

CONTRIBUTIONS
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366. INTERNAL STRUCTURE, STRATIGRAPHIC RANGE AND
PHYLOGENETIC RELATIONSHIPS OF CERTAIN
AMERICAN EOCENE FORAMINIFERA*

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ABSTRACT

The internal structure of topotypes of *Camerina catenula* (Cushman and Jarvis) and *Eoconuloides parvulus* (Cushman) and of specimens of *Eoconuloides wellsi* Cole and Bermudez and *Helicostegina polygyralis* (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 *Helicolepidina spiralis* Tobler. The phylogenetic relationships proposed by Barker and Grimsdale (1936) for the lepidocycline and helicolepidine 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 *Polylepidina* of the genus *Lepidocyclina* was derived from the *Helicostegina* lineage. *Helicostegina* had as its ancestor *Amphistegina lopeztrigoi* D. K. Palmer [= *Eoconuloides parvulus* (Cushman) of this article].

The proposal of Barker and Grimsdale has been accepted generally, as their postulate seemed to satisfy both the stratigraphic appearance of the genera and the progressive development of the internal structures by which these genera are interrelated (Cole, 1960a, p. 62). Recently, Hofker (1968, p. 24, 27) stated that *Lepidocyclina* (*Polylepidina*) *antillea* Cushman, the earliest known species of *Lepidocyclina*, could not have been derived from *Helicostegina*, as *L. antillea* does not possess siphonate apertures. Hofker (1968, p. 22) also wrote: "*Lepidocyclina* is known from the upper Eocene in the species *L. antillea* (see Cole, 1960a, p. 62); so I believe that *Lepidocyclina ecuadorensis* is somewhat older than *L. antillea* and may have been the ancestor of it. . ."

In my 1960a article I stated (p. 60): "Several of these specimens [*Lepidocyclina antillea*] . . . have the trochoid spire and apertures which supposedly characterize *Eulinderina*," a synonym of *Lepido-*

cyclina (*Polylepidina*). In 1963 (Cole, p. 20, pl. 7, figs. 5, 6) I published illustrations which show the siphonate apertures of *Lepidocyclina* (*Polylepidina*) *antillea* Cushman. Moreover, in my 1960a article (p. 62) cited by Hofker (1968, p. 22) I wrote: "During the upper middle Eocene the first subgenus, *Polylepidina*, of the genus *Lepidocyclina* was derived. . ." The middle Eocene age of *Lepidocyclina* (*Polylepidina*) *antillea* 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 *Helicolepidina nortoni* Vaughan." Later, Cole (1962, p. 147) concluded that *H. nortoni* was a synonym of *Helicolepidina spiralis* Tobler.

The specimens illustrated by Hofker (1968, pl. 11, fig. 3; pl. 14, fig. 2) as *Lepidocyclina ecuadorensis* should be compared with topotypes of *Helicolepidina nortoni* (Cole, 1962, pl. 24, figs. 1-3). All of these specimens have Type III_b embryonic apparatuses (Cole, 1962, p. 146), which is characteristic of upper Eocene specimens (Cole, 1962, p. 147) of *Helicolepidina 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 *Helicolepidina*, 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 *Helicolepidina spiralis* in association with abundant specimens

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which he referred incorrectly to the genus *Lepidocyclina* (his *Lepidocyclina ecuadorensis* = *Helicolepidina spiralis*). Other specimens in unit 4 were identified as *Helicolepidina paucispira*, 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 paucispira*) is not known to occur below the upper Eocene, and *Helicolepidina spiralis* with a Type III_b 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 wellsi* 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 topotypes 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 helicolepidine 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 helicolepidines, 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, topotypes, *Amphistegina lopeztrigoi* D. K. Palmer;” 6 specimens through the courtesy of Pedro J. Bermudez.
- 2—N. W. of Sibanicu, 23.3-4 km., on Maraguán-Camaguey road; topotypes; courtesy of the late Mrs. D. K. Palmer and the late Donald W. Gravell; topotypes.
- 3—Asphalt seep and quarry on Rancho Peñon, 7 kms. south of Martí (Hato Nuevo) and 850 m. northwest of the little settlement of Peñon, Matanzas Province; Donald W. Gravell and J. B. Klecker, collectors (reference: Cole and Gravell, 1952, p. 708).

Florida

- 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

- 5—Maerky's original sample 102_b 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.
- 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

- 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* Bruguière, 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.
1934. *Operculina bermudezi* D. K. PALMER, Mem. Soc. Cubana Hist. Nat., v. 8, no. 4, p. 238-240, pl. 12, figs. 3, 6-9.
1953. *Operculinoides catenula* (Cushman and Jarvis). COLE, Bull. Amer. Paleontology, v. 35, no. 147, p. 13, pl. 3, fig. 1.
1953. *Operculinoides bermudezi* (D. K. Palmer). COLE, *ibid.*, p. 35-37, pl. 1, figs. 5-7; pl. 3, figs. 2-12.
1957. *Operculinoides bermudezi* (D. K. Palmer). SACHS, Contrib. Cushman Found. Foram. Res., v. 8, pt. 3, p. 107-113, pl. 14, figs. 1-27 (references and discussion).
1960. *Camerina catenula* (Cushman and Jarvis). COLE, Bull. Amer. Paleontology, v. 41, no. 190, p. 193, pl. 25, figs. 3, 6; pl. 26, fig. 1.
1962. *Ranikothalia bermudezi* (Palmer). HANZAWA, Micropaleontology, v. 8, no. 2, p. 161, 162.

This species, including species which are considered to be synonymous with it, has been assigned to the genera *Operculina* (Cushman and Jarvis, 1932, p. 42; D. K. Palmer, 1934, p. 34); *Pellatispirella* (Hanzawa, 1937, p. 116); *Camerina* (Barker, 1939, p. 325; Cole, 1960b, p. 193); *Miscellanea* (Vaughan and Cole, 1941, p. 32; Vaughan, 1945, p. 23); *Ranikothalia* (Caudri, 1944, p. 17; Hanzawa, 1962, p. 161); and *Operculinoides* (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 *Camerina 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 *Operculina 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) “. . . *Operculinoides catenula* is similar to *O. bermudezi* . . . 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 102_b 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 102_b III) which are assumed to be topotypes of *O. catenula* were published in connection with a study of the genus *Camerina*. Cole (1960b, p. 193) assigned “*Operculina*” *catenula* to the genus *Camerina*, stating: “The description of the structure of *Camerina* is identical with that given by Cole and Herrick (1953, p. 53) for *Operculinoides georgianus* (= *Ranikothalia* of Nagappa, 1959, p. 159 = *Camerina catenula*).”

Sachs in 1957 (p. 107-113) had studied a large suite of topotypes of *Operculina bermudezi* 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 (1948; 1951), Vaughan and Cole (1941), Vaughan (1945), and Cole and Herrick (1953) were synonyms of *Operculina bermudezi*.

However, at that time Sachs could not analyze *Operculina 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. bermudezi* that these species cannot be separated.”

In 1959 Cole discussed briefly the geographic distribution and stratigraphic position of *Operculina catenula* and associated larger Foraminifera.

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

Additional illustrations (Pl. 17, figs. 1-4, 6, 8) of topotypes of *Camerina catenula* are presented to show variation and reinforce the conclusion that “*Operculina*” *bermudezi* is indeed a synonym of *Camerina 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 wellsii Cole and Bermudez, 1944

1950. *Tremastegina* Brönnimann - Type species, *Amphistegina senni* CUSHMAN (in VAUGHAN, 1945, p. 49).

The internal structure of topotypes (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. wellsii* 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. wellsii*.

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 chamberlets are formed in the final volution of *Helicostegina*.

Some median sections of *Eoconuloides* (Cole and Gravell, 1952, pl. 92, fig. 9) have small, irregular chamberlets in the final volution. 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 chamberlets 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.
1934. *Amphistegina lopeztrigoi* D. K. PALMER, Mem. Soc. Cubana Hist. Nat., v. 8, no. 4, p. 255, pl. 15, figs. 6, 8.
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.
1945. *Amphistegina senni* CUSHMAN, in VAUGHAN, Geol. Soc. Amer., Mem. 9, p. 49, pl. 19, figs. 1-4.
1950. *Tremastegina senni* (Cushman). BRÖNNIMANN, Eclogae geol. Helvetiae, v. 43, no. 2, p. 255-265, 7 text-figs.
1952. *Amphistegina lopeztrigoi* Palmer. COLE and GRAVELL, Jour. Paleontology, v. 26, no. 5, p. 714, pl. 91, figs. 6-8.
1957. *Amphistegina lopeztrigoi* Palmer. LEVIN, Micropaleontology, v. 3, no. 2, p. 146, 147, pl. 4, figs. 8, 9, 13-14.

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 topotypes 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 lopeztrigoi* 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 lopeztrigoi* 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 senni* from Barbados, writing: “This species differs from *Amphistegina lopeztrigoi* 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. senni* “. . . from the Middle Eocene Upper Scotland formation of Barbados” and erected the genus *Tremastegina* with *A. senni* the type.

Cole and Gravell (1952, p. 714) identified *Amphistegina lopeztrigoi* at Peñon Seep, Matanzas Province, Cuba, writing that it is “. . . impossible to distinguish between the smaller topotype specimens of *A. lopeztrigoi* and the larger (diameter up to 1.10 mm.) specimens of *A. senni*. 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 lopeztrigoi* 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. lopeztrigoi* 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* (*Polylepidina*) 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 lopeztrigoi*) in association with *Lepidocyclina antillea* (identified as *Eulinderina semiradiata* and *E. guayabalensis regularis*) at their locality 9 in sediments which they assigned to the lower middle Eocene.

These data demonstrate that *Eoconuloides parvulus* as well as *Eoconuloides wellsi* and *Helicostegina dimorpha* are middle Eocene species, as in Mexico and St. Bartholomew they are associated 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 lopeztrigoi*) at Peñon 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 Peñon 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 *Globigerapsis kugleri* zone and in the lower part of the *Globorotalia lehneri* zone.” Cole and Applin (1964, p. 19) wrote: “Although *Lepidocyclina* (*Polylepidina*) has not been reported from Peñon Seep, species of larger Foraminifera, such as *Pseudophragmina flintensis* and *Asterocyclina monticellensis*, do occur there. As these species are associated with *Lepidocyclina* (*Polylepidina*) *antillea* elsewhere, we suggest that Peñon Seep might as reasonably be cor-

related with the *Globigerapsis kugleri* zone of Trinidad.”

This suggestion of Cole and Applin (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 lopeztrigoi*) and *Helicostegina dimorpha* (identified as *H. gyralis*) occur in association with *Pseudophragmina cedarkeysensis* Cole in the Oldsmar Limestone (lower Eocene). Butterlin (1967, p. 549) identified *Pseudophragmina cedarkeysensis*, *P. stephensoni*, *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 cedarkeysensis* was associated with *P. stephensoni* (Vaughan) (identified as *Pseudophragmina cookei*) in a well in Nassau County, Florida. *P. stephensoni* 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 lopeztrigoi*) in Cuba as Paleocene into the middle Eocene (*Globorotalia velascoensis* - *G. pseudomenardii* planktonic zone to the *Globigerapsis kugleri* zone).

Brönnimann and Rigassi (1963, p. 292, 309) reported "*Amphistegina lopeztrigoi*" (= *Eoconuloides parvulus*) from the Apolo and Alkazar Formations in the vicinity of Habana, Cuba. They (Brönnimann 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.

1946. *Amphistegina ellioti* CUSHMAN and STAINFORTH, Contrib. Cushman Lab. Foraminif. Res., v. 22, no. 4, p. 118, 119, pl. 20, figs. 1-6.

1952. *Eoconuloides wellsi* Cole and Bermudez. COLE and GRAVELL, Jour. Paleontology, v. 26, no. 5, p. 713, pl. 92, figs. 1-10.

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 Gravell, 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 Gravell, 1952, pl. 91, fig. 7) than *E. wellsi* (Pl. 16, fig. 2; Cole and Gravell, 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 ellioti*, stating: "This species differs from *Amphistegina lopeztrigoi* 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. ellioti* 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 Gravell (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 ellioti*.

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).

Brönnimann 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 antillea* 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* Gümbel, 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.
1957. *Discocyclina* (*Discocyclina*) *barkeri* Vaughan and Cole. SACHS, Contrib. Cushman Found. Foramin. Res., v. 8, pt. 3, p. 113-115, pl. 15, figs. 1-12 (references and synonyms).
1959. *Discocyclina* (*Discocyclina*) *barkeri* Vaughan and Cole. COLE, Bull. Amer. Paleontology, v. 39, no. 182, p. 384.

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

Family LEPIDOCYCLINIDAE
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.
1934. *Helicolepidina polygyralis* Barker. BARKER, Jour. Paleontology, v. 8, no. 3, p. 347, pl. 47, figs. 5-11; text figs. 1b, e.
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. *Helicostegina soldadensis* GRIMSDALE, in VAUGHAN and COLE, Geol. Soc. Amer., Sp. Paper 30, p. 86, 87, pl. 46, figs. 1-7.

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.
1960. *Helicostegina polygyralis* (Barker). COLE, Contrib. Cushman Found. Foramin. Res., v. 11, pt. 2, p. 59, pl. 10, figs. 2-11; pl. 11, figs. 1-5, 7-10, 12.
1961. *Helicostegina polygyralis* (Barker). COLE and APPLIN, *ibid.*, v. 12, pt. 4, p. 133, pl. 6, figs. 2, 3.
1963. *Helicostegina polygyralis* (Barker). COLE, Bull. Amer. Paleontology, v. 46, no. 205, p. 42-44, pl. 10, figs. 5-8; pl. 11, figs. 1-9.
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.

Cole (1960a, p. 59; 1963, p. 42) discussed this species in detail, yet misunderstandings persist (Hanzawa, 1965, p. 252; Hofker, 1968, p. 19-21). An attempt will be made to clarify the situation.

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. soldadensis* 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 spire of the "paucispira" kind which cannot be traced to the periphery of the test, whereas another specimen (Pl. 16, fig. 11) has a longer spire of the "soldadensis" 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.

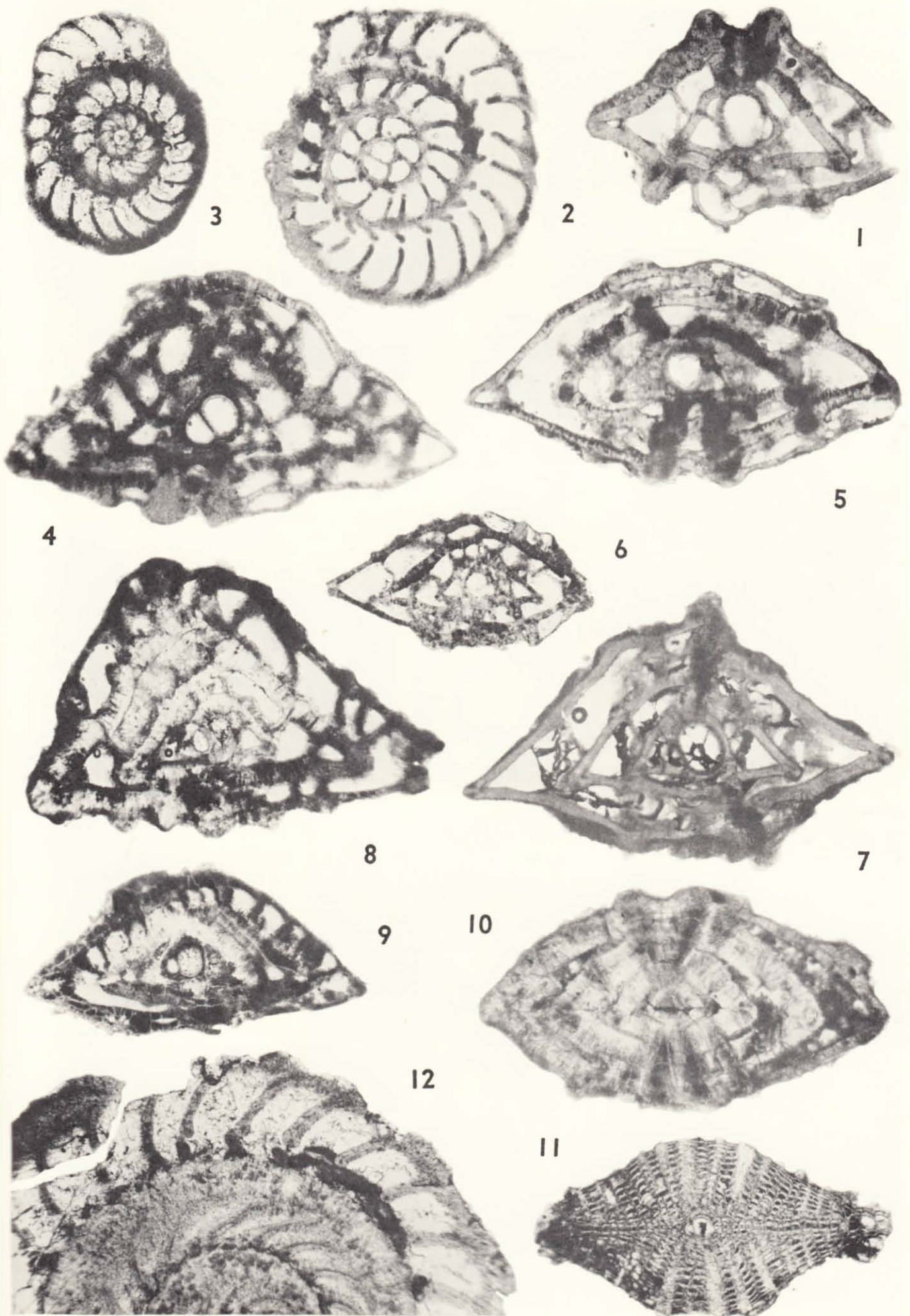
Stratigraphic range.—The types of *Helicostegina polygyralis*, by associated larger Foraminifera, are from the upper Eocene (Cole, 1963, p. 42, 43) of Ecuador. *Helicostegina polygyralis* (identified as *Helicolepidina paucispira*) occurs in the upper Eocene *Lepidocyclina chaperi* zone of Florida (Cole, 1945, p. 17) and, in Trinidad, in the *Globorotalia cerroazuelensis* 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).

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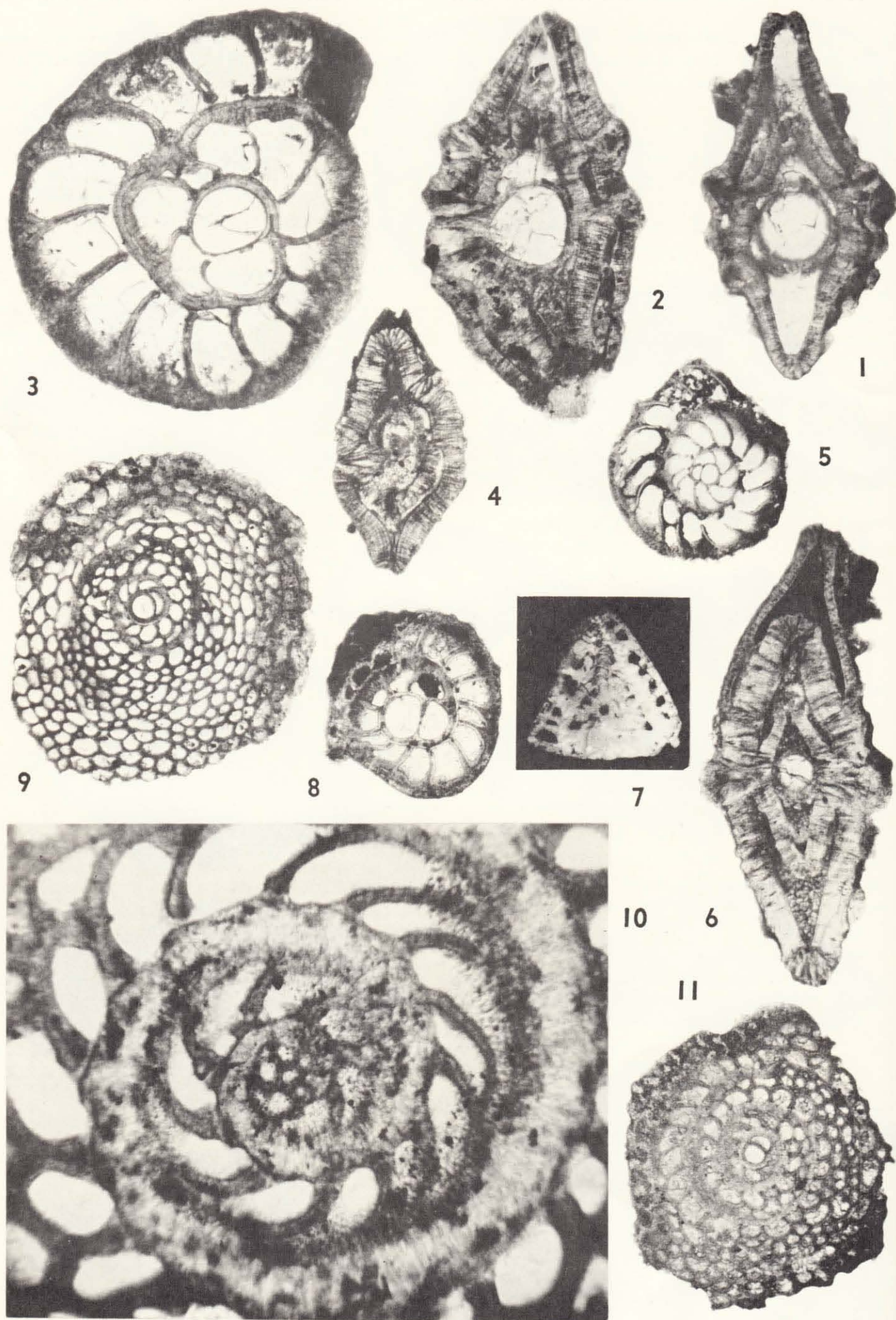
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EXPLANATION OF PLATE 16

FIGS.		PAGE
1, 3, 5-7, 10, 12.	<i>Eoconuloides parvulus</i> (Cushman).	80
	1, 5-7, 10. Transverse sections; 1, 5, 7, 10, $\times 40$; 6, $\times 20$; 1, 7, loc. 1; 3, 5, 6, loc. 2; 10, loc. 4	
	3. Median section, $\times 20$; loc. 2.	
	12. Part of a median section, $\times 40$; loc. 7.	
2, 4, 8, 9.	<i>Eoconuloides wellsi</i> Cole and Bermudez.	82
	2. Median section, $\times 40$; loc. 3.	
	4, 8, 9. Transverse sections; 4, 8, 9, $\times 40$; loc. 3.	
11.	<i>Discocyclina</i> (<i>Discocyclina</i>) <i>barkeri</i> Vaughan and Cole.	83
	Vertical section, $\times 40$; loc. 5.	



Cole: Studies on American Eocene Foraminifera



Cole: Studies on American Eocene Foraminifera

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EXPLANATION OF PLATE 17

FIGS.	PAGE
1-4, 6, 8. <i>Camerina catenula</i> (Cushman and Jarvis).	78
1, 2, 4, 6. Transverse sections; 1, 2, 6, $\times 40$; 4, $\times 20$; loc. 5.	
3, 8. Median sections; 3, $\times 40$; 8, $\times 20$; loc. 5.	
5. <i>Eoconuloides parvulus</i> (Cushman).	80
Median section; $\times 20$; loc. 1.	
7. <i>Eoconuloides wellsii</i> Cole and Bermudez.	82
Transverse section, $\times 20$, by reflected light; loc. 3.	
9-11. <i>Helicostegina polygyralis</i> (Barker).	83
9-11. Median sections, $\times 40$, of megalospheric specimens; loc. 6.	
10. Central part, $\times 210$, of a median section of a microspheric specimen; entire median section illustrated as fig. 3, pl. 11, Cole, 1963; loc. 6.	

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

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367. SEASONAL OCCURRENCES, STANDING CROP AND
PRODUCTION IN BENTHIC FORAMINIFERA OF
PUERTO DESEADO¹ESTEBAN BOLTOVSKOY² and HAYDÉE LENA³

ABSTRACT

A quantitative study of populations of *Buliminella elegantissima*, *Elphidium articulatum*, *Epistominella exigua* and *Rotalia beccarii* collected weekly (February, 1964 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, *Buccella 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 articulatum*, *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 *Buccella 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 1,050,000 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 (Boltovskoy, 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 (Boltovskoy, 1963; Boltovskoy 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 (Boltovskoy, 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-

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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.

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.

SEASONAL CHANGES

PARTICULAR SPECIES

The total number of living species found in the

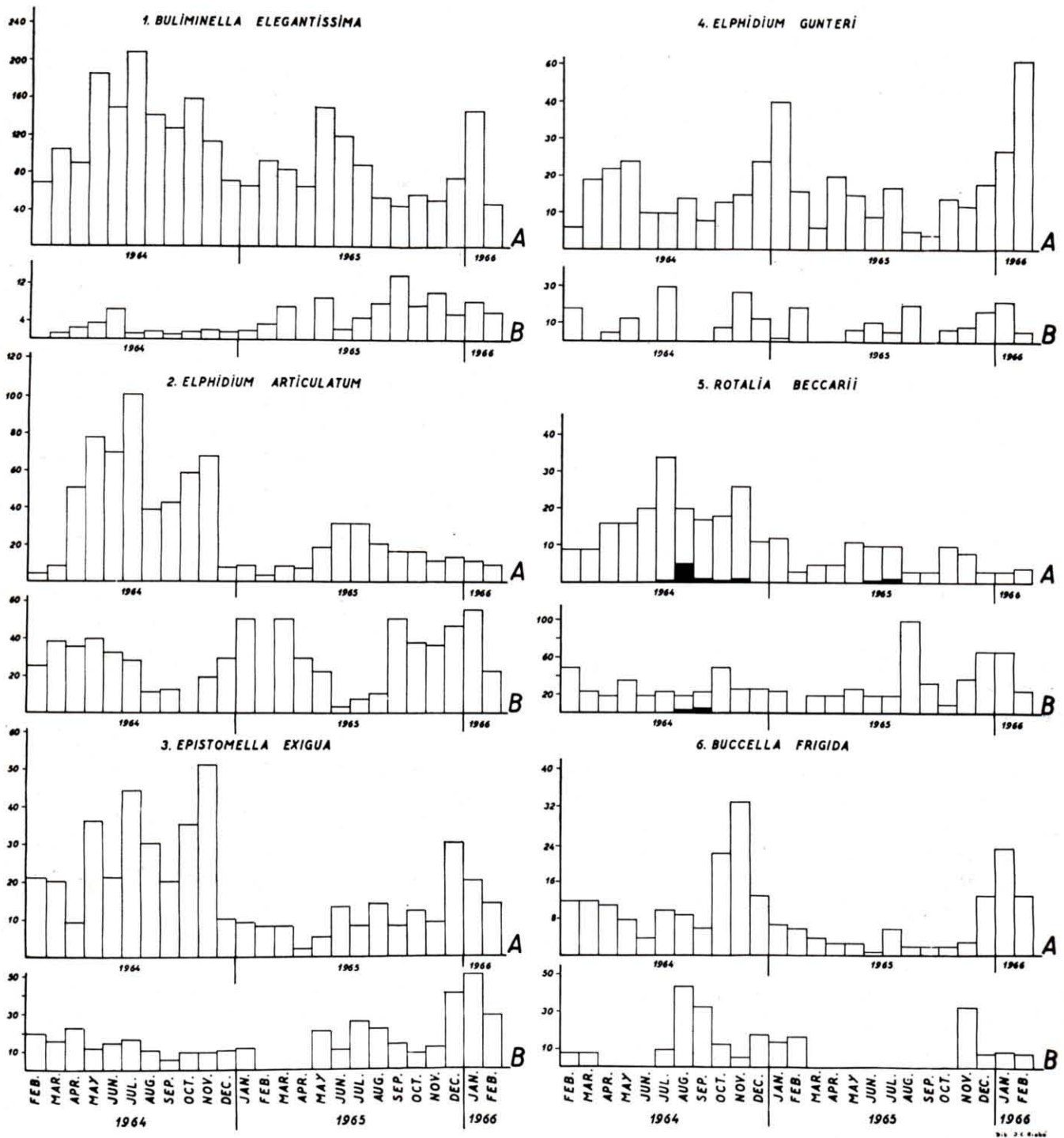


TABLE 1

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 elegantissima (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. elegantissima* calculated for each month. Fig. 1B shows the percentage of young specimens in the total population. *B. elegantissima* 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 (Linné)

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.

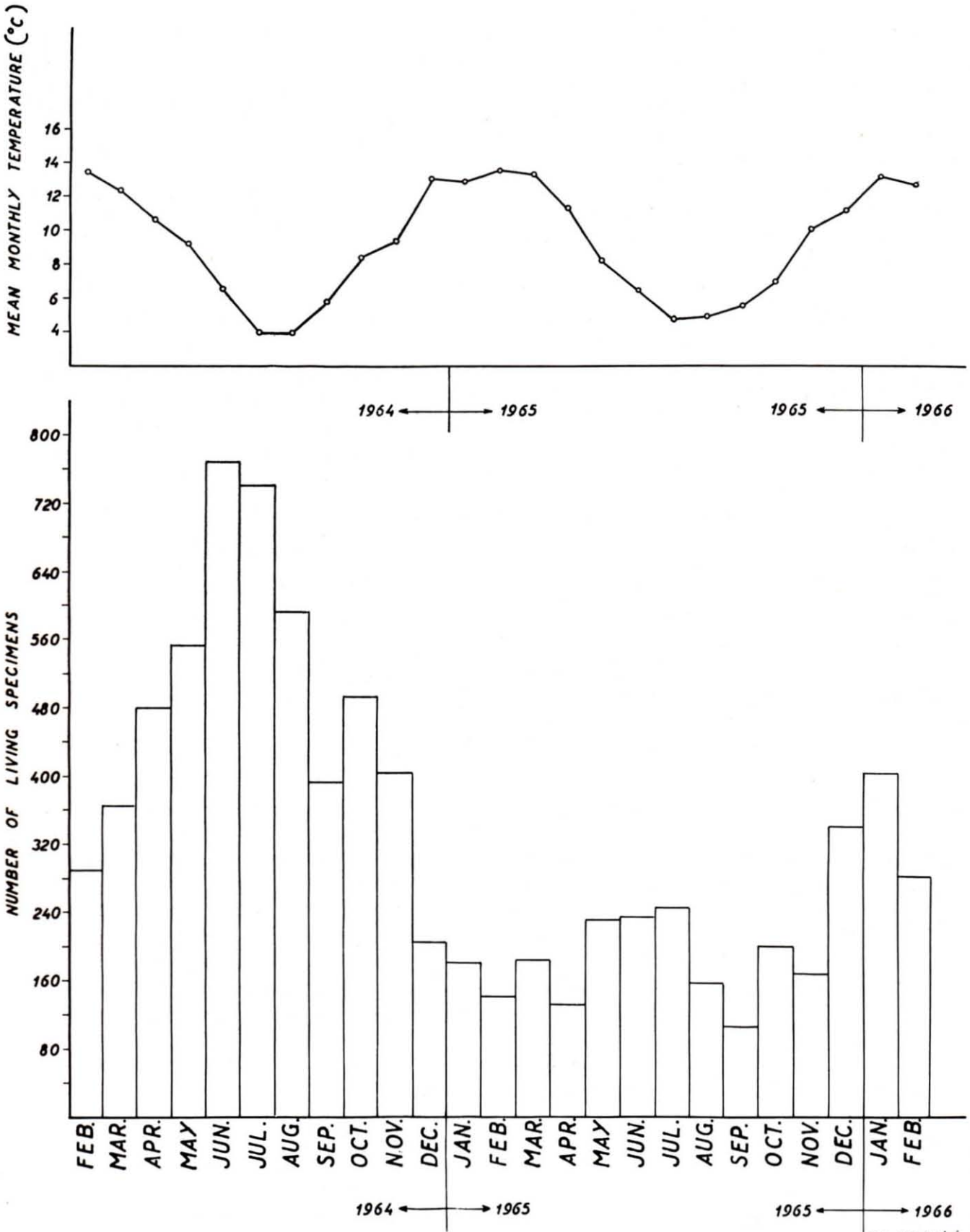
The analysis of the observations obtained reveals that *B. frigida* started reproduction in late winter

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-



D. b. J. C. Rioba

TABLE 2

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:

	1964	1965	1966
January	—	22.50	50.50
February	48.00	18.00	34.62
March	45.00	31.50	—
April	59.75	13.20	—
May	69.00	29.25	—
June	128.00	29.38	—
July	74.10	19.88	—
August	73.88	19.88	—
September	48.88	14.88	—
October	49.40	11.60	—
November	50.88	21.12	—
December	25.50	20.30	—

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 ($23.67 \div 8.24$). 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.

Average Numbers Of Specimens At Different Depths In Core

(According to Boltovskoy, 1966)

Depth in cm.	Specimens per cc
0 - 2	1.06
4 - 6	0.36
8 - 10	0.26
12 - 14	0.23
16	0.08

The interpolated values for the depth intervals lacking in the table cited are: 0.71 for 2 - 4 cm.; 0.31 for 6 - 8 cm.; 0.25 for 10 - 12 cm.; and 0.16 for 14 - 16 cm. From all these data the real standing crop for the Quinta Island area was found to average 9.24 benthic Foraminifera per square cm.

PRODUCTIVITY

Generalities

Production is a measure of the total number of organisms formed during a given time-span (usually for a year) in a given area (usually a square meter or a square kilometer). The problem of productivity of the oceans has been examined more thoroughly with respect to planktonic (especially phytoplanktonic) than to benthonic organisms. Little information is available for benthic Foraminifera, but this was recently summarized by Murray (1967). It is particularly interesting to study the production of benthic Foraminifera, because it appears rather clear that they are much more important in the biological productivity of the ocean than has as yet been admitted. This is especially true for those living at great depths, as recently shown by Saidova (1967). According to this author, in some places at depths between 1,000 and 2,000, 3,000 and 4,000, and 5,500 and 8,000 meters the number of living foraminiferal specimens reached up to 10 per square cm. (taking into account only the top cm.). Saidova calculated that the proplasmic biomass of Foraminifera was in some places up to 10 grams per square meter. Zenkevich (1967) emphasized that this quantity is completely sufficient to satisfy all the bottom-feeders that ingest Foraminifera. "It is possible that the role of Foraminifera in the bottom fauna in some degree is similar to that of phytoplankton in the upper layers of the pelagic zone, if we take into consideration that Foraminifera probably are able to use for their nutrition the organic matter dissolved in sea water" (Zenkevich, 1967, p. 23).

The problem of determining the productivity of benthic Foraminifera was studied by Murray (1967). Discussing the theoretical aspects of productivity, he stated that if the standing crop is uniform qualitatively and quantitatively throughout the year, the standing crop of those species which reproduce annually will be approximately equiva-

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 proto-

plasm 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:

	"R"		"R"
1964, February	23.4	1965, February	15.1
March	30.5	March	5.6
April	43.5	April	9.4
May	31.8	May	26.3
June	27.2	June	28.6
July	32.1	July	6.7
August	19.1	August	14.6
September	12.1	September	4.2
October	26.2	October	11.3
November	28.9	November	7.4
December	50.0	December	28.2
1965, January	31.6	1966, January	50.0

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: *Buliminella 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 *Buliminella 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.

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368. *TOSAIA LOWMANI*, A NEW SPECIES FROM OFF THE
PACIFIC COAST OF PANAMA¹

GEORGE A. SEIGLIE² and PEDRO J. BERMÚDEZ³

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.

Megalospheric form: diameter greater than height, trochospiral, two to three whorls with four

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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.

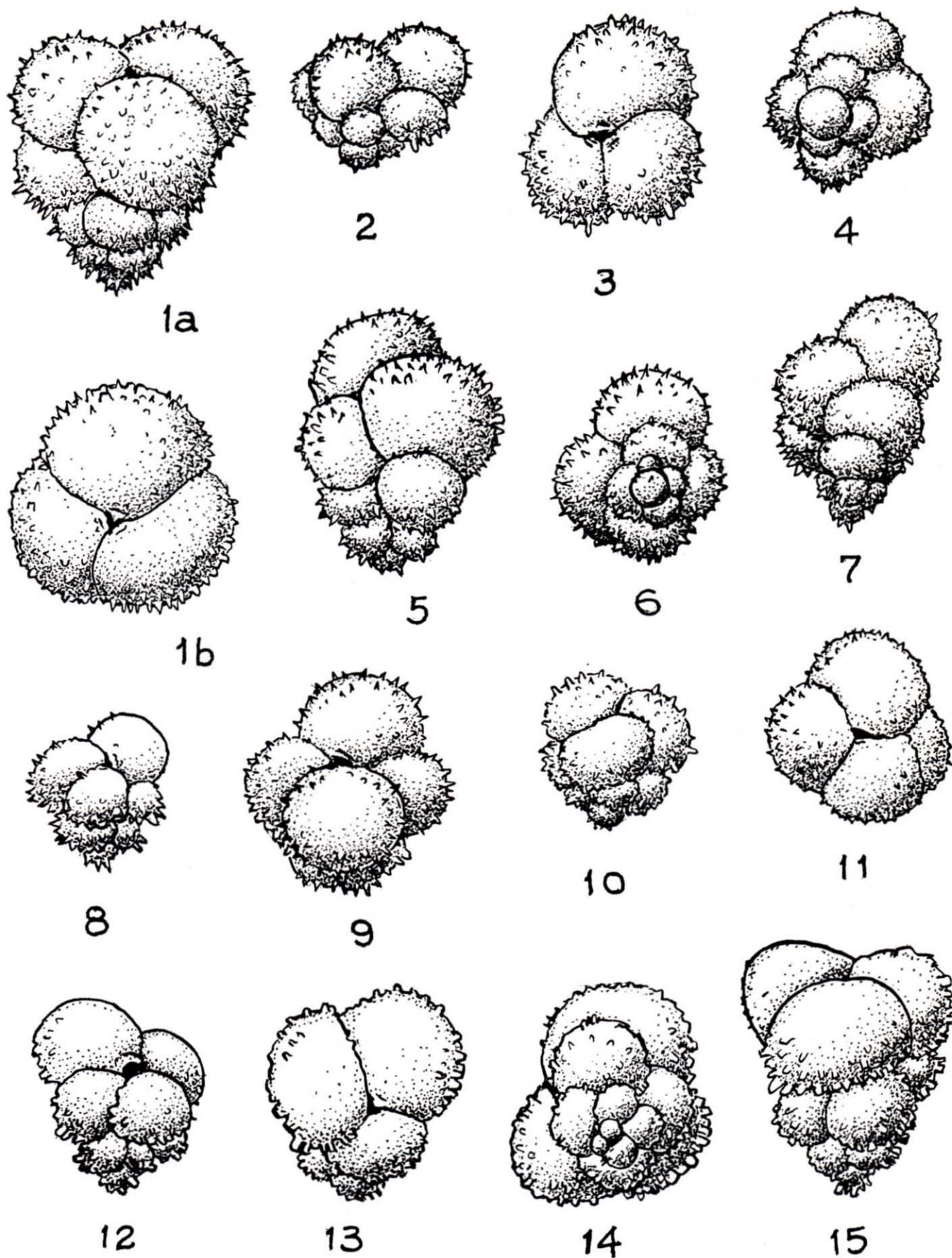
Type locality.—The type locality is station 45, Nuclear Center of Puerto Rico project on Panama, southwest off the mouth of Tapia River, Panama: 8°58'15" North Latitude and 79°25'15" West Longitude, Pacific Ocean, at a depth of 5.6 meters. Surface temperatures were from 22.5°C to 28.0°C, and surface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

FIGS.

- 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.



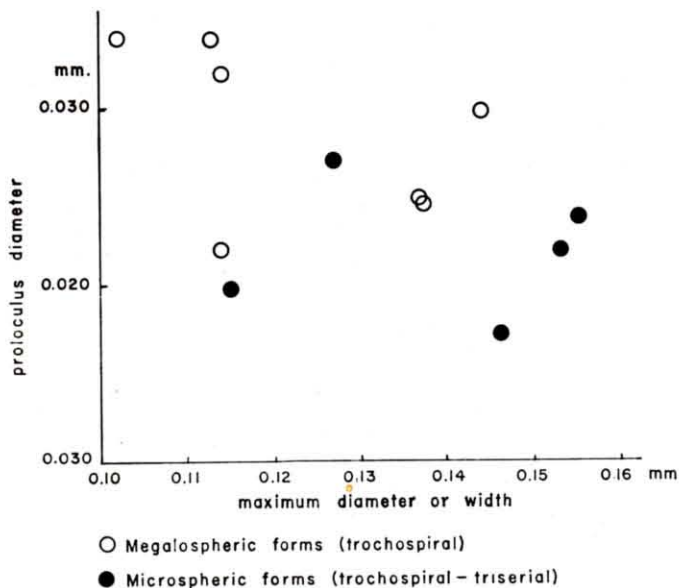
TEXT FIGURES 1 - 15

differentiation of megalospheric and microspheric 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 gen-

us 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 microspheric 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

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 sta-

tion 45, the type locality, (percentages are given in relation to the total foraminiferal population):

<i>Reophax</i> sp. cf. <i>R. communis</i> Lacroix	0.3%
<i>Textularia</i> sp.	0.3%
<i>Elphidium poeyanum translucens</i>	
Natland	12.0%
<i>E. spinatum</i> Cushman and Valentine	0.3%
<i>E. sp.</i>	9.5%
<i>Ammonia sarmientoi</i> (Redmond)	2.5%
<i>A. sp. cf. A. tepida</i> (Cushman)	40.7%
<i>Ammomarginulina foliacea</i> (Brady)	0.3%
<i>Florilus grateloupianus</i>	
(Cushman and Moyer)	1.6%
<i>Tosaia lowmani</i> 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.

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369. AN ABNORMAL *ASTACOLUS* FROM THE HOLOCENE,
GANTHEAUME BAY, WESTERN AUSTRALIA

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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.

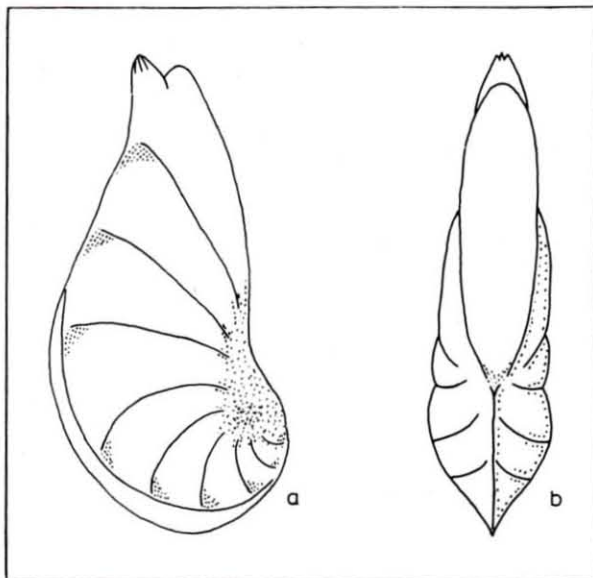
There is no other record of such an abnormal specimen of *Astacolus reniformis* (d'Orbigny) in the literature, but there are records of abnormal

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 cocoaensis* 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.



TEXT FIGURE 1

- a. *Astacolus reniformis* (d'Orbigny), side view of the abnormal specimen, R.R.C. No. 5963, Holocene, Indian Ocean. $\times 25$.
b. Apertural view of same specimen. $\times 25$.

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370. A NEW PLANKTONIC FORAMINIFER FROM THE LATE
TERTIARY OF CAR NICOBAR ISLAND, BAY OF BENGAL

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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 GLOBOROTALIINAE 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-angular 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, extra-umbilical.

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.

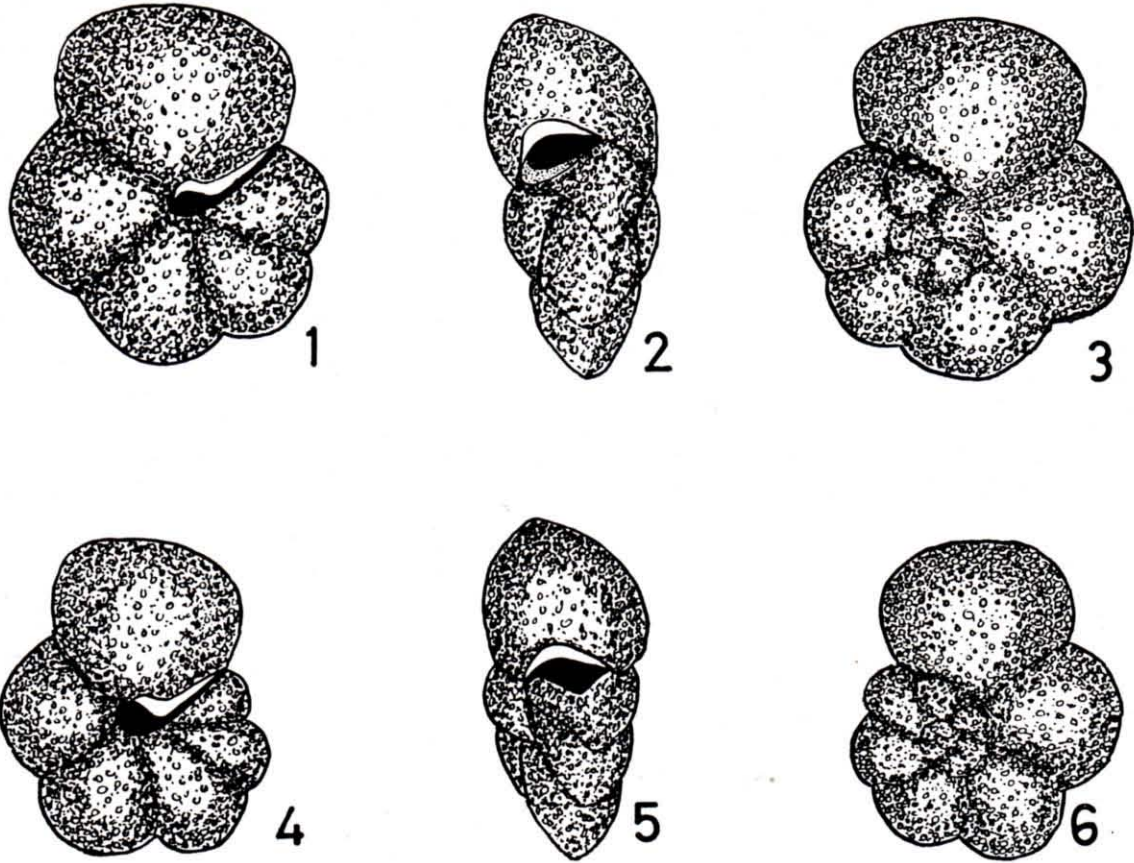
Dextrally and sinistrally coiled specimens are equally common.

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:

- Chiloguembelina globigera* (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. conglomerata (Schwager)
G. hexagona (Natland)
G. humerosa (Takayanagi and Saito)
Pulleniatina primalis Banner and Blow
Globorotalia cibaoensis Bermudez
G. cf. margaritae Bolli and Bermudez
G. menardii (d'Orbigny)
G. multicamerata Cushman and Jarvis
G. panda Jenkins
G. plesiotumida Banner and Blow
G. scitula (Brady)
G. tumida tumida (Brady)

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

The diagnostic assemblage of *Candeina nitida*, *Pulleniatina primalis*, *Globorotalia plesiotumida*, *G.*



TEXT FIGURES 1 - 6

Globorotalia nicobarica Srinivasan and Sharma, n. sp. Holotype (1-3) and paratype (4-6) from sample S 87 C/Mf 41, Sawai Bay Mudstone Formation, Car Nicobar island, Bay of Bengal. All $\times 85$.

tumida tumida, *G. multicamerata*, *G. menardii*, *Sphaeroidinella seminulina*, *S. subdehiscens*, *Globoquadrina humerosa*, *G. acostaensis*, *G. altispira*, accompanied by the characteristic late Miocene benthonic species *Bolivinita quadrilatera* (Schwager) and "*Euvigerina*" *hispida* (Schwager), suggests that the type sample was obtained from a horizon within zone N.18 [*Globorotalia* (*G.*) *tumida tumida* — *Sphaeroidinellopsis subdehiscens* partial-range-zone" of Banner and Blow, 1965b] or possibly basal N.19 [*Sphaeroidinella dehiscens* (s.s.)/*Globoquadrina altispira* (s.s.) concurrent-range-zone" of Banner and Blow, 1965b].

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

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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 *Nodosarids*, *Stilostomella*, *Osangul-aria*, *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 oc-

curred 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:

BENTHONIC FORAMINIFERA

- Alabamina* sp.
- Arenodosaria* sp.
- Awhea subtetragona* (Finlay)*
- Bolivinita elegantissima* Boomgaard*
- Brizalina turbiditorum* (Vella)
- B. alata* (Seguenza)
- B. bilaensis* Le Roy*
- B. aff. robusta* (Brady)
- B. numerosa* (Vella)
- B. lapsus* (Finlay)
- B. pusilla* (Schwager)
- Bulimina inflata* Seguenza*
- B. pupoides* d'Orbigny*
- Cassidulina delicata* Cushman
- C. subglobosa* Brady
- Chilostomella oolina* Schwager*
- Cibicides praecintus* (Karrer)
- Cibicides* sp.*
- C. aff. tapoenjensis* Le Roy
- Eouvigerina hispida* (Schwager)
- Fissurina marginata* (Montagu)
- Fissurina marginata* cf. *incomposita* Mathes
- F. orbignyana* Seguenza
- Fursenkoina squamosa* (d'Orbigny)
- Glandulina laevigata* d'Orbigny
- Globobulimina pacifica* Cushman*
- Gyroidina* sp.
- Gyroidinoides nitidula* (Schwager)*
- Hoeglundina elegans* (d'Orbigny)*
- Hofkeruva crasscostata* (Schwager)*
- H. cf. nitidula* (Schwager)
- Islandiella californica* (Cushman and Hughes)
- Karreriella bradyi* (Cushman)*
- Karreriella* cf. *siphonella* (Reuss)*
- Lagena anomala* Stache
- L. crenata* Parker and Jones
- L. nebulosa* Cushman

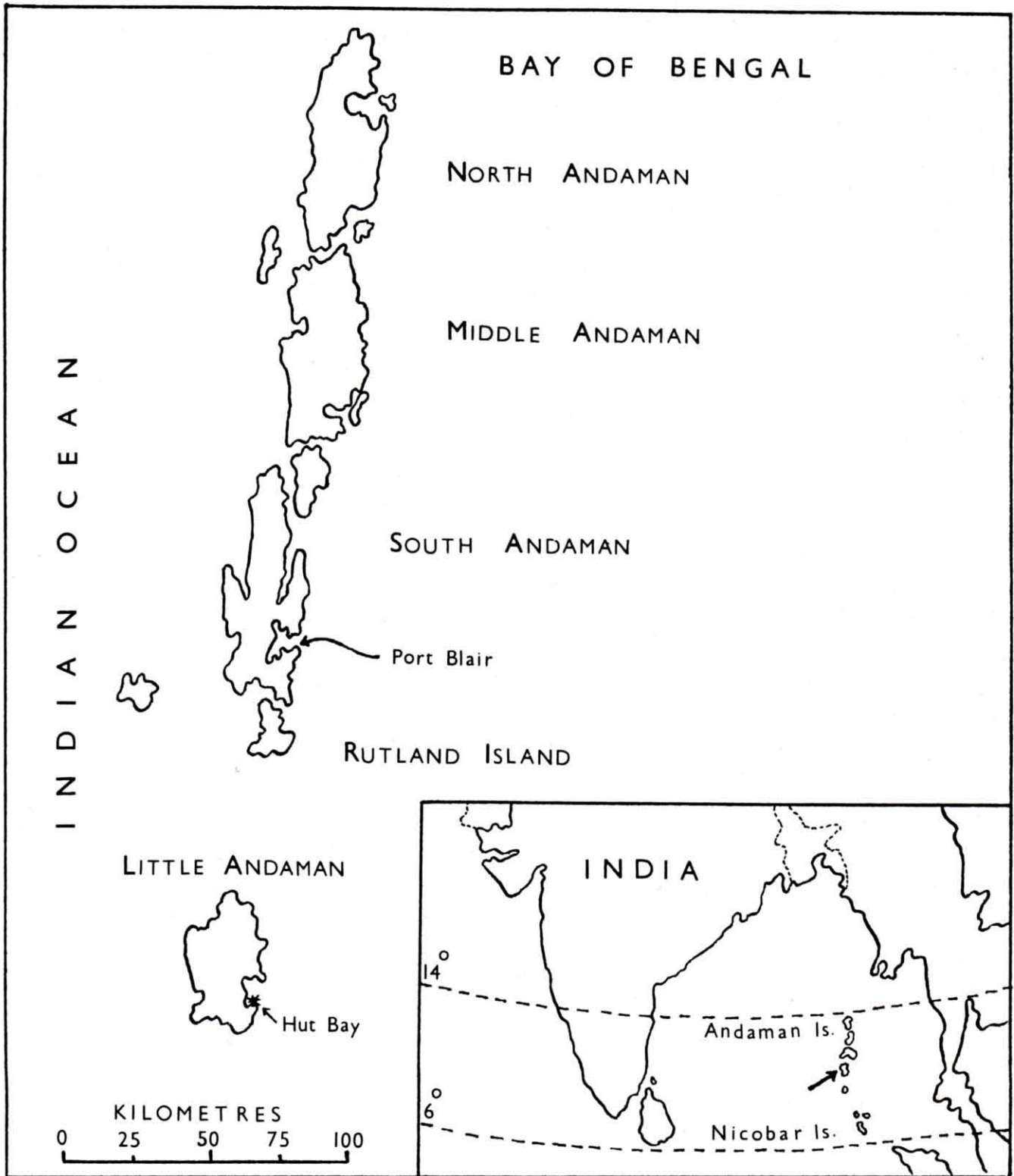


FIG. 1 LOCATION MAP

* 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. subtertenuata Schwager
N. tornata Schwager
N. aff. uniforminata Le Roy

N. vertebralis (Batsch)
Nodosaria sp.
Oridorsalis prominula (Stache)*
O. flosculiformis (Schwager)
Osangularia bengalensis (Schwager)*
Planulina wuellerstorfi (Schwager)*
Plectofrondicularia parri Finlay
Proxifrons foliacea (Schwager)
Pullenia bulloides (d'Orbigny)*
Quinqueloculina seminulum (Linné)
Rectobolivina aff. *striatula* (Cushman)
Reussella sp.
Robulus foliatus (Stache)
R. iotus (Cushman)
R. nicobarensis (Schwager)*
R. politus (Schwager)
R. aff. subumbonatus (Cushman)
Ruakituria magdalidaeforme (Schwager)
Saracenaria italica Defrance
Semivulvulina sp.*
Sigmoilopsis 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

Globigerinita glutinata (Egger)
Globigerina bulbosa Le Roy
G. decoraperta Takayanagi and Saito*
G. bulloides d'Orbigny*
Globigerinella siphonifera (d'Orbigny)*
Globigerinoides apertasuturalis Jenkins
G. bollii 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
Sphaeroidinella multiloba Le Roy
Globoquadrina 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 *Globoquadrina 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 *Pulleniatina* 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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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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372. MICROFACIES OF THE LOWER CARBONIFEROUS
DOLOMITIC LIMESTONE FORMATION OF THE
UM BOGMA TERRANE (SINAI, EGYPT)

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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 Krasheninikof, 1965; Omara and Wangerov, 1965). There is no apparent discrepancy between the phylogenetic development of the thirteen known families and approximately one hundred known 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 thin-

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.*

Brunsia pulchra Mikhailov and *Brunsia spirilinoidea* Grozdilova and Glebovskaia range from the Tournaisian to Late Visean, with a peak in Late Tournaisian-Middle Visean.

Similarly, *Calcisphaera laevis* Williamson, *Earlandia clavatula* (Howchin), *Earlandinita* sp., *Endothyra* sp., and *Eotuberitina* sp. are long ranging.

Calcisphaera pachysphaerica (Pronina), *Endothyra prisca* (Rauzer-Chernousova and Reitlinger), *Endothyra* of the group *Endothyra similis*, and *Tetrataxis* 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 *Planoarchaediscus* 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; Tcherbakhov *et al.*, 1964; Ganelina, 1966; etc.), *Planoarchaediscus* sp. and *Permodiscus* sp. are, therefore, characteristic Visean foraminifera; they flourished in mid-Visean time. [Recently Conil (personal communication) has observed *Planoarchaediscus aegyptiacus* in the Middle Visean (V₂) of Belgium.] The only exception to this range is the reported occurrence of

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LATE TOURNAISIAN		EARLY VISEAN		MIDDLE VISEAN		SUBSTAGES
9	10	11	12	13		FORAMINIFERAL ASSEMBLAGES
TN 3C	V 1A	V 1B	V 2A	V 2B		ZONAL SCHEME
						BRUNSA PULCHRA .
						BRUNSA SPIRILLINOIDES .
						CALCISPHAERA LAEVIS .
						CALCISPHAERA PACHYSPHAERICA .
						DIPLOSPHAERINA SP.
						EARLANDIA CLAVATULA .
						EARLANDINITA SP.
						ENDOTHYRA SP.
						ENDOTHYRA PRISCA .
						ENDOTHYRA EX. GR. E. SIMILIS .
						EOTUBERITINA SP.
						TETRATAXIS SP.
						GLOBOENDOTHYRA EMEND.
						PLANOARCHAEDISCUS SP.
						PERMODISCUS SP.
						KONINCKOPORA SP.
						OMPHALOTIS SP.
						ENDOTHYRA BOWMANI .
						DRAFFANIA QUASIBILOBA .

OLDEST
POSSIBLE
AGE
FOR THE
DOLOMITIC
FORMATION

TEXT FIGURE 1

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

Omphalotis sp. and *Endothyra bowmani*,

Phillips in Brown, emend ICZN 1965, appear in the Middle 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 (III β and III γ), 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 S₂-D₁ 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 Tournaisian 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 Tournaisian taxon, Omara and Conil gave the Dolomitic Limestone Formation a non-committal Tournaisian-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 (V₂b). 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 Kusnetz 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 (CV₁). 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 Krashennikov, 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 microfacies 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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RECENT LITERATURE ON THE FORAMINIFERA

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 γ in the Miogypsinidae.—*Rev. Española Micropaleontología*, 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.
- ASANO, K., INGLE, J. C. JR., and TAKAYANAGI, Y. *Globigerina quinqueloba* Natland; origin and distribution in Late Cenozoic of the North Pacific.—*Giornale Geol., Ann. Mus. Geol. Bologna*, ser. 2, v. 35, 1967, fasc. 2, 1968, p. 217-246, text figs. 1-15 (range charts, maps, drawings, comparison tables, graphs), table 1.—Republication of previous paper in *Sci. Repts. Tohoku Univ.*
- 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°C or less are characterized by a sinistral *pachyderma* polar fauna; those of 9-18°C by a dextral *pachyderma* transitional fauna; and those of 18°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.
- BERGGREN, 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.
- BERTOLINO, V., BORSETTI, A. M., CATI, F., CINELLI, D., COLALONGO, M. L., CRESCENTI, U., DALLAN, L., DE FRANCESCO, A., DONDI, L., D'ONOFRIO, S., GIANNELLI, L., PAPETTI, I., POMESANO, CHERCHI, A., SALVATORINI, G., SAMPO, M., SARTONI, S., and TEDESCHI, D. Proposal for a biostratigraphy of the Neogene in Italy based on planktonic Foraminifera.—*Giornale Geol., Ann. Mus. Geol. Bologna*, ser. 2, v. 35, 1967, fasc. 2, 1968, p. 23-30, correl. chart.—Five cenozones and 8 subzones in the Miocene and 4 cenozones and 3 subzones in the Pliocene.
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Phänotypische Varianten von *Globigerina duter-*

trei 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.

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