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Description of the species

Genus *Ranikothalia* CAUDRI, 1944

A more thorough discussion of the different forms included in this genus is postponed to a later date because the crucial material from Trinidad, especially from Lizard Springs, should be considered in the first place and this is beyond the scope of the present paper.

Only a few comments are offered here on the forms distinguished by VAUGHAN & COLE in 1941 and by VAUGHAN in 1945 under the names of *Miscellanea antillea* (HANZAWA), *Miscellanea tobleri* (VAUGHAN & COLE) and *Miscellanea soldadensis* (VAUGHAN & COLE), which are all three found on Soldado Rock.

At the moment, I am under the impression that all of them belong to one and the same species, "*Miscellanea*" *antillea* representing the robust specimens of the megalospheric form, "*M*".*tobleri*, a more flaring variety comprising both megalospheric and small microspheric specimens (actually very insufficiently defined), and "*M*".*soldadensis*, the fullgrown very large thin-flanged and heavy-rimmed B-form that develops under particularly favourable conditions.

I also think that there is no consistent difference between these three and the numerous "species" DE CIZANCOURT distinguishes in her Barbadian material in 1948. Likewise, I consider COLE to be right in putting "*antillea*" and "*tobleri*" in the synonymy of the Cuban species *Operculina bermudezi* PALMER and in including the isolated specimen of *Operculina catenula* CUSHMAN & JARVIS from Lizard Springs in the same species (COLE 1935, 1958b, 1959). The latter having priority over all the others, this species should carry the name "*catenula*", as COLE proposes, but I do not follow him in transferring it to the genus *Camerina* (1969b). These forms, distinguished by DE CIZANCOURT as the "nummulites cordelées", should be recognized, for morphological and stratigraphical reasons as a separate genus (*Ranikothalia* CAUDRI 1944). Strictly speaking, all our material from Trinidad and Soldado Rock should probably go under the name of *Ranikothalia catenula* (CUSHMAN & JARVIS) (see also DROOGER 1960a, p. 312–318).

In the Soldado material the forms *antillea*, *tobleri* and *soldadensis*, as characterized above, are more or less easy to separate from one another; there are few transitional specimens. Therefore, in order not to efface a difference which one day might turn out to be significant after all, I have continued to list them under their separate names in the present study. Non-typical specimens were marked down as *R. antillea*.

Of the three forms, only *R. soldadensis* has its type locality on Soldado Rock (T.L.L. 125, C-4, slumped *Ranikothalia* limestone in Bed 3). Large specimens, up to 9 mm in diameter, occur at various places (K. 2951 B; K. 3694, K. 10717). An exceptionally large one, with a diameter of at least 13 mm, was observed in the erratic limestone block Rz. 248 (F-3) (Pl. 7, Fig. 1).

Ranikothalia antillea is figured on Pl. 1, Fig. 5–7; Pl. 2, Fig. 2, 3, 5; Pl. 6, Fig. 4–6.

Ranikothalia tobleri: Pl. 1, Fig. 2, 3; Pl. 2, Fig. 4, 7; Pl. 6, Fig. 2.

Ranikothalia soldadensis: Pl. 1, Fig. 1, 4; Pl. 2, Fig. 1, 6, 8; Pl. 6, Fig. 1, 3; Pl. 7; Pl. 8, Fig. 1–3.

Occurrence: see Distribution Chart (Part 1).

Genus *Operculinoides* HANZAWA, 1935*Operculinoides soldadensis* VAUGHAN & COLE

(Pl. 1, Fig. 11, 19; Pl. 8, Fig. 5-8, 10 cf.)

- ?1937 *Operculina* ? *floridensis*, VAUGHAN, p. 159, Pl. 115, Fig. 1.
 1941 *Operculinoides soldadensis*, VAUGHAN & COLE, p. 18, 27, 40, Pl. 9, Fig. 5-8; Pl. 10, Fig. 1, 2.
 1947 *Nummulites (Operculinoides) soldadensis*, DE CIZANCOURT, Bull. Soc. géol. France, (5), 17, p. 517, Pl. 25, Fig. 8-10, 13.
 1958 *Operculinoides floridensis*, COLE 1958b, Pl. 22, Fig. 4.
 1962 *Camerina floridensis*, COLE 1962b, p. 148, 149.
 1974 *Operculinoides soldadensis*, CAUDRI, p. 302, Pl. 1, Fig. 3-5; Pl. 4, Fig. 2, 5, 6.

This species has been adequately illustrated in 1941, but a couple of photographs of topotypes are added here, mainly to accentuate the long curved chambers which distinguish *O. soldadensis* from the accompanying *O. ocalanus*.

A granulated variety of the species was found at K. 1499 (Bed 9) and K. 2651 (Bed 9a).

Pl. 8, Fig. 10, illustrates the isolated specimen of *Operculinoides* cf. *soldadensis* found in Bed 11 (K. 10721).

Syntypes: VAUGHAN & COLE 1941, Pl. 9, Fig. 5-8.

Type locality: K. 3692 (D-3).

Type level: Upper Eocene, Bed 10.

Occurrence: see Distribution Chart (Part 1); the frequency of *O. soldadensis* and *O. ocalanus* seems to alternate in the deposits of Soldado Rock, maybe under influence of fluctuating environmental conditions.

Operculinoides ocalanus (CUSHMAN)

(Pl. 1, Fig. 12; Pl. 8, Fig. 4, 9)

- 1921 *Operculina ocalana*, CUSHMAN, Prof. Pap. U.S. Geol. Surv., 128-E, p. 129, Pl. 19, Fig. 4, 5.
 1935 *Operculina (Operculinoides) ocalana*, HANZAWA, Sci. Rep., Tohoku Imp. Univ., (2), 18, p. 18.
 1937 *Operculina ocalana*, VAUGHAN, p. 158, 159, Fig. 113 (1-5), 114 (1-3).
 1939 *Operculinoides ocalanus*, BARKER, p. 316, 317, Pl. 12, Fig. 5; Pl. 15, Fig. 5.
 1941 *Operculinoides ocalanus*, VAUGHAN & COLE, p. 18, 27, 38, Pl. 8, Fig. 8, 9; Pl. 9, Fig. 1-4; Pl. 10, Fig. 11.
 1944 *Operculinoides ocalanus*, COLE, p. 48, Pl. 1, Fig. 5, 10; Pl. 2, Fig. 8; Pl. 5, Fig. 1, 4-6; Pl. 7, Fig. 18, 20.
 1958 *Operculinoides floridensis*, COLE 1958b, Pl. 18, Fig. 2, 7-10; Pl. 19, Fig. 8, 13.
 1974 *Operculinoides ocalanus*, CAUDRI, p. 302, Pl. 1, Fig. 1-2; Pl. 4, Fig. 1, 3, 4.

Most specimens from Soldado Rock have a smooth surface, though they are sometimes heavily ribbed, for instance at K. 2854. The granulated variety, like the one figured by VAUGHAN from Ecuador (1937, Fig. 113 (3)), was found at K. 2651 (Bed 9a).

Types: CUSHMAN 1921, Pl. 19, Fig. 4, 5.

Type locality: U.S.G.S. n° 6747, Escambia County, Alabama.

Type level: Upper Eocene (Ocala limestone).

Occurrence: see Distribution Chart (Part 1); the frequency of *O. ocalanus* and *O. soldadensis* seems to alternate in the Soldado deposits.

Operculinoides kugleri VAUGHAN & COLE

1941 *Operculinoides kugleri*, VAUGHAN & COLE, p. 18, 27, 42, Pl. 10, Fig. 3–5, 7, 8; Pl. 13, Fig. 1, 2, 3?

Syntypes: VAUGHAN & COLE 1941, Pl. 10, Fig. 3–5, 7, 8; Pl. 13, Fig. 1, 2.

Type locality: K. 1499 (E-2).

Type level: Upper Eocene, Bed 9.

Occurrence: see Distribution Chart (Part 1).

Operculinoides trinitatensis (NUTTALL)

(Pl. 1, Fig. 10, 16; Pl. 8, Fig. 14, 15)

1928 *Operculina trinitatensis*, NUTTALL, p. 102, 103, Pl. 8, Fig. 10, 11; Textfig. 7 (not 8 and 9).

1941 *Operculinoides trinitatensis*, VAUGHAN & COLE, p. 47, Pl. 10, Fig. 12; Pl. 13, Fig. 4–14 (pars).

1962 *Camerina trinitatensis*, COLE 1962b, p. 149.

Operculinoides trinitatensis, as described and figured by NUTTALL and by VAUGHAN & COLE, comprises a heterogeneous group of mutually related forms, linked together by so many gradual transitions that it is very difficult to tell them apart. When working together in Trinidad in 1940, Mr. Grimsdale and the present writer agreed that for practical purposes the species should be narrowed down, and that the name “*trinitatensis*” be given only to the thick-lenticular, narrow-coiled form.

This means that in NUTTALL’s paper the three specimens illustrated on Pl. 8 and as Textfig. 7 should be designated as the type specimens of the species, whereas Textfigs. 8 and 9 should be excluded. Textfig. 8 looks more like a specimen of *O. ocalanus* (CUSHMAN) or *O. kugleri* VAUGHAN & COLE, and Textfig. 9 represents *O. soldadensis* VAUGHAN & COLE.

In VAUGHAN & COLE’s study all the different forms are combined, but the authors recognized that some of them are grading into other species, like *O. kugleri* (p. 50, 97, Pl. 12, Fig. 13, 14). Typical are those reproduced (loc. cit.) on Pl. 13 as Fig. 4–7, 8 (righthand specimen), 9 (lefthand specimen) and on Pl. 10, Fig. 12.

Type specimens: NUTTALL 1928, Pl. 8, Fig. 10, 11; Textfig. 7.

Type locality: Tarouba Estate, Naparima (San Fernando) area, Trinidad, Test Well A at 570 feet.

Type level: Upper Eocene.

Occurrence: see Distribution Chart (Part 1); transitions to *O. kugleri* at K. 2651, K. 2854 and others.

Operculinoides trinitatensis granulatus n. subsp.

(Pl. 1, Fig. 15; Pl. 8, Fig. 11, 12)

1941 *Operculinoides trinitatensis*, VAUGHAN & COLE, Pl. 13, Fig. 9 (righthand specimen).

Typically, *Operculinoides trinitatensis* has a smooth surface on which, at the best, the septal filaments are accentuated as slightly raised radiating costae. But amongst the many non-typical forms there are also some rather rare specimens with more or less pronounced granulations along those ridges.

For these conspicuous “pillared” forms the name of *Operculinoides trinitatensis granulatus* is proposed. It is, to a minor degree, also represented in NUTTALL’s type material of *O. trinitatensis* from Trinidad (VAUGHAN & COLE 1941).

Holotype: Pl. 1, Fig. 15.

Type locality: K. 2855 (F-3).

Type level: Upper Eocene, Bed 7.

Occurrence: K. 1316, K. 2855

Operculinoides spiralis n. sp.

(Pl. 1, Fig. 20; Pl. 8, Fig. 13)

This is a very rare species, both in Trinidad and on Soldado Rock. Even in otherwise rich faunas hardly more than three or four specimens were encountered and mostly less.

Exterior: test extremely flat and thin, transparent so as to show the internal spiral on the outside. Spiral tending to become complanate, but very fine wavy filamental lines continue right to the center of the test even in the largest specimens, so it remains involute to the end. Surface mostly smooth, but sometimes (for instance in the holotype) very fine granulations are developed along the septa. Maximal diameter observed: 2.5 mm. (Our illustration of the external view was taken from the better preserved Trinidad material.)

Horizontal section: spiral rather slowly increasing in height, strikingly regular, with a great number of evenly curved septa, ± 25 in the last whorl. Nucleoconch very small, but in all cases clearly megalospheric.

Vertical section: unknown; it proved to be technically impossible to make a satisfactory section of this extremely thin and sparse form.

Holotype: Pl. 8, Fig. 13.

Type locality: K. 2651 (E-4).

Type level: Upper Eocene, Bed 9a.

Occurrence: K. 2651, K. 2854; K. 3692? (Bed 10).

Genus *Actinosiphon* VAUGHAN, 1929

Actinosiphon barbadensis (VAUGHAN)

(Pl. 9, Fig. 1)

1944 *Lepidorbitoides* cf. *planasi*, CAUDRI, p. 16–17, Pl. 1, Fig. 3; Pl. 2, Fig. 10; Pl. 3, Fig. 14.

1945 *Lepidocyclina* (*Polylepidina*) *barbadensis*, VAUGHAN, p. 49–50, Pl. 19, Fig. 6–9 (not Fig. 5).

non 1946 *Lepidorbitoides* cf. *planasi*, CUSHMAN & RENZ, p. 10.

1948 *Lepidorbitoides* cf. *planasi*, CAUDRI, p. 473, 476–479, Pl. 73, Fig. 1, 2, 9, 11.

1951 «*Lepidocyclina*» *barbadensis*, VAN RAADSHOOVEN, p. 478–481, Pl. 1, Fig. 1–5(?), Textfig. e–f(?).

1951 *Actinosiphon barbadensis*, DE CIZANCOURT, p. 56–58, 62, Pl. 5 (photographs), Fig. 3–12, 20; Pl. 6 (drawings), Fig. 1–8, 9?, 10–12, 13?, 14?, 15, 16?, 17?, 18, 19?, 21 (*A.* «*semmesi*»), 22, 23?, 24.

1959 *Actinosiphon semmesi*, COLE, p. 382 (pars; not *A. semmesi* VAUGHAN 1929).

1961 *Actinosiphon barbadensis*, CAUDRI, p. 286.

1962 *Lepidocyclina* (*Polylepidina*) *barbadensis*, HANZAWA, p. 146, Pl. 3, Fig. 19–23 (drawings).

1972 *Actinosiphon barbadensis*, CAUDRI 1972b, p. 224, 226, 227, 230, 231.

This is the form which I determined at first sight as *Lepidorbitoides* cf. *planasi* and which lead me to the belief that the genus *Lepidorbitoides* crossed the Cretaceous–Tertiary border (1948).

It was clear to me at the time that my material was identical to VAUGHAN's "*Polylepidina*" *barbadensis* and also that the latter species could not be a true *Polylepidina*; but to place it in the genus *Lepidorbitoides* was equally erroneous. The first student to point out its similarity to *Actinosiphon* was VAN RAADSHOOVEN. DE CIZANCOURT, independently of him, placed it squarely in that genus. This is correct, and there is no doubt that *Lepidorbitoides* is restricted to the Cretaceous and is replaced in the Tertiary by *Actinosiphon*. The latter is represented in the Caribbean area by *A. barbadensis* and perhaps a second species in Western Venezuela (VAN RAADSHOOVEN), and in the Paleocene of Mexico by *A. semmesi*.

VAUGHAN (loc. cit., p. 139) chose as syntypes for his new species two quite different specimens, from different localities (Pl. 19, Fig. 5 and 8). The one illustrated by Figure 5, described in detail on page 50, is obviously not typical of a "*Polylepidina*" and on closer observation it turns out to be *Hexagonocyclina inflata*; but he specifically mentions the second specimen (Fig. 8) as resembling *Polylepidina* in its auxiliary chambers. We hereby designate this second specimen as the lectotype of *A. barbadensis* (VAUGHAN).

On Soldado Rock, only one isolated specimen of *A. barbadensis* was found: in the clastic rubble at K.2951B, which is directly traceable to the Paleocene Soldado Formation.

The nearest other locality of *A. barbadensis* is Point Bontour near San Fernando, Trinidad, where it occurs in considerable numbers in an erratic block (St. 48) of Paleocene age, together with *Ranikothalia antillea*, *Hexagonocyclina inflata*, *Athecocyclina* sp. and *Neodiscocyclina aguerreveri*.

As the Soldado specimen was not satisfactory for photographic reproduction, another one from Point Bontour (reworked into the Upper Eocene at St. 63) was selected to illustrate the species (Pl. 9, Fig. 1).

Lectotype: VAUGHAN 1945, Pl. 19, Fig. 8.

Type locality: S. 97, block in Joes River mudflow, Barbados.

Type level: Paleocene.

Occurrence: K. 2951 B (D-4), Bed 4; reworked.

Genus *Hexagonocyclina* CAUDRI, 1944

Hexagonocyclina meandrica CAUDRI

(Pl. 3, Fig. 1, 12; Pl. 9, Fig. 8-12; Pl. 10, Fig. 1, 3-5)

1944 *Hexagonocyclina meandrica*, CAUDRI, p. 363, Pl. 2, Fig. 7, 9.

1945 *Discocyclina* (*Discocyclina*?) *meandrica*, VAUGHAN, p. 75, 76.

1948 *Bontourina meandrica*, CAUDRI, p. 477-479.

? 1951 *Bontourina saturniformis*, DE CIZANCOURT, p. 55, 62, Pl. 5, Fig. 18; Pl. 6, Fig. 25, 26, 31, 32 (not 27 and 28).

? 1957 *Discocyclina* (*Discocyclina*) *cristensis*, pars, SACHS, p. 115-117, Pl. 16, Fig. 5, 8, 9.

? 1972 *Hexagonocyclina* cf. *meandrica*, CAUDRI 1972b, p. 227.

The type material of *Hexagonocyclina meandrica* is enclosed in a hard limestone and it is very difficult to obtain good orientated sections of the specimens.

The species is rather rare in the material from Soldado Rock, but it is represented by loose specimens which are easier to handle and add a few points to the original description.

Exterior: test very flat, up to 3.5 mm in diameter, but edges mostly broken off; surface pillarless or very finely granulated; lateral chambers thin-walled, elongated to meandric.

Horizontal section: nucleoconch small, thin-walled, consisting of two subequal rounded chambers separated by a slightly curved wall, followed by two very large auxiliary chambers, often of unequal size, sometimes larger or at least longer than the embryonic chambers (Pl. 10, Fig. 1), and four irregular nepionic spirals; equatorial chambers at first rounded, soon changing to hexagonal, becoming more and more elongate towards the edge, peripheral chambers often rectangular. Radial walls thin and alternating in adjoining annuli. No stolons observed, but the distal end of the radial wall is sometimes thinning out or incomplete.

Vertical section: known with certainty only from one broken specimen from K. 2950, the other half of which was used for a horizontal section: all chambers thin-walled, median layer comparatively high, shape of lateral chambers not very clear but probably rectangular, stacked in 4 or 5 layers in the center, but lacking in the marginal part of the test which is formed by the uncovered equatorial chambers alone.

Hexagonocyclina meandrica differs from the more common *H. inflata* in the shape of the test and the pattern of the lateral chambers. Even in small specimens of *H. meandrica*, and in the inner layers of the larger ones, these chambers are already elongate in shape, versus the regular reticulate pattern in *H. inflata*.

Also the irregularity of the nepionic chambers seems to distinguish *H. meandrica* from *H. inflata*, which always shows a neat ring of small subequal periembryonic chambers (Pl. 9, Fig. 2, 3; Pl. 10, Fig. 2).

Thus far, all the specimens have turned out to be megalospheric, though in some of them the nucleoconch is very small. The microspheric form is as yet unknown.

Holotype: CAUDRI 1944, Pl. 2, Fig. 7.

Type locality: G. 128, San Juan de Los Morros, Guarico, Venezuela.

Type level: Paleocene.

Occurrence: (reworked from the Paleocene) see Distribution Chart (Part 1).

Hexagonocyclina inflata (CAUDRI)

[Pl. 3, Fig. 2, 3, 4, 11, 13; Pl. 9, Fig. 2-7; Pl. 10, Fig. 2 (note: the specimens illustrated by Pl. 3, Fig. 2; Pl. 9, Fig. 2, 3 and 6, and Pl. 10, Fig. 2 are from Point Bontour, Trinidad)].

- 1944 *Hexagonocyclina* sp., «undescribed small robustly lenticular species from Trinidad and Soldado Rock», CAUDRI, p. 363.
- ?1945 *Lepidocyclina* (*Polylepidina*) *barbadensis* pars, VAUGHAN, p. 50, Pl. 19, Fig. 5 (not Fig. 6-9).
- 1947 *Discocyclina* (*Discocyclina*) *barkeri*, COLE & BERMUDEZ, p. 201, Pl. 18, Fig. 7, 8.
? *Discocyclina* (*Discocyclina*?) sp., *ibid.*, p. 192, 203, Pl. 20, Fig. 1, 8.
- 1948 *Bontourina inflata*, CAUDRI, p. 477, Pl. 73, Fig. 6; Pl. 74, Fig. 5.
- 1951 *Bontourina* cf. *inflata* pars, DE CIZANCOURT, p. 13, 17, 23, 25, 28, 30, 32, 55, 62 (non p. 36, 42), Pl. 5, Fig. 23?; Pl. 6, Fig. 20, 27, 28.
- 1957 *Discocyclina* (*Discocyclina*) *barkeri* pars, SACHS, p. 115, Pl. 15, Fig. 1?, 6, 8 (not Fig. 2-5, 7, 9, 10 and 12, which represent real «*Discocyclina*» (*Neodiscocyclina*) *barkeri*).

This species was created and illustrated in 1948 under the invalid generic name *Bontourina* (a synonym of *Hexagonocyclina* 1944), but was not described in detail. The types are from Trinidad (Pl. 3, Fig. 2; Pl. 9, Fig. 2, 3, 6; Pl. 10, Fig. 2) and a full

description will be given in connection with that material. Meanwhile, the species can be characterized as follows:

Exterior: test small, robust lenticular, smooth or with tiny superficial granulations, surface covered with a regular network of thin-walled polygonal lateral chambers.

Horizontal section: nucleoconch small and thin-walled, composed of two subequal rounded chambers separated by a slightly curved wall. These are followed by two auxiliary chambers and four periembryonic spirals of one or two chambers each, often closed off by a symmetrical chamber. All of these chambers are subequal in size and form a rather regular complete ring around the nucleoconch. Equatorial chambers thin-walled, alternating, arranged in definite circles, at first rounded, then broad hexagonal, gradually growing more elongate hexagonal; in exceptionally well-preserved specimens with intact rim the chambers may finally assume a rectangular shape.

Vertical section: all chambers very thin-walled; median layer low, with curved vertical walls (tending to develop a "chainstitch" appearance); lateral chambers rectangular, in regular vertical rows, about 12 on either side of the nucleoconch.

No microspheric forms are known.

Locally, *Hexagonocyclina inflata* is quite a common species, associated with *Neodiscocyclina barkeri*, which is of the same general shape and size. It is not clear whether the pillarless form, which is particularly common in the Paleocene rubble in Soldado Bed 4 (K.2951 B), is a special variety of the species or the mere product of erosion. The granulations in other specimens prove to be entirely superficial: they get lost the moment the specimen is ground down. Real pillars were nowhere observed.

Holotype: CAUDRI 1948, Pl.74, Fig.5 (reproduced in the present paper as Pl.9, Fig.2 and Pl.10, Fig.2).

Type locality: Point Bontour near San Fernando, Trinidad (reworked specimens in the Upper Eocene, Cd.18).

Type level: Paleocene.

Occurrence: in the erratic Paleocene block Rz.248 (F-3), and as detached reworked specimens in the Upper Eocene (Beds 3, 4 and 10); see Distribution Chart (Part 1).

Genus *Athecocyclina* VAUGHAN & COLE, 1941

Athecocyclina soldadensis (VAUGHAN & COLE)

(Pl.11; Pl.12, Fig.1)

1941 *Pseudophragmina* (*Athecocyclina*) *soldadensis*, VAUGHAN & COLE, p.62, Pl.19, Fig.4-8.

1944 *Athecocyclina soldadensis*, CAUDRI, p.365, 366, 378, 379.

1945 *Pseudophragmina* (*Athecocyclina*) *soldadensis*, VAUGHAN, p.101, 105, 115, Pl.44, Fig.3, 4.

1948 *Athecocyclina soldadensis*, CAUDRI, p.478, 479?

1961 *Pseudophragmina soldadensis*, O. RENZ in: CAUDRI 1961, p.285.

1972 *Athecocyclina soldadensis*, CAUDRI 1972a, p.217.

The type sample of *Athecocyclina soldadensis* was taken from a big block of hard limestone embedded in the Upper Eocene on the S.E. shore of the Rock (K.2851, E-4). This is KUGLER's "Discocyclina limestone" (1938). The fauna in this limestone is very unevenly distributed: actually, only one section of a real "*Discocyclina*"

(probably *Neodiscocyclina aguerreveri*) was observed in it, but locally it carries *Athecocyclina soldadensis* in great abundance, whereas in other spots the rock-building elements are Smaller Foraminifera (chiefly Globigerinas), echinoids or pelecypods or algae. A more correct name for this rock is the "Athecocyclina limestone". The Athecocyclinas cannot be detached from this hard matrix. VAUGHAN realized that the type material at his disposal in 1941 was not very satisfactory, and it was at his request that the present writer made a couple of orientated horizontal sections of the species from duplicate material of this same sample in the collection at Pointe-à-Pierre. Two of those sections, which show the embryonic and nepionic development in a very convincing way, were reproduced in VAUGHAN's subsequent paper (1945, Pl. 44). As neither VAUGHAN & COLE, nor VAUGHAN afterwards, chose a particular specimen as the holotype, one of those presented in 1945 (Pl. 44, Fig. 4) is herewith designated as the lectotype of *Athecocyclina soldadensis*.

The type description of *A. soldadensis* is rather sketchy and not too reliable in some respects, partly due to the circumstance that the authors did not have any detached specimens at their disposal. I had the good luck to encounter them, as reworked specimens in several Eocene samples, but the poor state of preservation does not permit an exhaustive description of the external features of the test, either. However, a few supplemental remarks on the habitus as well as on the horizontal and vertical sections can be added here.

Exterior: VAUGHAN & COLE describe the species as pillarless. In general, this is correct, but several specimens in K. 2951 and K. 2951 B have small pillars, arranged in concentric rows.

Horizontal section: VAUGHAN's figures (1945) show the normal megalospheric form. Its nucleoconch consists of a globular protoconch and a kidney-shaped second chamber, which is followed by 2 or 3 far-embracing nepionic chambers before the adult annular pattern sets in. However, the embryonic development is not always that regular. Sometimes, the nucleoconch is followed by a loose spiral of two or three equally large chambers before the first nearly complete annular chamber is formed (Pl. 11, Fig. 4). The same was, somewhat doubtfully, also observed in a specimen of *A. soldadensis calebardensis* VAUGHAN from the Paleocene of Barbados (Joes River blocks).

Judging from their figures, it is difficult to say whether VAUGHAN & COLE have also encountered the microspheric form of their species, but in my own material from K. 2951 and K. 2951 B some of the specimens definitely turned out to be B-forms (Pl. 11, Fig. 1; Pl. 12, Fig. 1). Their initial development corresponds with that of *A. soldadensis calebardensis*, described by VAUGHAN as "flabelliform" (1945, p. 46, Pl. 18). This type of development places the genus *Athecocyclina* in the Family of the Discocyclinidae s. s. (CAUDRI 1972a).

Vertical section: as stated by VAUGHAN & COLE, the test of *A. soldadensis* is very thin and has only four or five layers of very low lateral chambers, the vertical walls of which are so thin that they tend to escape observation. On the other hand, the thickness of the horizontal walls of both the equatorial layer and the lateral chambers does not exceed the height of the cavities, as described by them: in a good vertical section, like the one reproduced here (Pl. 11, Fig. 3, 5), the cavities prove to be low but well developed and the horizontal walls are exceedingly thin.

Lectotype: VAUGHAN 1945, Pl. 44, Fig. 4.

Type locality: K. 2851 (E-4).

Type level: Paleocene (reworked block lying in Upper Eocene).

Occurrence: enclosed in the typical *Athecocyclina* limestone blocks K. 2851 (E-4), K. 10720 (B-2) and Cd. 22 (G-3) and, as loose reworked specimens, scattered through the Upper Eocene Beds 3 and 4; see Distribution Chart (Part 1).

Genus *Proporocyclina* VAUGHAN & COLE, 1941

Proporocyclina tobleri (VAUGHAN & COLE)

(Pl. 1, Fig. 13, 14; Pl. 3, Fig. 5, 6; Pl. 12, Fig. 2-5; Pl. 13, Fig. 1-4, 7)

- 1941 *Pseudophragmina* (*Proporocyclina*) *tobleri*, VAUGHAN & COLE, p. 62, Pl. 21, Fig. 6; Pl. 22, Fig. 3, 4.
 1944 *Pseudophragmina* (*Proporocyclina*) *tobleri*, CAUDRI, p. 385.
 1945 *Pseudophragmina* (*Proporocyclina*) *tobleri*, VAUGHAN, p. 65, 67, 94, 106, 107, 115, Pl. 37, Fig. 4, 5.
 non 1946 *Pseudophragmina* (*Proporocyclina*) cf. *tobleri*, CUSHMAN & RENZ, p. 11.
 1947 *Pseudophragmina* (*Proporocyclina*) *tobleri*, COLE & BERMUDEZ, p. 21.
 ? *Pseudophragmina* (*Proporocyclina*) *habanensis*, *ibid.*, p. 19, Pl. 6, Fig. 5-8.
 1948 *Proporocyclina tobleri*, CAUDRI, p. 478, 479.
 1958 *Pseudophragmina* (*Proporocyclina*) *tobleri*, COLE 1958c, p. 414, 416, 417.
 1959 *Pseudophragmina* (*Proporocyclina*) *tobleri*, COLE, p. 380, 381, 385, 386, Pl. 32, Fig. 5-12.
 1962 *Pseudophragmina* (*Proporocyclina*) *tobleri*, COLE 1962b, p. 149.
 1964 *Pseudophragmina* (*Proporocyclina*) *tobleri*, COLE & APPLIN, p. 21, 26, 33, 34, Pl. 11, Fig. 4-6, 10-12.
 1968 *Pseudophragmina* (*Proporocyclina*) *tobleri*, BUTTERLIN, p. 183.
 1969 *Pseudophragmina tobleri*, COLE 1969a, p. 10, 11, 12, 48.
 1972 *Proporocyclina tobleri*, CAUDRI 1972a, p. 217.
 ? 1972 *Proporocyclina tobleri*, CAUDRI 1972b, p. 224, 230-231.

The species is well characterized by its authors and only a few additional observations are needed.

In spite of the heavy recrystallization of the material, a wide variation was noticed in the external features, even between specimens from the same sample. The test may be flat and pillarless, or flat with pillars (in part even with heavy pillars), or lenticular with pillars.

Internally, the diagnostic features are:

- a) very narrow annuli in comparison with other species of the genus;
- b) wide equatorial "chambers" which right to the edge of the test retain their squarish shape; radially elongated "chambers", up to 1½ times longer than wide (Pl. 12, Fig. 2, 4), occur occasionally, especially after regeneration (K. 3878, E. L. 1440);
- c) radial walls very thin, wavy and hesitating in their direction, often not quite complete;
- d) lateral chambers irregular, slitlike very low and with heavy roofs.

Of the three syntypes illustrated by VAUGHAN & COLE, two represent the megalospheric form; they were later also reproduced in VAUGHAN's work (1945). The third one (Pl. 22, Fig. 4), which was left out of the type description, is microspheric. Another microspheric specimen was figured by COLE in 1959 and a couple more are added here (Pl. 13, Fig. 1, 2, 4), all from K. 3878, but they were also found in other places, for instance at K. 10721, K. 10722 and E. L. 1440 in Bed 11 and reworked at K. 1316, K. 3690, K. 3692 and K. 10718. They show the complicated initial pattern typical of

the Family Discocyclinidae s.s. (CAUDRI 1972a). The "equatorial chambers" of the species are, therefore, morphologically secondary chamberlets. There is no external difference between the two generations, either in size or shape or decoration of the test. Sample K.10718 contains a monstrous megalospheric specimen with triple nucleocoench.

The type locality of *Proporocyclina tobleri*, K.3878, lies in Bed 11, topographically the highest horizon of the Soldado section, overlying typical Upper Eocene beds. Several other samples from the same bed yielded great quantities of this fossil and it was found throughout the rest of the Upper Eocene. But morphologically *P. tobleri* cannot be accepted as a Late Eocene form. As far as we know at the moment, it is the most primitive of all Proporocyclinas. Other primitive species, like *P. clarki* and *P. psila* from California, *P. peruviana* from Peru and *P. cushmani* from Mexico (and Florida?), which are with certainty placed in the Middle Eocene, are already of a more advanced type as regards the firmness of their radial walls and the tendency towards more elongated chamberlets. Also, they have better developed lateral chambers. In comparison, *P. tobleri* seems to precede them all in the line of evolution, and tentatively its age is placed at the turn of the Early to the Middle Eocene. Its position in the field section does not correspond with its original stratigraphical level and is due to secondary deposition. As a matter of fact, in various samples from Beds 9, 9a and 10 (K.1499; K.1316; K.10716, K.10718) the difference in preservation between the specimens of *P. tobleri* and the normally present Jacksonian species definitely points to reworking. Bed 11, in which *P. tobleri* is autochthonous, is a slipmass into Bed 10 (see p.535).

The geographical distribution of *P. tobleri* is still incompletely known. Outside of Soldado Rock it has been found in Trinidad in an erratic block of typical Proporocyclina tobleri limestone in the Southern Range and, as isolated specimens, in the Middle Eocene Navet Formation at Dunmore Hill, East of San Fernando; further, it is recorded from two wells in the Walton County of Florida (identified chiefly on vertical sections in hard rock; COLE & APPLIN 1964) and from the lower part of a well in Campeche, Mexico (BUTTERLIN 1968; convincing, but recrystallized and in hard rock only), and it occurs perhaps in the Habana Province of Cuba (described as "*P. habanensis*" by COLE & BERMUDEZ in 1947).

On the strength of the accompanying fauna, COLE & APPLIN (loc.cit., p.21, 34) came to the same conclusion on the age of *P. tobleri* as I did on account of the above mentioned reasons of evolutionary development: "it would appear in Florida that *P. tobleri* marks a zone within the Lower Eocene, although there is a possibility that the strata may be lower Middle Eocene"; COLE (1969a, p.48) puts the Soldado type locality without further comments in the Lower Eocene. The association in which *P. tobleri* occurs in Mexico is of a more pronounced Middle Eocene character.

Syntypes: VAUGHAN & COLE 1941, Pl.22, Fig.3 and 4; Pl.21, Fig.6 (for better photographs of Fig.3 and 6: see VAUGHAN 1945).

Type locality: K.3878 (C-3), Bed 11.

Type level: lowest Middle Eocene or uppermost Lower Eocene (Boca de Serpiente Formation).

Occurrence: abundant in Bed 11, where it is the main component of the *Proporocyclina tobleri* limestone; scattered throughout Beds 4, 9, 9a and 10; see further Distribution Chart (Part 1).

Proporocyclina mirandana (HODSON)

(Pl. 13, Fig. 5, 6)

- 1926 *Discocyclina mirandana*, HODSON, p. 8, Pl. 1, Fig. 3, 10, 13 (see also VAUGHAN 1945).
 ?1932 *Discocyclina (Discocyclina) flintensis*, GORTER & VAN DER VLERK, p. 111, Pl. 16, Fig. 5, 6.
 1941 *Pseudophragmina (Proporocyclina) flintensis*, VAUGHAN & COLE, p. 10, 20, 27, 61, Pl. 20, Fig. 8, 9.
 1945 *Pseudophragmina (Proporocyclina) mirandana*, VAUGHAN, p. 92-94, Pl. 37, Fig. 2, 3 (much improved reproduction of HODSON's types!)
 1972 *Proporocyclina flintensis*, CAUDRI 1972a, p. 217, Pl. 1, Fig. 4.

Proporocyclina mirandana is rather regularly present in the Upper Eocene samples from Soldado Rock, but it is scarce. The only locality where it is represented by any considerable number of specimens is K. 1499 (Bed 9).

HODSON's type description refers to the microspheric form of the species. Her Venezuelan material did not contain any A-forms, but she reports a megalospheric specimen from Trinidad (Point Bontour).

Nearly all the material from Soldado Rock turned out to be megalospheric (see VAUGHAN & COLE's illustration of two specimens from K. 1499), but one microspheric form has been found in the sample from K. 3677. It shows the "discocyclinid" type of nepiont, which places the genus *Proporocyclina* in the family of the Discocyclinidae (CAUDRI 1972).

Syntypes: HODSON 1926, Pl. 1, Fig. 3, 10, 13.

Type locality: locality number 3256, State of Zulia, Venezuela.

Type level: Eocene (probably Upper Eocene).

Occurrence: see Distribution Chart (Part 1); microspheric form at K. 3677.

Genus *Pseudophragmina* H. DOUVILLÉ, 1923

Pseudophragmina (?) sp. indet.

(Pl. 13, Fig. 8)

Sample E. L. 1440 yielded one highly recrystallized specimen which is tentatively assigned to this genus (*Pseudophragmina* s. s. in the sense of VAUGHAN & COLE 1941). Because the fauna in this sample contains a large number of specimens of *Proporocyclina tobleri*, some with unusually long chamberlets, the form under consideration might perhaps be nothing more than an aberrant individual of that species, but it has a much larger embryonic apparatus and at the same time very close-set radial septa.

For a *Pseudophragmina* s. s., one may object that there are too many complete septa in this specimen. On the other hand, it may well be that incompleteness of the septa in this genus is everywhere a secondary feature, caused by recrystallization and the effects of light refraction.

Occurrence: E. L. 1440 (C-1), Bed 11.

Genus *Neodiscocyclina* CAUDRI, 1972*Neodiscocyclina barkeri* (VAUGHAN & COLE)

(Pl. 3, Fig. 7, 9; Pl. 14, Fig. 1-4, 6-10; Pl. 23, Fig. 1)

- 1941 *Discocyclina* (*Discocyclina*) *barkeri*, VAUGHAN & COLE, p. 9, 24, 25, 57, Pl. 18, Fig. 4, 6, 7 (not 5); Pl. 21, Fig. 1-2.
- 1945 *Discocyclina* (*Discocyclina*) *barkeri*, VAUGHAN, p. 18, 19, 31, 57, 59, 64, 65, 104, 105, 112, Pl. 6, Fig. 1-10.
- 1947 *Discocyclina* (*Discocyclina*) *barkeri*, COLE & BERMUDEZ, p. 200-202, Pl. 17, Fig. 1-5; Pl. 18, Fig. 9, 10 (not p. 201, Pl. 18, Fig. 7, 8, *Hexagonocyclina inflata*).
- 1948 *Discocyclina barkeri*, CAUDRI, p. 476-479.
- ? 1951 *Discocyclina* (*Discocyclina*) *barkeri*, DE CIZANCOURT, p. 10-14, 16-17, 19-28, 30-32, 50-51, Pl. 4, Fig. 18?, 19?; Pl. 6, Fig. 30? (not 29).
- 1957 *Discocyclina* (*Discocyclina*) *barkeri*, SACHS, p. 113-115, Pl. 15, Fig. 1?, 2-5, 7, 9-11 (not 6, 8, 12?, which represent *Hexagonocyclina inflata*).
- non 1969 *Discocyclina* (*Discocyclina*) *barkeri*, COLE 1969b, p. 83, Pl. 16, Fig. 11 (*Neodiscocyclina caudriae*).
- 1972 «*Discocyclina*» (*Neodiscocyclina*) *barkeri*, CAUDRI 1972a, p. 216, Pl. 1, Fig. 2.
- 1972 *Neodiscocyclina barkeri*, CAUDRI, p. 224, 230.

The syntypes of *Neodiscocyclina barkeri* are from K. 2951, but the description also includes material from K. 2950, a sample taken from the same restricted outcrop of the marly matrix of Bed 3. In 1945, VAUGHAN speaks of specimens from the latter locality as "topotypes" and this is for all practical purposes correct.

The species has been so well described and illustrated by VAUGHAN & COLE in 1941 and VAUGHAN in 1945 that it is hardly necessary to go into the details again.

However, it may be useful to stress the shape and the position of the main auxiliary chambers as one of the most important characteristics of the species, and to draw special attention to the tendency towards a polygonal pattern of the equatorial layer. Also, the description and illustration of the microspheric form is added.

The periembryonic annulus is described by VAUGHAN (p. 31) as follows: "There are two long narrow principal auxiliary chambers, one leading from each end of the crescent of the deuteroconch and meeting at the end of the nucleoconch axis on the periphery of the protoconch. Around the periphery of the deuteroconch between the ends of the auxiliary chambers there are five shorter chambers, making seven periembryonic chambers."

The number of these shorter chambers is variable and the main auxiliary chambers do not always meet exactly, but the presence of these two large chambers around the protoconch and their peculiar elongated or wedge-shaped form seem to be constant and diagnostic. They are shown in one of the syntypes (1941, Pl. 18, Fig. 7) and some of the "topotypes" from K. 2950 (1945, Pl. 6, Fig. 3-5)²). Another "topotype", with slightly separated auxiliary chambers, and a (less convincing) specimen from Cuba are figured by SACHS (1957, Pl. 15, Fig. 7 and 11, 5 and 10)³). Also COLE & BERMUDEZ's

²) On pages 31 and 59, VAUGHAN describes Figure 5 as an exceptional case in which the protoconch is completely surrounded by a circular deuteroconch. This is an error: it is a normal specimen with a reniform deuteroconch and two enormous auxiliary chambers, as is stated by VAUGHAN himself in the explanation of the plate, page 126.

³) The magnification of Figures 1-7 and 12 is given as $\times 20$, but it seems that this is correct only for Figure 5; for the others, a magnification of $\times 40$ is more likely.

material from Cuba shows this peculiar feature (1947, Pl. 18, Fig. 9–10). We here add some photographs of our own (Pl. 14, Fig. 1–3, 6).

As to the equatorial layer, its irregularity is another characteristic of the species. Various authors, who objected to the creation of the genus *Hexagonocyclina* (“*Bontourina*”), a form which, amongst other more important points, features a predominantly hexagonal shape of the median chambers, have pointed out that also in *N. barkeri* the chambers are frequently hexagonal instead of rectangular. This cannot be denied, but in the adult stage the rectangular shape is the rule.

More than this variability in the shape of the chambers, their arrangement deserves our closer attention. VAUGHAN & COLE state: “(the chambers) occur in definite but rather wavy annuli.” In our rich material, especially in that from K. 2950, but also from other samples (K. 2951, 2951 B, 9453, 10721; Rz. 252, 253, 255) and from other areas (Trinidad, Barbados), there are many specimens in which these waves become definite radii of a polygonal growth pattern, at least in the central part of the test. This was observed in both megalospheric and microspheric forms (Pl. 14, Fig. 7, 8, 10). Because of the recrystallization of the specimens, our photographs did not turn out well, but they are adequate to show this arrangement; we further refer to SACHS’ “topotype” (loc. cit., Pl. 15, Fig. 7).

The microspheric forms of *N. barkeri* (Pl. 3, Fig. 7; Pl. 14, Fig. 8; Pl. 23, Fig. 1) are sometimes slightly larger than the megalospheric form, but mostly they are of the same size. As a rule, they have relatively heavy pillars. Recrystallization makes a thorough study of the internal features all but impossible, but it was observed that the initial spiral is of the simple type, characteristic of the genus *Neodiscocyclina*, and is about 75 μ in diameter. A peculiarity of the species seems to be that the later chambers of this spiral are not rounded but become sickle-shaped. The first median chambers around the spiral are mostly very low and broad.

Recrystallization has done its worst damage to the vertical section of these forms. Its most characteristic features seem to be the low neatly defined median layer with its rounded partly involute chambers (“chain stitch” effect) and (in the best preserved sections, like Pl. 14, Fig. 4) the thin curved roofs of the lateral chambers. Our picture should be compared with COLE’s vertical section of “*Discocyclina barkeri*” (in fact the closely related *N. caudriae*) from Lizard Springs, Trinidad (1969b, Pl. 16, Fig. 11). In the hard limestone K. 906 (C-4) a thin flange is developed around the lenticular body, which may be a common but seldom preserved feature also in other localities.

Syntypes: VAUGHAN & COLE 1941, Pl. 18, Fig. 4, 6 and 7.

Type locality: K. 2951 (C-4).

Type level: Paleocene, Ranikothalia limestone, but reworked into the Upper Eocene Bed 3.

Occurrence: probably already in Bed 2, K. 9454 (B-4); see further Distribution Chart (Part 1).

Neodiscocyclina (?) aff. *barkeri*, B-form

The “*Neodiscocyclina* aff. *barkeri* B” recorded from the hard limestone K. 10721 of Bed 11 is not a typical *N. barkeri* at all and may even belong to a different genus. It is represented by one single very small specimen with extremely low nepionic median chambers around an embryonic spiral which measures 100 μ in diameter.

Neodiscocyclus caudriae (VAUGHAN)

(Pl. 14, Fig. 5)

- 1945 *Discocyclus* (*Discocyclus*) *caudriae*, VAUGHAN, p. 70, Pl. 23, Fig. 1–4.
 1948 *Discocyclus* cf. *caudriae*, CAUDRI, p. 478–479.
 1951 *Discocyclus* (*Discocyclus*) *caudriae*, DE CIZANCOURT, p. 11, 12, 13, 14, 16, 17, 19, 62,
 ?*Discocyclus* (*Discocyclus*) *vautrini*, *ibid.*, p. 36, 52, 62, Pl. 5, Fig. 17, 21.
 1969 *Discocyclus* (*Discocyclus*) *barkeri*, COLE 1969b, Pl. 16, Fig. 11.

Neodiscocyclus caudriae is very closely related to *N. barkeri* and may even be nothing but a heavy-pillared, thin-flanged variety of that species, but for the time being the two are kept apart as separate species. VAUGHAN's most convincing specimen is the vertical section illustrated by his Fig. 4, and this piece is here proposed as the lectotype of *N. caudriae*.

On Soldado Rock the form is rare. Some of the more heavily pillared specimens from K. 2950 and 2951, the marl matrix of Bed 3 (originally reworked from the Ranikothalia limestone) seem to form a transition between *N. barkeri* and *N. caudriae* and the best specimen was found in the rubble bed of the Upper Eocene transgression (K. 2951 B).

Syntypes: VAUGHAN 1945, Pl. 23, Fig. 1–4 (lectotype: Fig. 4).

Type locality: Lizard Springs, Trinidad (Maerky 102b III).

Type level: Paleocene.

Neodiscocyclus grimsdalei (VAUGHAN & COLE)

(Pl. 3, Fig. 8; Pl. 15; Pl. 23, Fig. 2)

- 1941 *Discocyclus* (*Discocyclus*) *grimsdalei*, VAUGHAN & COLE, p. 9, 24, 25, 58, Pl. 18, Fig. 8, 9;
 Pl. 19, Fig. 1–3; Pl. 21, Fig. 3.
 1945 *Discocyclus* (*Discocyclus*) *grimsdalei*, VAUGHAN, p. 18, 19, 39–42, 57, 104, 105, 112, Pl. 13,
 Fig. 1–3, 4–5a; Pl. 14, Fig. 1–7 (non Pl. 6, Fig. 11, 12; Pl. 13, Fig. 6, 6a).
 1948 *Discocyclus* *grimsdalei*, CAUDRI, p. 476–479.
 1951 *Discocyclus* (*Discocyclus*) *grimsdalei*, DE CIZANCOURT, p. 10, 12, 13, 16, 18, 19, 22, 23, 26, 27,
 28, 30, 31, 32, 62, Pl. 2, Fig. 4, 5.
 1959 *Discocyclus* (*Discocyclus*) *weaveri*, COLE, p. 384, 385, table 1 (not the illustrations).
 1972 "*Discocyclus*" (*Neodiscocyclus*) *grimsdalei*, CAUDRI 1972a, p. 216.
 1972 *Neodiscocyclus* *grimsdalei*, CAUDRI 1972b, p. 224–228, 230, 231.

The species has been adequately described and figured by VAUGHAN & COLE in 1941 and by VAUGHAN in 1945, though the latter included specimens from Barbados which on close observation do not belong to it. Its main characteristic are: a flat-lenticular test, often with a marked central depression, which is not the result of erosion but of a diagnostic reduction in the number of lateral layers in that area (well developed at K. 10717 and K. 10725); subequal pillars, evenly distributed over the surface; a "loose" protoconch, in well orientated horizontal sections completely surrounded by a circular deuteroconch⁴); thickened concentric walls of the equatorial chambers, and fissiform to low-lenticular lateral chambers (in vertical section).

⁴) VAUGHAN & COLE state on page 58 that the protoconch is "entirely surrounded in two sections by an outer chamber." This wording may lead to misunderstanding. What is meant is: "in two of the horizontal thin sections at our disposal" (not: in both horizontal and vertical sections). In vertical section the deuteroconch touches the protoconch at top and bottom.

Neodiscocyclus grimsdalei is very variable in size. In our type sample (K.2950), for instance, two specimens of 4.5 and 5.0 mm, respectively, stand out against all the others which have a diameter of only 1.5 to 2.5 mm.

Microspheric specimens were found in several samples (K.2951, 2951 B, 10718; Rz.248, 255), but they are relatively rare. Generally they are of the same size as the megalospheric generation (e.g. 2.5 mm in K.2951), but occasionally a diameter of up to 8 mm is reached (K.2951 B). The shape of the test is the same as in the A-form but it seems a little more undulated. Surface features were not well preserved in any of the B-forms, but are presumably much the same. Nor is there any difference in the adult equatorial chambers. The embryonic spiral is small (80–90 μ) and of the simple type (characteristic of *Neodiscocyclus*; Pl.15, Fig.2; Pl.23, Fig.2). Already in the early rings, the median chambers are arranged in circles.

Syntypes: VAUGHAN & COLE 1941, Pl.18, Fig.8, 9; Pl.19, Fig.1–3 (see present paper: Pl.15, Fig.1, 4).

Type locality: K.2951 (C-4).

Type level: Paleocene, level of the Ranikothalia limestone, Soldado Formation; reworked in the Upper Eocene Bed 3.

Occurrence: see Distribution Chart (Part 1); sometimes rockbuilding: K.9453 cf. (G-3), K.10710 (D-3), K.10717 (B-2), K.10724 (D-1), Rz.248 (F-3), forming the so-called *Neodiscocyclus grimsdalei* limestone unit of the Soldado Formation.

Neodiscocyclus aguerreveri (CAUDRI)

1944 *Discocyclus aguerreveri*, CAUDRI, p.361, 378, 379, 398, Pl.2, Fig.8, 11; Pl.3, Fig.13; Pl.4, Fig.17.

1945 *Discocyclus (Discocyclus) aguerreveri*, VAUGHAN, p.74.

?*Discocyclus (Discocyclus) grimsdalei*, specimen with partly embraced protoconch from Soldado Rock, *ibid.*, p.59.

1948 *Discocyclus aguerreveri*, CAUDRI, p.477–479.

1951 *Discocyclus (Discocyclus) aguerreveri*, DE CIZANCOURT, p.16, 17, 19, 26, 62.

1959 *Discocyclus (Discocyclus) weaveri*, COLE, p.384, 385.

1972 *Discocyclus aguerreveri*, CAUDRI 1972a, p.216.

1972 *Neodiscocyclus aguerreveri*, CAUDRI 1972b, p.224, 230.

This still insufficiently characterized species, which differs from the very similar *N.grimsdalei* chiefly in the reniform shape of the deuteroconch, is found in situ in the samples K.2950 and K.2951?, and in erratic blocks from the Paleocene at K.2851, at K.10720 and probably at K.10724. The latter sample is a hard “*Discocyclus*” limestone entirely built up of either *N.grimsdalei* or *N.aguerreveri*, or a mixture of both.

Specimens of *N.aguerreveri* in a detached state were also spotted in the Upper Eocene (K.2951 B, K.2691?, K.10716 cf.).

Syntypes: CAUDRI 1944, Pl.2, Fig.8, 11; Pl.3, Fig.13; Pl.4, Fig.17.

Type locality: G.125c, San Juan de los Morros, Guarico, Venezuela.

Type level: Paleocene.

Neodiscocyclus(?) mestieri (VAUGHAN)

- 1945 *Discocyclus* (*Discocyclus*) *mestieri*, VAUGHAN, p. 18, 19, 37, 65, 104, 112, Pl. 12, Fig. 1–6.
 1947 *Discocyclus* (*Discocyclus*) *mestieri*, COLE & BERMUDEZ, p. 192, 202, Pl. 3, Fig. 3; Pl. 4, Fig. 6–8; Pl. 7, Fig. 4?
 1951 *Discocyclus* (*Discocyclus*) *mestieri* pars, DE CIZANCOURT, p. 13, 17, 22, 30–32 (non 36?), 45, 52, 62, Pl. 2, Fig. 7; Pl. 4, Fig. 17.
 1972 “*Discocyclus*” (*Neodiscocyclus?*) *mestieri*, CAUDRI 1972b, p. 227.

Neodiscocyclus(?) mestieri, originally described from the hard Paleocene limestone blocks in the Joes River mudflows of Barbados, is a badly diagnosed species, closely related to *N. grimsdalei*, but differing from it mainly in the lateral parts: it lacks the central depression, which is characteristic of the latter, but is robust-lenticular with a great many layers of lateral chambers in the center. Nothing is known about the microspheric form.

It has been found, together with *N. grimsdalei* and *N. barkeri*, “in situ” in the slumped banks of the Ranikothalia limestone (Bed 3), as well as reworked in the Upper Eocene beds, but only as very rare specimens.

Syntypes: VAUGHAN 1945, Pl. 12, Fig. 1–3.

Type locality: S. 96, block in Joes River mudflow, Barbados.

Type level: Paleocene.

Occurrence: K. 10701 (C-4), K. 10702 (D-4), K. 10707 (D-3), K. 10724? (D-4).

Neodiscocyclus fonslacertensis (VAUGHAN)

(Pl. 3, Fig. 10; Pl. 16)

- 1941 *Discocyclus* (*Discocyclus*) *crassa*, VAUGHAN & COLE, p. 59, Pl. 20, Fig. 4–7.
 1945 *Discocyclus* (*Discocyclus*) *fonslacertensis*, VAUGHAN, p. 72, 107, 112, Pl. 24, Fig. 3–6; Pl. 26, Fig. 3.
 1948 *Discocyclus fonslacertensis*, CAUDRI, p. 478.
 1959 *Discocyclus* (*Discocyclus*) *weaveri*, COLE, p. 384, 385, Table 1.
 1972 “*Discocyclus*” (*Neodiscocyclus*) *fonslacertensis*, CAUDRI 1972a, p. 216.
 1972 *Neodiscocyclus fonslacertensis*, CAUDRI 1972b, p. 224, 230.

Through a regrettable error, the Upper Eocene sample M.12 from the Lizard Springs area of Trinidad has been chosen in 1945 as the type material for this species. Actually, *Neodiscocyclus fonslacertensis* is not a Late Eocene species, but belongs to the fauna of the Paleocene Lizard Springs Formation. It occurs in fair numbers at the type locality of that formation, Maerky 102b III; its presence in M.12 is due to reworking only.

On Soldado Rock the species was not found in situ, but it is common in the Upper Eocene rubble which has directly derived from the Paleocene (K. 2951 B). Also some microspheric specimens were encountered.

N. fonslacertensis is very closely related to *N. grimsdalei*, but it tends to be thick-lenticular with a thin margin instead of rather flat and centrally depressed. The pillars are sub-equal all over or heavier in the center. Internally, the species shows the same kind of median chambers with thin radial walls and thickened concentric walls, but the diagnostic feature lies in the peculiar undivided first periembryonic chamber which, in an accurately centered section, usually forms a complete ring around the nucleoconch. The nucleoconch itself consists of a round protoconch and a half-embracing reniform

deuteroconch. VAUGHAN already remarked that the annular chamber might be the secondary result of resorption of the radial walls of a normal subdivided periem-bryonic ring, and as a matter of fact traces of incomplete subdivisions were occasionally observed in the Soldado material, but the occurrence of an entirely undivided annular chamber is too consistent to be dismissed as insignificant.

All the specimens are affected by recrystallization and the vertical section has suffered from it even more than the horizontal. Generally, the Soldado material is somewhat better preserved in this respect than that of the Lizard Springs type locality (Maerky 102 b III), but nevertheless the details are blurred. None of our sections turned out better than one of VAUGHAN's types (1945, Pl. 24, Fig. 6; = Pl. 26, Fig. 3). A comparison with other species remains difficult, but it seems that the lateral chambers are slightly more rectangular than those of *N. grimsdalei*, which has fissiform to low-lenticular lateral chambers.

The following is a short description of the Soldado material:

Megalospheric form:

Exterior: Test lenticular, up to 3.5 mm in diameter. Pillars mostly rather uniform in size, evenly distributed; some specimens have two or three large pillars in the center, which gives a low bi-conical shape to the test.

Horizontal section: Median layer without a trace of a polygonal pattern. Periem-bryonic annulus occasionally with a faint indication that it may have been formed by two or three very broad crescent chambers, but mostly totally undivided, with a firm circular outline.

Vertical section: Median layer in vertical section with firm horizontal roofs, well set off against the lateral tissue; lateral chambers recrystallized, unrecognizable.

Microspheric form:

Externally the same as the megalospheric generation, same diameter.

Horizontal section hardly distinguishable from that of *N. grimsdalei* (compare Pl. 15, Fig. 2 and Pl. 16, Fig. 4); initial spiral very small, rostralid (observed during sectioning).

Syntypes: VAUGHAN & COLE 1941, Pl. 20, Fig. 4–7 (see better photographs in VAUGHAN 1945, Pl. 24, 26).

Type locality: M. 12, Ravine Djalan, Lizard Springs area, Trinidad (reworked specimens in Upper Eocene).

Type level: Paleocene (Lizard Springs Formation of Trinidad).

Occurrence: K. 2855, K. 2951 B (common, A- and B-forms), K. 3690?; all reworked in the Upper Eocene.

Neodiscocyclus bullbrooki (VAUGHAN & COLE), A- and B-forms
(Pl. 17; Pl. 19, Fig. 2, 5; Pl. 23, Fig. 3)

1941 *Discocyclus* (*Discocyclus*) *bullbrooki*, VAUGHAN & COLE, p. 59, Pl. 21, Fig. 4, 5; Pl. 22, Fig. 1, 2.

1944 *Discocyclus* (*Discocyclus*) *bullbrooki*, CAUDRI, p. 385.

1945 *Discocyclus* (*Discocyclus*) *bullbrooki*, VAUGHAN, p. 106, 107, 108, 112.

1948 *Discocyclus* cf. *bullbrooki*, CAUDRI, p. 477, 478.

1959 *Discocyclus anconensis* (pars), COLE, p. 380, 381, 383, Pl. 33, Fig. 2?, 6, 7, 9?, 10?.

1972 "*Discocyclus*" (*Neodiscocyclus*) *bullbrooki*, CAUDRI 1972a, p. 216, Pl. 1, Fig. 1.

1972 ?*Neodiscocyclus* cf. *bullbrooki*, CAUDRI 1972b, p. 224, 230.

The type locality of *Neodiscocyclina bullbrooki* is K. 3878, in Bed 11, topographically just above the top of the typical Upper Eocene section. It has further been found in several other samples from that same bed, and also as scattered isolated specimens in Beds 4 to 10. However, this does not mean that it is a Late Eocene species: *N. bullbrooki* belongs to the *Proporocyclina tobleri* fauna, the age and significance of which are discussed in the first part of this study (chapter on Bed 11, p. 411–419). Actually, the age determination of this fauna was in part established as a consequence of the evolutionary character of *N. bullbrooki* itself.

In the type description of this form, VAUGHAN & COLE note: “the median sections did not expose the embryonic chambers”. They had obviously expected to find a large nucleoconch in the center and at that time missed the point that all their specimens were microspheric. As a matter of fact, some of their sections did disclose the initial stage quite satisfactorily and both of their photographs (Pl. 22, Fig. 1 and 2) show the microspheric spiral more or less convincingly.

Microspheric specimens are by far the most common, but in connection with them, at the type locality K. 3878 and in several other samples, a megalospheric form was also found, which shows such a striking resemblance to them, both in median layer and lateral tissue, that there is little doubt about its identity as the A-form of the same species.

The original description can be supplemented by the following notes:

Microspheric form:

Exterior: from the type locality, *N. bullbrooki* has been described as lenticular, umbonate, pillared in the center and with very small pillars near the edge. In other samples (e.g. K. 10709) there are also forms without an umbo, varying in shape from subglobose to very flat, all heavily pillared. Intact specimens may even have a thin flange (see under *N. mauryae*, p. 559).

Horizontal section: embryonic spiral large and conspicuous, 120–140 μ in diameter, definitely trochoid (like a miniature *Globorotalia*). Median chambers thin-walled and wide, showing a certain tendency towards a hexagonal shape, arranged at first in a polygonal or at least radiate pattern, later in irregular cyclic annuli. Sometimes, especially in regenerated parts of the test, the annular walls are slightly thickened.

Vertical section: apart from the more lenticular shape of the test (no central depression) and the heavier pillars, this section shows a certain affinity to *N. grimsdalei* (VAUGHAN & COLE): it has the same low equatorial layer and fissiform lateral chambers. (For further remarks on the B-form, see p. 559).

The absence of a narrow-chambered zone of equatorial chambers around the initial spiral, such as occurs in *N. grimsdalei*, *fonslacertensis*, *barkeri*, etc., indicates an acceleration of the ontogenetic development and proves *N. bullbrooki* to be less primitive than those Paleocene forms and closer to *N. anconensis* in this respect. In the features of the vertical section, however, the species is “older” than the airily built *N. anconensis*. This suggests that the *Proporocyclina* fauna, to which *N. bullbrooki* belongs, is younger than the Paleocene, but older than the *N. anconensis* Zone of the Lower Middle Eocene (see for additional data under *N. mauryae*, p. 557–558).

Megalospheric form (Pl. 17, Fig. 4–7; Pl. 19, Fig. 2):

Exterior: maximal diameter of detached specimens 2 mm. Test lenticular, with heavy pillars. In the hard matrix of J. S. 1955 a thin flange is preserved surrounding the lenticular body in some of the larger specimens.

Horizontal section: nucleoconch of the “nephrolepidine” type, with a circular protoconch and a partly embracing second chamber, thinwalled. Periembrionic chambers as a rule subequal in size, but sometimes the two chambers that cover the “top” of the protoconch are conspicuously enlarged, resembling those of *N. barkeri* (p.550). Median chambers thinwalled, tending towards a hexagonal shape, arranged in a faintly polygonal pattern, at first about 40 μ long but near the edge reaching a length of 60 μ or more.

Vertical sections are bound to occur in the random thin sections of the hard limestone J.S.1955, but they are inextricably mixed with those of *N. mauryae* and highly recrystallized. No details can be given.

The discovery of this A-form cancels COLE’s postulation of 1959 that *N. bullbrooki* should be considered as the microspheric form of *N. anconensis* (BARKER) and the name “*bullbrooki*” remains valid. Moreover, the determination of COLE’s A-form in E.L.1440 as “*Discocyclina anconensis*” cannot be accepted (see under *N. mauryae*). The typical *N. anconensis* of the Middle Eocene of Barbados does not occur on Soldado Rock.

Syntypes: VAUGHAN & COLE, Pl.21, Fig.4, 5; Pl.22, Fig.1, 2.

Type locality: K.3878 (C-3), Bed 11.

Type level: Boca de Serpiente Formation, uppermost Lower or lowest Middle Eocene.

Occurrence: in Bed 11 and reworked through Beds 4–10; see Distribution Chart (Part 1).

Neodiscocyclina mauryae n.sp.

(Pl. 18, Fig. 1, 4–6; Pl. 19, Fig. 1, 3, 4, 6; Pl. 20, Fig. 1, 3–7)

1959 *Discocyclina* (*Discocyclina*) *anconensis* (including *Discocyclina* (*Discocyclina*) *bullbrooki*), COLE, p. 380, 383, Pl. 33, Fig. 1, 2, 7?, 9, 10 (not Fig. 6, 8).

At its type locality K. 3878 (Bed 11), *Neodiscocyclina bullbrooki*, one of the elements of the *Proporocyclina tobleri* assemblage, has at first been found exclusively in the microspheric generation. In 1959, COLE drew attention to the find, in another sample of Bed 11 (E.L. 1440), of a megalospheric form of *Discocyclina*, likewise in combination with *Proporocyclina tobleri* and with microspheric *Discocyclinas* of the *bullbrooki*-type. This form he identified as *Discocyclina anconensis* BARKER and assumed that it was the matching A-form of *Discocyclina bullbrooki*, thereby putting the latter in the synonymy of *D. anconensis*. On the strength of this determination, the “*Proporocyclina tobleri* Zone” was provisionally correlated with the Upper Scotland Formation of Barbados, which is Middle Eocene.

Plausible as it seemed at the time, this trend of thought can no longer be accepted. First of all, since in the meantime a more eligible megalospheric companion for *Neodiscocyclina bullbrooki* has been found at K. 3878 and elsewhere (see above), there is no need to combine COLE’s A-form with that species and the name “*bullbrooki*”

remains valid. Further, COLE's identification of the form as *Discocyclina* (*Neodiscocyclina*) *anconensis* is open to question. This determination was based chiefly on the shape of the nucleoconch as seen in horizontal section: a "floating" protoconch in a circular second chamber, illustrated in Figure 1 of his Plate 33, but apart from *N. anconensis*, several other species also have this type of embryonic apparatus. Judging from the photograph, the median chambers of this specimen look too small for *N. anconensis* (their maximal radial length is 50–60 μ). Also in vertical section, COLE's species (Pl. 33, Fig. 2, 9, 10) is not identical with *N. anconensis*, which is clearly demonstrated by the picture of the Barbadian specimen he himself gives for comparison (loc. cit., Fig. 8): in the latter the equatorial layer appears twice as high as in the form from Soldado Rock.

The difference between the two species shows also in the vertical section of the B-forms (compare VAUGHAN & COLE 1941, Pl. 21, Fig. 4–5 and COLE 1959, Pl. 33, Fig. 6 with VAUGHAN 1945, Pl. 8., Fig. 5). *N. anconensis* has wide open thinwalled lateral chambers also in the peripheral region, in contrast with *N. bullbrookii* where they become low lenticular to fissiform towards the edge. On all counts, COLE's A-form from E. L. 1440 gives the impression of being of a more primitive type than *N. anconensis* from Barbados.

With the rejection of the specific determination, correlation of our Bed 11 with the Upper Scotland Formation of Barbados (and the San Eduardo Limestone of Ecuador, type locality of *N. anconensis*) also falls through. The *Proporocyclina tobleri* horizon is probably slightly older: basal Middle Eocene or even very high Lower Eocene. It would be tempting to identify COLE's form with DE CIZANCOURT's "*Discocyclina anconensis*" (1951), which crowds the highest bed of the La Paz Limestone (uppermost Lower Eocene) of Western Venezuela, but her illustration of a vertical section proves that this is not the same species.

Apart from E. L. 1440, COLE's A-form with the "floating" protoconch occurs in two other washable samples from the North shore of the Rock, K. 10721 and 10722, and it is apparently abundant in the hard limestone J. S. 1955 from the same area. Detailed study is made difficult by the fact that all these fossils are badly affected by recrystallization and that the richest material is enclosed in hard rock. Nevertheless, I am under the impression that we are dealing with an undescribed new species. The horizontal section is similar to that of *Neodiscocyclina grimsdalei*, though thickening of the concentric walls is less pronounced, but the vertical section is very different indeed. The name of *Neodiscocyclina mauryae* is proposed for this new form.

The following provisional diagnosis can be given:

Exterior: maximal diameter observed 4.2 mm.; thickness \pm 1.4 mm., central body lenticular, without a central depression, surrounded by a thin flange. Pillars more or less of equal size, evenly distributed over the whole body.

Horizontal section: megalospheric; protoconch seemingly floating within the circular deuteroconch. Diameter of the deuteroconch mostly between 300 and 340 μ (exceptionally as small as 220 μ), of the protoconch between 160 and 200 μ (exceptionally as small as 120 μ), both thinwalled. Equatorial chambers in irregular wavy, repeatedly regenerated rings; radial length \pm 60 μ , near the edge up to 80 μ (with wall); thinwalled; thickening of the concentric walls locally developed, but not very pronounced.

Vertical section: robust lenticular, with heavy pillars all over. Median layer thin, with a very low lumen between fairly thick horizontal walls, 40–50 μ high (with walls); vertical walls tending to curve outwards. Lateral chambers in central body low lenticular, getting lower and even fissiform near the edge.

The differences between this new form and *Neodiscocyclina anconensis* show up in my own material as clearly as they did in COLE's specimens, especially in the vertical section. For comparison, we here present a horizontal and a vertical section of a couple of small specimens of *Neodiscocyclina anconensis* from Barbados (Pl. 18, Fig. 2 and 3).

This new species is, no doubt, also represented by its microspheric generation, but in the unsatisfactory material at hand it is impossible to separate it from the B-form of *N. bullbrooki* with which it is mingled.

The best impression of the general appearance of these B-forms is gained from the rock sections of J.S. 1955, because in this limestone the specimens are preserved with their edges intact. The sections show that these forms possess a very wide flange, formed by an irregular median layer (with outwards curved vertical walls presenting a chain-stitch pattern) which is covered on both sides by a few layers of very low lateral chambers, and studded with heavy pillars right down to the edge (Pl. 20, especially Fig. 5). The median layer, with wall, is about 40 to 60 μ high (in rare cases up to 80 μ at the very edge) and has apparently rather thick walls (recrystallized). The microspheric spiral is of the simple type (like in all *Neodiscocyclinas*) and, where measurable, its diameter is of the order of 100–120 μ (K. 10721), which is slightly less than the values found for *N. bullbrooki*-B in K. 3878.

The above may apply to *Neodiscocyclina mauryae* and *N. bullbrooki* alike. Even the unusual development of large pillars on the thin flange may prove to be a common variation of *N. bullbrooki* rather than a diagnostic feature of the new species (see VAUGHAN & COLE 1941, Pl. 21, Fig. 5). One peculiarity which has not been observed in any of our badly preserved loose specimens but which is revealed in some of the random sections of J.S. 1955, is the occasional occurrence of thickened rays(?) across the test, reminding of a tangential section of *Asterocyclina* (Pl. 20, Fig. 4). Presumably, these ridges correspond with undulating rays of the equatorial layer. The median layer is not higher in these rays than in the thinner interradian fields. Maybe the fossils in question should be referred to *N. bullbrooki* rather than to *N. mauryae*, in which we have thus far not observed this same pronounced radiate growth pattern. But for the rest all these B-forms, in as far as they occur in samples which carry the megaspheric forms of both *N. bullbrooki* and *N. mauryae*, have to be lumped together until better material is available.

Holotype: Pl. 18, Fig. 1.

Type locality: K. 10722 (C-1).

Type level: upper part of Bed 11 (Boca de Serpiente Formation), of very late Lower Eocene or very early Middle Eocene age).

Occurrence: K. 10721 (common), K. 10722 (few), E. L. 1440 (few), J. S. 1955 (in hard limestone; presumably abundant).

Neodiscocyclina(?) sp. indet. 1

For the record, a very rare "*Discocyclina*" should be mentioned here which cannot be identified with any of the known species. It resembles a *Hexagonocyclina* in that it has large thin-walled median chambers, more often of a hexagonal than rectangular shape, but its nepionic development is probably different from *Hexagonocyclina*; it may belong to the genus *Neodiscocyclina*.

No further details are thus far available.

Occurrence: K. 3694 (Paleocene block) (D-2), Rz. 248 (Paleocene block) (F-3).

Genus *Asterocyclina* GÜMBEL, 1868*Asterocyclina asterisca* (GUPPY)

(Pl. 4, Fig. 1–12, 14–16; Pl. 21, Fig. 1, 3, 4, 5, 9, 10; Pl. 22, Fig. 2, 5, 6; Pl. 23, Fig. 4, 5)

- 1866 *Cisseis asteriscus*, GUPPY, p. 584, Pl. 25, Fig. 19a–b (cited in: HODSON 1926, p. 11–12).
 1892 *Tinoporos asteriscus*, GUPPY, p. 434–435.
 1915 *Asterodiscus asteriscus*, DOUVILLÉ, p. 90.
 Orthophragmina asteriscus, *ibid.*, p. 92.
 Orthophragmina stellata, *ibid.*, p. 90, 91, 92.
 1917 *Asterodiscus asteriscus*, DOUVILLÉ, p. 843, 845–847.
 Orthophragmina (Asterodiscus) stellata, *ibid.*, p. 843.
 Asterodiscus stellatus, *ibid.*, p. 847.
 1922 *Orthophragmina (Asterocyclina) asteriscus*, TOBLER 1922a, p. 343?, 344?, 345.
 1926 *Asteriacites asteriscus* ("*Cisseis asteriscus*"), HARRIS, p. 104, 176, Pl. 18, Fig. 3.
 1926 *Cisseis asterisca*, *asterisca venezuelana*, *asterisca zuliana*, *bontourana*, *pariana*, *harrisi*, *trinidadensis*, *weeksi*, *weeksi maracaibensis*, *parva*, *sanfernandana*, HODSON, p. 11–18, Pl. 2; Pl. 3; Pl. 4, Fig. 2–4.
 1928 *Asterocyclina asteriscus*, VAUGHAN, p. 286.
 1928 *Cisseis asteriscus*, NUTTALL, p. 105–107, Pl. 8, Fig. 8, 9, Textfig. 11.
 ?1932 *Actinocyclina cf. asteriscus*, BARKER, p. 305, 307, Pl. 21, Fig. 3, 5, 6, Textfig. 3.
 1932 *Discocyclina (Asterocyclina) georgiana*, GORTER & VAN DER VLERK, p. 96–99, 112, Pl. 17, Fig. 4–6.
 1933 *Discocyclina (Asterocyclina) asterisca*, GRAVELL, p. 8, 22.
 1941 *Discocyclina (Asterocyclina) asterisca*, VAUGHAN & COLE, p. 20, 27, 60, Pl. 23.
 1945 *Discocyclina (Asterocyclina) asterisca*, VAUGHAN, p. 78, Pl. 27, Fig. 3–5.
 Discocyclina (Asterocyclina) georgiana, *ibid.*, p. 79, Pl. 27, Fig. 6, 7.
 1952 *Asterocyclina georgiana*, COLE, p. 31, Pl. 27, Fig. 6–12.
 1962 *Asterocyclina asterisca*, COLE 1962b, p. 149.
 1968 *Asterocyclina asterisca*, EAMES et al., p. 287.
 ?1974 *Asterocyclina cf. asterisca*, CAUDRI, p. 316, Pl. 13, Fig. 5.

GUPPY's type description of this form is full of misinterpretations and his types are lost, but there is no doubt about what kind of microfossil was meant by him. HODSON revalidated the species in 1926 and designated new type specimens for it from toptype material (Point Bontour, Trinidad).

The bewildering variability in external appearance within the Point Bontour population lead HODSON to believe that it was a mixture of several different species and varieties, only one of which, the usually four-rayed stellate form, would be the typical *Cisseis asterisca*. VAUGHAN & COLE (1941) came to the conclusion that all these widely different individuals belonged to one amazingly variable species and in eight photographs they illustrated this diversity in habitus.

Apart from those illustrated in 1941, there are also large quantities of less conspicuous forms: subglobular or lenticular specimens with hardly an indication of the stellate pattern showing on the outside. Such forms predominate in the very small specimens, although there are also many flat-polygonal or starshaped ones amongst them. In the large stellate specimens the points vary from sharp to rounded, flat or inflated, or they can be club-shaped. There is also a flat square variety with paper-thin webbed interradiial areas, very similar to *A. georgiana* (CUSHMAN) or perhaps even identical to it. Large specimens of this type are particularly numerous in Bed 10 at K. 1500, K. 3692 and K. 10707, at K. 1499 in Bed 9 and at K. 1316 in Bed 9a, but they are frequent also in other localities. There is never the slightest trace of solid radial rods.

Asterocyclina asterisca is one of the most conspicuous and constant components of the Upper Eocene fauna. In several samples whole populations are represented, including all the external varieties and ranging from minute embryos to full grown specimens of 8 mm and more. The fine fraction of the residue is often flooded with specimens of less than 1 mm. Such populations occur at K. 1316, 1499, 1500, 2854 and 2855; at K. 3677 the specimens do not reach their full size. In localities with a generally poor fauna, *A. asterisca* remains small. The species seems to have been extremely sensitive to environmental variations.

Actually, the species *A. asterisca* as such is badly diagnosed. From the above it is clear that it is all but impossible to give a concise description of the external features, but also the common internal characteristics, which unite all these forms into one species and set it off against all other *Asterocyclinas*, are nowhere properly defined. The following observations on the material of Trinidad and Soldado Rock may contribute to recognize *A. asterisca* specifically:

Exterior: *A. asterisca* is completely devoid of solid radial ridges such as are known in some of the Middle Eocene species (*A. monticellensis*, *A. barbadensis*, etc.). The radii are sometimes accentuated by rows of extra large or even transversely broadened pillars, but they are never fused into radial rods.

In the material from Trinidad and Soldado Rock, *A. asterisca* is readily distinguishable from *A. soldadensis*, with which it is sometimes associated, by its much finer structure. Though the pillars, which are always well developed, may be heavy in the center and along the rays, they are in general remarkably fine. So is the mesh of lateral chambers between them.

Internal structure: also internally *A. asterisca* is much finer than *A. soldadensis*, both in horizontal and in vertical section (see illustrations). In particular, this applies to the median chambers in the inter-radial fields. In topotype material (from Trinidad), the average length of the chambers in the radius is about 60 μ , in the interradius often less than 10 μ .

Apart from these general statements, which may at best serve as a point of departure for further comparative studies, there is one special point which is more diagnostic: the development of the periembryonic ring. Providing the section is orientated exactly through the center, *A. asterisca* consistently shows the type of ring illustrated in Fig. 9 and 10 on Pl. 21 and Fig. 4 on Pl. 23, in which the rays of the median layer each have their origin in a group of two to four specialized, radially elongated peri-

embryonic chambers. This is the main feature by which *A. asterisca* is distinguished from *A. preasterisca*, the Late Middle Eocene species of Margarita Island which lacks such elongated chambers (CAUDRI 1974).

The number of rays in *Asterocyclina asterisca* generally varies from 4 to 5. Very rarely is it three (in a B-form from K. 903) or six (K. 1316); VAUGHAN & COLE also had a 6-rayed specimen, from K. 2854. In some of the deposits 4-rayed specimens predominate, in others they are outnumbered by 5-rayed ones. This point deserves closer attention as it might have a certain stratigraphical significance. The already mentioned Middle Eocene precursor *A. preasterisca* is invariably 4-rayed. Further, the 4-rayed type prevails in Bed 10, which is considered to be the lowest Upper Eocene in the Soldado section, where 5-rayed megalospheric individuals are very rare or absent (K. 903, 1500, 3677, 3691, 3692, 10707, 10716; Rz. 250, 251). The two types are balanced in K. 1499 (Bed 9) and K. 2651 (Bed 9a). Five-rayed specimens predominate in some of the richest localities apparently under optimal conditions for the species: at K. 1316 and 2854 of Bed 9a, but also at K. 2855 (Bed 7). The 6-rayed forms were found in Bed 9a, the youngest Eocene bed on Soldado. This record suggests a gradual development from the 4-rayed to the 5-rayed type in the course of time, but environmental factors may also have been of influence.

Microspheric forms (Pl. 4, Fig. 14, 15; Pl. 21, Fig. 4; Pl. 22, Fig. 6; Pl. 23, Fig. 5). Though always scarce, B-forms have been found in many samples. It is a very remarkable fact, seemingly unique amongst all Larger Foraminifera, that the B-form in *Asterocyclina asterisca* (and in the very closely related species *A. preasterisca*; CAUDRI 1974, p. 316, Pl. 13, Fig. 2) is always very small, considerably smaller than the adult megalospheric specimens with which it occurs.

Externally, these microspheric forms are thick-lenticular with hardly an indication in outline or on the surface of the internal stellate growth pattern. At the most, they show some faint broad ridges corresponding with the rays. Internally, they often prove to be 5-rayed, even in populations of almost exclusively 4-rayed megalospheric specimens like, for instance, in the samples K. 903 and 10707. Of the very few 5-rayed forms in K. 903, the majority turned out to be microspheric, but there are also some 4-rayed B-forms in this sample and even one with only three rays. In sample K. 10707 three 5-rayed microspheric forms were found, with a diameter of 4.2, 2.0 and 2.0 mm, respectively, but the conspicuous large stellate and square specimens in this assemblage, of 4.5 mm and over, are all 4-rayed A-forms.

The equatorial layer shows definite rays, but it is irregular and its growth is repeatedly disturbed by interruption and regeneration, which may have something to do with the process of spawning. From what could be seen during grinding of the sections, the tiny initial spiral seems to be rotalid. The first interradial median chambers around it can be very broad, but for the rest the equatorial layer does not differ from that of any small non-stellate A-form.

Type specimens: HODSON 1926, Pl. 2, Fig. 1, 2, 10.

Type locality: Point Bontour, San Fernando area, Trinidad.

Type level: Upper Eocene.

Occurrence: see Distribution Chart (Part 1); B-forms were found at: K. 903, 2854, 2855, 2951 B, 3677 and 10707.

Asterocyclina vaughani (CUSHMAN)

This species has been reported from Soldado Rock by VAUGHAN & COLE (1941, p. 61, Pl. 20, Fig. 10). I did not encounter it in my own material, but their illustration is convincing.

Occurrence: K. 1499 (Bed 9), K. 1500 (Bed 10).

Asterocyclina soldadensis n. sp.

(Pl. 4, Fig. 13; Pl. 21, Fig. 2, 6–8; Pl. 22, Fig. 1, 3, 4)

Exterior: this form is readily distinguishable from the much more common *A. asterisca* (GUPPY) in all its diverse varieties by its blunt-pointed shape and its much coarser structure.

In habitats where it is particularly well developed (for instance in the Navette area in S. E. Trinidad), the species may reach a diameter of 8 mm and more, but the largest specimen found on Soldado Rock measured 6.5 mm and the holotype is only 5 mm.

Outline wobbly polygonal or stellate with short stout blunt points. Usually the number of rays is five or six, rarely seven. Small juvenile specimens may have a lenticular body with faintly indicated rays; larger forms are evenly thickened in the center and along the rays or (as is the case in some of the specimens from Trinidad, but not from Soldado Rock) there may be a prominent central knob and fixed or disconnected spikes accentuating the rays, but never are there any radial rods of solid shell material (this in contrast with several Middle Eocene species of *Asterocyclina*). Pillars usually well developed, especially in the center and along the radii, but sometimes lacking. Lateral chambers triangular or polygonal, thickwalled.

Horizontal section: apart from the coarse structure of the chambers, the most striking peculiarity of the species lies in the periembryonic ring, which consists of only a couple of large tangentially elongated chambers. Nucleoconch large, 350–450 μ along the main axis; deuteroconch larger than the protoconch and slightly embracing. On Soldado Rock only A-forms were found, but a few of the largest Trinidad forms proved to be microspheric.

Equatorial chambers robust, large and elongate even in the interradial fields, but radii well delineated and narrow, though in large specimens broadening towards the edge. Regeneration often causes a more circular pattern with very long chambers all around, in which the rays are obliterated. Concentric walls sometimes heavier than the radial ones.

Vertical section: characterized by the spacious structure of both median and lateral tissue. Robust walls, but floor and bottom of the median layer not particularly accentuated. Usually, conspicuous pillars are visible. Full grown specimens have about 11 to 15 layers of lateral chambers.

Holotype: Pl. 21, Fig. 6; Pl. 22, Fig. 1.

Type locality: K. 2651 (E-4), Bed 9a.

Type level: Upper Eocene.

Occurrence: K. 2855, K. 2954 (Bed 7); K. 2651 (common) (Bed 9a).

Asterocyclina aff. *monticellensis* COLE & PONTON

(Pl. 22, Fig. 7)

Compare: *Asterocyclina monticellensis*, COLE & PONTON 1934, p. 141, Pl. 2, Fig. 6–11.*Asterocyclina monticellensis*, CAUDRI 1974, p. 313, Pl. 6, Fig. 12; Pl. 14, Fig. 1; Pl. 15, Fig. 3.
not: *Discocyclina* (*Asterocyclina*) *monticellensis*, COLE 1944, p. 76, Pl. 1, Fig. 8; Pl. 2, Fig. 11; Pl. 8, Fig. 23; Pl. 13, Fig. 5; Pl. 23, Fig. 1–12.

Amongst the numerous specimens of *Asterocyclina asterisca* in sample K. 1499 one single individual, which externally did not particularly distinguish itself from the less stellate forms of that species, proved in horizontal section to be of a much coarser structure and, moreover, in possession of radial rods of solid shell material. Provisionally, this specimen was determined as *Asterocyclina* aff. *monticellensis* because of the general resemblance of its nepionic stage and equatorial chambers to those of *A. monticellensis* COLE & PONTON from Florida and Margarita Island. The lack of external protruding rods, typical of that species, could, however, serve as an argument against this identification.

The presence of such a form in the Upper Eocene of Soldado Rock is surprising. Generally, *Asterocyclina*s with solid radial rods are typical of the latter part of the Middle Eocene in the Americas, and reworking from that source can be ruled out in this case. The only other record we have of a ribbed *Asterocyclina* in the Upper Eocene is that of *Asterocyclina maracaibensis* GORTER & VAN DER VLERK (1932) from the "Menegrande and Paloma Alta series" in Central Falcón, Venezuela, but it is not quite clear whether these costae are really solid rods or not. The Soldado specimen might correspond to this form rather than to *A. monticellensis*, but the species needs restudying and our Soldado material is sadly inadequate.

Genus *Amphistegina* D'ORBIGNY, 1926*Amphistegina undecima* n. sp.

(Pl. 1, Fig. 8, 9; Pl. 5, Fig. 11, 12; Pl. 19, Fig. 6; Pl. 20, Fig. 1–5, 7; Pl. 23, Fig. 6–16, 20, 21)

?1951 *Amphistegina schoeffleri* (pars), DE CIZANCOURT, p. 17, 20, 21, 59, Pl. 4, Fig. 20, 21 (non *A. schoeffleri* from Barbados, loc. cit., p. 59, Pl. 5, Fig. 13, 19).

Amphistegina undecima, though not an easily recognizable form, is stratigraphically interesting because it is a constant and often abundant element of the *Proporocyclina tobleri*–*Neodiscocyclina bullbrooki* assemblage in the newly described Boca de Serpiente Formation (p. 535).

Characterization of the species is made very difficult by the high degree of recrystallization of all of the available material which has largely obliterated both the external and the internal features of the specimens.

Because K. 3878 is the type locality of the entire *Proporocyclina tobleri* fauna, it is also designated as the type locality of *A. undecima*, but the best preserved material of the species comes from K. 10721 and K. 10722 in Bed 11 and K. 10718 in Bed 10.

Exterior: diameter up to 0.7–1.0 mm. Test thick-lenticular in well developed specimens, sometimes clearly asymmetric, with prominent pillars and with a tendency

to form a distinct umbo. Septal filaments often visible. Smaller specimens may be flattish, with inconspicuous granulations (in cases where these granulations are heavier in the center and surrounded by smaller ones, these forms resemble the Upper Eocene species *A. grimsdalei*).

Horizontal section: septa numerous and strongly curved backwards (but not in the exaggerated way of *A. grimsdalei*!). No trace of counterseptal hooks. At the type locality, only microspheric specimens were found, but K.10721 and K.10722 also yielded forms with a very small megalospheric nucleocoenoch. There is no difference in size and appearance between the two generations.

Vertical sections: walls very heavy and evenly curved; a flat variety occurs at J.S.1955 (Pl.23, Fig.20, 21). Pillars are not, as a rule, conspicuous in this section, but show up clearly in the preparations of J.S.1955.

Amphistegina undecima is essentially an element of the *Proporocyclina tobleri* association, which is of very late Lower Eocene or earliest Middle Eocene age. But there are some indications that it may have started already in the Paleocene. A few very badly preserved specimens of *Amphistegina* in the samples K.2948 (Bed 2) and K.2950 (reworked Paleocene in Bed 3), and also from the Midwayan limestone of the Marac Quarry in Southern Trinidad, may have to be determined as *undecima* as well. Also, DE CIZANCOURT's forms of "*Amphistegina schoeffleri*" from the Paleocene Morros limestone at La Puerta and near San Sebastian in Central Venezuela seem to belong to this species. But in all these cases, the poor preservation of the material makes identification unreliable.

Holotype: Pl.23, Fig.8.

Type locality: K.3878 (C-3), Bed 11.

Type level: Boca de Serpiente Formation, latest Lower Eocene or earliest Middle Eocene.

Occurrence: in situ in Bed 11 and perhaps already in Bed 2; reworked in Bed 3?, 10 and 9a; see Distribution Chart (Part 1).

Amphistegina pauciseptata n. sp.
(Pl.23, Fig.17, 18, 22; 19 cf.)

The Boca de Serpiente Formation also furnished a second form of *Amphistegina*, far less numerous than the previous species and distinguished from it by the smaller number of septa per whorl. It is similar in general appearance and equally badly preserved.

Exterior: maximal diameter 1.0 mm. Surface smooth, except for a few pillars in the center. Septal filaments few, somewhat raised or visible through the transparent wall.

Horizontal section: septa few, about eleven in the last whorl, not as strongly curved as in *A.undecima*. No counter-septal hooks. Microspheric form found only.

Holotype: Pl.23, Fig.18.

Type locality: K.3878 (C-3), Bed 11.

Type level: Boca de Serpiente Formation, latest Lower or earliest Middle Eocene.
 Occurrence: in situ in K. 3878, K. 10709?, K. 10722?, E. L. 1440. Reworked in Bed 10:
 K. 3690, K. 10718 (obviously reworked), Rz. 250.

Amphistegina grimsdalei n. sp.
 (Pl. 5, Fig. 8, 9, 13, 14; Pl. 24, Fig. 1-3)

1941 *Amphistegina* sp. indet., VAUGHAN & COLE, p. 77, Pl. 45, Fig. 3.

A small delicately granulated *Amphistegina*, very common in the Jacksonian Upper Eocene of Trinidad and Soldado Rock, characterized in horizontal section by the exaggerated curvature of its septa, and in vertical section by the peculiar semblance of a specialized median layer.

The species is considered as the direct morphological precursor of *Helicosteginospis soldadensis* (GRIMSDALE), with which it is currently associated.

Exterior: maximal diameter 1.2 mm. Test varying from very flat to thick lenticular; larger fully-developed specimens relatively flat, surrounded by a thin flange.

Surface smooth but for some small but conspicuous granulations in the center; often there is one slightly larger "pillar", surrounded by a circle of smaller ones from which radiate the septal filaments (Pl. 5, Fig. 14). In the flat specimens very fine granulations also mark the strongly curved filamental lines right to the edge, for instance at K. 2651 (Pl. 5, Fig. 13) and at K. 3741.

Horizontal section: spiral rather narrow. Septa numerous, about 25 to 30 in the last whorl, thinwalled, curved backwards in such an exaggerated way that the lumina of the chambers in the flange sometimes extend over 90–120 degrees of the whorl. Stolons at the very base of the septa; no counterseptal hooks.

Vertical section: thinwalled, with wide open spaces between the walls. Because the section slices through so many of the narrow chambers in each whorl, a false impression is created of a median layer of secondary chamberlets.

Holotype: Pl. 24, Fig. 2.

Type locality: K. 2651 (E-4).

Type level: Upper Eocene, Bed 9a.

Occurrence: Beds 7, 9, 9a, 10; see Distribution Chart (Part 1).

Amphistegina sp. (cf. *pregrimsdalei* CAUDRI)
 (Pl. 24, Fig. 4-7)

Sample K. 2652 (Bed 10) contains a species of *Amphistegina* which externally resembles the common lenticular form of *A. grimsdalei*, but in both horizontal and vertical section proved to be different. It does not have the exaggeratedly curved septa of the latter and therefore also lacks the illusion of a primitive "equatorial layer" in vertical section.

The form seems to correspond closely to *Amphistegina pregrimsdalei* of the Punta Mosquito Formation in Margarita Island, where it occurs in a sample which contains a predominantly Late Middle Eocene fauna mixed with some Late Eocene material (CAUDRI 1974, p. 303, Pl. 1, Fig. 6, 7, 10, 11; Pl. 2, Fig. 14-17; Pl. 5, Fig. 6, 8, 9, 12; Pl. 6, Fig. 1-4).

Because of its resemblance in habitus to the common *A. grimsdalei*, it is possible that the species has passed undetected in several other samples. Its stratigraphical range has not been established.

The genera *Helicolepidinoides* TAN, 1936, and *Helicosteginopsis* n. gen.

The systematics of *Helicostegina*, *Eulinderina*, *Helicolepidina* and the other genera grouped around it by BARKER & GRIMSDALE in 1936 have immediately met with the criticism of TAN SIN HOK (1936a, b). Amongst other suggestions he lifted *Helicolepidina paucispira* out of the *Helicolepidinas*, and placed it in a separate genus (*Helicocyclina*). But his conclusions remained also unsatisfactory because, at the time, the missing link "*Helicostegina*" *soldadensis* GRIMSDALE was still unknown.

When the latter species was discovered on Soldado Rock in 1941, GRIMSDALE was under the impression that it was phylogenetically directly connected with *Helicostegina gyralis* BARKER & GRIMSDALE, but both morphologically and in terms of geological time this view is untenable. It has become necessary to re-evaluate its systematical position and to place it in a new genus, for which the name *Helicosteginopsis* is herewith proposed.

The genus *Helicostegina* is based on the species *Helicostegina dimorpha* BARKER & GRIMSDALE, a derivate of "*Amphistegina*" (*Eoconuloides*) *lopeztrigoi* PALMER, in which no secondary chamberlets are formed until after completion of the "amphisteginoid" (eoconuloid) stage. In other words: the chamberlets are developed as a spreading flange outside of the primary spiral.

In a second species, "*Helicostegina*" *gyralis*, on the contrary, secondary chamberlets are being formed already inside the spiral, which continues its growth right up to the edge of the adult form. It is this species (not *H. dimorpha*) which, with the addition of lateral tissue, leads up to *Helicolepidina polygyralis* BARKER. TAN (1936a, b) created a new genus, *Helicolepidinoides*, for *H. gyralis*⁵). *Helicostegina dimorpha*, on the other hand, evolved in a different direction: along the phylogenetic line which, via *Eulinderina* with its still solid lateral lamellae but essentially circular equatorial pattern, leads to the three-layered forms *Polylepidina* and *Lepidocyclina*⁶).

Now, "*Helicostegina*" *soldadensis* GRIMSDALE, in which the spiral itself is filled with secondary chamberlets, would morphologically have to find its place in *Helicolepidinoides*. As a matter of fact, it was later transferred to that genus by GRIMSDALE himself (1959). But this is not correct: there are between "*gyralis*" and "*soldadensis*" a couple of very important differences which make it impossible to unite them in one genus. First of all, whereas *H. gyralis* develops its secondary chamberlets on the ventral side only, GRIMSDALE clearly states in 1941 that in *H. soldadensis* "the chambers of the

⁵) In the same article (1936a, p. 994) he also mentions the term "*Helicosteginoides*", but that is obviously a slip of the pen. From the next paragraph of his text it is clear that he means "*Helicolepidinoides*".

⁶) TAN (1936a, p. 992) thought that, in principle, the growth pattern of *Helicostegina dimorpha* was the same as that of *Eulinderina* BARKER & GRIMSDALE; to him, *Helicostegina* is a synonym of *Eulinderina*. However, his argument is based exclusively on the horizontal section. In vertical section it is clear that *Eulinderina* represents a more advanced stage because it develops a true equatorial layer, which justifies a generic separation. *Helicostegina* should continue to be considered as a valid genus.

spire ... are subdivided in the equatorial plane ... from the second whorl outwards, into chamberlets ... ; these appear in both dorsal and ventral alar extensions and in the main peripheral cavities ... at about the same stage of growth". Also, *H. soldadensis* develops in its final stage a flange of secondary chamberlets in which the spiral is all but lost, a feature unknown in *H. gyralis*. GRIMSDALE describes this flange as follows: "It consists of a single layer of small irregular arcuate or flattened-hexagonal chamberlets in which the spire persists only as a line of somewhat larger cavities."

Finally, in *H. gyralis* the *Amphistegina*-like slit apertures connecting the spiral chambers are "separated from the wall of the inner coil by countersepta terminating in strong anteriorly directed apertural lips" (BARKER & GRIMSDALE 1936). In 1941, GRIMSDALE observes for *H. soldadensis*: "The split (sic) apertures in the primary septa are of the '*Amphistegina*-type' with counter septa which are very short and not developed in the equatorial plane; for this reason they are seldom visible in equatorial sections." Also COLE (1969b, p. 83) claims to have seen such countersepta, but in all the hundreds of sections that have passed under my own microscope I have never observed anything more than a thickening of the septal wall on either side of the aperture, but no real counterseptum and no trace of a hook.

These differences would in themselves amply justify a new generic name for *H. soldadensis*, but apart from this, the species cannot even belong to the same phylogenetic line as *Helicolepidinoides*. Already within the course of the Middle Eocene, *Helicolepidinoides gyralis* gave rise to *Helicolepidina polygyralis*, a form with well-developed lateral chambers, and itself became extinct. The assumption that in Late Eocene times that same line could have branched off into the more primitive form *H. soldadensis*, which lacks lateral chambers, is hardly acceptable.

Instead, it seems that *H. soldadensis* (from here on called *Helicosteginopsis soldadensis*) can claim its place in a phylogenetic sequence all its own. In its initial stage and in its vertical section it resembles *Amphistegina grimsdalei* to such an extent that we can almost surely see in the latter the un-subdivided prototype of *H. soldadensis*. At the opposite end of the line, through nearly total reduction of the spiral pattern in favour of a cyclic layer of chamberlets coupled with the development of lateral tissue, *H. soldadensis* clearly grades, towards the close of the Late Eocene, into "*Helicolepidina*" (*Helicocyclina* TAN 1936) *paucispira* BARKER & GRIMSDALE.

Instead of dealing with one group of mutually interrelated forms developing throughout the Middle and Late Eocene, we have to do with two distinct and entirely different groups. The first one originates in the Early or early Middle Eocene from *Eoconuloides* ("*Amphistegina*" *lopeztrogoi*) and evolves on the one hand into the line of *Helicostegina*-*Eulinderina*-*Polylepidina*-*Lepidocyclina* and on the other into *Helicolepidinoides* and *Helicolepidina*. The second one starts much later, at the turn of Middle to Late Eocene, not from *Eoconuloides* but from *Amphistegina* and develops, via *Helicosteginopsis soldadensis*, into *Helicocyclina paucispira*.

I would suggest that textfigure 1 be substituted for the diagram of those relationships as given by BARKER & GRIMSDALE in 1936.

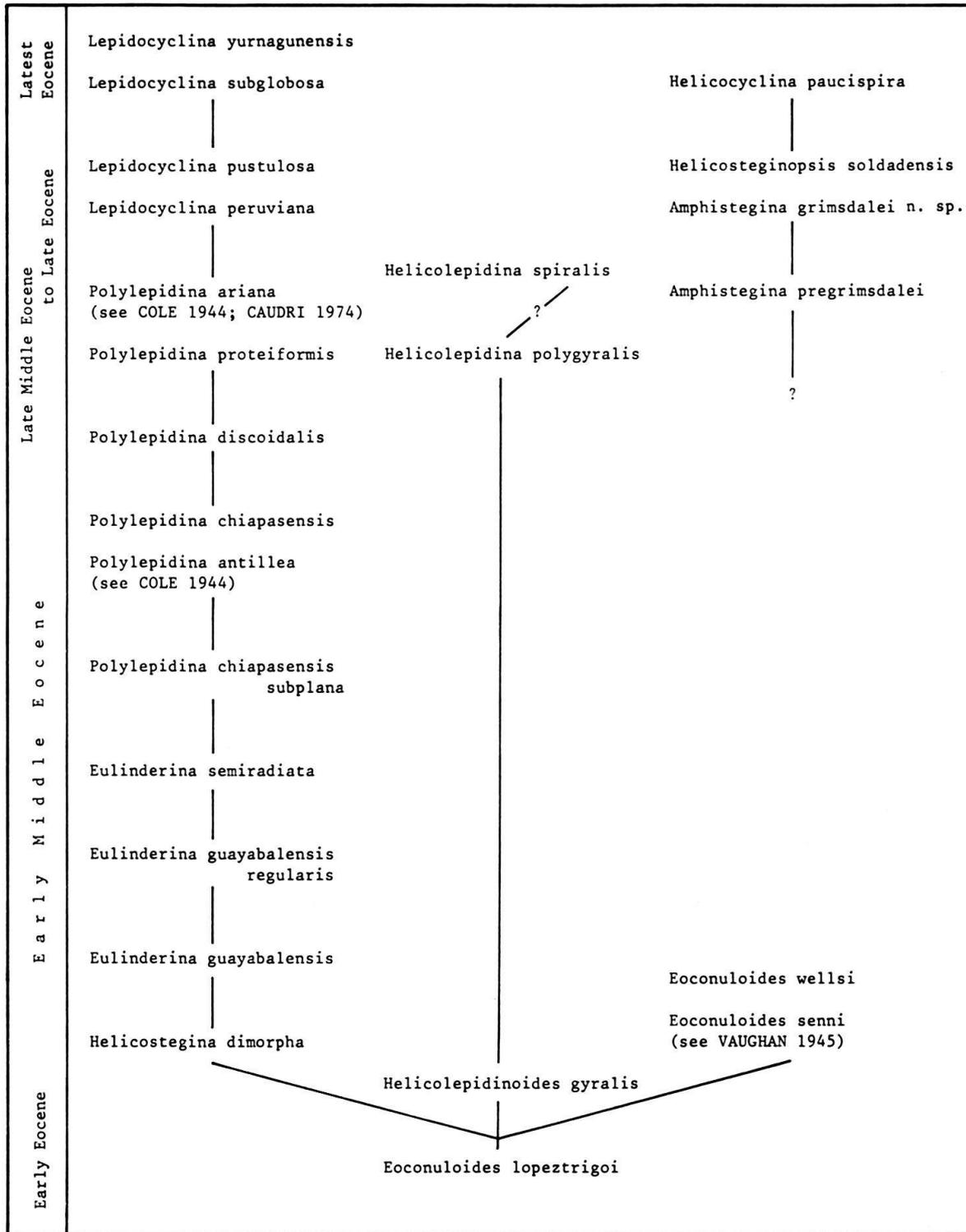


Fig. 1. Diagram of the suggested phylogenetic relationships of some orbitoidal foraminifera in the Caribbean Eocene.

Genus *Helicosteginopsis* n. gen.

Type species: *Helicostegina soldadensis* GRIMSDALE 1941.

A small lenticular form, similar to a close-wound *Amphistegina*, but from about the second whorl onward the chambers are subdivided into numerous chamberlets, of which the inner ones, next to the spiral wall of the previous coil, stand out like a string of pearls because of their larger size and their rounded shape. According to GRIMSDALE's description, this subdivision affects the equatorial plane and both dorsal and ventral alar prolongations. Actually, the alar prolongations of the chambers are hardly touched by it. Towards the axis of the test they remain undivided, though the filaments are meandric and develop a certain amount of anostomosing ramifications (Pl. 5, Fig. 16, present paper). The spiral growth pattern persists to the end, but in the final stage a single-layer flange is developed in which the original pattern is only faintly indicated by a spiral row of somewhat larger chamberlets.

The apertures between the primary chambers are slitlike, flanked on either side by a thickened rim; no countersepta have been observed. No lateral chambers are developed.

Helicosteginopsis soldadensis (GRIMSDALE)
(Pl. 5, Fig. 7, 10, 15, 16; Pl. 24, Fig. 8–15, 19?, 20)

- 1941 *Helicostegina soldadensis*, GRIMSDALE, p. 86, Pl. 46.
 1948 *Helicostegina soldadensis*, STAINFORTH, p. 134.
 1951 *Helicostegina soldadensis*, VAN RAADSHOOVEN, p. 482.
 non 1951 *Helicostegina soldadensis*, DE CIZANCOURT, p. 37, 38, 41, 42, 62, Pl. 5, Fig. 14, 15.
 1952 *Helicostegina soldadensis*, COLE, p. 4, 14, Pl. 6, Fig. 9–12.
 1959 *Helicolepidinoides soldadensis*, GRIMSDALE, p. 16, 17, 30.
 1960 *Helicostegina polygyralis* (pars), COLE, p. 59, Pl. 10, Fig. 2–4, 7, 11; Pl. 11, Fig. 2–4, 8.
 1962 *Helicostegina soldadensis*, HANZAWA, p. 143, Pl. 6, Fig. 34 (very bad figure); Pl. 7, Fig. 24.
 1963 *Helicostegina polygyralis* (pars), COLE, p. 42, Pl. 10, Fig. 6–8; Pl. 11, Fig. 1, 3, 4, 6–9.
 1969 *Helicostegina polygyralis* (pars), COLE 1969b, p. 83, Pl. 17, Fig. 10, 11.
 1974 *Helicostegina soldadensis*, CAUDRI, p. 304, Pl. 2, Fig. 18; Pl. 6, Fig. 5, 6, 9, 11.

GRIMSDALE's original description and illustration of the species are in all respects satisfactory and nothing needs to be added apart from the remark on its "countersepta" made in the above diagnosis of the genus, and the designation of an exact type locality.

H. soldadensis was described from "black silts exposed on the South shore" of Soldado Rock, but in private correspondence GRIMSDALE later mentioned to me the observation number Gr. 33, more accurately specified in his field book as "Astero-cyclina shale on the S. E. shore". No spot map goes with it to indicate its exact position.

However, this sample Gr. 33 was collected on October 12, 1935, the same date Dr. Kugler re-sampled this Astero-cyclina shale at the exceptionally rich locality K. 2854. We may safely assume that Dr. Kugler guided Mr. Grimsdale to this very spot to take his sample. K. 2854 is, therefore, from now on designated as the type locality of *Helicosteginopsis soldadensis*.

The length of the amphistegine stage and the width of the subdivided spiral are very variable, and so is the development of the flange. Some of the specimens in Bed 9a

give the impression, through the wide spread of the spiral or through its discontinuity in the peripheral part of the test, of being transitional forms between *Helicosteginopsis* and *Helicocyclina* (Pl. 24, Fig. 14, 15, 19), but they have no lateral chambers and the spiral is too long and too heavy for the latter genus. They are still to be considered as representing *Helicosteginopsis soldadensis*.

H. soldadensis has been reported from a number of localities outside Soldado Rock, but the specific character of this form has not always been well understood. The irregularities in its nomenclature as listed above will be discussed at a later date in connection with our material from Trinidad.

B-form: it is interesting to note that amongst the innumerable A-forms only one microspheric specimen of the species has thus far been found on Soldado Rock (K. 1499, E-2, Bed 9; Pl. 24, Fig. 12). Microspheric forms were encountered at various localities in Trinidad by the present author and by COLE (1963, Pl. 11, Fig. 1, 3, 4; 1969b, Pl. 17, Fig. 10), but they are always rare. One specimen was recorded from Margarita Island (CAUDRI 1974, Pl. 2, Fig. 18; Pl. 6, Fig. 11).

As a rule, these B-forms are slightly larger and thicker than the A-form and very thickwalled. Also the internal spiral is exceptionally heavy; it continues undiminished for several whorls and is then abruptly cut short, after which the chambers go on growing in an irregular fashion. No thin flange is developed in this generation.

Syntypes: VAUGHAN & COLE 1941 (appendix by GRIMSDALE), Pl. 46, Fig. 1–6.

Type locality: K. 2854 (Gr. 33; E-5), Bed 9a, "Asterocyclina marl".

Type level: Upper Eocene.

Occurrence: Beds 7–9a (not in Beds 4 and 10); see Distribution Chart (Part 1).

Helicocyclina paucispira (BARKER & GRIMSDALE)?

(Pl. 24, Fig. 16?, 17?, 18, 19?, 21?, 22, 23; Pl. 25, Fig. 1)

Compare: 1936 *Helicolepidina paucispira*, BARKER & GRIMSDALE, p. 243, Pl. 31, Fig. 11, 12; Pl. 33, Fig. 4–6; Pl. 36, Fig. 1, 3.

1941 *Helicolepidina paucispira*, VAUGHAN & COLE, p. 76, Pl. 45, Fig. 2.

Typical *Helicocyclina paucispira*, with a short spiral followed by a wide cyclic equatorial layer and with several layers of well-developed lateral chambers, has not been found on Soldado Rock, but a few small juvenile specimens in sample J. S. 1223 (Bed 9a) come very near to this species. Externally, they distinguished themselves from the rather numerous normal forms of *Helicosteginopsis soldadensis* in the same material by having a very small central body and a relatively very wide thin flange on which the equatorial chamberlets were clearly visible.

In horizontal section, they proved to have an exceptionally short spiral followed by a circular growth pattern (Pl. 24, Fig. 18, 19?, 21?, 22, 23; Pl. 25, Fig. 1). None of the specimens is fully and normally developed; in one, for instance, the spiral seems to contain nothing more than the amphistegine stage of the species (Pl. 24, Fig. 22; Pl. 25, Fig. 1). In the vertical section there are sometimes faint indications of the beginning of lateral tissue (Pl. 24, Fig. 16, 17); this is not convincing, but it may be that lateral tissue does not develop until later in the life of the individual.

The presence of *H. paucispira* on Soldado Rock is not proved by these freak specimens, but their development in the highest bed of the section, which also contains *Lepidocyclina subglobosa* and some doubtful fragments of *L. sanfernandensis*, is nevertheless interesting. The combined appearance of such forms, which in Trinidad are indicative of the highest level of the Upper Eocene, suggests that also in Bed 9a we are already pretty high in the section.

Genus *Helicolepidina* TOBLER, 1922

Helicolepidina spiralis TOBLER

(Pl. 25, Fig. 2-6)

- 1922 *Lepidocyclina (Helicolepidina) spiralis* TOBLER 1922a, p. 343, 345.
 1922 *Helicolepidina spiralis*, TOBLER 1922b, p. 380-384, Textfig. 1-3.
 1934 *Helicolepidina spiralis*, BARKER, p. 345-346, Pl. 47, Fig. 1-4, Textfig. 1 a, c (with synonyma list).
 1936 *Helicolepidina spiralis*, BARKER & GRIMSDALE, p. 243, Pl. 33, Fig. 7.
 1936 *Helicolepidina spiralis*, VAUGHAN, J. Paleont. 10, p. 248, 251, Pl. 39, Fig. 5; Pl. 40, Fig. 6-8
Helicolepidina nortoni, VAUGHAN, ibid., p. 248-251, Pl. 39, Fig. 1-4; Pl. 40, Fig. 1-5.
 1941 *Helicolepidina spiralis*, VAUGHAN & COLE, p. 11, 22, 27, 76, Pl. 45, Fig. 1.
 1962 *Helicolepidina spiralis*, COLE 1962b, p. 145-151, Pl. 23; Pl. 24; Pl. 25; Pl. 26, Fig. 1-6, 9; Pl. 27,
 Fig. 1, 2, 4-6.
 1974 *Helicolepidina spiralis*, CAUDRI, p. 310, Pl. 8, Fig. 1, 2.

Both types of nepionic development, with one or with two auxiliary chambers, were observed in the Soldado material, seemingly indiscriminately mixed and unconnected with the stratigraphical level. Nevertheless, one or the other of the two can be predominant in certain populations. The roughly biserial type (with one auxiliary chamber) is in the majority in the upper part of Bed 10 (K. 3690, 3691) and the quadriserial type in the lower part (K. 1500).

In sample K. 10707 of the same bed both types occur side by side, but it was observed that in the specimens with two auxiliary chambers only one gives rise to nepionic spirals. Particularly good material, including the microspheric form, came from K. 2855 (Bed 7) and from K. 903 and K. 3677 (Bed 10).

In the microspheric form, the embryonic spiral consists as a rule of up to 20 thinwalled undivided chambers; occasionally it develops a thick outer wall around the first 8 or 10 of them (K. 3677). Particularly in one of these thickwalled specimens, but also in others, it became clear during the process of grinding, that the spiral is trochoid, not planispiral (Pl. 25, Fig. 2).

At K. 1500 (Bed 10) some tricarinate monstrosities were encountered.

Syntypes: TOBLER 1922b, Fig. 1-3.

Type locality: Rio San Pedro, Baralt District, State of Zulia, Venezuela.

Type level: Rio San Pedro limestone, Pauji-Menegrande series, upper Middle Eocene.

Occurrence: see Distribution Chart (Part 1); K. 903 (A-form abundant, B-form common); K. 1500 (both A- and B-forms common, also rare tricarinate specimens); K. 2651 (A- and B-forms common); K. 2855 (A- and B-forms); K. 2951 B (A- and B-forms); K. 3677 (abundant, also B-forms).

Genus *Lepidocyclina* GÜMBEL, 1870*Lepidocyclina peruviana* CUSHMAN

(Pl. 5, Fig. 4; Pl. 25, Fig. 7–14; Pl. 26, Fig. 1–4, 8)

- 1922 *Lepidocyclina* (*Nephrolepidina*) *peruviana*, CUSHMAN, p. 138, Pl. 24, Fig. 1.
Lepidocyclina antillea, *ibid.*, p. 137, Pl. 24, Fig. 2 (not *L. antillea* CUSHMAN 1919).
- 1928 *Lepidocyclina peruviana*, NUTTALL, p. 104.
- 1932 *Lepidocyclina* (*Lepidocyclina*) *peruviana*, TODD & BARKER, p. 535–537, Pl. 41, Fig. 1–4; Pl. 42, Fig. 2, 3, 5–7.
 ?*Lepidocyclina* (*Lepidocyclina*) sp. aff. *sherwoodensis*, *ibid.*, p. 537, Pl. 40, Fig. 1; Pl. 41, Fig. 6; Pl. 42, Fig. 4.
Lepidocyclina (*Lepidocyclina*) sp. aff. *kugleri*, *ibid.*, p. 538, Pl. 40, Fig. 2; Pl. 41, Fig. 5 (?not Pl. 42, Fig. 1).
- 1937 *Lepidocyclina* (*Lepidocyclina*) *peruviana*, VAUGHAN, p. 165–171, Pl. 118, Fig. 2–8; Pl. 119, Fig. 1–3 (not 4–6); Pl. 120, Fig. 1–2 (?not 3–4) (not Pl. 117, Fig. 1–4).
- 1948 *Lepidocyclina peruviana*, STAINFORTH, p. 134, 141.
- 1944 *Lepidocyclina* (*Pliolepidina*) *peruviana*, COLE, p. 62, Pl. 2, Fig. 3; Pl. 8, Fig. 19; Pl. 15, Fig. 1–10.
Lepidocyclina (*Pliolepidina*) *pustulosa*, *ibid.*, Pl. 8, Fig. 18.
- 1955 *Lepidocyclina peruviana*, STAINFORTH, p. 2074.
- 1959 *Lepidocyclina peruviana* (including *Triplalepidina veracruziana*), GRIMSDALE, p. 8, 12, 18, 19, 21, 26, 29.
- 1963 *Lepidocyclina* (*Lepidocyclina*) *pustulosa* pars (including *Lepidocyclina peruviana* and *Triplalepidina veracruziana*), COLE, p. 33, Pl. 6, Fig. 2; Pl. 10, Fig. 9, 12.
- 1964 *Lepidocyclina* (*Lepidocyclina*) *pustulosa* pars, COLE & APPLIN, p. 29, Pl. 6, Fig. 6.
- 1974 *Lepidocyclina peruviana*, CAUDRI, p. 313, Pl. 12, Fig. 5.

Lepidocyclina peruviana is present in all the Upper Eocene beds of Soldado Rock, as it is also throughout the Upper Eocene of Trinidad, but only in small specimens. Often they represent an unsorted natural population, attaining a maximum diameter of 3 mm, but mostly very much less than that. In some of the richer samples the very small specimens make up the bulk of the fine fraction of the washed residue. Good material for a detailed study of this species was collected at localities K. 1500 and K. 2652 (Bed 10).

In this area, *Lepidocyclina peruviana* occurs everywhere in the company of *L. pustulosa*. The difference between the two species is difficult to describe, but with some training it is rather easy to pick out the specimens of *L. peruviana* from the overwhelming mass of *L. pustulosa* in a sample: the surface network and pillars are somewhat finer, and in good specimens the lateral chambers are arranged in definite radial rows towards the edge (Pl. 5, Fig. 4).

Also the equatorial layer shows a pronounced tendency to develop radial rows of chambers. Like in *L. pustulosa*, the nepiont is quadriserial, but as a rule the nucleocoach is smaller, relatively thickwalled and not always exactly in the median plane, and the periembryonic ring is sometimes strikingly regular, all the chambers being more or less of the same size.

The vertical section is similar to that of *L. pustulosa*, though the lumina of the lateral chambers are in general a little more rounded. Some specimens show the phenomenon of duplication of the equatorial layer towards the edge, sometimes with a more or less distinct wedge of solid shell material between the two layers (Pl. 25, Fig. 9, 14), but in how far this is a realistic observation or only an optical delusion (because the section cuts through two or more of the high peripheral median cham-

bers) is open to question. A similar effect is sometimes produced in *L. pustulosa* (Pl. 27, Fig. 11), where there is certainly no duplication, but in that case no wedge was ever observed. The duplication of the median layer has once been described as typical of the genus *Triplalepidina* VAUGHAN & COLE (1938), but in 1963 COLE himself put the genotype *T. veracruziana* in the synonymy of *Lepidocyclina peruviana*.

Small microspheric forms of *L. peruviana*, with a diameter varying from 1,4 to 2,4 mm, were found at K. 1499 and K. 3692 (Pl. 26, Fig. 8).

Holotype: CUSHMAN 1922, Pl. 24, Fig. 1, exterior (first description of internal features: TODD & BARKER 1932).

Type locality: not specified; in N. W. Peru.

Type level: Upper Eocene (Verdun Formation) (see GRIMSDALE 1959, p. 19).

Occurrence: see Distribution Chart (Part 1); especially common in Bed 10.

Lepidocyclina peruviana nana n. subsp.

(Pl. 26, Fig. 5)

Of the very small forms of *Lepidocyclina peruviana* the majority turns out to consist of immature individuals, representing only the nepionic stage, perhaps surrounded by one or two rings of neanic median chambers. But amongst them there is also a fair number of true miniatures, which look like fully developed specimens of *L. peruviana*, only on a much smaller scale.

Provisionally, this miniature form is considered as a variety of the normal *L. peruviana* and the name *L. peruviana nana* is proposed for it.

Holotype: Pl. 26, Fig. 5.

Type locality: K. 3692 (D-3).

Type level: Bed 10, lower part of the Upper Eocene.

Lepidocyclina pustulosa (H. DOUVILLÉ)

(Pl. 1, Fig. 17, 18; Pl. 5, Fig. 1, 3, 5, 6; Pl. 26, Fig. 6, 7, 9, 12, 13, 14; Pl. 27; Pl. 28, Fig. 1, 3, 4; Pl. 29, Fig. 5, 7)

Reference is made to VAUGHAN & COLE's "Preliminary Report on Trinidad", 1941, for synonymy of the species as well as for the detailed description and illustration of the material from K. 2854 of Soldado Rock.

1944 *Lepidocyclina (Pliolepidina) pustulosa*, COLE, p. 66, Pl. 7, Fig. 5-7, 13-15; Pl. 8, Fig. 1-5, 8 (not 18); Pl. 16, Fig. 1, 2, 4, 7, 8.

1959 *Lepidocyclina pustulosa* and *Lepidocyclina tobleri*, GRIMSDALE, p. 8, 19, 21, 22, 29.

1962 *Lepidocyclina (Pliolepidina) pustulosa*, COLE, 1962a, p. 33, 34, 37, 38, 42, 44, 50, Pl. 5, Fig. 4; Pl. 6, Fig. 2-4; Pl. 7, Fig. 1-6; Pl. 8, Fig. 1, 2, 4-8.

1962 *Lepidocyclina (Pliolepidina) pustulosa*, COLE 1962b, p. 149, Pl. 27, Fig. 3.

1963 *Lepidocyclina pustulosa*, *Lepidocyclina trinitatis* and "*Pliolepidina*" (*Lepidocyclina*) *tobleri*, COLE, p. 18-35.

1974 *Lepidocyclina "pustulosa"* sensu lato, CAUDRI, p. 312, Pl. 1, Fig. 27-29; Pl. 11, Fig. 3, 8-12; Pl. 12, Fig. 1, 4, 6.

Besides *Asterocyclina asterisca*, this is the most abundant species of the Upper Eocene in the Trinidad area. The Soldado material is exceedingly rich and excellently preserved in a number of localities. In several of them the fauna can be considered as an undisturbed complete population comprising all the stages of individual development, from embryo to fullgrown, of both generations.

All the different varieties (probably all of at least subspecific rank) that have been distinguished in this variable "species": the typical pillared *L. pustulosa* s. s., the smooth "forma *trinitatis*" H. DOUVILLÉ, the "forma *tobleri*" H. DOUVILLÉ with its multilocular embryonic apparatus, and a small narrow-chambered form described below as *compacta*, are represented on Soldado Rock.

The typical form is illustrated on Pl. 5, Fig. 1; Pl. 26, Fig. 6, 7, 9, 13; Pl. 27, Fig. 3, 8, 12; Pl. 28, Fig. 1, 3, 4; Pl. 29, Fig. 5.

L. pustulosa trinitatis: Pl. 1, Fig. 17, 18; Pl. 5, Fig. 3, 5, 6; Pl. 26, Fig. 14; Pl. 27, Fig. 1, 9–11; Pl. 29, Fig. 7.

The development of the so-called "teratological" form *tobleri* (Pl. 27, Fig. 2, 4–7) cannot be compared with that of the specimens found in its type area in Trinidad (Vistabella near San Fernando). This form makes its appearance at the top of Bed 10 (K. 2652, D-1) and continues through Beds 7, 9 and 9a, but it remains rare and irregular. At several spots in Bed 10, non-typical transitional forms were found: at K. 903 and K. 1500 (B-3) and at K. 3692 and K. 10707 (D-3); see also COLE 1962a, Pl. 7, Fig. 6 and 1962b, Pl. 27, Fig. 3. In several specimens the wide open lumen of the large central chamber has been secondarily invaded by an irregular tissue of lateral(?) chambers (present paper: Pl. 27, Fig. 4 and 5).

Also microspheric specimens were found, sometimes in large numbers, for instance at K. 903, K. 1499, K. 2855 and K. 3677. Very large specimens are rare but do occur in a few samples (K. 903); mostly, they are small to medium sized, e. g. K. 2855 (Bed 7). Their nepionic development deserves a detailed study. In some cases, the first equatorial chambers are arranged in radial rows, in others there is first a more or less spiral arrangement followed by radial rows, and there are also specimens in which the adult concentric or fan-shaped pattern is assumed from the beginning (Pl. 28, Fig. 1, 3, 4). All three types may occur together in the same sample.

Type area: San Fernando area, Trinidad.

Type horizon: San Fernando Formation, Upper Eocene.

Occurrence (of all the various forms): see Distribution Chart (Part 1).

Lepidocyclina pustulosa compacta n. subsp.

[Pl. 26, Fig. 12 (holotype, specimen from Trinidad!)]

1974 *Lepidocyclina pustulosa*, small-chambered variety, CAUDRI, p. 312, Pl. 12, Fig. 1.

This mostly small, narrow-chambered variety of *Lepidocyclina pustulosa* was found scattered throughout the Upper Eocene of Trinidad and Soldado Rock, but can be recognized only after sectioning. It is never common. It was also found in Margarita Island, in a mixed Middle and Late Eocene fauna.

Some specimens of *L. pustulosa* have normal larger chambers in the center, but become very narrow-chambered towards the periphery (on Soldado Rock in the samples P. J. 1146, 1147 and 1162). Because of those transitional forms, *compacta* is left in the super-species "*pustulosa*" and not given the rank of a separate species.

Holotype: Pl. 26, Fig. 12.

Type locality: Point Bontour near San Fernando, Trinidad, St. 63.

Type level: Upper Eocene.

Occurrence (on Soldado Rock): K. 2954 (D-4), Bed 7; transitional forms in Bed 9a.

Lepidocyclina spatiosa n. sp.

(Pl. 1, Fig. 21 (specimen from Trinidad!); Pl. 28, Fig. 2; Pl. 29, Fig. 1, 2)

1941 *Lepidocyclina* (*Lepidocyclina*) sp. aff. *ocalana* var. *pseudocarinata*, VAUGHAN & COLE, p. 68, Pl. 31, Fig. 10, 11.1974 *Lepidocyclina spatiosa*, CAUDRI, p. 299, 312, Pl. 12, Fig. 2 (*nomen nudum*).

This species is very rare on Soldado Rock, but it is well known to the author from the Upper Eocene of the Navette area in S. E. Trinidad, where it is abundantly represented in both megalospheric and microspheric forms. A more extensive description of its external and internal features will be given in a later publication dealing with the Larger Foraminifera of Trinidad, which today is in an advanced stage of completion.

If well preserved, *Lepidocyclina spatiosa* is a conspicuous species, already at first sight clearly different from *L. pustulosa*, with which it occurs together. It is a flat, rather thin form, occasionally slightly sellaeform, with a smooth surface, flush pillar-heads and large meandric lateral chambers (Pl. 1, Fig. 17). In a less perfect condition, like the Soldado material, it is, however, indistinguishable from *L. pustulosa* and the differences show up only after sectioning.

L. spatiosa is no doubt related to *L. pustulosa*: it has a similar periembryonic development and fan-shaped equatorial pattern, but its median chambers are much larger (compare Pl. 29, Fig. 1 and 2 with Pl. 26, Fig. 9, and the different B-forms on Pl. 28). Both species suffer from repeated growth interruptions, but because of the larger size of the chambers this is particularly conspicuous in *L. spatiosa*. The vertical section (known from Trinidad) shows the difference between the two species in no uncertain way: *L. spatiosa* is characterized by low, nearly slitlike lateral chambers with heavy continuous roofs.

Holotype: Pl. 28, Fig. 2.

Type locality: K. 1316 (D-5).

Type level: Bed 9a, Upper Eocene.

Occurrence: K. 1499 (Bed 9); K. 1316, K. 2854 (Bed 9a).

Lepidocyclina cf. *sanfernandensis* VAUGHAN & COLECompare: 1941 *Lepidocyclina* (*Nephrolepidina*) *sanfernandensis*, VAUGHAN & COLE, p. 73, Pl. 42, 43, 44.

Sample K. 2651 (Bed 9a) yielded a few fragments of microspheric *Lepidocyclina*s, of which the large thinwalled rounded equatorial chambers show a great resemblance to those of *L. sanfernandensis* from Trinidad. The identification is doubtful but may be significant in combination with the occurrence of *L. subglobosa* and (untypical) *Helicocyclina paucispira* in the same bed. In Trinidad, all these forms indicate the uppermost part of the Upper Eocene.

Lepidocyclina subglobosa NUTTALL

(Pl. 26, Fig. 10, 11)

1928 *Lepidocyclina subglobosa*, NUTTALL, p. 104, Pl. 8, Fig. 3, 5-7.1941 *Lepidocyclina* (?*Pliolepidina*) *subglobosa*, VAUGHAN & COLE, p. 65, 67, Pl. 31, Fig. 8-9.1959 *Lepidocyclina subglobosa*, GRIMSDALE, p. 8, 19, 30.

Of this species, which in all probability is nothing but a form of *L.yurnagunensis* CUSHMAN, one single specimen was found on Soldado Rock: at K. 3741, in Bed 9a (D-5).

L.subglobosa is characterized by its small "isolepidine" nucleocoenoch surrounded by a quadriserial ring of small equally-sized perieubryonic chambers and by its very small thinwalled rhomboid equatorial chambers. On Pl.26, the specimen is figured side by side with one of the common juvenile forms of *L.pustulosa* in the same assemblage, in order to emphasize these specific characteristics.

In the San Fernando area of Trinidad, *L.subglobosa* is an index fossil of the uppermost strata of the Upper Eocene and its presence here in Bed 9a is taken as an indication that this bed represents a high level of the Upper Eocene also on Soldado.

Syntypes: NUTTALL 1928, Pl.8, Fig.3, 5-7.

Type locality: Naparima (San Fernando) region, Trinidad, Testwell A, at depth 525 feet.

Type level: Mount Moriah (San Fernando) Formation, Upper Eocene.

Lepidocyclina cf. *yurnagunensis* CUSHMAN

Compare: 1941 *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* CUSHMAN, VAUGHAN & COLE, p.72, Pl.38, Fig.1-7.

Bed 9a contained, in the samples P.J.1147 and 1162, some very rare and very small peripheral fragments of a form of *Lepidocyclina* with thinwalled rhomboid equatorial chambers, much more like those of *L.yurnagunensis* than of *L.pustulosa*. The material is insufficient for specific determination, but the presence of such a form in the same bed as *L.subglobosa*, *L.sanfernandensis*? and juvenile *Helicocyclina paucispira* is nevertheless worth mentioning.

Lepidocyclina sp.indet.1

A strongly inflated microspheric form with tapering flange, heavily pillared in the center, resembling the B-form of *L.pustulosa* but with smaller chambers and with two rows of lateral chambers between the pillars instead of one. Lateral chambers rounded, $\pm 70 \mu$. Diameter of test about 8 mm.

Nepionic spiral fairly large, rotalid. Median chambers very small, lozange-shaped, pointed-ogival or rounded, at first arranged in radial rows, later more cyclic. Vertical section unknown.

In Trinidad (Vista Bella Quarry, San Fernando area) a megalospheric specimen was found, which shows two rows of lateral chambers between the pillars and which may correspond to this same species.

Type locality: K.2954 (D-4).

Type level: Upper Eocene, Bed 7.

Occurrence: K.2954 (one specimen; C 31171); ?K.2854 (Bed 9) (one subglobular specimen, diameter 2 mm; C 31109).

Lepidocyclina sp.indet.2

Fragmentary specimens of an extremely thinwalled *Lepidocyclina* with arcuate to hexagonal median chambers with six stolons per chamber: four diagonal and two concentric. Megalospheric and microspheric forms. No further diagnosis possible.

Occurrence: K. 2855, K. 2954.

Level: Upper Eocene, Bed 7.

Note: This is not the same species as VAUGHAN & COLE's "sp. indet. 2" (1941, p. 69, Pl. 33, Fig. 3, 4), which is a tiny B-form from K. 1499, probably very closely related to *Lepidocyclina pustulosa*.

Genus *Sphaerogypsina* GALLOWAY, 1933

Sphaerogypsina globulus sensu lato

Globular "Gypsinas", which can be brought under this general name, were found in Bed 11 (K. 10721), Bed 10 (K. 903, K. 1500, K. 10707, Rz. 250, Rz. 251) and, doubtfully, in Bed 7 (K. 2855). They are always scarce.

These forms were not studied in detail. It may be that various different species are represented.

Genus *Cyclolocolina* HERON-ALLAN & EARLAND, 1923

Because of its trochoid initial stage and its coarsely porous walls, CUSHMAN (1940) places this genus in the Globorotaliidae, but its further development separates *Cyclolocolina* from all normal members of that family. At a very early stage it starts to develop practically undivided annular chambers, though never giving up a pronounced difference between the flat-conical dorsal side of the test and the slightly concave ventral side.

There is little doubt that the form found in the Upper Eocene of Soldado Rock is the same as *Cyclolocolina jarvisi* CUSHMAN described from the Eocene(?) of Trinidad. The nomenclature and the systematical place of the genus should, however, be checked.

The genotype of *Cyclolocolina* (*C. annulata* HERON-ALLAN & EARLAND) comes from the Eocene(?) of the South Coast of England and the genus is also mentioned from the Paris Basin (CUSHMAN 1929). Later, it was reported also from the Upper Eocene of Panama and from the Miocene of Florida. CUSHMAN (1940) gives as the stratigraphical range: Eocene to Recent.

Apart from *Cyclolocolina*, CUSHMAN also places in the Globorotaliidae the very similar genus *Sherbornina*, described in 1922 by CHAPMAN from the Miocene of Tasmania. The relationship between these two genera seems to be extremely close. A comparison of our specimens of *Cyclolocolina* with CUSHMAN's figures (1940, Pl. 35) shows that the dorsal side of our B-form corresponds in general with his Fig. 19-22 (*Cyclolocolina annulata*) and the ventral side with Fig. 18 (*C. miocenica* COLE & PONTON) but, judging from the picture, it is actually Fig. 24 (*Sherbornina atkinsi* CHAPMAN) which comes closest to the Soldado form. The description of *Sherbornina* given by CUSHMAN 1940, p. 296 is not particularly clear. The annuli seem to be subdivided into a small number of very wide chamberlets and the author mentions an "external layer" of "superimposed chamberlets", the nature of which is rather enigmatic, but which could perhaps correspond with the network of incomplete ventral chamberlets observed in our specimens. Both genera should be carefully restudied together. For an understanding of their systematical place, attention is also drawn to the genus *Eoannularia* COLE & BERMUDEZ from the Cuban Eocene (Bull. amer. Paleont., 1944, 28/113), and to *Epiannularia* CAUDRI from the Upper Middle Eocene of Margarita (1974, p. 305).

Cyclolocolina jarvisi CUSHMAN

(Pl. 5, Fig. 2, 17; Pl. 29, Fig. 3, 4, 6, 8–13)

1929 *Cyclolocolina jarvisi*, CUSHMAN, p. 4, 5, Pl. 1, Fig. 8–10.1962 *Cyclolocolina jarvisi*, COLE 1962b, p. 149, Pl. 26, Fig. 7, 8.

Cyclolocolina jarvisi is, in spite of its small size, a conspicuous fossil which is not easily overlooked. It has been found in several samples, nearly always in very small numbers, but it is plentiful and very well preserved in sample K. 3692, from which it has also been mentioned by COLE.

Both microspheric and megalospheric specimens were encountered. When fully developed, *C. jarvisi* may reach a diameter of about 1.2 mm and assume the shape of a very low cone with a slightly concave ventral base (one specimen in K. 3691, Pl. 29, Fig. 9). Most specimens are much smaller and are flat, but nearly all show a marked difference between the dorsal and the ventral side.

The walls of the test are thin, transparent and coarsely porous. On the dorsal side the ringshaped chambers are visible as completely undivided rings (Pl. 5, Fig. 17). On the ventral side, however, a conspicuous network of extremely delicate hexagonal "chamberlets" was seen, especially in the large specimen from K. 3691 mentioned above. The walls of these "chamberlets" remain incomplete and only occasionally reach the dorsal wall of the chamber; as was clearly observed in the large specimen, they correspond with radial rows of pores on the dorsal side of the test. The same thing is also seen in CUSHMAN's figures of *C. jarvisi* from Trinidad: the dorsal side of an A-form shows undivided chambers, but the partitions are evident in the ventral view of the B-form.

The width of the annuli appears to be variable. In the population of K. 3692, some of the specimens have fairly wide rings whereas in others the rings are much narrower. This may be due to individual variation only or perhaps to a difference between the megalospheric and the microspheric generation, but it is also possible that more than one species is represented. This needs further study.

The embryonic stage of the microspheric generation is sometimes very low trochoid (Pl. 29, Fig. 3), which may justify CUSHMAN's inclusion of the genus in the Family of the Globorotaliidae, but this development seems to be rather the exception than the rule: in most of our specimens the initial spiral looks more like *Planulina*, thinwalled, with the successive chambers increasing in length until they reach the annular stage. The megalospheric embryonic apparatus is bilocular and is immediately followed by the first undivided annular chamber (Pl. 29, Fig. 10).

COLE's figure (1962b, Fig. 8) is probably of a microspheric specimen. In its center, it shows a coarsely porous *Globorotalia*-like initial test, similar to our own Figure 3 on Pl. 29, and then passes through a biserial stage between the trochoid nepiont and the adult annular pattern. This seems to be quite an abnormal development, but also on this point further study of the material of K. 3692 is recommended.

According to CUSHMAN, the types of *C. jarvisi* are from the Eocene on the Lothian Estate, South of Princes Town, Trinidad. As in that area only Oligocene deposits (in the Nariva and Cipero facies) are exposed, his specimens, if really of Eocene age according to the accompanying fauna, must have come from an erratic boulder.

Syntypes: CUSHMAN 1919, Pl. 1, Fig. 8–10.

Type locality: Lothian Estate, Princes Town, Trinidad (Cushman collection n° 10095).

Type level: Eocene.

Occurrence: Bed 7, K. 2954; Bed 10, K. 3690, K. 3691, K. 3692 (common, A- and B-forms), Rz. 250.

Dasyclad (?) algae

(Pl. 29, Fig. 14; Pl. 30, Fig. 1, 2)

1944 "tubiform ooliths", CAUDRI, p. 24, Pl. 1 (30), Fig. 1, 3, 5.

Under the non-committal name of "tubiform ooliths" I have described and figured some peculiar organisms that occur in rock-building quantities in the fossiliferous part of the limestones at San Juan de los Morros in Central Venezuela, in association with a typically Paleocene fauna of Larger Foraminifera.

On Soldado Rock, these same fossils were found in several erratic blocks embedded in the Upper Eocene, also as rockbuilding elements, but here they are not accompanied by an indicative Larger Foraminifera fauna. Nevertheless, in comparison with the Venezuelan limestones they are, without hesitation, also assigned to the Paleocene.

The organisms appear in two different forms: large tubes, circular in cross section and elongate with bluntly thickened ends in longitudinal section, and very thin even more elongate, closed tubes, likewise circular in cross section (Fig. 2). Oblique sections at all conceivable angles are, of course, legio in all preparations.

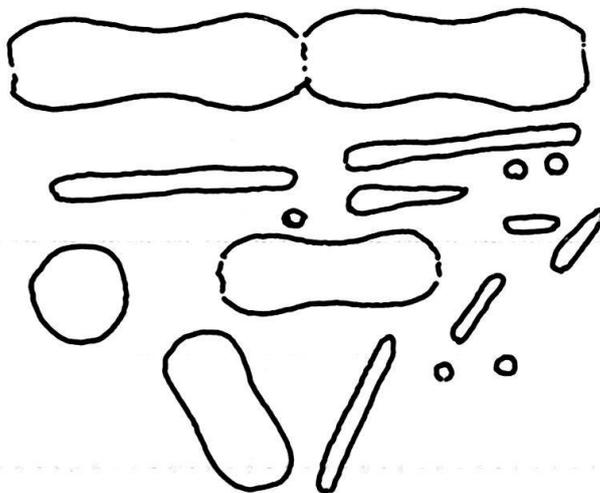


Fig. 2. Random sections of the disjointed members of the rock-building algae.

The thin bodies correspond entirely with the "tubiform ooliths" of San Juan de los Morros. The large ones are obviously of the same nature. All have a thin outer wall without pores and the interior is filled with clear crystallized calcite in which precipitation of a darker mineral sometimes gives the impression of some kind of original structure. Occasionally, the larger ones are seen to be linked together end to end.

A reconstruction of the organism of which all these scattered tubular bodies seem to belong may result into something like Textfig. 3, or an articulated stem with a

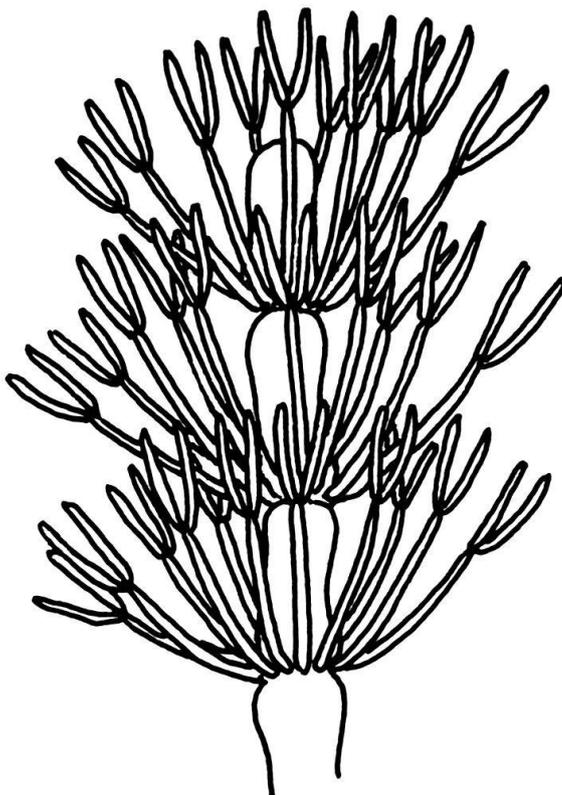


Fig. 3. Tentative reconstruction of the thallus of the algae, presumably belonging to the family of the Dasycladaceae.

dense terminal tuft of thin hairs. The exact nature of the fossils remains enigmatic but it seems safe to consider them as calcareous algae, belonging to the Class of the Chlorophyceae and more especially to the Order of the Siphonales, Family Dasycladaceae (see WETTSTEIN's Systematical Botany, 1924, p.167). This family, many members of which are highly calcareous, is known in a fossilized state as far back as the Carboniferous. In general shape, the fragments in our material resemble the ramifications of the (non-calcareous) genus *Dasycladus* as illustrated by WETTSTEIN (Textfig.4), though it is not clear whether that genus has any articulated stems or

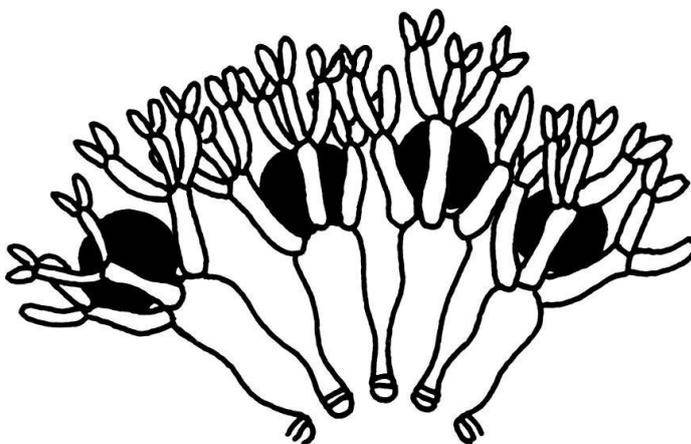


Fig. 4. *Dasycladus clavaeformis*, Recent; schematical cross section of the main stem of the thallus (with appendages bearing the gametangia); after WETTSTEIN 1924, Figure 104.

branches like our Paleocene form; articulated stems do, however, occur in other members of the family.

Thin sections of this peculiar limestone were submitted to Dr. E. Gasche of the Basel Museum of Natural History for a preliminary examination. In one case, Dr. Gasche thought the fossils might be related either to the genus *Acicularia*, one of the Dasycladaceae, or to the Family of the Codiaceae, which likewise belongs to the Order of the Siphonales. No trace, however, was found of the matted "tissue" of combined "hairs" which is often characteristic of the latter family. It was also suggested by him that the common single tubes in the rock sections of J. S. 1954 (Pl. 29, Fig. 14) might be *Ovulites cf. elongata* LAMARCK and that some other specimens would represent a new species of *Marinella*. Meanwhile, awaiting the thorough study they deserve, these peculiar organism are here recorded as "Dasyclad algae".

Because of the lack of Larger Foraminifera in the Dasyclad algae limestone and, on the other hand, the abundance of mollusks in some of the samples, these reef deposits are considered as closely linked to the coquinas of Bed 2 and thus as a slightly older element of the Soldado Formation than the Ranikothalia limestone.

Occurrence: K. 3876 (abundant, together with common gastropods and pelecypods), K. 10711 (rock-building), K. 10724 (rock-building), K. S. 25? (very rare, in an Amphistegina-Lithothamnium limestone), Z. 444 B? (very rare, in a pelecypod- and gastropod-coquina), J. S. 1949 (rock-building; sample showing evidence of tidal currents), J. S. 1954 (rock-building).

Unidentified fossils

(Pl. 30, Fig. 3, 4)

At K. 10711 was found a boulder of recrystallized limestone composed of a kind of organisms (algae?) that are similar in shape to the Dasyclad algae, but are much larger and apparently also of a different texture. They have to be left unidentified at the present moment.

List of samples examined

For the spotmap of all the fossil localities mentioned above the reader is referred to the first part of this study on Soldado Rock (Eclogae geol. Helv. 68/2, after p. 430).

The following is a list of all the samples studied for their fossil contents, in numerical order and with the indication of their stratigraphical position and their location on the map:

T. L. L. 125, block in Bed 3 (C-4)	K. 2651, Bed 9a (E-4)
K. 903, Bed 10 (B-3)	K. 2652, Bed 10 (E-1)
K. 906, block in Bed 3 (C-4)	K. 2851, Paleocene block (E-4)
K. 1316, Bed 9a (D-5)	K. 2854, Bed 9a (E-5)
K. 1321, Bed 4 (B-3)	K. 2855, Bed 7 (F-3)
K. 1496, Bed 11 (B-1)	K. 2948, Bed 2 (C-5)
K. 1499, Bed 9 (E-2)	K. 2949, Bed 2 (C-5)
K. 1500, Bed 10 (B-3)	K. 2950, Bed 3 (C-4)
K. 2650, Bed 9a (D-5)	K. 2951, Bed 3 (C-4)