalia menardii fauna. A model on a bipolar scale shows incursions of the sinistral pachyderma polar fauna into low latitudes during later Miocene, middle Pliocene, and Quaternary.

BERGER, WOLFGANG H. Ecologic patterns of living planktonic Foraminifera.—Deep-Sea Research, v. 16, No. 1, Feb. 1969, p. 1-24, text figs. 1-5 (graphs), tables 1-6.—Abundances are correlated with food supply. Highest concentrations (North Pacific) are about a thousand times greater than the lowest ones (Sargasso Sea). Small specimens dominate in cold, phosphate-rich regions and large ones in warm, less fertile regions. Species distributions correlate equally well with surface temperatures and salinities and with subsurface parameters defining water masses. Depth distributions of living specimens and empty shells suggest turnover rates of a few days may be possible. Species depth patterns are similar for Pacific and Atlantic. Diurnal abundance variation is strongest among small species and in cold to temperate regions.

BERGREN, W. A. Micropaleontology and the Pliocene/Pleistocene boundary in a deep-sea core from the south-central North Atlantic.—Giornale Geol., Ann. Mus. Geol. Bologna, ser. 2, v. 35, 1967, fasc. 2, 1968, p. 291-311, text figs. 1-6 (graphs, diagram, correl. chart, evolution diagram, drawings).—In a 7-meter core, the base of the Quaternary—dated micropaleontologically by end of Globorotalia miocenica and transition from G. tosaensis to G. truncatulinoides at about 1.85 million years—coincides with the appearance of Globigerina inflata. Initiation of continental glaciation coincides with a marked cooling, denoted by increase in G. inflata and Globorotalia hirsuta and local disappearance of Pulleniatina obliquiloculata and Sphaeroidinella dehiscens, and is dated at about 0.9 million years.


BOLTOVSKOY, ESTEBAN. Living planktonic Foraminifera of the eastern part of the Tropical Atlantic.—Revue de Micropaléontologie, v. 11, No. 2, Sept. 1968, p. 85-98, pls. 1, 2, text figs. 1, 2 (maps).—Discussion of quantitative occurrence of 15 species, 3 having several forms. Based on plankton hauls obtained by ships of Equallon I and II expeditions.

Living planktonic Foraminifera at the 90° E meridian from the equator to the Antarctic.—Micropaléontologie, v. 15, No. 2, April 1969, p. 237-255, pls. 1-3, text figs. 1-4 (map, check list, graphs, chart), table 1.—Twenty-seven species and 5 water zones: equatorial, subtropical, transitional, subantarctic, Antarctic (low and high Antarctic subzones). Study based on 206 samples from the surface to 1500 meters depth in the Indian Ocean.


CHARRIER G., REYNALDO, and LAHSEN A., ALFREDO. Contribution à l'étude de la limite Crétacé-Tertiaire de la Province de Magellan, extrême-sud du Chili.—Revue de Micropaléontologie, v. 11, No. 2, Sept. 1968, p. 111-120, pl. 1, text figs. 1, 2 (map, range charts).—Three planktonic species indicating the placement of the basal Agua Fresca in the upper Paleocene and/or lower Eocene.


ESPIRITU, ERNESTO A., ORDONÉZ, ELVIRA P., and FLORES, MANUEL G. Biostratigraphy of Bondoc Peninsula, Quezon.—The Philippine Geologist, v. 22, No. 2, June 1968, p. 63-90, pls. 1-4, text figs. 1, 2 (maps), table 1.—Five formations, between Miocene and Pleistocene, dated by Foraminifera.

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Gámez, Héctor A. Algunas especies de Lagena y Fissurina (Foraminíferos) del Eoceno de Margarita, Venezuela.—Rev. Española Micropaleontología, v. 1, No. 1, 1969, p. 95-101, pl. 1.—Fifteen species, 5 new.


Hiltemann, H. Neuere paläontologische Daten zum Flysch-Problem.—Erdoel-Erdgas-Zeitschrift, Wien-Hamburg, Jahrb. 84, Heft 5, 1968, p. 151-157, text figs. 1-3 (graph, range chart, geol. sections), tables 1, 2.—Repeated cycles in Flysch begin with a Rhabdamminafauna and end at the top with a fauna of multilocular agglutinated species.


Hornibrook, N. de B. Distribution of some warm water benthic Foraminifera in the N. Z. Tertiary.—Tuatara, v. 16, No. 1, April 1968, p. 11-15.—Modern faunas of New Zealand and the equatorial Pacific are strikingly different due to climatic differences. But faunal differences were less marked in the Tertiary, hence the Tertiary temperatures are interpreted as warmer in variable amounts.
HOTTINGER, L. Foraminifères imperforés du Mésozoïque marocain.—Notes et Mem. Morocco Serv. Geol., No. 209, 1967, p. 1-168, pls. 1-20, text figs. 1-61 (diagrams, drawings, graph, maps, phylogenetic diagram, columnar sections, photomicrographs).—Well illustrated monograph includes 19 genera (4 new) and 2 subgenera (1 new). Over 40 species are described (14 species and 2 subspecies new and 1 given a new name). New are Rectocyclamina (generotype R. chouberti n. sp.), Pseudospirocyclina (generotype P. mayni n. sp.), Aliveosepta (generotype Cyclamina jaccardi Schrod 1894), Pseudopfenderina (generotype Pfenderina butterlini Brun 1962), and Streptocyclamina n. subgen. (type Pseudocyclus (Streptocyclamina) parvula n. sp.).


JENDRYKA, BRONISLAWA. On abnormal morphology of the genus Lenticulina Lamarck, 1804 (Foraminifera).—Acta Palaeont. Polonica, v. 19, No. 6, 1968, p. 631-643, pls. 1-3, text figs. 1, 2 (drawings).—Trochospirally coiled specimens are found in various species. Their placement in Darbyella is groundless as they are merely abnormal individuals.

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LANGER, WOLFHART. Neue Miliolacea (Foraminifera) aus dem mittleren Trias Kleinasiens.—Senckenbergiana lehthea, Band 49, No. 5, Dec. 16, 1968, p. 587-593, pl. 1.—Three new species and 1 new genus: Karaburunia (type species K. rendeli n. sp.) and 1 new subspecies: Eooophthalmium (type species Praeoophthalmium (Eooophthalmium) tricki n. sp.) from Karaburun peninsula, Turkey.

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Carpathian Paleogene.—Bratislava, 1968, 232 p., 31 pls., 51 text figs., 30 tables.—Five zones subdivide the Paleocene and 6 the Eocene and lower Oligocene, all based on planktonic Foraminifera. Illustrated systematic catalog includes 106 planktonic species, none new.


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SEGLIE, GEORGE A. Relationships between the distribution of Amphistegina and the submerged Pleistocene reefs off western Puerto Rico.—Tulane Studies in Geol., v. 6, No. 4, Dec. 30, 1968, p. 139-147, text figs. 1-4 (maps, profiles), tables 1, 2.—Glaucocitized specimens of Amphistegina gibbosa are concentrated on reefs at about 80 meters depth. The species is found living on shallow reefs off Puerto Rico.

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WAGNER, FRANCES J. E. Illustrated check-list of marine Pleistocene invertebrate fossils of Que­bec.—Le Naturaliste Canadien, v. 95, No. 6, Nov.-Dec. 1968, p. 1409-1433, pls. 1-5.—Six­teen species of Foraminifera are figured.


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Phänotypische Varianten von Globigerina dutertrei Orbigny (Foram.); ihre Bedeutung für die Stratigraphie in quartären Tiefsee-Sedimenten.

—Geol. Jahrb., Hannover, Band 85, Jan. 1968, p. 97-122, text figs. 1-5 (drawings, graphs), tables 1-5.—Four temperature sensitive variants.

RUTH TODD
U. S. Geological Survey
Washington, D. C. 20560