SOME LARGER FORAMINIFERA FROM THE TERTIARY OF CENTRAL AMERICA

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ABSTRACT. Some larger foraminifera are recorded from various localities in the Central American region, many of them being illustrated. Additional information concerning, and new illustrations of, topotype material of some previously known forms are given. New subgenera *Vlerkina* and *Vlerkinella* (of the genus *Heterostegina*) are proposed; four new species and one new subspecies are described and illustrated. Certain aspects of the stratigraphy of the region are discussed, and the genus *Pliolepidina* is acknowledged to range down to the Late Eocene. The Oligocene age of certain occurrences of large foraminifera is confirmed by the associated planktonic foraminifera.

RECENTLY, one of us (W. H. B.) has had the opportunity of studying good planktonic foraminiferal assemblages from the Oligocene of Ecuador, Jamaica, and Alabama and from the Early Miocene of Puerto Rico. He has found that in each of these areas larger foraminifera are closely associated with planktonic foraminiferal assemblages which can be placed accurately in the planktonic foraminiferal scheme outlined by Banner and Blow (1965). In Ecuador, Jamaica, and Alabama the larger foraminiferal species are associated with the Early Oligocene Zone P. 18 planktonic faunas, whilst in Puerto Rico the Early Miocene (Zones N. 1 in part, and N. 2) has been recognized. Zone N. 2 on Carriacou has yielded *Miogypsina* cf. *gunteri* and *M. septentrionalis* and therefore we have little hesitation in considering this Zone N. 2 Early Miocene. Zone N. 1 (= P. 20), however, may be entirely Miocene or entirely Oligocene, or more probably includes both the latest Oligocene and the earliest Miocene, but as yet no direct independent evidence of its age has been found. On the other hand, Zone P. 19 has yielded *Nummulites fichteli* in East Africa (Eames *et al.* 1962) and therefore represents much of the so-called Rupelian (Middle Oligocene) of authors. In this paper we discuss those larger foraminifera from Ecuador, Jamaica, Alabama, and Puerto Rico which have been found associated with good Oligocene or Miocene planktonic assemblages and which can be placed in the zonal scheme of Banner and Blow, as well as some Late Eocene faunas from Venezuela and Panama. Synonymies are deliberately restricted to accurately identified material. British Museum (Natural History) registration numbers of material are in the sequence P47281 to P47352. Measurements of all chambers are external dimensions.

There are many varied opinions about the precise application of age and stage divisions in the Cainozoic sequence, and we have not attempted to resolve these problems in this paper. However, in order to provide the reader with an unambiguous biostratigraphic frame of reference, we have referred the horizons of provenance of the assemblages to the sequence adopted by Eames *et al.* (1962). For example, 'early part of Early Miocene' refers to faunas of which those listed (loc. cit., pp. 12, 14) against the column 'Aquitanian' constitute a part, and 'late part of Early Miocene' refers to faunas of which those listed (loc. cit., pp. 12, 14) against the column 'Burdigalian' constitute a part.

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REVIEW OF THREE PERTINENT SPECIES

Some of the material to be described had to be compared with, among other forms, *Lepidocyclina yurnagunensis*, *Eulepidina undosa*, and *L. armata*. It appeared to us that the morphological characters of these forms were not adequately known and we are indebted to Dr. R. Cifelli for providing some topotype material of the first two species and to Dr. C. W. Drooger for lending us the type material of *L. armata* for study; the additional information concerning these three species is given below.

Lepidocyclina yurnagunensis Cushman 1919

Plate 49, figs. 1–5

1919 *Lepidocyclina canellei* Lemoine and Douvillé var. *yurnagunensis* Cushman, p. 57, text-fig. 6, pl. 12, figs. 7, 8.

Type locality. Dr. Cifelli informs us that the original information was incorrectly given, and that 'Sample 7348' should have read 'Sample 7548'. The locality is 'U.S. Geol. Surv. Locality 7548: Yuraguana, near Guantanamo, prov. Oriente, Cuba; flexure in rocks on west side of Yateras R., about 2½ miles south of Yuraguana, 3 miles (more or less) north of El Jigue; altitude, short distance above stream level, perhaps 150 ft. A.T.; from folded beds near contact between conglomerate and shale with overlying limestone'.

Remarks. The thin section from which Cushman's pl. 12, figs. 7 and 8 illustration was taken has kindly been re-photographed at the Smithsonian Institution, and is re-illustrated here as Plate 49, figs. 1, 2. The illustrations clearly show the very low and broad lateral chambers with convexly arched floors as originally mentioned, and also an indication that some specimens have a few small pillars, in spite of the fact that *yurnagunensis* was originally proposed as a variety of *L. canellei*, which has no pillars. Consequently, oriented sections of topotype specimens of *yurnagunensis* were prepared and are illustrated here as Plate 49, figs. 3–5 (P47281–3); they show that there may be a few small pillars having diameters of up to about 0·07 mm.

As is well known, the nucleoconch of this species is a little variable, and may be iso-lepidine or slightly pseudonephrolepidine; the example shown in Cushman's text-fig. 6*a* is not, however, of pliolepidine type as originally stated, and we have never seen an equatorial section, with a pliolepidine nucleoconch, which could be ascribed to the species *yurnagunensis*. Both Vaughan (1924, pl. 33, fig. 8) and Vaughan and Cole (1941, pl. 38, fig. 3) have published illustrations of the equatorial section of topotype specimens of *L. yurnagunensis*. The figures published by Seiglie (1965), if not strictly topotypic, are effectively very near topotypes.

EXPLANATION OF PLATE 49

Figs. 1, 2. *Lepidocyclina yurnagunensis* Cushman (×20). Re-illustration of original figures. U.S. Geol. Surv. Locality 7548, Cuba.

Figs. 3–5. *Lepidocyclina yurnagunensis* Cushman (×20). Topotype. 3, axial section, P47281; 4, axial section, P47282; 5, equatorial section, P47283.

Figs. 6, 7. *Eulepidina undosa* (Cushman) (×15). Topotype, U.S. Geol. Surv. Locality 6869, Antigua. 6, equatorial section, P47284; 7, axial section, P47285.

Eulepidina undosa (Cushman) 1919

Plate 49, figs. 6, 7

1919 *Lepidocyclina undosa* Cushman, p. 65, pl. 2, fig. 1*a*.

Type locality. U.S. Geol. Surv. Station 6869, Long Island, Antigua.

Remarks. The original single illustration represented numerous entire specimens embedded in a lump of rock. Vaughan (1924, pl. 34, figs. 6, 7; *non* fig. 5 = *Lepidocyclina* (*s.s.*) or *Lepidocyclina* (*Nephrolepidina*)) illustrated the central portions of the equatorial sections of two megalospheric individuals from the type locality, and Vaughan and Cole (1941, pl. 41, fig. 1) illustrated an axial section of a topotype specimen. We illustrate here an equatorial (P47284) and an axial (P47285) section of topotype *E. undosa* to supplement previous descriptions.

The megalospheric nucleoconch has a protoconch of about 1·75 mm. diameter and a deuteroconch of about 2·6 mm. diameter. In equatorial section it is seen that the chambers of the median chamber layer are arcuate; the section does not show any hexagonal chambers such as originally recorded, those visible being more like those in the example illustrated by Vaughan (1924) as his pl. 34, fig. 6. However, Vaughan's fig. 7 shows the presence of hexagonal median chambers at later growth stages, and such chambers may well occur in specimens referable to *E. undosa*. In axial section it is seen that, in contradiction to the original record that the species had no pillars, small pillars attaining a diameter of 0·15 mm. are present. In axial section, chambers of the equatorial layer, close to the nucleoconch, have at least 10 foramina penetrating each intercameral septum, the layer itself being up to 0·27 mm. thick there, but near the margin (eighteenth cycle of equatorial chambers) it is only 0·2 mm. thick.

No other references are included at present since it is evident that other forms have been incorrectly included in *E. undosa*. For example, specimens illustrated by Cole (1934, pl. 4, figs. 4, 5, ?10, 11, ?14, *non* fig. 13) have no centrum, no pillars, are not saddle-shaped, and have too small a megalosphere to be *E. undosa*.

Lepidocyclina armata Rutten 1928

Plate 50, figs. 1–5

1928 *Lepidocyclina* (*Isolepidina*) *rdouvillei* Lisson var. *armata* Rutten, p. 944, text-figs. 24*l–m*, 29*a–d*; pl. 2, figs. 27, 28.

Type locality. Locality 42, west of Cerro Pinal, neighbourhood of Punta Sal, north-west Peru.

Remarks. The syntypic series described by Rutten consisted of four slides (D10591, 10597–9) from the type locality, three slides (D10600–2) from locality 69 Los Organos, and unillustrated forms from locality 44 Quebrada Seca, all being of Eocene age. The lectotype here selected is specimen no. 2 on Slide D10591; this and four other thin sections from the syntypic series are illustrated in Plate 50, figs. 1–5.

In addition to the characters recorded by Rutten, the following observations have been made. Specimen 1 on Slide D10599 shows that the true pillars attain a diameter of about 0·1 mm. at the surface: the same specimen shows that the equatorial chamber layer attains a thickness of 0·1 mm. at a distance of 0·9 mm. from the centre. The microspheric form shows that the equatorial chambers attain a radial length of 0·055–0·06 mm. at the margin, their shape being arcuate, adjoining chambers in an annulus not touching. A specimen 0·85 mm. thick has 8 lateral chambers in a tier in the central region, the dimensions of the lumen of the eighth chamber being about 0·03 mm. high and 0·1 mm. wide. In axial section the chambers of the equatorial layer are seen to have only two apertures per chamber in the region of the centrum. Dimensions (in mm.) of three nucleoconchs are:

		Slide 10591 specimen 1	*Slide 10591 specimen 2*	*Slide 10601*
Protoconch:	*width*	0·20	0·21	0·22
	height	0·12	0·16	0·14
Deuteroconch:	*width*	0·19	0·23	0·21
	height	0·15	0·16	0·16
Sum of heights		0·27	0·32	0·30

There are two primary auxiliary chambers, and about eight other auxiliary chambers, apparently symmetrically disposed in four spirals; although larger than the earlier equatorial chambers, they are not very noticeably so. The combined information given above and by Rutten convinces us that *armata* is specifically different from *L. rdouvillei* Lisson; the nucleoconch of *armata* is somewhat smaller, its test possesses distinct pillars, and its centrum is more clearly defined.

LATE EOCENE OF VENEZUELA

Faunas are recorded from the following three samples kindly made available for study by the Bataafse International Petroleum Maatschappij N.V.:

(*a*) Beach of Laguna Unare, Estado Anzoategui; Peñas Blancas Limestone (type area).
(*b*) Sample Kb5018, Cerro La Pedrera, 6 km. south of Boca de Unare, 14 km. north of Clarines, Distrito Peñalver, State of Anzoategui; Peñas Blancas Limestone (type locality).
(*c*) Sample Kb5019, Cerro La Pedrera, 6 km. south of Boca de Unare, 14 km. north of Clarines, Distrito Peñalver, State of Anzoategui; Peñas Blancas Limestone (type locality).

Faunas are also recorded from the following two samples kindly made available for study by the Creole Petroleum Corp.:

(*d*) Sample 110746, Rio Chacual section, 1·85 km. upstream from Manarito; Peñas Blancas Limestone.
(*e*) Sample 110786, 6 ft. from 110746; Peñas Blancas Limestone.

EXPLANATION OF PLATE 50

Figs. 1–5. *Lepidocyclina armata* Rutten (×20). Locality 42, W. of Cerro Pinal, Peru, Eocene. 1, equatorial section, lectotype; 2, equatorial section, syntype; 3, axial section, syntype; 4, axial section, syntype; 5, equatorial section of microspheric form, syntype.

Figs. 6, 7. *Palaeonummulites kugleri* (Vaughan and Cole) (×20). Sample 110786, Rio Chacual section, Venezuela, Peñas Blancas Limestone, Late Eocene. 6, equatorial section P47288; 7, axial section, P47289.

Figs. 8, 9. *Palaeonummulites palmarealensis* (Barker) (×20). Beach of Laguna Unare, Peñas Blancas Limestone, Late Eocene. 8, equatorial section, P47290; 9, axial section, P47291.

Asterocyclina asterisca (Guppy) 1866

1866 *Cisseis asteriscus* Guppy, p. 584, pl. 25, figs. 19*a*, *b*.
1941 *Discocyclina* (*Asterocyclina*) *asterisca* (Guppy); Vaughan and Cole, p. 60, pl. 23. (*cum bibl.*)

Material. Several thin sections in sample Kb5018.

Helicolepidina paucispira Barker and Grimsdale 1936

1936 *Helicolepidina paucispira* Barker and Grimsdale, p. 243, pl. 31, figs. 11, 12; pl. 33, figs. 4–6; pl. 36, figs. 1, 3; pl. 38, fig. 4.
1941 *Helicolepidina paucispira* Barker and Grimsdale; Vaughan and Cole, p. 76, pl. 45, fig. 2.
1962*a* *Helicolepidina spiralis* (Tobler); Cole, p. 145 (*pars*).
1962 *Helicolepidina paucispira* Barker and Grimsdale; Hanzawa, p. 144, pl. 6, fig. 32.

Material. One thin section in sample Kb5019.

Remarks. We agree with Hanzawa in regarding *paucispira* distinct from *spiralis*.

Helicostegina soldadensis Grimsdale *in* Vaughan and Cole 1941

1941 *Helicostegina soldadensis* Grimsdale, *in* Vaughan and Cole, pp. 77, 86, pl. 45, fig. 4; pl. 46, figs. 1–7.

Material. Many thin sections in sample Kb5018, a few thin sections in sample 110786, and several thin sections in the sample from Laguna Unare.

Lepidocyclina montgomeriensis Cole 1949

1949 *Lepidocyclina montgomeriensis* Cole, p. 270. (*cum bibl.*)

Material. Numerous thin sections from sample Kb5019.

Palaeonummulites kugleri (Vaughan and Cole) 1941

Plate 50, figs. 6, 7

1941 *Operculinoides kugleri* Vaughan and Cole, p. 42, pl. 10, figs. 3–5, 7, 8; pl. 13, figs. 1, 2.
1952 *Operculinoides kugleri* Vaughan and Cole; Cole, p. 9, pl. 3, figs. 1, 5, ?6, ?7.

Material. Several thin sections (including P47288–9) from sample 110786, many thin sections from sample Kb5018, and one thin section from sample Kb5019.

Remarks. The two illustrations of axial sections given by Cole (1952) do not seem to match well the original illustrations of axial sections given by Vaughan and Cole (1941). Although Cole (1958, p. 273) placed *kugleri* in the synonymy of *P. trinitatensis* (Nuttall), our material from Venezuela is a good match compared with the type description and illustrations of *kugleri*, but is not so inflated or so tightly coiled as *trinitatensis*, which we accordingly regard as different.

Palaeonummulites palmarealensis (Barker) 1939

Plate 50, figs. 8, 9

1939 *Operculinoides palmarealensis* Barker, p. 314, pl. 13, fig. 8; pl. 18, fig. 1; pl. 22, figs. 7, 8.

Material. Several thin sections (including P47290–1) from the Laguna Unare sample.

Remarks. The original type material was recorded as having come from the 'Lower Oligocene Alazan formation', but one of us (W. H. B.) has evidence to show that it is really of Late Eocene age.

Palaeonummulites stainforthi sp. nov.

Plate 51, figs. 6, 7

Material. Several thin sections (including P47292, the holotype, and P47293) from sample 110786, abundant thin sections in sample Kb5018, and one thin section in the Laguna Unare sample.

Description. The axial section (of a representative specimen) indicates a diameter of 3·35 mm. and a thickness of 0·5 mm., giving a ratio of 6·7:1, so that the species is a fairly flat one. The small protoconch has a diameter of 0·13 mm. There is 1 whorl in a radius of 0·24 mm., and there are 2 in 0·4 mm., 3 in 0·73 mm., 4 in 1·4 mm., and $4\frac{1}{2}$ in 1·55 mm. There are 7 septa in the first whorl, 14 in the second whorl, 24 in the third whorl, and 31 in the fourth whorl; they are quite closely spaced so that the chambers are considerably higher than long, and their tips are moderately well curved backwards distally.

Remarks. Although similar to the Early Miocene species *P. dia* (Cole and Ponton) in its great compression and general septal shape, it is more tightly coiled and the septal ends are less strongly curved distally than in that species. Compared with the Middle Eocene *P. prenummulitiformis* (Barker), while similarly compressed, the new species lacks the granules (showing as small pillars in axial section) and the septal ends are distinctly less curved backwards distally.

EXPLANATION OF PLATE 51

Figs. 1, 2. *Heterostegina* (*Vlerkina*) *kugleri* subgen. et sp. nov. (×25). Beach of Laguna Unare, Peñas Blancas Limestone, Late Eocene. 1, equatorial section, P47286; 2, axial section, holotype, P47287.

Figs. 3, 4. *Halkyardia bikiniensis* Cole (×50). Sample 2049, type area of Playa Rica Formation, Ecuador, Early Oligocene. 3, transverse section, P47309; 4, vertical section, P47310.

Fig. 5. *Helicolepidina paucispira* Barker and Grimsdale (×30). Ecuador, Playa Rica Sands, Early Oligocene. Equatorial section, P47311.

Figs. 6, 7. *Palaeonummulites stainforthi* sp. nov. (×20). Sample 110786, Rio Chacual section, Venezuela, Peñas Blancas Limestone, Late Eocene. 6, equatorial section, holotype, P47292; 7, axial section, P47293.

Figs. 8, 9. *Palaeonummulites antiguensis* (Vaughan and Cole) (×20). Sample PO. 35–1, La Rambla, Puerto Rico, Juana Diaz Formation, Early Miocene. 8, equatorial section, P47351; 9, axial section, P47352.

Pliolepidina tobleri (Douvillé) 1917 subsp. *panamensis* (Cushman) 1918

Plate 52, figs. 1–5; Plate 53, figs. 1–4; Plate 54, fig. 3

1918 *Lepidocyclina panamensis* Cushman, pp. 94, 95, pl. 39, figs. 1–6; pl. 42.
1924 *Lepidocyclina (Pliolepidina) panamensis* Cushman; Vaughan, p. 819, pl. 33, fig. 1.

Material. Numerous thin sections (P47294–303) from sample 110746, and numerous thin sections from the Laguna Unare sample.

Remarks. The material illustrated here is a reasonable match for the form illustrated by Vaughan (1924, fig. 1) which is re-illustrated later in this paper. In our opinion these populations from Venezuela and Panama differ from those from Trinidad in that they are less inflated, the nucleoconch walls are thinner, and there may be as many as 7 to 12 small chambers arranged within the large nucleoconch chamber; the relationship is close, but since the different populations can be recognized, we regard *panamensis* as a subspecies of *P. tobleri* (neotypified by Eames and Clarke 1965). The general form of our megalospheric forms of *Pliolepidina* from the Vista Bella Limestone of Trinidad is strongly inflated, and they are referable to *P. tobleri* (*s.s.*). Again, some of the specimens illustrated by Sachs (1964, e.g. pl. 2, figs. 1–4, 6–9) as *Lepidocyclina* (*Eulepidina*) *undosa* are, in our opinion, *Pliolepidina tobleri* (*s.s.*); the specimens are from his Locality 3 (Cibao formation of Puerto Rico), which is within one foot of a sample yielding a rich *opima* Zone planktonic fauna and is therefore of Early Miocene age. Certain illustrated equatorial sections such as those of Cole (1960, pl. 3, fig. 1; 2 miles north of David, Panama) and Cole (1962*b*, pl. 8, fig. 8; loose block from Grenada) probably belong to the subspecies *panamensis* rather than to *P. tobleri* (*s.s.*).

Pliolepidina(?) *sp.*

Plate 54, figs. 1, 2

Material. A few specimens in matrix and one axial thin section (P47305) and one equatorial thin section (P47304) from the Laguna Unare sample; a few specimens in matrix and one axial thin section from sample 110746.

Description. These are microspheric forms. The equatorial section from the Laguna Unare sample was distinctly more than 11·0 mm. in diameter, and its accompanying axial section had a diameter of a little more than 14·0 mm. and a thickness of 2·0 mm. The axial section from sample 110746 had a diameter of more than 13·0 mm. and a thickness of 2·8 mm. In equatorial section the chambers are low-arcuate, with an occasional tendency to be slightly spatulate, attain a radial length of 0·12 mm. near the periphery, and adjacent ones of a cycle are not touching or occasionally just touching. In axial section the pillars are seen to attain a diameter of 0·11 mm., and in the equatorial chamber layer at least 14 intercameral apertures are developed in each septum near the periphery.

Remarks. In both these samples these microspheric forms appear to be the B form of *Pliolepidina tobleri panamensis.* It is noteworthy that they are considerably less inflated than the microspheric form of *Lepidocyclina trinitatis* and also *L. pustulosa* (possibly the microspheric form of *P. tobleri*), and that the pillars are also smaller.

Pseudophragmina (Proporocyclina) flintensis (Cushman) 1917

1917 *Orthophragmina flintensis* Cushman, p. 115, pl. 40, figs. 1, 2.
1941 *Pseudophragmina (Proporocyclina) flintensis* (Cushman); Vaughan and Cole, p. 61, pl. 20, figs. 8, 9.

Material. Two thin sections in sample Kb5018.

Some heterosteginid forms

Family NUMMULITIDAE
Genus HETEROSTEGINA d'Orbigny 1826
Subgenus HETEROSTEGINA

Type species. Heterostegina depressa d'Orbigny 1826; Recent.

Remarks. The subgenus is characterized by having the chamber lumina completely evolute, at least in the megalospheric form.

Subgenus VLERKINA subgen. nov.

Type species. Heterostegina borneensis van der Vlerk 1929, early part of Early Miocene ('e' stage).

Comparative diagnosis. The subgenus is characterized by having the chamber lumina partly involute, at least in the megalospheric form.

Remarks. Topotypic or near-topotypic material, donated to the British Museum (Natural History) by Professor I. M. van der Vlerk, has been sectioned by Dr. C. G. Adams, who has kindly let us study the material. The subgeneric comparative diagnosis is based on the axial section, which matches van der Vlerk's original description and illustration. *Vlerkina* differs from the genus *Grzybowskia* Bieda 1950 in lacking the pentagonal/hexagonal chamberlets which are arranged in a favose pattern in equatorial view. The subgenus is named after Professor van der Vlerk.

'*Heterostegina borneensis*' auct. has been used extensively in the Far East to indicate the early part of the T_e 'letter stage' (Leupold and van der Vlerk 1931, van der Vlerk 1955). These forms, originally called 'spiroclypoid heterostegina' by Rutten (MS.), have proven stratigraphic value but poorly known infrageneric taxonomy. '*H. borneensis*' auct. probably comprises many species of *H. (Vlerkina)*; however, the new subgeneric taxon can now be used biostratigraphically for the various forms which have been recorded (e.g. Adams 1965, cf. Cole 1957*c*) as '*H. borneensis* van der Vlerk'.

The stratigraphically youngest record of *Vlerkina* which can be related directly to planktonic foraminiferal zones is that by Coleman and McTavish (1964), who found

EXPLANATION OF PLATE 52

Figs. 1–5. *Pliolepidina tobleri* (Douvillé) subsp. *panamensis* (Cushman). Sample 110746, Rio Chacual section, Venezuela, Peñas Blancas Limestone, Late Eocene. 1, equatorial section (×25), P47294; 2, equatorial section (×25), P47295; 3, axial section (×25), P47296; 4, equatorial section (×25), P47297; 5, three axial sections (×15), P47298.

'*H. borneensis*' in direct association with *Miogypsina*, *Miogypsinoides*, *Eulepidina*, *Spiroclypeus*, *Globigerinoides quadrilobatus*, *Globoquadrina dehiscens*, *Globigerinita dissimilis*, and *G. unicava*. This assemblage is clearly referable to the T_e 'letter-stage', to the interval from latest Zone N. 4 to Zone N. 6, and to the Aquitanian stage.

Subgenus VLERKINELLA subgen. nov.

Type species. Heterostegina (Vlerkinella) kugleri sp. nov.; Late Eocene.

Comparative diagnosis. Axial section of the megalospheric form completely involute, the alar prolongations of the chambers extending to the centre; equatorial section of the megalospheric form as in *Heterostegina* (*s.s.*).

Remarks. Compared with *Vlerkina*, the alar prolongations of the chamber lumina in axial section extend to the centre, the test being completely involute. *Vlerkinella* also differs from the genus *Grzybowskia* Bieda 1950 in lacking the pentagonal/hexagonal chamberlets which are arranged in a favose pattern in equatorial view. The subgenus is named after Professor van der Vlerk.

Heterostegina (*Vlerkinella*) *kugleri* subgen. et sp. nov.

Plate 51, figs. 1, 2

Material. One axial section (the holotype, P47287) and one equatorial section (P47286) in the sample from Laguna Unare.

Specific description. The axial section is of a specimen with a diameter of 4·14 mm. and a thickness of 0·93 mm., the species being complanate with a gently convex median portion, and completely involute. The megalosphere is subcircular, with a diameter of about 0·12 mm. There is 1 whorl in a radius of 0·21 mm., there are 2 in a radius of 0·51 mm., and 3 in a radius of 1·43 mm. There are 5 septa in the first whorl, 12 in the second whorl, and 15 in the third whorl. The first 9 chambers are undivided, and in the later stages 4–6 chamberlets are developed from each primary chamber; proximal chamberlets are subpentagonal, the others subhexagonal.

Remarks. We can find no record of any closely similar species in the literature. The species is named after Dr. H. G. Kugler.

LATE EOCENE OF PANAMA

Lepidocyclina rdouvillei Lisson 1921

Plate 55, fig. 4

1921 *Lepidocyclina* (*Isolepidina*) *rdouvillei* Lisson, p. 53, pl. 3, figs. 1–3; pl. 4, fig. 1; pl. 5, figs. 1–3.

Material. Four equatorial sections (of which one, P47306, is illustrated here) from U.Ş. Geol. Surv. Locality 6586*e*, given as near mouth of Tonosi River, Panama.

Pliolepidina tobleri (Douvillé) 1917 subsp. *panamensis* (Cushman) 1918

Plate 55, figs. 1–3

Synonymy. See p. 289.

Material. Two equatorial sections (P47307–8 here illustrated) from U.S. Geol. Surv. Locality 6586*e*, given as near mouth of Tonosi River, Panama. By kind permission of the Smithsonian Institution, Vaughan's (1924, pl. 33, fig. 1) illustration of an equatorial section from the same locality is reproduced (Pl. 55, fig. 1).

EARLY OLIGOCENE OF ECUADOR

During the Caribbean Geological Congress held in Trinidad in 1965, Dr. Stainforth drew attention to his earlier (1948, p. 134) record of *Lepidocyclina yurnagunensis*, *L. undosa*, and *L.* (*Pliolepidina*) *tobleri* from beds regarded as of Early Oligocene age in Ecuador, although the presence of the latter species was regarded by him as puzzling since it had been considered an established Late Eocene index form.

The material described here has two origins. First, sample 2049, collected by Mr. Benton Stone and donated to the American Museum of Natural History, and subsequently presented, by exchange, to Dr. W. H. Blow, from the type area of the Playa Rica Formation in Ecuador. Second, three *Lepidocyclina*-bearing samples (nos. 17332, 17441, and 17429) forming part of a series of samples collected along the type section (17332 an offset sample) of Cushman and Stainforth's Unit 18 (Playa Rica Sands), all of which were kindly loaned to us by Drs. F. Zúñiga y Rivero and A. D. Euribe of the International Petroleum Co. Ltd. in Peru. The faunas are described below.

Halkyardia bikiniensis Cole 1954

Plate 51, figs. 3, 4

1954 *Halkyardia bikiniensis* Cole, p. 584, pl. 210, figs. 1–5.
1957*b* *Halkyardia bikiniensis* Cole; Cole, p. 336, pl. 102, figs. 10, 11.

Material. One specimen, and two thin sections (P47309–10) from the Early Oligocene sample 2049 of the Playa Rica Formation.

Remarks. The species was previously recorded from the probable Oligocene of Bikini and the Late Eocene of Saipan.

Helicolepidina paucispira Barker and Grimsdale 1936

Plate 51, fig. 5

1936 *Helicolepidina paucispira* Barker and Grimsdale, p. 243, pl. 31, figs. 11, 12; pl. 33, figs. 4–6; pl. 36, figs. 1, 3; pl. 38, fig. 4.

Material. Five hand specimens and one thin section (P47311) from the Early Oligocene sample 17441.

Remarks. Neither the genus nor the species has been recorded from above the Late Eocene before. Sample 17441 contains a planktonic fauna representative of an Early

EXPLANATION OF PLATE 53

Figs. 1–4. *Pliolepidina tobleri* (Douvillé) subsp. *panamensis* (Cushman) (×25). Sample 110746, Rio Chacual section, Venezuela, Peñas Blancas Limestone, Late Eocene. 1, two axial sections, P47299; 2, two axial sections, P47300; 3, three axial sections, P47301; 4, equatorial section, P47302.

Oligocene age (Zone P. 18, *teste* W. H. B.), but, before extending the range of the genus and species up into the Early Oligocene, it would be advisable to await further knowledge of the stratigraphy of underlying horizons in the area, since the specimens might be reworked. In the initial stage of the equatorial section here illustrated there are 9 undivided chambers as against 5 in the type material, but we know of no reason at present why this should be regarded as even of subspecific value.

Lepidocyclina yurnagunensis Cushman 1919 subsp. *morganopsis* Vaughan 1933*a*

Plate 55, figs. 5–9; Plates 56, figs. 1, 2

1919 *Lepidocyclina morgani* Lemoine and R. Douvillé; Cushman, p. 59, text-fig. 7; pl. 11, figs. 1–3.
1933*a* *Lepidocyclina yurnagunensis* Cushman var. *morganopsis* Vaughan, p. 354.
1948 *Lepidocyclina yurnagunensis* Cushman; Stainforth, p. 134.

Material. Numerous hand specimens (1 registered P47312) and 7 (6 registered P47313–8) thin sections from sample 2049; 6 hand specimens and 1 thin section from sample 17441; 11 hand specimens and 1 thin section from sample 17429; numerous specimens and 3 thin sections from sample 17322. All four samples associated with planktonic faunas of Early Oligocene age.

Description of Ecuadorean material. The hand specimens have an inflated median centrum surrounded by a thin flange. An axial section (P47315) has a diameter of 3·3 mm. and a thickness of 1·0 mm.; another axial section has a diameter of 2·5 mm. and a thickness of 0·9 mm. An equatorial section has a diameter of 4·0 mm. The hand specimens have up to 16 pillars in the region of the centrum, such pillars attaining a diameter of 0·15 mm. to 0·2 mm., and not reaching the equatorial chamber layer. The lateral chambers attain approximately the same dimensions. The nucleoconch is isolepidine, dimensions (in mm.) of four examples being:

		(*a*)	(*b*)	(*c*)	(*d*)
Protoconch:	*width*	0·25	0·27	0·23	0·19
	height	0·15	0·14	0·14	0·10
Deuteroconch:	*width*	0·23	0·28	0·23	0·19
	height	0·16	0·18	0·16	0·12
Sum of heights		0·31	0·32	0·30	0·22

There are two primary auxiliary chambers which are usually a little larger than other chambers of the equatorial chamber layer, but no adauxiliary chambers; there are two or three smaller inter-auxiliary chambers in series in each of the four quadrants of the embryont; the periembryonic chambering is completed by one protoconchal and one deuteroconchal symmetrical auxiliary chamber. The normal equatorial chambers are ogival, but become spatulate later and attain a radial length of about 0·11 mm. near the periphery; they present a fairly definite engine-turned appearance in general view; some are separate, some just contiguous. In axial section the equatorial chamber layer attains a thickness of 0·15 mm. near the margin. In the outer 0·3 mm. of the central region there are 6 lateral chambers in a tier. Although the lumina of these lateral chambers attain a height of 0·03 mm. and a width of 0·11 mm. in the central region near the bigger pillars, normal lumina have a height of 0·03 mm. and a width of 0·08 mm.

Remarks. This form shows some similarity to *L. armata* (Rutten) which differs, however, in having smaller pillars which reach the equatorial chamber layer, and in having ogival equatorial chambers which do not present any marked engine-turned appearance. Although *L. yurnagunensis* (*s.s.*) is somewhat similar, the nucleoconch is usually more elongate, true pillars are smaller or absent, and the lateral chambers as seen in axial section are normally relatively wider and less high; these characters readily distinguish *L. yurnagunensis* (*s.s.*) from the subspecies *morganopsis* with which we identify the Ecuadorean material described above. It is evident that there has been some confusion in the identification of these two forms, but, although the subspecies *morganopsis* was originally described from beds we believe to be of Early Miocene age and is now shown to range down into the Early Oligocene, we have no acquaintance with, or knowledge of any reference to, *yurnagunensis* (*s.s.*) occurring below the Early Miocene.

Lepidocyclina (*Nephrolepidina*) *wilsoni* sp. nov.

Plate 56, figs. 3–5

1948 *Lepidocyclina undosa* Cushman; Stainforth, p. 134.

Material. Nine hand specimens, and three thin sections (P47319–21, of which P47321 is the holotype) from the Early Oligocene sample 2049 from the type area of the Playa Rica formation. Eighteen specimens and three thin sections from the Early Oligocene sample 17322.

Description. Flatly lenticular, the holotype having a diameter of 4·85 mm. One topotype specimen has a diameter of 6·6 mm. and a thickness of 1·9 mm., giving a ratio of 3·5:1; a second topotype specimen has a diameter of 4·8 mm. and a thickness of 0·8 mm., giving a ratio of 6:1. The holotype shows that the megalospheric nucleoconch is nephrolepidine and has the following dimensions:

Protoconch: width 0·45 mm., *height* 0·29 mm.
Deuteroconch: width 0·55 mm., *height* 0·28–0·36 mm.
Sum of heights (*along median line*)*:* 0·55 mm.

The auxiliary chambers are not well seen, but, although a few may be rather long, they are not conspicuously larger than the subsequent chambers of the equatorial layer. The equatorial chambers are low ogival, conjoint, not separate, with a radial length of about 0·1 mm. near the outer margin of the holotype. Tangential and axial sections confirm the appearance of the hand specimens in that there is no sign of pillars. In axial section there are 7 lateral chambers in a tier in the central region of the test; they are wide and low, their lumina being about 0·09 mm. wide and 0·02 mm. high.

Remarks. This species is named after Mr. C. C. Wilson who has contributed much to the stratigraphy of the Central American region. The most closely similar species seems

EXPLANATION OF PLATE 54

Figs. 1, 2. *Pliolepidina*(?) *sp.* (×15). Sample 110746, Rio Chacual section, Venezuela, Peñas Blancas Limestone, Late Eocene. 1, axial section of microspheric specimen, P47305; 2, equatorial section of microspheric specimen, P47304.

Fig. 3. *Pliolepidina tobleri* (Douvillé) subsp. *panamensis* (Cushman) (×25). Sample 110746, Rio Chacual section, Venezuela, Peñas Blancas Limestone, Late Eocene. Tangential section, P47303.

to be *L.* (*N.*) *sanfernandensis* Vaughan and Cole, which, however, is papillate and has small pillars, and which has a nucleoconch about twice as large as *L.* (*N.*) *wilsoni*; the illustrations of *L.* (*N.*) *sanfernandensis* also indicate the presence of a median boss on many of the specimens.

Dr. Hofker has kindly let us see some notes and illustrations of a form from the same or an equivalent horizon in Ecuador. His form evidently belongs, at least in part, to *L.* (*N.*) *wilsoni*; although the nucleoconchs of some of his specimens are rather more trybliolepidine in form, they are not eulepidine, and, like our specimens, they also differ from *E. undosa* in the complete absence of pillars and in the nucleoconch being less than half as large.

EARLY OLIGOCENE OF JAMAICA

Lepidocyclina yurnagunensis Cushman 1919 subsp. *morganopsis* Vaughan 1933*a*

Plate 56, fig. 6, 7

Synonymy. See p. 293.

Material. Two rock slides (P47322–3) from sample 621 (presented by Mr. E. Robinson), uppermost part of the Bonny Gate Formation in St. Mary's Parish, Jamaica, of Early Oligocene age.

Remarks. This material is indistinguishable from the specimens of the same subspecies from the Early Oligocene of Ecuador (see p. 293). The Jamaican sample also contains a good planktonic fauna of Early Oligocene age (Zone P.18, *teste* W. H. B.).

EARLY OLIGOCENE OF ALABAMA

Lepidocyclina mantelli (Morton) 1833

Plate 56, figs. 8–11; Plate 57, figs. 1–5

1833 *Nummulites mantelli* Morton, p. 291, pl. 5, fig. 9.
1928 *Lepidocyclina* (*Lepidocyclina*) *mantelli* (Morton); Vaughan, pl. 23, fig. 2.
1965 *Lepidocyclina mantelli* (Morton); Ellis and Messina (*pars*), e.g. figs. 67, 68.

Material. Several specimens from the Red Bluff (Early Oligocene) samples UWS110 and 111 (P47324–5 from UWS111); several specimens from samples UWS124, 125, 126, 127, 132, 133, many specimens from UWS134, 135, several specimens from UWS 136, 137, 138, and many specimens from UWS139, 140, and 141, all from the so-called Marianna Limestone (Early Oligocene) of Little Stave Creek (P47326–31, from sample UWS140).

Remarks. We illustrate (Pl. 57, fig. 4) for comparison an equatorial view of topotype *L. mantelli* from the Professor Morris Collection in the British Museum (Natural History). Material from samples UWS 109–41 was provided by Dr. Brooks Ellis and Miss Messina.

EARLY MIOCENE OF PANAMA

Miogypsina cushmani Vaughan 1924

1924 *Miogypsina cushmani* Vaughan, pp. 802, 813, pl. 43, figs. 1, 2 (*non* figs. 3–8).

Material. Many specimens from the Culebra Formation at sample stations 6010 and 6012*a*. 6010 is 600–700 ft. south of Miraflores Locks and also contains a rich planktonic fauna of Zone N. 7/N. 8 (high in the early part of the Early Miocene) age; 6012*a* is from south of Empire Bridge, Gaillard Cut, and is probably of much the same age. From what we have seen in the portions of these samples lent to us by Dr. Cifelli, we can confirm Cole's (1952, p. 17) statement that *Pliolepidina tobleri* does not occur in them as had been suggested earlier by Cushman (1918 (1919)).

EARLY MIOCENE (EARLY PART) OF PUERTO RICO

Dr. K. N. Sachs Jr. kindly donated a sample (PO35-1) to Dr. W. H. Blow for study. The sample comes from near the middle of the Juana Diaz Formation, from an excavation for a new house, NE.-trending segment of Calle G, La Rambla, Ponce quadrangle SW., Puerto Rico. The location is only 1 m. below other samples which, according to Blow, yield good planktonic foraminiferal faunas determinative of the *opima* Zone (of Bolli 1957, see also Pessagno 1963); this is virtually equivalent to Zone N. 2 of Banner and Blow (1965) which they consider to be very early in the Early Miocene.

Eulepidina favosa (Cushman) 1919

Plate 57, fig. 6

1919 *Lepidocyclina favosa* Cushman, p. 66, pl. 3, figs. 1*b*, 2; pl. 15, fig. 4.
1941 *Lepidocyclina* (*Eulepidina*) *favosa* Cushman; Vaughan and Cole, p. 75, pl. 40, figs. 1–4 (*cum bibl.*).
1952 *Lepidocyclina* (*Eulepidina*) *favosa* Cushman; Cole, p. 30, pl. 22, figs. 1–5 (*cum bibl.*).

Material. Two hand specimens and one thin section (P47332).

Remarks. These specimens are fully representative of the species, which has not yet been found below the early part of the Early Miocene (see Eames *et al.* 1962).

Eulepidina undosa (Cushman) 1919 subsp. *laramblaensis* subsp. nov.

Plate 57, figs. 7, 8

1962 *Lepidocyclina* (*Eulepidina*) *undosa* Cushman; Sachs and Gordon, p. 15 (*pars*), pl. 1, fig. 9.

Material. Four hand specimens, one equatorial section (the holotype, P47333), and one axial section (P47334).

Description. The specimens are gently saddle-shaped, and have a small, distinct centrum; one specimen has a diameter of 7·2 mm. and a thickness of 1·2 mm. The holotype has a diameter of 3·7 mm. The centrum occupies about one-quarter to one-half of the diameter; it has a regular scatter of pillars attaining a diameter of up to 0·13 mm. and they are from 0·15 mm. to 0·2 mm. apart (centre to centre), gradually decreasing in size on the flange, and have 4–7 lateral chambers around them. The megalosphere is eulepidine,

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EXPLANATION OF PLATE 55

Figs. 1–3. *Pliolepidina tobleri* (Douvillé) subsp. *panamensis* (Cushman) (×25). U.S. Geol. Surv. Locality 6586*e*, near mouth of Tonosi River, Panama, Late Eocene. 1, reproduction of Vaughan's (1924, pl. 33, fig. 1) illustration of an equatorial section; 2, equatorial section, P47307; 3, equatorial section, P47308.

Fig. 4. *Lepidocyclina rdouvillei* Lisson (×25). U.S. Geol. Surv. Locality 6586*e*, near mouth of Tonosi River, Panama, Late Eocene. Equatorial section, P47306.

Figs. 5–9. *Lepidocyclina yurnagunensis* Cushman subsp. *morganopsis* Vaughan (×20). Sample 2049, Ecuador, type area of Playa Rica Formation, Early Oligocene. 5, hand specimen, P47312; 6, equatorial section, P47313; 7, equatorial section, P47314; 8, axial section, P47315; 9, axial section, P47316.

the protoconch being rounded (with one side a little flattened) and measuring (holotype) 1·05×0·85 mm., the deuteroconch being rounded and with a diameter of 1·55 mm. The chambers of the equatorial layer are ogival to subhexagonal and do not vary much in size with growth although somewhat variable individually; their radial length varies from about 0·06 mm. to 0·1 mm. The equatorial chamber layer has a thickness of about 0·15 mm. both near the margin and near the middle; on the outer part of the flange the equatorial chambers do not seem to develop more than 6 intercameral apertures.

Remarks. This subspecies evidently includes some forms included by some authors in *E. undosa* (*s.s.*). However, in the subspecies *laramblaensis* the megalosphere is distinctly smaller, and the equatorial chamber layer is less massive, has thinner walls, and is not so thick, and the chambers themselves have fewer intercameral apertures.

Lepidocyclina (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé 1904

Plate 59, fig. 7

1904 *Lepidocyclina canellei* Lemoine and R. Douvillé, pp. 20, 22, pl. 1, fig. 1; pl. 3, fig. 5.
1941 *Lepidocyclina* (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé; Vaughan and Cole, p. 70, pl. 35, figs. 6, 7; pl. 41, figs. 4, 5 (*cum bibl.*).
1962 *Lepidocyclina* (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé; Sachs and Gordon, p. 14, pl. 3, fig. 3 (*cum bibl.*).

Material. One hand specimen, one polished specimen, and one thin section (P47335).

Remarks. The characters of these specimens are typical of the species, which has not yet, apparently, been recorded from below the Miocene (see Eames *et al.* 1962).

Lepidocyclina (*Lepidocyclina*) cf. *crassicosta* Vaughan and Cole 1933

Plate 58, figs. 1–3

1962 *Lepidocyclina* (*Lepidocyclina*) *giraudi* R. Douvillé; Sachs and Gordon (*pars*), p. 14 (*pars*), pl. 1, figs. 8, 11; pl. 2, fig. 9; pl. 3, figs. 2, 9 (*non* pl. 1, fig. 6 = *L* (*L.*) *sachsi* sp. nov.; *nec* pl. 3, fig. 4 = ?)

Material. Two hand specimens, and three thin sections (P47336–8).

Description. Test lenticular, not clearly differentiated into centrum and flange. An axial section has a diameter of 2·75 mm. and a thickness of 1·15 mm., and cuts 3 large pillars. A hand specimen shows about 13–14 pillars in the middle half of the surface and attaining a diameter of 0·15 mm. on it, although as much as 0·3 mm. in the axial section. The nucleoconch is isolepidine and has the following dimensions:

Protoconch:	*height* 0·12 mm.
	width 0·18 mm.
Deuteroconch:	*height* 0·13 mm.
	width 0·18 mm.
Sum of heights:	0·25 mm.

There are two fairly distinct primary auxiliary chambers but no adauxiliary chambers. The chambers of the equatorial layer are very squat ogival and noticeably annular in their arrangement; they attain a radial length of 0·07 mm. near the margin. In axial section the equatorial chamber layer is 0·08 mm. thick near the middle and 0·16 mm. thick near the margin, where as many as 4 apertures are developed. The floors of the lateral chambers are relatively quite thick, and the lateral chambers themselves are not very wide.

A larger individual, 6·7 mm. in diameter, proved on sectioning to be microspheric, the chambers of the equatorial layer being of the same general shape and same general size as in the megalospheric individuals, attaining a radial length of 0·15 mm. near the margin.

Remarks. This material matches very well those specimens illustrated by Sachs and Gordon (1962) on their pl. 1, figs. 8, 11, pl. 2, fig. 9, and pl. 3, figs. 2, 9 as *L.* (*L.*) *giraudi*. These combined collections, however, completely lack the 'long, radial pustules' and flattened centrum of that species. Compared to the specimens from the Morne Diablo Quarry (Trinidad) that Cole (1957*a*) illustrated as *L.* (*L.*) *giraudi* the nucleoconchs of these combined collections are only about one-third the size; on their morphological characters the specimens illustrated by Cole in 1957 are neither *L.* (*L.*) *giraudi* nor the species here recorded. Although Cole (1957*a*) placed both *L.* (*L.*) *parvula* and *L.* (*L.*) *parvula crassicosta* in the synonymy of *L.* (*L.*) *giraudi*, we would, on their morphological

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EXPLANATION OF PLATE 56

Figs. 1, 2. *Lepidocyclina yurnagunensis* Cushman subsp. *morganopsis* Vaughan (×20). Sample 2049, Ecuador type area of Playa Rica Formation, Early Oligocene. 1, equatorial section, P47317; 2, tangential section, P47318.

Figs. 3–5. *Lepidocyclina* (*Nephrolepidina*) *wilsoni* sp. nov. (×15). Sample 2049, Ecuador, type area of the Playa Rica Formation, Early Oligocene. 3, tangential section, P47319; 4, axial section, P47320; 5, equatorial section, holotype, P47321.

Figs. 6, 7. *Lepidocyclina yurnagunensis* Cushman subsp. *morganopsis* Vaughan (×20). Sample 621, St. Mary's Parish, Jamaica, uppermost part of Bonny Gate Formation, Early Oligocene. 6, equatorial section, P47322; 7, axial section, P47323.

Figs. 8, 9. *Lepidocyclina mantelli* (Morton) (×15). Sample UWS111, Little Stave Creek, Alabama; Red Bluff, Early Oligocene. 8, axial section, P47324; 9, equatorial section, P47325.

Figs. 10, 11. *Lepidocyclina mantelli* (Morton) (×15). Sample UWS140, Little Stave Creek, Alabama, so-called Marianna Limestone, Early Oligocene. 10, equatorial section, P47326; 11, axial section, P47327.

EXPLANATION OF PLATE 57

Figs. 1–3, 5. *Lepidocyclina mantelli* (Morton) (×15). Sample UWS140, Little Stave Creek, Alabama, so-called Marianna Limestone, Early Oligocene. 1, equatorial section, P47328; 2, tangential section, P47329; 3, equatorial section of a microspheric specimen, P47330; 5, axial section of a microspheric specimen, P47331.

Fig. 4. *Lepidocyclina mantelli* (Morton) (×20). View of equatorially split megalospheric topotype specimen from the Professor Morris collection in the British Museum (Natural History).

Fig. 6. *Eulepidina favosa* (Cushman) (×15). Sample PO.35–1, La Rambla, Puerto Rico, Juana Diaz Formation, Early Miocene. Equatorial section, P47332.

Figs. 7, 8. *Eulepidina undosa* (Cushman) subsp. *laramblaensis* subsp. nov. (×15). Sample PO.35–1, La Rambla, Puerto Rico, Juana Diaz Formation, Early Miocene. 7, axial section, P47334; 8, equatorial section, holotype, P47333.

characters, regard them as specifically distinct from *L.* (*L.*) *giraudi*, and, moreover, regard themselves as different species. The megalospheric forms here recorded from Puerto Rico seem to match best the microspheric forms described as *L.* (*L.*) *parvula* Cushman var. *crassicosta* Vaughan and Cole 1933*a*, and are here provisionally referred to that form. It should be recalled that *crassicosta* greatly resembles *L. partita* Douvillé 1925 from the Mediterranean area, which, however, although only known by the microspheric form, has been referred to the subgenus *Nephrolepidina*.

Lepidocyclina gigas Cushman 1919

1919 *Lepidocyclina gigas* Cushman, p. 64, pl. 1, figs. 3–5; pl. 5, fig. 4.
1941 *Lepidocyclina gigas* Cushman; Vaughan and Cole, p. 76 (*cum bibl.*).

Material. One hand specimen and one thin section.

Remarks. The Puerto Rican material conforms well to the known characters of the species. Vaughan and Cole (1941, p. 76) and Sachs and Gordon (1962, pp. 15, 16), amongst others, have suggested that *L. gigas* is the microspheric form of *L. undosa*; Sachs and Gordon (loc. cit.), however, place *gigas* in the synonymy of *undosa* although the name *gigas* has page priority. The type material of the two species does not come from the same locality, although both localities are on Antigua. Since *gigas* is not saddle-shaped and *undosa* is strongly saddle-shaped, the two forms are here retained separately. The suggestion by Cole and Applin (1961) that *L.* (*Eulepidina*) *favosa* should also be included in synonymy cannot, in our opinion, be maintained, because the two forms are morphologically quite different. As far as we know, the species has not yet been recorded from below the Early Miocene (see Eames *et al.* 1962).

Lepidocyclina (*Lepidocyclina*) *sachsi* sp. nov.

Plate 58, figs. 4–6

1962 *Lepidocyclina* (*Lepidocyclina*) *giraudi* R. Douvillé; Sachs and Gordon, p. 14 (*pars*), pl. 1 fig. 6. (*non* pl. 1, figs. 8, 11; pl. 2, fig. 9; pl. 3, figs. 2, 4, 9. *Max. pars* = *L.* (*L.*) cf. *crassicosta* (Vaughan and Cole).)

Material. Two hand specimens and three thin sections (P47339–41), of which the equatorial section (P47339) is the holotype.

Description. The megalospheric hand specimen has a diameter of about 1·65 mm. and a thickness of about 0·75 mm., and the axial section has a diameter of 1·75 mm. and a thickness of 1·1 mm. There is a prominent centrum passing with slightly concave curvature into a small flange; the centrum itself is almost completely formed of one large pillar. The nucleoconch is isolepidine, the dimensions of that of the holotype being:

Protoconch:	*height* 0·11 mm.
	width 0·16 mm.
Deuteroconch:	*height* 0·08 mm.
	width 0·16 mm.
Sum of heights:	0·19 mm.

The nucleoconch in a second equatorial section is slightly smaller, the sum of the heights being 0·15 mm. There are two relatively small primary auxiliary chambers, but no adauxiliary chambers can be distinguished. The chambers of the equatorial chamber layer are ogival-rhombic, without a very strong appearance of engine-turning, attain a radial length of about 0·06 mm. near the margin, and are noticeably smaller than the lateral chambers. In axial section the equatorial chamber layer attains a thickness of 0·08 mm. near the margin, and the chamber walls do not seem to develop more than 2 apertures; apart from the 2 huge central pillars there are no others, and the floors of the lateral chambers are fairly thin and the chamber lumina not very wide.

A larger specimen with a diameter of 3·2 mm. and a thickness of 1·6 mm., very similar in appearance but with a relatively somewhat smaller median pillar, proved on polishing to be a microspheric individual with the chambers of the equatorial layer of the same shape and same general size as in the megalospheric forms described above.

Remarks. The external appearance and internal characters are quite different from those of *L.* (*L.*) *giraudi* (e.g. the complete lack of 'long radial pustules'); of the forms illustrated by Sachs and Gordon (1962) as *L.* (*L.*) *giraudi*, the axial section (loc. cit., pl. 1, fig. 6) differs from the others and is referable to *L.* (*L.*) *sachsi*, which is named after the senior author.

Lepidocyclina (*Nephrolepidina*) *bikiniensis* Cole 1954

Plate 58, figs. 7–9

1954 *Lepidocyclina* (*Nephrolepidina*) *bikiniensis* Cole, p. 586, pl. 214, figs. 1–8.

1954 *Lepidocyclina* (*Nephrolepidina*) *bikiniensis* Cole var. *unipilaris* Cole, p. 587, pl. 214, figs. 11–14, 18.

1962 *Lepidocyclina* (*Eulepidina*) *yurnagunensis* Cushman; Sachs and Gordon, p. 16 (*pars*), pl. 1, fig. 1. (*non* pl. 2, figs. 1, 3–6, 8 = *L.* (*N.*) *bikiniensis* Cole subsp. *pumilipapilla* Cole; *nec* pl. 2, fig. 7; pl. 3, fig. 8 = *L.* (*L.*) *yurnagunensis* Cushman.)

Material. Six hand specimens and three thin sections (P47342–4).

Remarks. This material forms an excellent match with *L.* (*N.*) *bikiniensis* from the upper part of the 'e' stage (early part of Early Miocene) of Bikini. The 'variety' *unipilaris* being merely an extreme variant, we would place it in synonymy. One of the specimens (an axial section) illustrated by Sachs and Gordon (1962) as *L.* (*Eulepidina*) *yurnagunensis* is neither a *Eulepidina* nor, on the characters of the lateral chambers, does it belong to the species *yurnagunensis*; it matches well the 'variety' *unipilaris* of *L.* (*Nephrolepidina*) *bikiniensis*.

EXPLANATION OF PLATE 58

Figs. 1–3. *Lepidocyclina* cf. *crassicosta* Vaughan and Cole. Sample PO.35–1, La Rambla, Puerto Rico, Juana Diaz Formation, Early Miocene. 1, equatorial section of a microspheric specimen, ×15, P47336; 2, equatorial section, ×20, P47337; 3, axial section, ×20, P47338.

Figs. 4–6. *Lepidocyclina sachsi* sp. nov. (×25). Sample PO.35–1, La Rambla, Puerto Rico, Juana Diaz Formation, Early Miocene. 4, equatorial section, holotype, P47339; 5, equatorial section, P47341; 6, axial section, P47340.

Figs. 7–9. *Lepidocyclina* (*Nephrolepidina*) *bikiniensis* Cole (×25). Sample PO.35–1, La Rambla, Puerto Rico, Juana Diaz Formation, Early Miocene. 7, equatorial section, P47342; 8, axial section, P47343; 9, tangential section, P47344.

Lepidocyclina (*Nephrolepidina*) *bikiniensis* Cole 1954 subsp. *pumilipapilla* Cole 1954

Plate 59, figs. 1–6

1954 *Lepidocyclina* (*Nephrolepidina*) *pumilipapilla* Cole, p. 592, pl. 214, figs. 15–17, 19; pl. 215, figs. 1–8.
1962 *Lepidocyclina* (*Eulepidina*) *yurnagunensis* Cushman; Sachs and Gordon, p. 16 (*pars*), pl. 2, figs. 1, 3–6, 8. (*non* pl. 1, fig. 1 = *L.* (*N.*) *bikiniensis* Cole; *nec* pl. 2, fig. 7; pl. 3, fig. 8 = *L. yurnagunensis* Cushman.)

Material. One microspheric hand specimen, 1 microspheric equatorial section (P47345), and 1 microspheric axial section (P47346); 35 megalospheric hand specimens and 5 megalospheric thin sections (4 registered as P47347–50).

Remarks. This material matches well that recorded by Cole as *L.* (*N.*) *pumilipapilla* which, on account of its very close relationship, we would regard merely as a subspecies of *L.* (*N.*) *bikiniensis*. Cole's original material came from the upper part of the 'e' stage (early part of Early Miocene) of Bikini.

Palaeonummulites antiguensis (Vaughan and Cole) 1936

Plate 51, figs. 8, 9

1936 *Operculinoides antiguensis* Vaughan and Cole, p. 492, pl. 38, figs. 7–10.
1941 *Operculinoides antiguensis* Vaughan and Cole; Vaughan and Cole, p. 53 (*cum bibl.*).
1962 *Camerina dia* (Cole and Ponton); Sachs and Gordon, p. 13, pl. 1, figs. 2–4, 7; pl. 2, fig. 2; pl. 3, figs. 6, 7.

Material. Numerous hand specimens and 3 thin sections (including P47351–2).

Remarks. Although Cole (1958) placed *antiguensis* in the synonymy of *dia*, the consistently more tightly coiled spire and distinctly more inflated external appearance fully merit it to be specifically different. The form illustrated by Sachs and Gordon (1962) as *dia* agrees in all respects with *antiguensis*. The species has not yet, in our opinion, been recorded from below the Miocene (see Eames *et al.* 1962).

STRATIGRAPHICAL PALAEONTOLOGY

The larger foraminifera recorded in this paper have been studied in order that their evidence may be coordinated with that of the planktonic foraminifera in the successions in the same region; the evidence of the latter is to be published shortly in detail in a book by Blow and Banner.

In Venezuela the Peñas Blancas Limestone samples have yielded *Asterocyclina asterisca*, *Helicolepidina paucispira*, *Helicostegina soldadensis*, *Heterostegina* (*Vlerkinella*) *kugleri*, *Lepidocyclina montgomeriensis*, *Palaeonummulites kugleri*, *P. palmarealensis*, *P. stainforthi*, *Pliolepidina tobleri panamensis* and its probable microspheric form associated with the worm *Tubulostium*. These forms occur in natural association, and there can be no doubt as to their Late Eocene age.

In Eames *et al.* (1962) there were recorded six localities (in Costa Rica, p. 35; in Venezuela, p. 39; on Soldado Island, p. 42; on Carriacou, p. 43; in Jamaica, p. 46; and in Cuba, p. 47) which were regarded as being of early part of Early Miocene age on the presence of *Pliolepidina tobleri*, associated Eocene foraminifera being suggested to be derived. It is now recognized that these faunas are of Late Eocene age, and that only pre-Late Eocene foraminifera are derived. On the other hand, the study of samples from the Early Oligocene Playa Rica Formation of Ecuador (reputed to contain *Pliolepidina tobleri*) has failed to yield any trace of the species or the genus. In Panama, Eames *et al.* (1962, p. 36) recorded *P. tobleri* with an early part of Early Miocene foraminiferal fauna from the Bohio Formation, but the *P. tobleri* does not come from the same sample as the Early Miocene foraminifera. Again, the records of *Pliolepidina tobleri* from the Culebra Formation and Emperador Limestone of Panama have been indicated by Cole (1952, p. 17) to be incorrect, and our own studies of portions of the Culebra Formation samples have also failed to find any trace of the species or the genus.

The study of duplicate material from Ecuador has also shown that neither *Eulepidina undosa* nor *Lepidocyclina yurnagunensis* (*s.s.*) occurs in them. The form previously believed to be *undosa* is a new species of *Lepidocyclina* (*Nephrolepidina*), so that the genus *Eulepidina* is still unknown below the Middle Oligocene. The form recorded as *L. yurnagunensis* belongs to the subspecies *morganopsis*, so that this subspecies is now to be regarded as ranging from Early Oligocene to Early Miocene; we are not aware of any substantiated record of *L. yurnagunensis* (*s.s.*) from below the Early Miocene. The early Oligocene Ecuadorean faunas have also been found to contain *Halkyardia bikiniensis* and (in one sample near the base) *Helicolepidina paucispira*; until further knowledge is obtained of the stratigraphy of the underlying horizons in the area we feel that it would be unwise unequivocally to extend the range of the genus *Helicolepidina* up into the Early Oligocene because the relatively few specimens found might be derived.

In Jamaica, *Lepidocyclina yurnagunensis* subsp. *morganopsis*, as in Ecuador, occurs in association with good planktonic faunas of Early Oligocene age, in the uppermost part of the Bonny Gate Formation.

In Alabama, *Lepidocyclina mantelli* occurs in association with rich planktonic foraminiferal faunas (identified by W. H. B.) of Early Oligocene age in beds which have been referred to as Red Bluff and Marianna Limestone. However, there seems to be little in common with the fauna of the type Marianna Limestone in Florida, and, indeed, there does not seem to be agreement as to the stratigraphical succession in Little Stave Creek, Alabama. Whereas the UWS samples collected in Little Stave Creek by Stanley Wissler were indicated to have come from a succession including Red Bluff, Mint Springs, and Marianna Limestone, Dr. Stearns MacNeil has informed us (*verb.*) that there is no Mint Springs in the succession since he considers it to be cut out. Again,

EXPLANATION OF PLATE 59

Figs. 1–6. *Lepidocyclina* (*Nephrolepidina*) *bikiniensis* Cole subsp. *pumilipapilla* Cole. Sample PO.35–1, La Rambla, Puerto Rico, Juana Diaz Formation, Early Miocene. 1, equatorial section of a microspheric specimen, ×15, P47345; 2, axial section of a microspheric specimen, ×25, P47346; 3, equatorial section, ×25, P47349; 4, axial section, ×25, P47347; 5, axial section, ×25, P47348; 6, equatorial section, ×25, P47350.

Fig. 7. *Lepidocyclina canellei* Lemoine and R. Douvillé (×20). Sample PO.35–1, La Rambla, Puerto Rico, Juana Diaz Formation, Early Miocene. Equatorial section, P47335.

although Wissler records *Pecten* cf. *poulsoni* from low in the Mint Springs equivalent and *Pecten poulsoni* (*s.s.*) from the upper part of the Mint Springs equivalent and from throughout the Marianna Limestone, and although Dr. Stearns MacNeil has identified a specimen from sample UWS138 (sent to him on loan) as the flat valve of *Pecten poulsoni*, we consider that these forms need a thorough revision. We have abundant pectinid material from throughout this succession, and not only is there no trace whatsoever of a strongly inflated *Pecten* right valve, but the extremely dominant form present throughout the succession consists of one species of *Chlamys* (*Aequipecten*), there being over 30 portions of valves with ctenolia/byssal sinuses in our collections, such morphological characters being completely absent in the genus *Pecten*.

In Puerto Rico, a sample from within 1 m. of another containing a rich Zone N. 2 (early part of Early Miocene) planktonic foraminiferal fauna, both in the Juana Diaz Formation, contained *Eulepidina favosa*, *E. undosa* subsp. *laramblaensis*, *Lepidocyclina canellei*, *L.* cf. *crassicosta*, *L. gigas*, *L. sachsi*, *L.* (*Nephrolepidina*) *bikiniensis*, *L.* (*N.*) *bikiniensis* subsp. *pumilipapilla*, and *Palaeonummulites antiguensis*. On its own evidence this assemblage of larger foraminifera would be dated as early part of Early Miocene, and the associated planktonic foraminifera confirm this. From the point of view of the palaeogeography of the region it is most interesting to find that the Pacific 'e'-stage form *Lepidocyclina* (*Nephrolepidina*) *bikiniensis* (*s.l.*) occurs also in the early part of the Early Miocene in the Caribbean region.

Finally, some of the specimens illustrated by Sachs (1964, e.g. pl. 2, figs. 1–4, 6–9) from Locality 3 on Puerto Rico (from the Cibao Formation, which overlies the Juana Diaz Formation) as *Lepidocyclina* (*Eulepidina*) *undosa* are, in our opinion, *Pliolepidina tobleri* (*s.s.*); however, some of the specimens from the same Locality (e.g. his pl. 1, fig. 4) are typical *Eulepidina*. We have found no evidence whatsoever that pliolepidine and eulepidine embryonts intergrade morphologically, and are in full agreement with Hanzawa (1962) that *Eulepidina* and *Pliolepidina* are generically distinct. For example, in some of the Peñas Blancas Limestone samples in particular, *P. tobleri* subsp. *panamensis* is extremely abundant, is very uniform in its total morphology, and there is no other form whatsoever present in the samples, of which it could be a freakish variant. Consequently, the species *Pliolepidina tobleri* is to be accepted as ranging from Late Eocene to Early Miocene; we are not aware of any true Oligocene record of the species in the Central American region, this doubtless being due to the markedly regressive nature of the Oligocene period over so much of the area.

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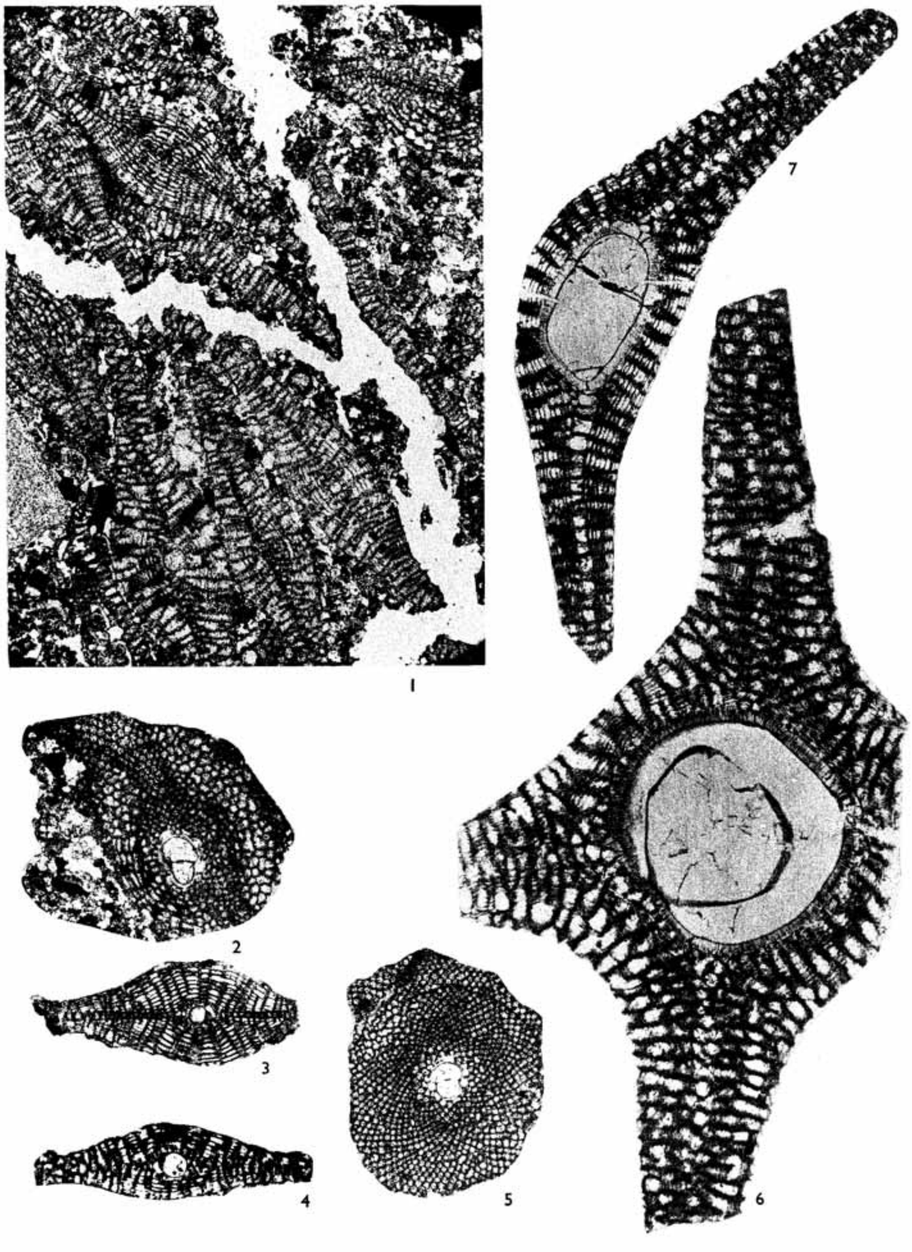

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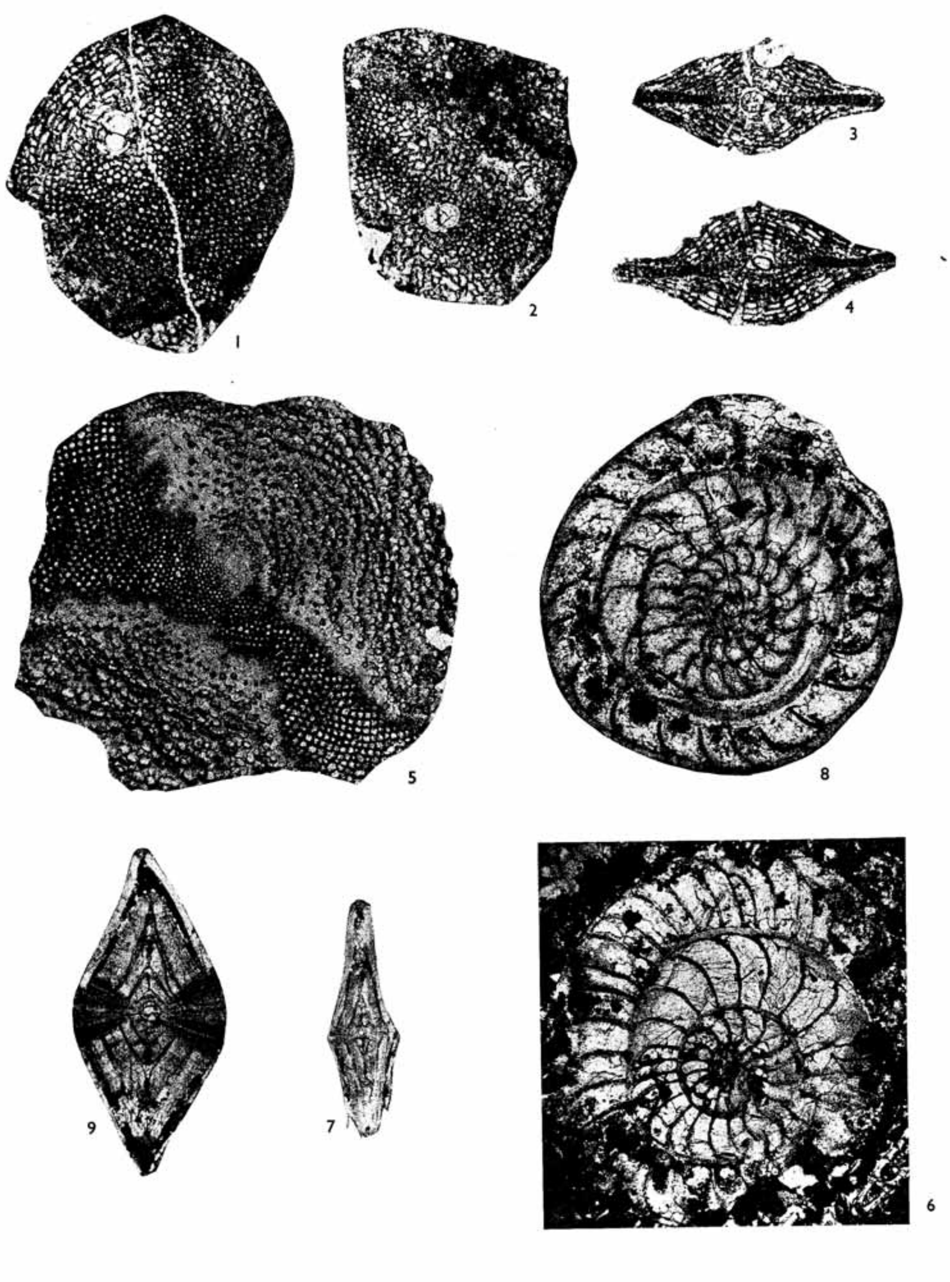

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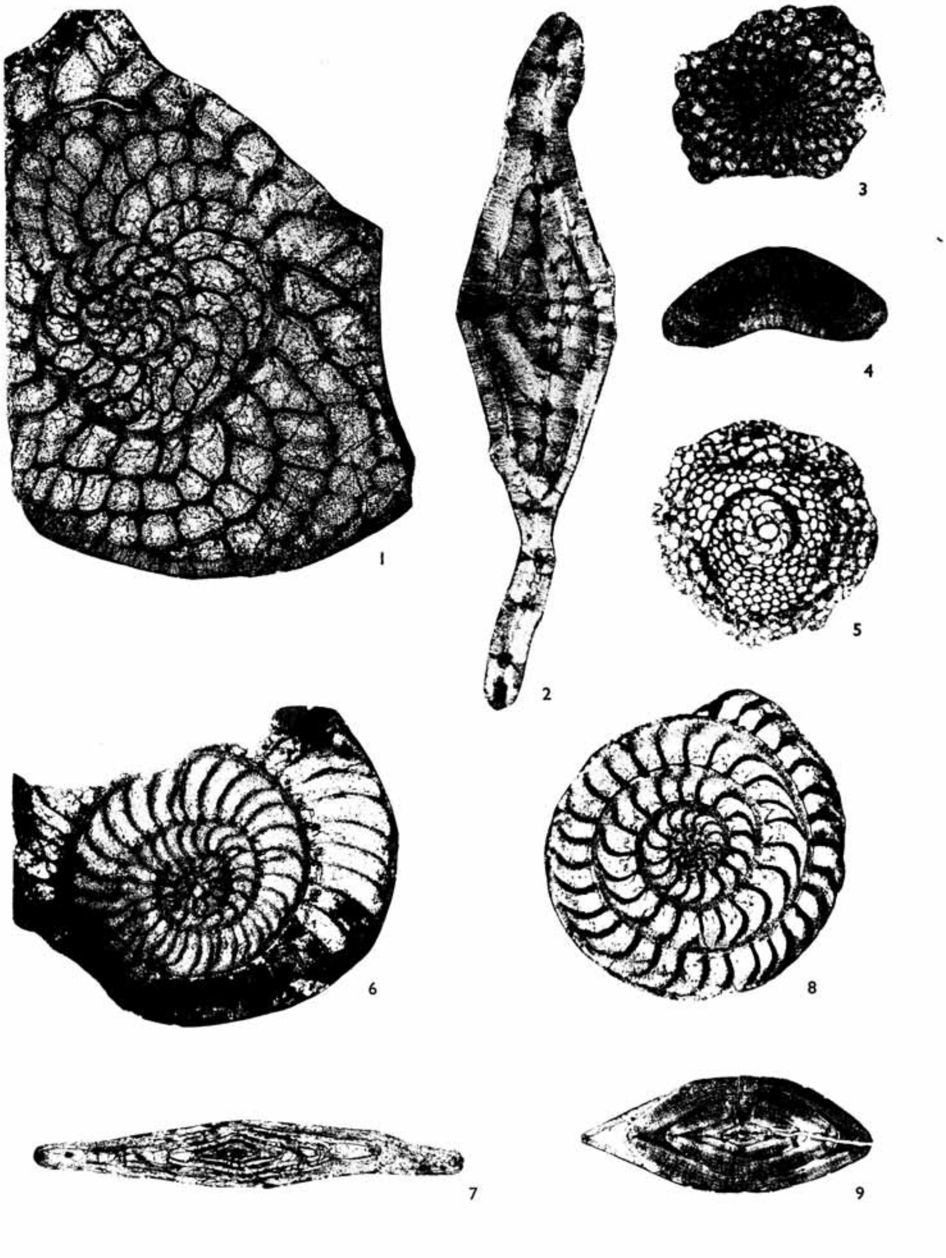

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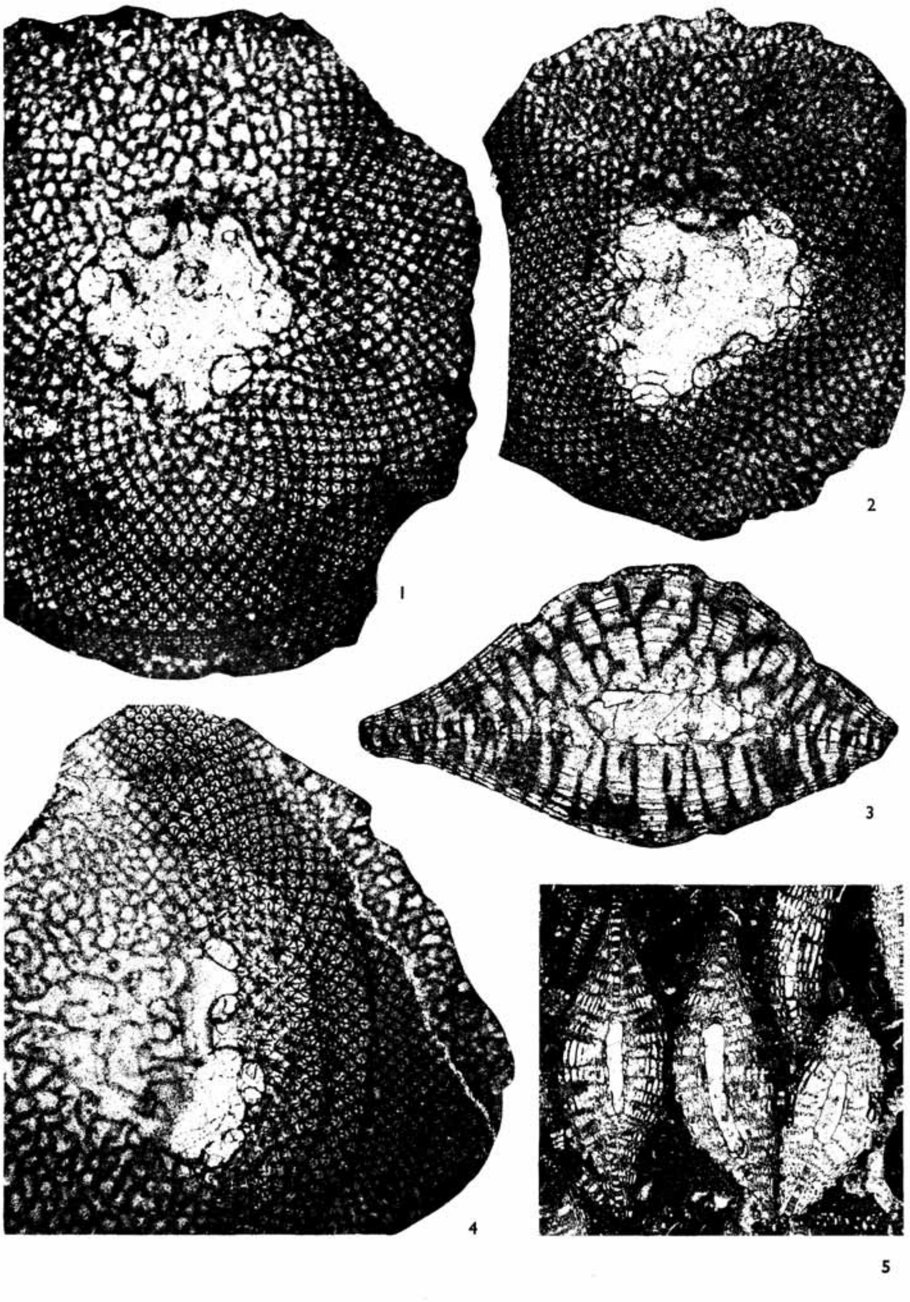

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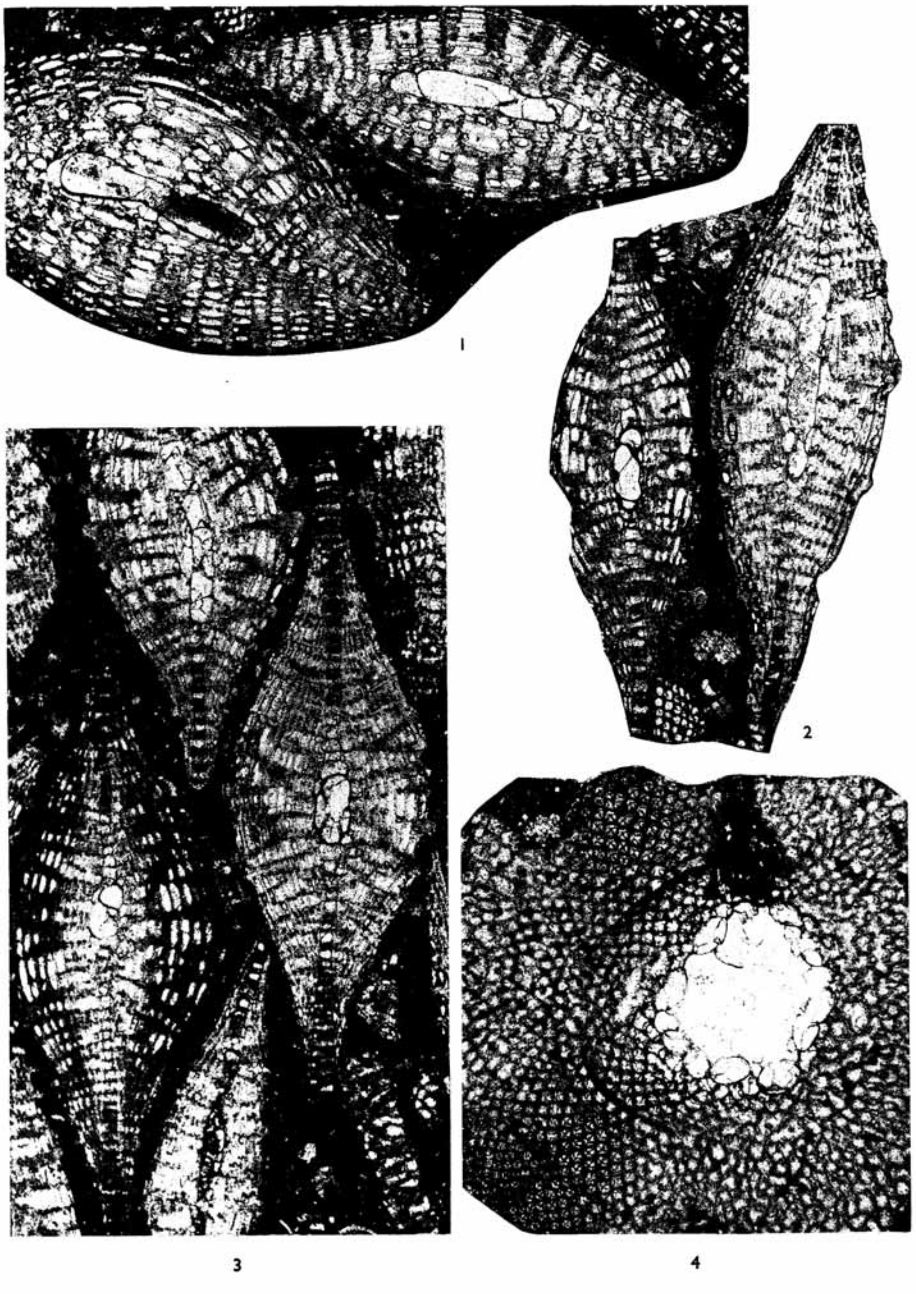

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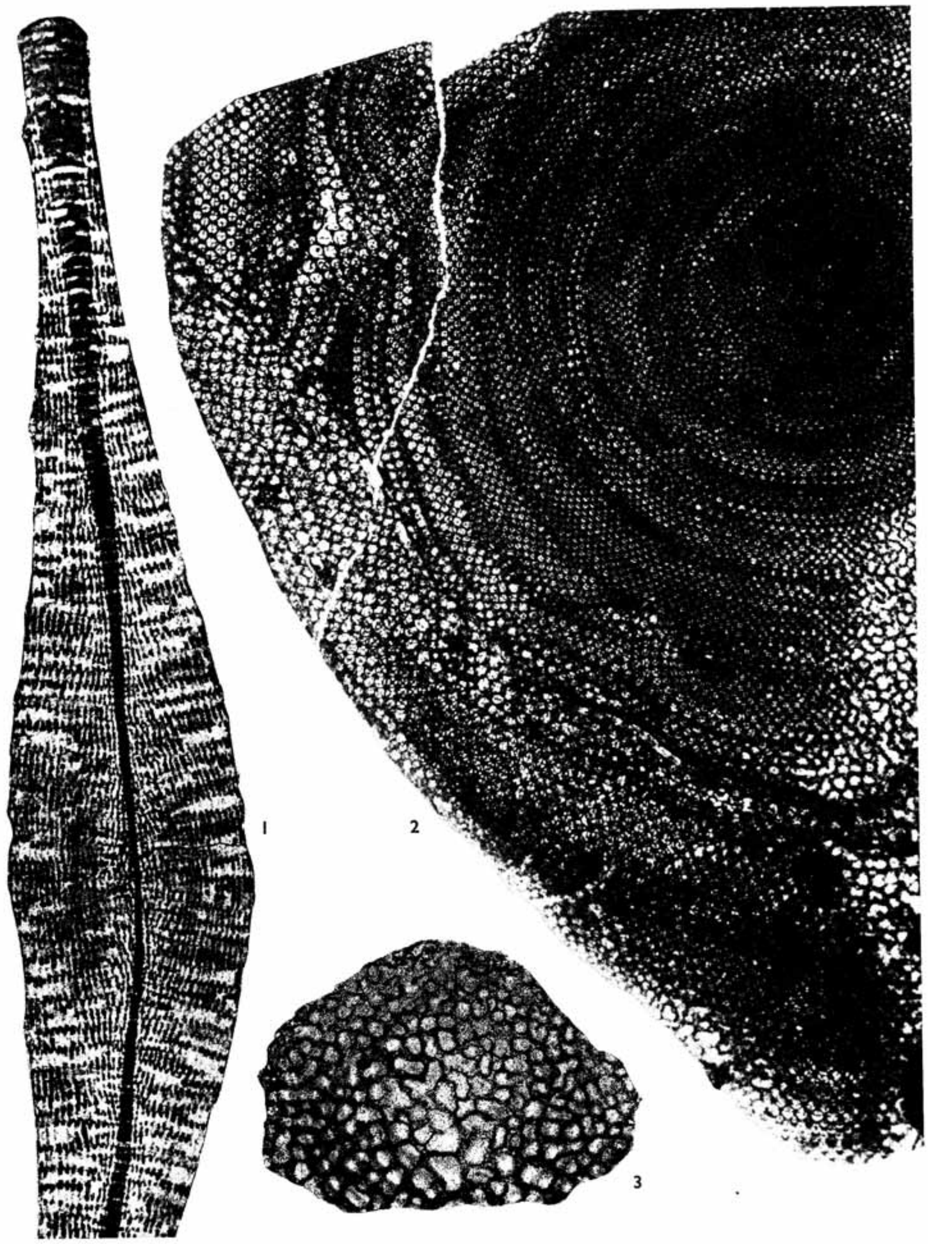

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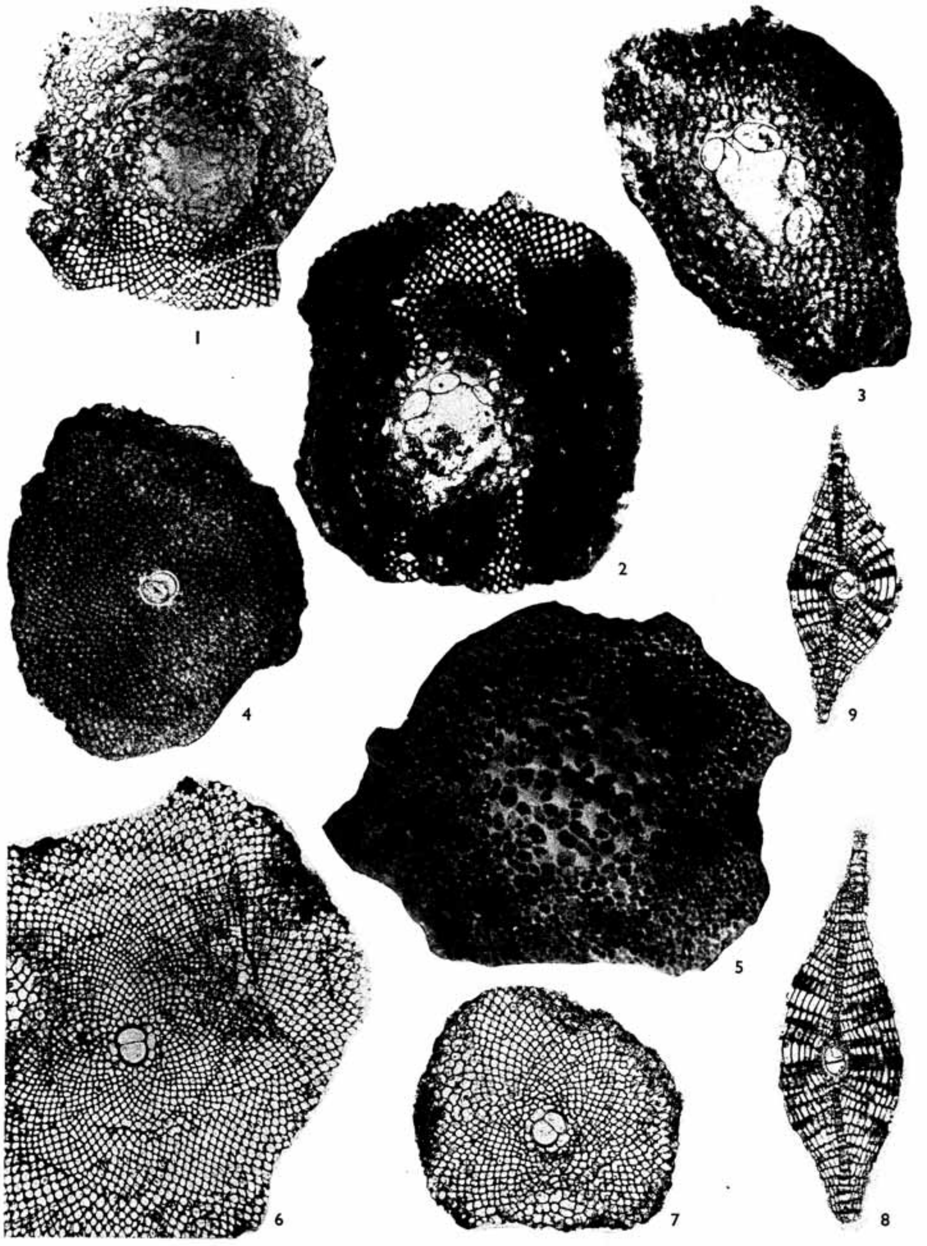

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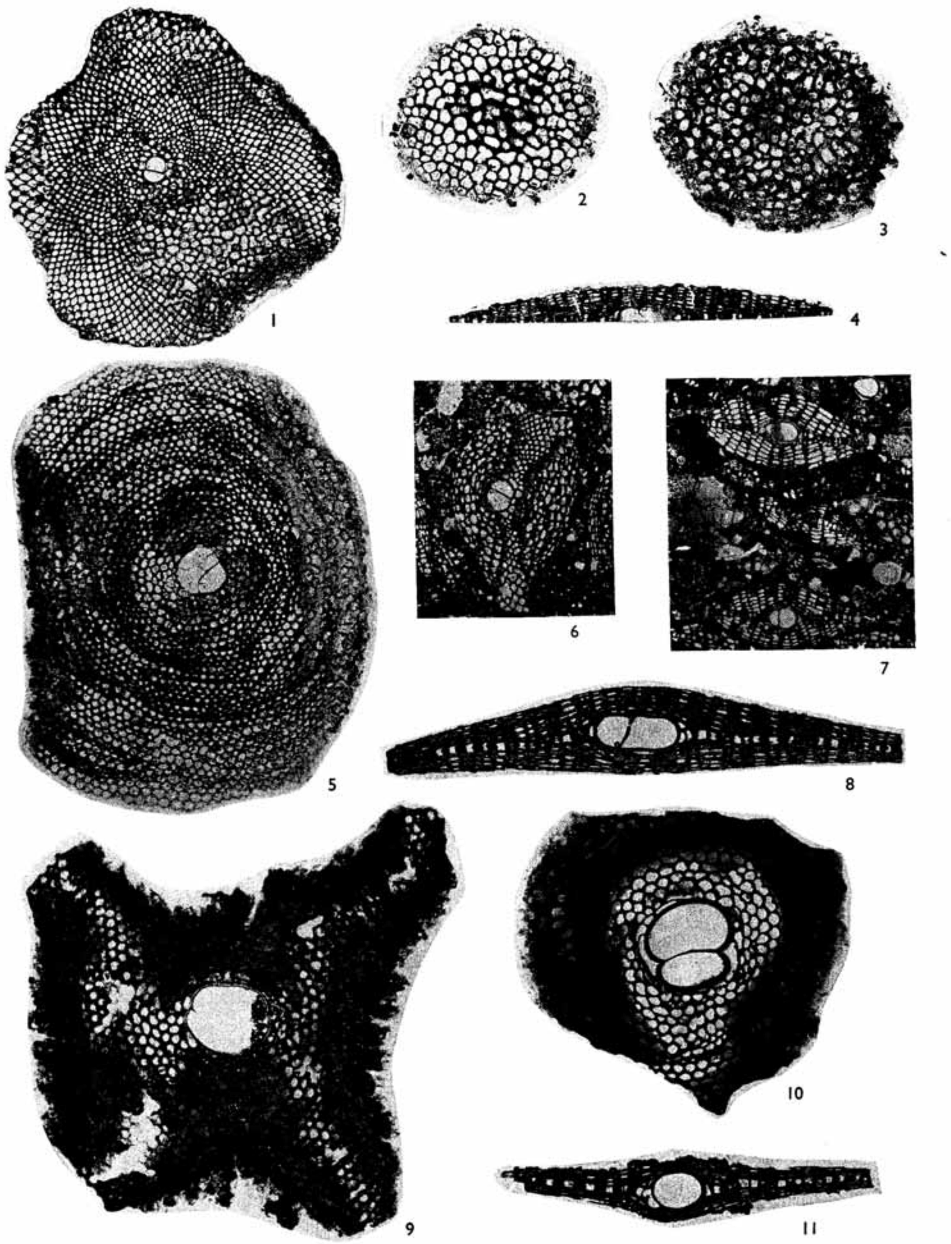

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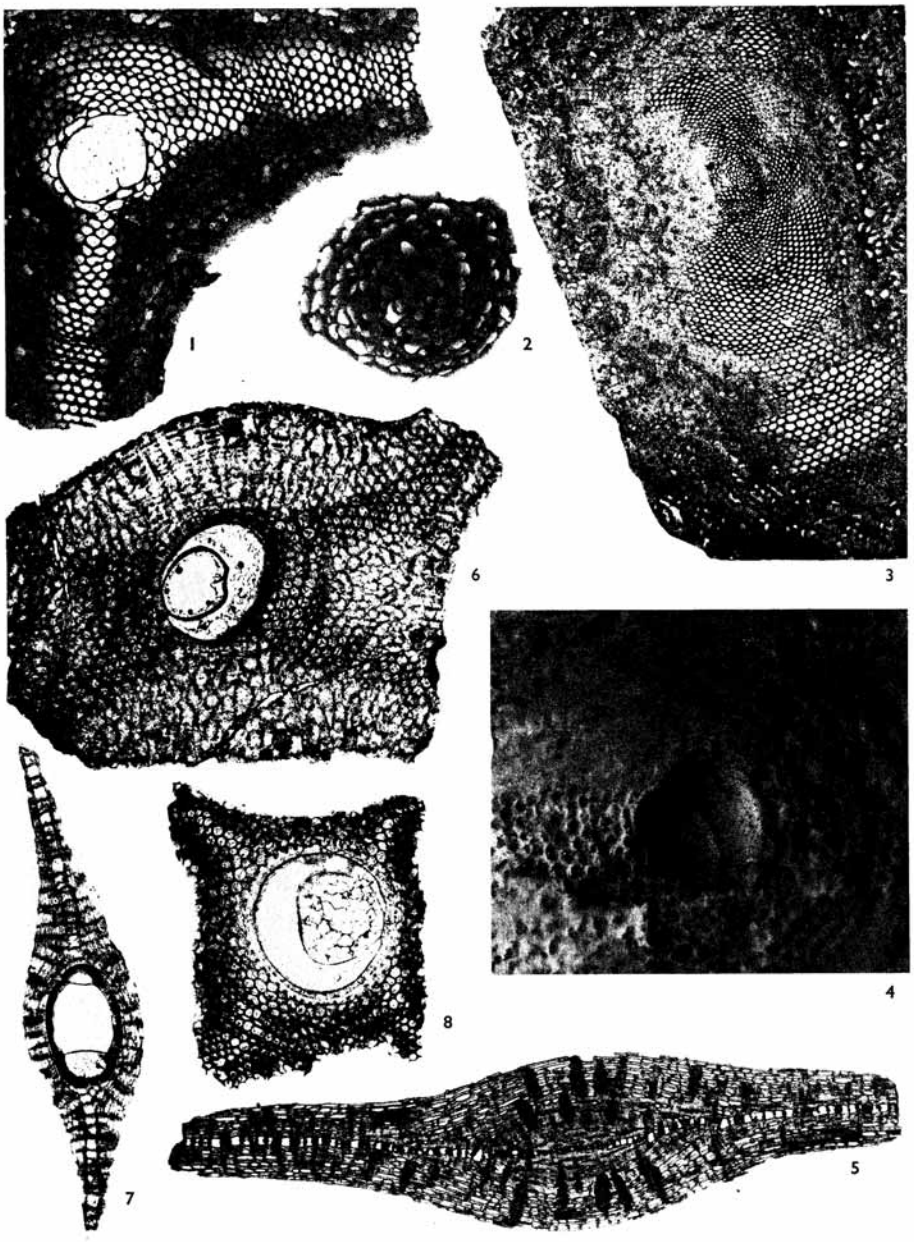

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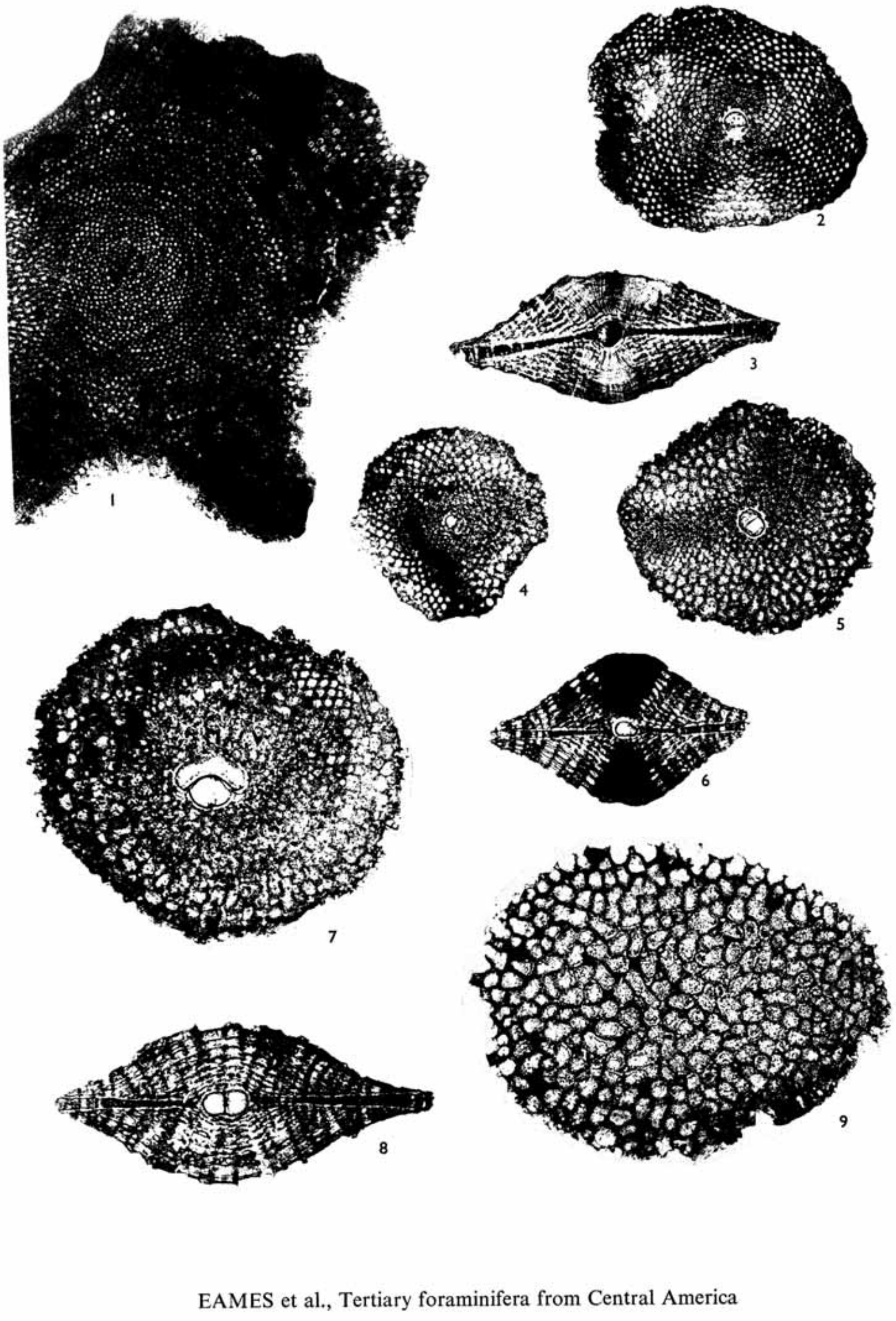

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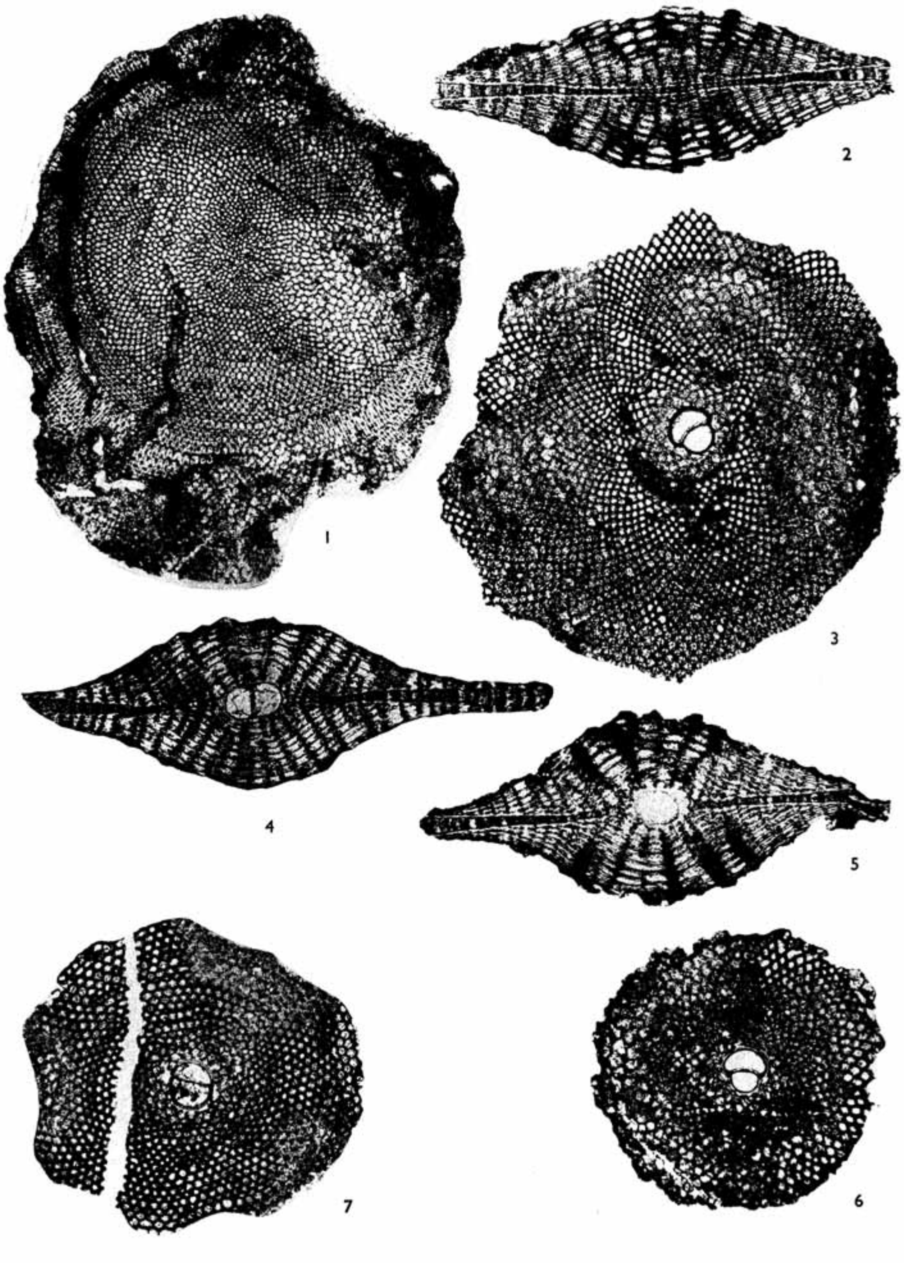

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